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"Experimentation with Network Enabled Joint Tactical Training"

Topic 3: Modeling and Simulation
Topic 4: Cognitive and Social Issues
Topic 7: Network-Centric Experimentation and Analysis

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Experimentation with Network Enabled Joint Tactical Training

Abstract

This paper describes the Joint Air Defence Training Simulation (JADE) II, an experimental synthetic exercise performed in late October 2007. The exercise provided training for an Anti-Air Warfare (AAW) organization including two naval frigate AAW teams, an air surveillance and combat management team at a Control and Reporting Centre (CRC) and two combat aircraft pilots, training air-maritime cooperation and coordination procedures. The synthetic exercise was enabled by interconnecting stand-alone training simulation systems and their voice and tactical data link systems, creating the JADE II Joint Tactical Training Capability Prototype (JJTTCP). The JADE II experiments evaluated the JJTTCP's ability to provide relevant and cost-effective training. For this purpose, a set of subjective and objective data were collected. The paper outlines the experimental setup employed to measure training effectiveness, and describes the JJTTCP. The results of the JADE II experiment were positive, indicating that a network enabled training capability, like the one described, can provide relevant and realistic joint tactical training. The training can be improved in terms of reduced cost and increased availability and it can increase the value of live joint exercises. In addition, it enables trainees to explore and understand network enabled concepts of their domain, and the command and control organization and functions in and adjacent to their domain.

Keywords: Distributed Simulation, Training, Network Enabled Capability, Synthetic Environment, Experimentation, Command and Control.

1 Introduction

NATO describes Network Enabled Capability (NEC) as the cognitive and technical ability to federate the various components of the operational environment at the different echelons through a networking and information infrastructure (NII) [1]. Training, especially simulation based training, will be key to achieve the aims of NEC and be able to deliver training required for Network Based Defence (NBD) [2]. On the other hand, a NII will enable new opportunities in training as long as training systems are designed to exploit the technical capabilities of a NII.

The paper presents ongoing research at FFI (Norwegian Defence Research Establishment) addressing NEC training concepts and new training concepts enabled by a NII. Part of this research is an experimental campaign into (geographically) distributed simulation based joint collective tactical training as an important component of collective training for NEC. The experiments explore both operational and technical issues in network enabled training capabilities and the campaign has so far included two experiments, one in 2006 and one in 2007. Additional experiments are planned for 2008 and 2009. NEC is in an early phase of development in Norway, thus the NEC environment in which the experiments are performed as well as the prototype network enabled training capability employed are rather restricted.

The experiments performed up to now have been concerned with training of command and control (C2) and air picture production for joint air defense, and have included an air surveillance and combat management element, a maritime task group, combat aircraft and a minor part of an air operational command element. Planned experiments are also to include land command teams and combat elements, in addition to operational command elements. The focus of this paper is on the experiments conducted in October 2007. These were accomplished as a three day experimental synthetic exercise (hypothesis testing experiment [3]) plus a demonstration experiment on the fourth day. The experiments were called JADE II, short for Joint Air Defence Training Simulation II.

The objectives of the paper are to describe the JADE II hypothesis testing experiment and its findings in a NEC context, and the JADE II Joint Tactical Training Capability Prototype (JJTTCP) developed to support the experiment.

The rest of the paper is organized as follows: Section 2 reviews background and related work, and sets the JADE II experiment in context by describing the JADE experimentation campaign. Section 3 describes the JADE II hypothesis testing experiment, including experiment formulation, measurements, training objectives and scenario. Section 4 describes the JJTTCP developed to support the experiment, before Section 5 goes on to describe the experiment execution. Section 6 lists the experiment results, before Section 7 concludes the paper.

2 Background and related work

NEC will have a major impact on training. Training is crucial to be able to achieve the ambitions of NEC since it, in essence, is there to support people to employ an information rich networked environment to conduct operations in a better way. NEC will impact all levels of training; individual, team and collective training. NEC individual training includes training of information management skills and NEC team training includes training of exploitation and sharing of information, and employing decision support tools within a command team to make timely and good decisions. Especially joint collective training is important to be able to support training of ad hoc organizations and agile mission groups. Collective training is the main vehicle to build trust and confidence between command teams across traditionally organizational borders which collaborate on an ad hoc and temporary basis. According to the *power to the edge* principle [4], agile mission groups will cross services at a lower level, and decision-making will move downwards in the military organization. Thus, collective NEC training needs to be joint, including not only the operational level, but also the tactical and the combat levels.

The paper focuses on joint collective training at the tactical level while individual and team training are outside its scope. The NII technical capabilities in which the training took place were rather limited, restricted to networked C2 information systems, tactical data links and voice communications. [5] describes some of the needs and changing training requirements to be able to support the aims of NEC with an emphasis on collective training in the land domain, while [6] discusses concepts for embedded training for NEC.

New training opportunities are enabled by a NII underpinning NEC. It promises greater flexibility as it is founded upon service oriented architecture and training could be provided more widespread both in time and space, due to the reach and persistency of a NII. However, to be able to achieve this greater flexibility and availability, training systems must be designed to take advantage of the future capabilities of a NII. Many of today's training systems are stand alone, monolithic, and tailored to a specific platform or force component. They are not designed to be able to participate in a federation to support collective joint training. A first step to a NEC collective training capability could be to federate legacy training system employing a simulation infrastructure. A next step would be to take full advantage of the promised capability of a NII by covering specific training needs by composing and utilizing common simulation services. The work presented in this paper belongs to the first step.

As described in [7], a complex endeavor is an undertaking in which there are multiple interdependent chains of command, and the participating organizations typically have differing goals and perceptions of the situation. In addition, the desired effect of a complex endeavor is often not just military, but also economic, social and political. Simulation based training capabilities like the one presented in this paper are well suited to enable training of Command and Control (C2) for complex endeavors, e.g. by adding interfaces to other organizations or simply by having inputs from such elements played by instructors and directing staff. The latter approach was used in the JADE II experiments.

2.1 Related Work

Distributed simulation for military training purposes has it's origin in the 1980's and has been under development since then. Distributed simulation based training is in use by several nations today. Most efforts have been for single service needs although in a joint context, especially in the air domain. Some examples are described in [8], [9] and [10]. There are fewer examples of using distributed simulations for joint tactical training. Three examples including joint tactical training are [5], describing work in the UK's Joint Collective NEC Training Capability (JCNTC), [11], describing the US Joint National Training Capability (JNTC) and [12], describing the US Global Joint Training Capability (GJTC).

Several other experiments using distributed simulation for training purposes can be mentioned. [13] describes a recent experiment in which distributed simulation was used to train air battle managers from Australia and the US. [14] describes an experiment where two naval frigate teams train surface warfare together. This experiment trained teams from Canada, the US and Australia. In the JADE experiments air battle managers train together with naval Anti-Air Warfare (AAW) teams and a fighter controller (FC) embarked on board one of the frigates.

The paper adds to the experience of efforts in distributed simulation based training in general and contributes in the efforts towards network enabled tactical level joint training. More specifically the work reported in this paper gives insights in experience of

employing the Code of Best Practice for Experimentation [3] in the field of simulation based training of C2 teams.

2.2 The JADE Experimentation Campaign

[15] divides experiments into three categories; discovery experiments, hypothesis testing experiments and demonstration experiments. An experimentation campaign consists of all these three experiment types in succession. Sometimes several experiments of the same type are performed before moving on to the next type.

JADE [16;17] was a discovery experiment. Its focus was to establish whether or not interconnecting and adjusting existing trainers could be a viable approach as a first step to obtain a joint tactical training capability. The conclusion from JADE was that the technical solution was viable, and it had the potential to provide joint tactical training.

JADE II, the focus of this paper, was a hypothesis testing experiment and a demonstration experiment. The hypothesis testing experiment was designed to test whether or not the training capability provided by interconnecting and adjusting existing trainers could provide a joint tactical training capability that is cost-effective, has high availability and is able to increase the competency of the trainees.

The last day of JADE II was a demonstration of the training enabled by the JJTTCP, and so this demonstration can be seen as a demonstration experiment in the JADE experimentation campaign.

3 The JADE II hypothesis testing experiment

This section describes the planning, preparation and setup of the JADE II hypothesis testing experiment, from the formulation of the experiment to the measurement regime applied to test the hypothesis. The training objectives, scenario and operational plans are also described, but first an introduction to the operational context of JADE II is given, in order to give a background for the coming discussions.

3.1 The JADE II operational context and training audience

JADE II enabled joint collective tactical training by interconnecting existing, stand-alone training simulation systems and game based desktop combat aircraft simulators at three geographically distributed sites.

The organizations trained in JADE II included a Control and Reporting Centre (CRC) team, an AAW organization consisting of two frigate AAW teams, and two combat aircraft pilots. The CRC team utilized the operational system for air surveillance and combat management in the CRC at Mågerø, Norway. The frigate personnel operated a naval tactical trainer located at the Royal Norwegian Navy Training Establishment KNM Tordenskjold (KNM T) at Haakonsvern naval base, Norway. The combat aircraft pilots operated desktop game based combat aircraft simulators located at FFI Battle Lab, Kjeller. In addition, a Joint Air Operations Centre (JAOC) representative was involved to

supply realistic commands and other input during the training sessions. The JADE II operational organization is shown in Figure 1.

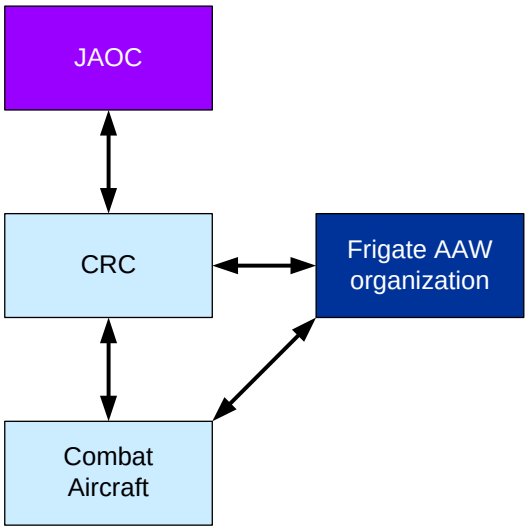

Figure 1: The JADE II operational organization.

3.2 Experiment formulation

The structure applied to the JADE II experiment formulation is that suggested by [3], and consists of a definition of the *treatment*, the *hypothesis*, the *baseline* and the *variables* of the experiment. These terms will be briefly described in the following along with their meaning in the JADE II experiment.

The treatment(s) of an experiment is the proposed solution to an operational problem, and can be e.g. a new capability, an innovation that influences how an operational unit operates or a re-organization of an operational unit. The treatment of the JADE II experiment is the *JADE II Joint Tactical Training Capability Prototype (JJTTCP)*, which is a synthetic environment in which to perform joint tactical training.

The hypothesis of an experiment is chosen to concisely describe the fundamental question that the experiment should answer. The hypothesis should be of the form IF A, THEN B, where A is a treatment and B is the effect of the treatment. The purpose of an experiment is to verify that A causes B. The JADE II hypothesis was:

> *If the JJTTCP is used, then the training of air-maritime cooperation and coordination procedures will improve compared to today's training methods.*

The variables of an experiment are the measurements of the experiment. These are usually divided into dependent and independent variables. The independent variables can be thought of as input variables that can be varied. The dependent variables are the output variables of the experiment, and they are dependent on the independent variables. An experiment plan needs to identify all such variables and how each is going to be

measured. It must also specify how the independent variables will be controlled. The dependent variables of the JADE II experiment were

- the cost of training
- the availability of training and
- the competency gained by the trainees

No independent variables were controlled in the JADE II experiment.

To be clear about which manipulations and comparisons are being made, it is important to establish an experiment baseline. The baseline is the original system (or capability or organization), and measures of performance of this system. Typically, during an experiment a new system is tested and the results are compared to the baseline. Today's training methods for air-maritime cooperation and coordination in Norway implies live exercises, meaning that the baseline of the JADE II experiment is joint tactical training through live exercises. The most important limitation of this baseline is the cost of using it.

Of the three variables defined, this study has focused on the last variable, competency. This is because we believe that cost will decrease and availability increase in almost any kind of simulation training compared to live exercises when considering joint tactical training. The main factor that may falsify the hypothesis is that the training provided by JJTTCP does not increase the competency of the trainees. The measurements designed to measure competency are given in the next section.

3.3 Experiment measurements

In order to measure an increase in competency, several measurements were devised, including:

- theoretical tests
- normative models of procedures
- questionnaires and
- technical measurements.

These measurements are described in the following.

3.3.1 Theoretical tests

Two theoretical tests were made in cooperation with the CRC and KNM T instructors. The tests were multiple-choice, and the questions were selected to address topics of air-maritime cooperation and coordination. One test was taken before the first day of exercise, and the second was taken after the final day of the exercise. All trainees but the pilots participated in the tests.

3.3.2 Normative models of procedures

Normative models were developed that documented how certain procedures should be performed, and were to be used to assess such procedures whenever executed by the teams during the exercise. They took the form of a list describing the different tasks and communications a specific procedure should entail, and allowed the supervising instructor to evaluate the trainee executing the procedure in an objective way. Two procedures were selected to be our test procedures, namely fighter control handover and Electronic Support Measures (ESM) reporting. The normative models were developed in cooperation with the CRC and KNM T instructors, and were based on NATO procedures.

3.3.3 Questionnaires

A survey was conducted among three groups of respondents. These were the training audience and instructors after the training sessions, and guests attending the demonstration experiment. The questionnaires were used to collect the respondents' opinion about different aspects of the exercise, including their opinion about the concept in general, the JJTTCP and which organizations to be included if the JJTTCP was to be expanded. The questionnaires also asked the teams and instructors how they assessed the development of the team competency during the exercise.

3.3.4 Transactive memory system

JADE II was used as an arena for performing an experiment investigating the development of transactive memory system. This study is described in [18].

3.3.5 Technical measurements

In order to fully document the experiment and to collect objective data about what transpired in the exercise, several measurements were taken directly from the JJTTCP. This included voice communication recordings, tactical data link logs and ground truth logs. These data can also be used to derive objective measures about team performance. All training session runs were logged and recorded.

3.4 Training objectives and scenario

The training objectives and scenario of JADE II were important parts of the experiment planning and were developed in parallel with the measurement scheme.

The training objectives were established in dialog with instructors from the CRC and KNM T. The objectives resulting from this process were e.g.

- Use of basic Recognized Air Picture (RAP) production procedures
- ESM data exchange between frigates and CRC
- Handover of combat aircraft control to a frigate FC and
- Coordination of weapon usage between frigates and combat aircraft.

The tasks listed as the training objectives are part of or related to the C2 functions defined in [19]. For example, establishing a RAP is part of the C2 function "monitoring and assessing the situation and progress", while control handover and weapon usage coordination is part of the C2 function "determining roles, responsibilities and relationships". In other words, the tasks trained with the JJTTCP were C2 related tasks.

A scenario was developed that addressed the training objectives. The scenario evolved from peace-time via crisis to war-time and was divided into four vignettes of special interest. The scenario involved enemy and friendly combat aircraft, civilian aircraft, naval frigates, missiles, radar emission, ground based radar, secondary radar and static entities that acted both as targets and assets to protect. The crisis part of the scenario included elements of complex endeavors, e.g. unconventional forces, interaction with civilian authorities, etc. This was partly simulated and partly played out by the instructors and directing staff, who provided realistic input and responses from the civil authorities. The JAOC representative provided responses from the strategic and political level.

3.5 Operational planning: orders and briefs

In order to prepare the operational personnel for the exercise, several orders had to be created. These orders were used as input to the exercise. This included an Air Tasking Order (ATO), an Air Control Order (ACO), and an Operational Tasking for Anti-Air Warfare (OPTASK AAW). In addition, several briefs to prepare the teams for the different scenarios were made. The training instructors at the KNM T and CRC created these orders and briefs. The orders are operational command elements that would normally be created by the JAOC and issued to the CRC and the frigates.

4 The JADE II Joint Tactical Training Capability Prototype (JJTTCP)

The JJTTCP created to enable the teams to train together, was a synthetic environment developed using a tailored process based on the Synthetic Environment Development & Exploitation Process (SEDEP) [20]. A conceptual model of the JJTTCP is given in Figure 2.

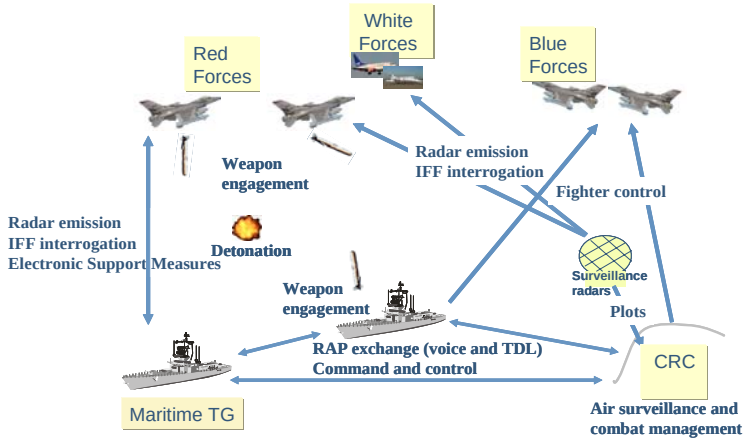

Figure 2: The JJTTCP objects, interactions and relations

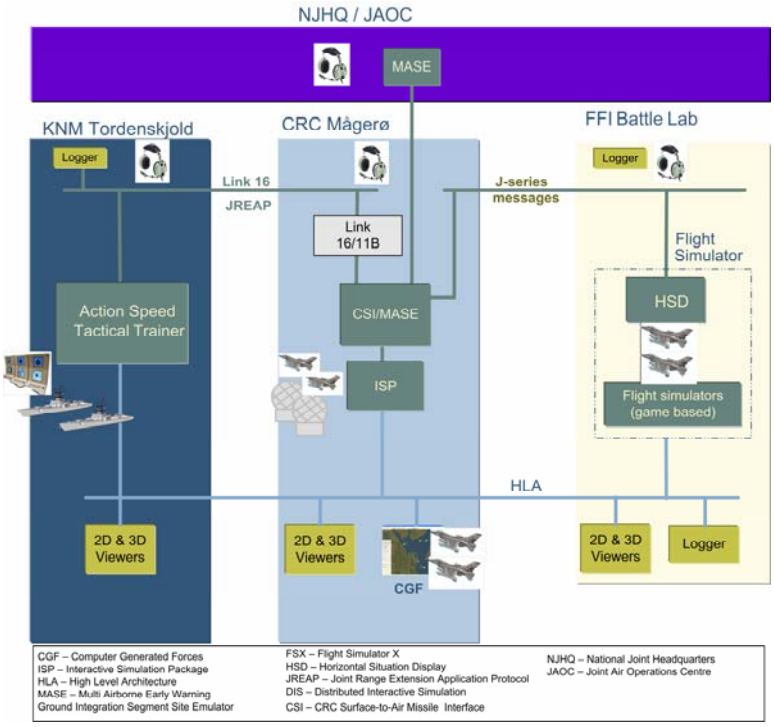

Figure 3: Overview of the JJTTCP

The added functionalities of the JJTTCP compared to the prototype developed for JADE [16] were radar emission and ESM, and the possibility of fighter control from frigates.

The JJTTCP reused much of the technical solutions from JADE [16]. This paper will only describe the JJTTCP briefly, focusing on the new functionality added in order to support JADE II. [21] provides more technical details about the JJTTCP.

The JJTTCP, illustrated in Figure 3, consisted of:

- A simulation system responsible for generating common ground truth for all participants
- a command and control system, a multi tactical data link network
- a voice communication system for the training audience, instructors and the technical support team.
- a secure Wide Area Network (WAN) connecting the sites.

4.1 Simulation system

The simulation backbone of the JJTTCP was based on High Level Architecture (HLA) 1516 [22-25] and Real-time Platform Reference Federation Object Model (RPR FOM) v2.0 draft 17 [26]. In order to integrate non-HLA simulations, gateways towards Distributed Interactive Simulation (DIS) [27;28] and Microsoft® SimConnect® [29] were used.

An embedded training capability of an air control and surveillance system, a dedicated naval training system and game-based desktop combat aircraft simulators were interconnected. A Computer Generated Forces (CGF) component was used to provide simulation of entities not supported by the existing training simulations.

The embedded training capability at the CRC consists of the Interactive Simulation Package (ISP) [30] and the operational system for air surveillance and combat management, Multi Airborne Early Warning Ground Integration Segment Site Emulator (MASE) [31]. ISP interfaces to MASE by stimulating it with simulated radar plots. ISP is developed by the NATO Programming Centre (NPC). ISP simulated all civilian aircraft and ground based radars during JADE II.

Proteus Action Speed Tactical Trainer (ASTT) [32] is a generic naval tactical trainer that can simulate several types of entities, with focus on maritime entities. It is capable of training command teams in tactical decision making processes. The trainer can emulate the consoles of the equipment onboard frigates and some of the other entities it is able to simulate. The ASTT simulates ship movements, weapons, sensors, communication systems and a tactical data link. The ASTT simulated two frigates during JADE II, thus training an AAW organization consisting of two frigate AAW teams. The ASTT is developed by Kongsberg Defence and Aerospace (KDA).

The combat aircraft simulators used in the JJTTCP were based on the commercial game Microsoft Flight Simulator X (FSX) [33]. FSX is simple, with no simulation of sensors, weapons or tactical support functions. In order to use FSX in the federation developed for JADE II, a HLA gateway and a plug-in framework that provided tactical functionality was developed. The functionality added for JADE II was Identification Friend or Foe (IFF) and a Horizontal Situation Display (HSD). The HSD displayed the RAP and necessary air space control means to allow ground based fighter control, and it included navigation functionality. FSX with plugins simulated two friendly combat aircraft during JADE II, training two pilots.

A Commercial Off-the-Shelf (COTS) CGF component was used in the JJTTCP to simulate enemy aircraft and missiles with radar emitters. It was also used to simulate wingmen for the pilots, thus creating 2-ship configurations consisting of one virtual component and one constructive component. Other components like COTS HLA 2D and 3D visualization software and a HLA logger were also part of the JJTTCP.

4.2 Tactical data links (TDLs)

The transfer of tactical data between the sites was implemented using the Joint Range Extension Application Protocol (JREAP). The JJTTCP also utilized a multi-TDL solution encompassing and integrating Link 16, Link 11B and Link 1 systems. The RAP was also distributed to the JAOC representative. The HSD plugin of the desktop combat aircraft simulators displayed the RAP to the pilots.

4.3 Voice communication

The existing voice communication systems at the CRC and KNM T were interconnected by a Voice over IP (VoIP) backbone in the JJTTCP. A channel for tactical voice communication between the CRC and the frigates, and a channel between FCs at the CRC and at KNM T to the pilots were established. A channel for instructor communication and a channel for the technical team monitoring and supervising the experiment were also set up. In addition, the CRC had voice communication with the representative at the JAOC during the exercise.

4.4 Secure network

The three sites and their information systems were connected through a WAN that provided secure data exchange by the use of IP crypto equipment. All data transport, including simulation data exchange, voice communications, tactical data link and video streaming used the established secure WAN. The network had ample bandwidth and low latency between the sites.

5 Experiment execution

The JADE II exercise and experiment was performed October 22-25, 2007. During the three first days seven training sessions took place, where each vignette was run two to three times each. After each run the teams performed local and distributed debriefs. The last day was a demonstration experiment where the training enabled by the JJTTCP was demonstrated to guests. During this day two vignettes were run.

All in all the JADE II amounted to 9 hours of training for about 20 persons. The number of simulated entities was relatively modest, amounting to a maximum of 70 entities.

Figure 4: Images from the training sessions. To the left a pilot operating a desktop combat aircraft simulator, in the middle the operation room at the CRC, and to the right a naval AAW team with an embarked FC.

During the training sessions the teams were able to perform many different types of tasks, matching the training objectives. The tasks trained included:

- fighter control handover
- ESM-reporting

- track correlation
- cooperation on setting identification on tracks
- coordination of threat identification and handling, and
- weapon coordination.

6 Results and Experiences

This section describes the results of the JADE II measurement analysis and the lessons learned from the experiment.

6.1.1 Theoretical tests

There were 16 respondents to each test. The mean score increased by 6 percentage points from the test before the exercise to the test after. Due to the small number of respondents and the large variance in performance, these results are not statistically significant to claim an increase in competency. However, the results indicate that those who scored lowest in the pre-exercise test did much better in the post-exercise test, and they had the greatest benefit theoretically from JADE II.

The theoretical tests were criticized by some of the instructors as not being suitable for measuring training effectiveness, as they felt that the training simulation systems were most suitable to provide practical training, not theoretical knowledge. For the majority of the respondents this seems to be the case, as little or no progress was measured. However, the large improvement in those with a low score in the pre-experiment test is an indication that some theoretical knowledge can be gleaned from the kind of training the JJTTCP provided.

6.1.2 Normative models of procedures

Due to instructor shortage, the normative models were tested against the actual procedures the teams performed in only a few cases. Those observation forms that were completed indicated that the teams conformed well to the normative models, and that this conformance was constant throughout the exercise. Thus, no increase of competency could be proven by these measurements. This result is likely due to the fact that the chosen procedures were too well-known by the teams. In hindsight, the procedures should have been chosen with more care, as the FC handover procedure is a mainly CRC-internal procedure, and ESM-reporting is mainly used by the naval frigate AAW teams. If a procedure that involved both organizations to an equal degree had been chosen, it would have been more relevant as a measurement method. A better procedure to use would be e.g. friendly combat aircraft fly-through of a frigate's Missile Engagement Zone. Such a procedure would involve more interaction between the frigates, the CRC and the combat aircraft.

The use of normative models is a good method for obtaining objective results about how well procedures are being followed by a team, and can be recommended as a

measurement method. Instead of having an instructor complete observation forms during the exercise, the forms can be filled out by e.g. analyzing voice communication recordings after the exercise (if the procedure is a voice procedure), or from logged TDL data (if the procedure is a link procedure).

6.1.3 Questionnaires

The results from the surveys conducted to chart opinions and expectations regarding joint simulation based training and the JJTTCP are given in this section.

The results from the training audience show that most of them were experienced users of stand alone training simulators. The opinions of the respondents on the value of the JJTTCP are summarized in the following:

- The need for live exercises could be reduced. The training audience at the CRC trained on the systems they use on a daily basis. From the CRC viewpoint, the JJTTCP succeeded in involving frigate AAW teams into their training in a way that was minimally different from how it would be in live operations.
- The training audience saw the value in gaining basic skills for operating in a joint environment with a simulator, and thereby being better prepared for live exercises. This has an impact both on the return on live training and the complexity of the live exercises that can be conducted.
- The training audience was unanimously positive in using the system for developing and improving tactics and procedures. The scenarios developed for JADE II demanded knowledge of a wide array of tasks and procedures. When using these, a need to refine some of them was uncovered.
- The training audience felt that the performed tasks were relevant, and the skills trained and learned were transferable to live operations. The pilots saw the value of training the C2 functions of an organization, but indicated that they had less benefit from the exercise. They train regularly on communicating with an FC and have little contact with the rest of the organization. Some pilots indicated that adding a more advanced combat aircraft simulator would increase the sense of realism and thereby getting more benefit from the exercise. However, the feedback from the FCs was that training with real pilots increased the sense of realism in the exercise for them and the rest of the CRC personnel.
- The training audience at the CRC reported that it would be beneficial to include higher echelon entities like a JAOC in the exercise. The naval teams had similar requests.
- The instructors saw a decisive training effect when running the same vignette multiple times and reported observing a more capable organization after the exercise.
- The guests placed an emphasis on using a joint training capability like the one demonstrated in JADE II as a tool for preparing for training with allies and coalition partners, as well as developing new concepts for NEC.

6.1.4 Transactive memory system

[18] presents the results of the transactive memory system study. In summary, the study saw indications that the trust between the participants increased during the exercise.

6.1.5 Technical measurements

The voice recordings were analyzed after the exercise, and some indications of improvements that could be found are e.g.:

- During the first runs the participants would break to Norwegian while talking on the voice communication channels if they encountered situations that were confusing or otherwise foreign to them. There were no breaks to Norwegian after the first day of the exercise, indicating that the trainees became more comfortable with the situation, the equipment and their collaboration partners.
- After a few runs, agreements about how information was to be shared on the voice communication channels were made in the beginning of each run, indicating that the teams mutually became more aware what the team in the other end could provide and what it needed. This could e.g. be agreements that the AAW organization should provide reports about all ESM findings on certain types of tracks.
- During the exercise the structure of the organization was altered to adapt to the situation. More specifically, the AAW organization shifted most of the picture compilation responsibilities to one of the frigates, while the other took most of the responsibility for weapon coordination. These adaptations included new voice communication arrangements, e.g. splitting the tactical coordination channel mentioned in section 4.3 into a surveillance channel and a weapon coordination channel. This and other events that happened during the exercise indicate that the JJTTCP is useful for providing a setting in which to experiment with C2 organizations and procedures.

Due to some technical and operational difficulties described in the following sections the TDL and HLA logs were not analyzed. The difficulties encountered introduced variability in the execution of the training sessions, which meant that the sessions could not be compared to each other in a way that would yield valid results.

6.2 Technical evaluation

The JJTTCP was successful in providing a synthetic environment that enabled joint tactical training for joint air defence purposes. However, some technical problems were experienced. The pros and cons of the JJTTCP are given in this section.

The simulation components were quite stable, and the use of international standards made the integration of these components relatively straightforward. The VoIP solution applied was also stable, and enabled a low-cost and simple method for interconnecting the existing voice systems at the sites. Both of these solutions are flexible and easily extended to add more trainers or other components.

In a couple of runs simulation components failed due to software errors. Fallouts of the voice communication between the CRC and the ASTT also occurred. The tactical data link system established contained a limitation that excluded the use of some ID categories, forcing the teams to adjust their procedures somewhat. Although these errors were undesirable, they were not severe. Some of the errors that were experienced also occur in the real world (e.g. voice communication fallouts), meaning that the teams should be used to handling such errors.

With regards to the network, there are a number of issues that have to be overcome when coupling classified stand-alone simulators at geographically distributed locations. Most of these are time consuming and have to be planned at the very beginning of an experiment if not to become showstoppers. Interconnecting data networks has to be done with confidentiality, integrity and availability of the information systems in mind. The proper permissions must also be in place before information can cross the system boundaries. In addition, getting the network to function technically in a satisfactory manner can be quite time-consuming and can interfere with other integration tasks.

6.3 Threats to the JADE II experiment

The GUIDex [34] describes 21 threats to the validity of an experiment. The initial phases of JADE II included planning to avoid these threats. After the experiment, the threats were revisited to see which had not been fully eliminated. Those identified are given in Table 1.

GUIDEX threats	**Explanation**
1: Capability variability, 8: Trial conditions variability, 11: Capability changes over time	The JJTTCP was not stable enough to fully eliminate these threats. The technical problems introduced variability in the training capability between runs and during runs.
9: Low statistical power	The size of the organizations trained was not sufficient to obtain statistically significant results.
12: Player changes over time	There were personnel changes in the teams during the exercise.

Table 1: GUIDex threats that were not fully eliminated in the JADE II experiment

6.4 Lessons learned

A series of lessons were learned during the JADE II experiment, these are summarized in the following.

- JADE II suffered from not having enough technical and scientific personnel available. This had many consequences, the main one being that there was little room for separation of concerns. The team responsible for the technical development of the JJTTCP was also responsible for developing scenarios, administering the exercise, collecting measurements and analyzing the collected

data. Although this had some ill effects, it did give the technical/scientific team a comprehensive view of all aspects of the experiment.

- The operational teams assigned to JADE II changed over time and it was difficult to get personnel to commit to the exercise. By including the event as a regular synthetic exercise in the training schedule of the participating units, assignment of personnel to the exercise would become easier and more predictable.

- The integration tests were mainly performed with technical personnel manning the equipment. This led to several errors not being discovered until the actual experiment week with full manning by operational teams. Integration tests should be performed using as close to full teams as possible, and running through all scenarios that would be run during the actual exercise. Again, getting hold of the personnel to test the system can be difficult.

- Establishing and maintaining a fault-free secure network that could support the exercise was time-consuming, and errors in the network postponed and prolonged testing.

7 Conclusion

JADE II was an experimental synthetic exercise in joint air defense involving a CRC team, an AAW organization consisting of two frigate AAW teams and two combat aircraft pilots. Geographically distributed training simulation systems were interconnected to create a synthetic training environment called the JJTTCP, which enabled joint tactical training of air-maritime coordination and cooperation.

Several measurements were devised to test the hypothesis that use of the training concept of JADE II improved the competency of the teams trained. Although none of the objective measurements could be used to conclude that an increased level of competency was reached during the exercise, most measurements indicated development in the positive direction, and no measurements indicated a negative effect. The subjective measurements were positive, as the teams themselves reported much improvement in their own competency, and the instructors also reported to have observed a general improvement in the execution of different procedures.

An important point to make is that the training audience evaluated the involvement of other teams as a positive and valuable addition to their training simulation, which gave an increased sense of reality and relevance of the training. By making simulators interoperate, which has a relatively small implementation cost, the value of the resulting training simulation is increased in comparison with training stand-alone. Not just by adding new functionality to the trainer, but also by increasing the realism and relevance, and building trust between teams.

Even if an increase in competency could not be shown by this experiment, it is clear that a distributed simulation based joint training capability like the one demonstrated in JADE II can be a valuable supplement to live exercises. It can provide teams with a basic

understanding of the network enabled concepts of their domain, and prepare teams better for live training. It provides an environment in which to experiment with C2 organizations and concepts, which will teach the teams involved how to adapt to new situations and utilize each other. For obtaining joint tactical training in the quantities needed, distributed simulation based training seems the most viable, if not the only realistic solution.

7.1 Future work

The JJTTCP can be extended with new trainers and functionality that will add new elements to the training capability. E.g. by adapting and connecting an Army tactical trainer to the JJTTCP fully joint training would be possible. The operational level could also be introduced as part of the training audience by including the C2 systems of this level. This would involve a larger part of the C2 organizations and add operational C2 to the exercise. Naturally, such expansions would also add new possibilities for experimenting with C2 organizations and systems. A third expansion is to add interfaces to non-military organizations. A fourth would be inclusion of the JJTTCP in similar coalition synthetic exercises, to add the complexities of cooperating in a coalition organization. These expansions would be steps towards simulation based training of C2 for complex endeavors.

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