JADE – An Experiment in Distributed Simulation Based Joint Tactical Training

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ABSTRACT

JADE, or Joint Air Defence Training Simulation, was an experiment conducted in Norway in March 2006 to explore whether connecting existing training simulators and operational systems is a suitable tool for joint tactical training. The embedded training capability of a Control and Reporting Centre, a naval tactical trainer and game-based fighter simulators located at three different sites were connected over a secure wide area network. Additionally, JADE was a test case for a simulation infrastructure in support of training and experimentation developed by FFI. An overview of the joint tactical training prototype capability established for JADE is given. It consists of three main parts; a distributed simulation system, a command and control system and tactical data links, and a voice communication system. A brief outline of the experimental training event is given, and both operational and technical experiences are discussed.

1.0 INTRODUCTION

This paper presents a concept development and experimentation (CD&E) activity which was performed in Norway in March 2006. The CD&E activity was an experiment in distributed simulation based joint tactical training, where adapted and interconnected existing simulations and operational systems were employed. The objective of the experiment was to explore the possibility to utilize legacy simulations for joint tactical training.

The experiment was called JADE, short for Joint Air Defence Training Simulation and involved virtual simulators, constructive and embedded simulations, a command and control system, tactical data links (TDLs), a commercial game and support tools such as visualization and simulation management. Three sites were involved; Control and Reporting Centre (CRC) at Mågerø, Royal Norwegian Navy Training Establishment KNM Tordenskjold at Haakonsvern and FFI Battle Lab at Kjeller. The locations of these sites are shown in Figure 1. The experimental training event involved a CRC, three frigates and fighter aircraft, and covered joint recognized air picture production, air-sea procedures and fighter control. Although simulators within the same functional area have been linked, JADE was the first joint training event in Norway based on distributed simulation. JADE was performed by FFI project SIMUTREX (Simulation technology for training and experimentation).

The objectives of the paper are to give the background and motivation for the experiment, give an introduction to the prototype capability which was developed for JADE and discuss operational and technical experiences. The results of JADE indicate promising operational benefits by networking legacy simulators and real systems to achieve a joint tactical training capability. However, the prototype training system was technically fairly complex because of the constraints posed by the legacy systems. E.g. several bridges and mappings were necessary both within the simulation system and for the various TDLs involved.

The rest of the paper is organized as follows. Section 2.0 gives the background and motivation for the work reported in this paper. Section 3.0 gives an overview of the prototype capability which was developed for the experiment. Before the experiences, both operational and technical are discussed in section 5.0, a brief outline of the experimental training session is given in section 4.0. The paper ends with some concluding remarks.
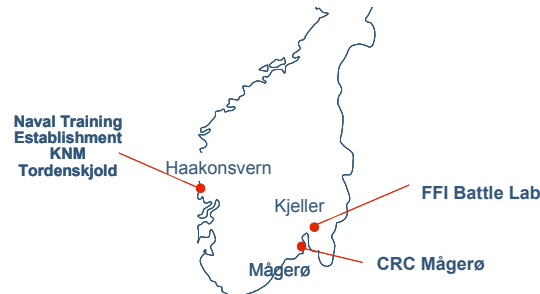
Figure 1: The locations of the three sites of JADE.

2.0 BACKGROUND AND MOTIVATION

The need for collective and joint training is increasing as a result of the transformation to a network based defence (NBD) - the Norwegian term for network enabled capability [1]. The operational concept of NBD calls for training across former traditional organizational borders. A simulation based NBD training capability is lacking, but a first step towards such a capability could be to federate (some of) the legacy stand alone, often platform oriented training simulators if technically feasible. Technical feasibility in this respect includes both whether the simulators can be adapted and interconnected, and whether the simulations are semantically compatible. From a technical viewpoint JADE was an experiment to investigate the feasibility of such an approach.

Another step in the direction to accomplish a simulation based joint tactical training capability would be to establish a simulation infrastructure which future training simulations should adhere to. Additionally, simulations for a force structure element should provide functions necessary to take part in a joint simulation. In this way future simulation could both fulfil the needs of simulation based training for a specific force component and also be part of an NBD training capability. Project SIMUTREX has defined an architecture for a simulation infrastructure to enable distributed joint training and experimentation. JADE employed a preliminary version of an infrastructure according to this architecture. Thus, JADE provided a test case for the infrastructure.

In the same way as a simulation infrastructure is important to achieve a simulation based joint/NBD training capability, a similar infrastructure is key to achieve cost-effective simulation based military experimentation. Experiments which employ human-in-the-loop simulations have a number of commonalities with simulations based joint tactical/NBD training. Although the objectives of an (simulation based) experiment and a training session are quite different, the tools which are employed have a lot in common. Thus, a common (with some variations) simulation infrastructure architecture to accommodate both support of experimentation and joint/NBD training should be defined. As mentioned above FFI project SIMUTREX has been working to define such a simulation infrastructure architecture.

The architecture is defined by a run-time architecture including services, component types and standardized data models. The run-time architecture is based on the High Level Architecture (HLA) [2]. Additionally, a development process based on the Synthetic Development and Exploitation Process (SEDEP) [3] with supporting tool types has been defined. This development process is utilized to develop

a specific federation to support either an experiment or a joint training capability. The architecture is based on the use of open international standards and provides basic services for distributed simulation and component types such as middleware, gateways, 2D/3D visualization, simulation management, loggers and computer generated forces.

Implementation of the infrastructure relies heavily on the use of COTS. Specific simulations are not considered as part of the simulation infrastructure itself. As specific components are shown to comply with the infrastructure architecture, they add to the list of available components which could be exploited for a specific experiment or be part of a specific joint training capability. Thus, we envision an evolving and expanding ability to support greater varieties of experiments and joint training needs.

It is outside the scope of this paper to address the infrastructure in detail. The main role of the infrastructure in JADE was simulation management, to provide the interconnection between the different components, data logging and basic 2D/3D visualization. This preliminary version of the infrastructure is described below as part of the prototype capability developed for JADE.

3.0   JOINT TACTICAL TRANING PROTOTYPE CAPABILITY

The prototype of the joint tactical training capability consisted of systems located at the three sites mentioned earlier. Specifically, a naval tactical trainer at Haakonsvern, the embedded training capability at Mågerø and two game-based fighter aircraft simulators at Kjeller. Figure 2 gives an overview of the synthetic environment used in JADE. The synthetic environment consisted of the following three parts:

• A simulation system responsible for generating common ground truth for all participants,

• a command and control system, a TDL network and

• a voice communication system for the training audience, instructors and the technical support team.

In addition, a secure Wide Area Network (WAN) had to be established between the sites.

The instructor support in JADE was based on the functionality already available in the systems that were interconnected. Additional instructor support was limited to providing plan view displays, and establishing a dedicated voice communication channel for coordination.

The technical support team used several tools to monitor and control different aspects of the system including the network, the simulation components and the TDLs. A voice channel and chat were used for communication within the technical team.

3.1   Simulation system

Enabling simulation interoperability may involve bridging several types of middleware, translating between different data models and ensuring that environment databases are consistent. The simulation backbone in JADE was based on HLA 1.3 [4] and Real Time Platform Reference Federation Object Model (RPR FOM) v. 1.0 [5]. In order to integrate non-HLA simulations, there were gateways towards Distributed Interactive Simulation (DIS) [6] and Microsoft® DirectPlay®.

The systems interconnected during JADE had different characteristics; an embedded training capability of an air control and surveillance system, a dedicated training system and a commercial game.
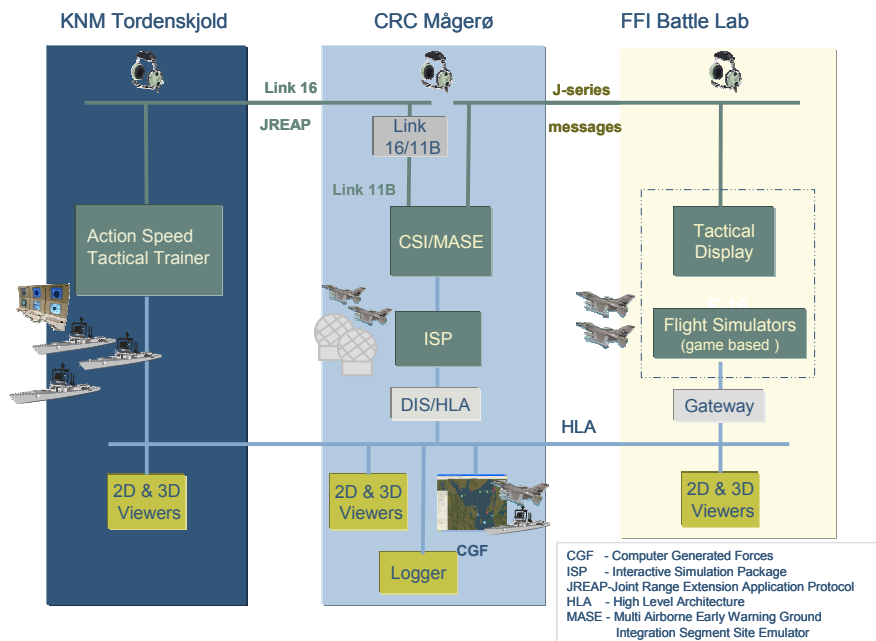
Figure 2: JADE synthetic environment

The embedded training capability at CRC Mågerø is comprised of the Interactive Simulation Package (ISP) and the operational system for air control and surveillance, Multi Airborne Early Warning Ground Integration Segment Site Emulator (MASE) [7]. ISP [8] stimulates MASE with simulated radar plots, and is capable of simulating large and complex air scenarios. In JADE, ISP was responsible for simulating all computer generated aircraft, threat missiles and ground based surveillance radars. ISP has a DIS interface in order to exchange simulation data between ISPs or with other simulation components. ISP is developed by the NATO Programming Centre (NPC) in Belgium.

Proteus - Action Speed Tactical Trainer [9] is a generic naval trainer capable of training command teams in tactical decision making processes. Proteus was used in JADE to train the anti-air warfare organisation onboard three frigates, simulating ship movement, sensors, weapons, communication systems and TDLs. Due to the experiment the existing Proteus HLA interface was adapted to support HLA 1.3 and a subset of RPR FOM v. 1.0. Proteus is developed by Kongsberg Defence and Aerospace (KDA).

In order to explore the potential of simple game-based fighter aircraft flight simulators, two simulators based on Microsoft Flight Simulator 2004 (FS-2004) [10] with the FS Falcon add-on [11] were set up at FFI Battle Lab. The FS-2004 multi-player option is based on Microsoft® DirectPlay®, thus a dedicated gateway [12] was to exchange data with the HLA run-time infrastructure.

3.2   Tactical data links

One important aspect of the joint training prototype capability was to provide training for establishing a common recognized air picture based on both land based sensors and surveillance sensors onboard naval vessels. This was accomplished by a TDL network.

The transfer of tactical data between sites was based on transmitting J-series messages according to the Joint Range Extension (JRE). JRE is a concept for sending tactical data over distances beyond the coverage of radio networks, e.g. connecting two Link 16 networks. JRE Application Protocol (JREAP) [13] defines a protocol for exchanging tactical data over digital media and networks not developed for

tactical data transmission, including common Internet transport protocols (TCP/UDP unicast and multicast).

For the modifications of existing systems to be minimized, the TDL network implemented in JADE had to rely upon existing TDL systems. Another requirement was that the TDL network should use the secure WAN for the experiment. A data link processor capable of interfacing and translating between several different TDL standards was used to interconnect the systems at each site [14]. At the CRC the CRC Link 11B Surface-to-Air Missile (SAM) Interface (CSI) was used. In the case of the naval trainer the existing simulated data link was connected to the TDL network using a gateway. The tactical picture available at the CRC was disseminated to the flight simulators, and made available to the pilots by a stand alone system.

Figure 3 shows the operational architecture of the implemented solution.
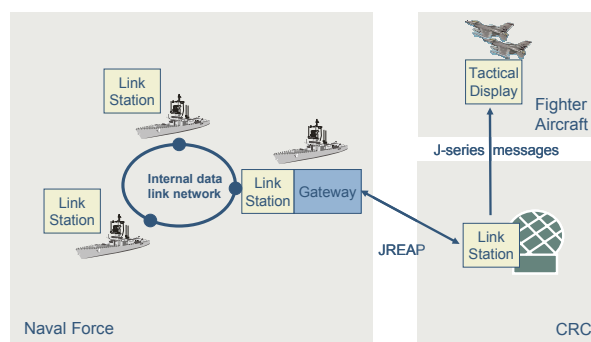
Figure 3: TDL operational architecture of JADE

3.3   Voice communication system

The experiment depended upon a reliable and seamless voice communications system. Voice communication was used between the trainees, between instructors and within the technical support team. It was desirable to use the same technical solution for all users. The approach was to build a common backbone based on voice-over-IP (VoIP) using IP multicast. The use of multicast made the voice communication system flexible, scalable and also made it easy to monitor the different channels. The VoIP solution was based on Robust Audio Tool (RAT) [15]. RAT is a simple freeware application for transferring voice between a set of computers using IP multicast.

As for the TDL, one of the challenges in establishing the voice communication system was to develop an integrated system with no or minor modifications to existing systems. The simulated voice communication system, both intercom and radio, in the naval trainer is based upon VoIP. At the CRC the operational voice communication system was interfaced to the VoIP backbone.

In addition to the use of intercom within the CRC and the naval trainer, four logical communication channels were set up for the experiment:

- A channel for tactical coordination between the CRC and the naval force. This channel was used for air threat warning reports, engagement coordination and for coordinating picture production. Coordination between the pilots and the naval force was done through the CRC.

- A channel between the CRC and the pilots for fighter control.

- A channel for inter-site coordination between instructors at the CRC and the naval trainer.

• A channel for the technical team monitoring and supervising the experiment.

Figure 4 gives an overview over the voice communication system.
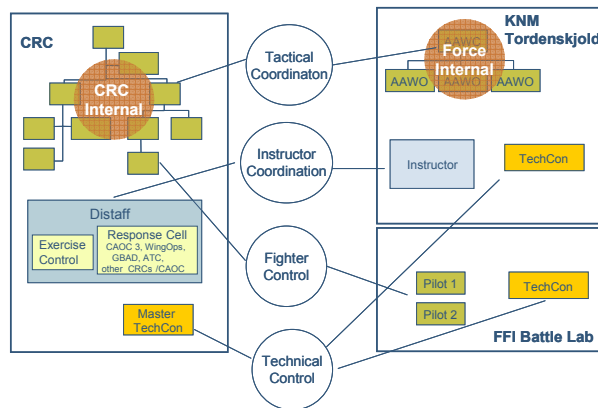
Figure 4: Voice communication system of JADE

3.4 Secure network

JADE relied upon one WAN connecting all three sites. This network was used for all data transport: simulation data exchange, voice communication, tactical data link, video streaming, etc.

The WAN provided secure data exchange by the use of IP crypto equipment [16]. The network established had limited throughput, both due to the use of crypto equipment and limited available bandwidth between the sites. Multicast support between sites was thus highly desirable for both scalability and flexibility. This enables best effort multicast transport of federate attributes with frequent updates (e.g. kinematics) possible. In our case this reduced bandwidth usage due to data loggers and 2D/3D viewers.

In order to get multicast support, dedicated Generic Routing Encapsulation tunnels were set up between the sites.

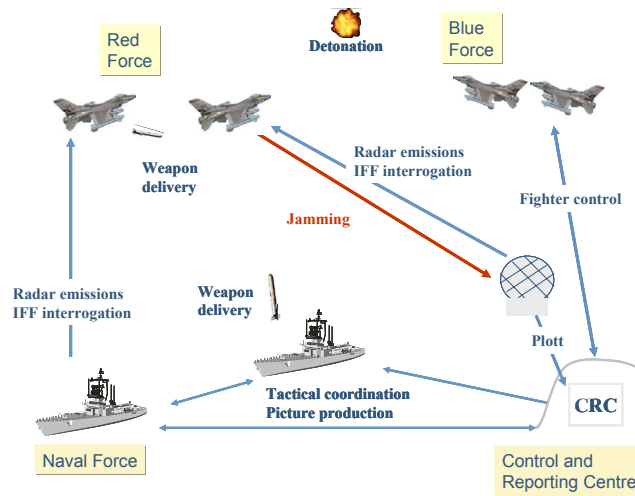## 4.0 THE EXPERIMENTAL TRAINING EVENT

The Code of Best Practice for Experimentation [17] distinguishes between three different types of experiments: discovery, hypothesis and demonstration experiments. JADE was a discovery experiment. It was performed to explore potential benefits and generate hypotheses to be investigated in experiments to follow. However, the general issue to be explored in JADE was whether *connecting current training simulators and operational systems can be a suitable tool for joint tactical training*. The training effectiveness of such a tool was however not examined. Thus, the focus of JADE was the prototype capability and on the technical feasibility of establishing the capability with relation to cost and complexity.

As indicated earlier, JADE also provided a test case for the architecture and a preliminary implementation of the simulation infrastructure for training and experimentation developed by FFI. Lastly, it was hoped that JADE could give some indication of the possibility of utilizing existing trainers as assets for NBD CD&E activities.

The JADE scenario was based on the scenario used in the NATO synthetic air exercise (SYNAX) Bold Axis 05. For JADE this scenario was adapted and extended to include maritime components. The Bold

Axis 05 scenario consists of a large number of air entities. In Figure 5 the main objects simulated in JADE are depicted. Additionally, the main relations and interactions between these objects are shown.

Figure 5: Conceptual model of the simulation of JADE

The performance of JADE itself consisted of three parts:

- A common distributed brief
- The experimental training session
- Local debriefs/after action review

A common distributed brief was accomplished by streaming video between the three sites. The experimental training session lasted for about three hours.

The main measurement method of JADE was questionnaires which provided subjective views from the three groups involved in JADE, namely the training audience, the instructors and the observers. There was a different questionnaire for each group. The main sections of the questionnaires covered personal background information, the concept of simulation based distributed training, potential benefits of JADE, and the prototype capability. About 50 responses were collected evenly spread between the sites. 90% of those who responded had either a naval and/or air warfare background.

5.0 EXPERIENCES

Even though measuring training effectiveness was outside the scope of JADE, useful opinions were collected from users, instructors and observers. Below some of the main issues raised in the questionnaires are discussed. Section 5.2 discusses technical experiences.

5.1 Operational experiences

The general opinion of the concept was positive, both with respect to joint tactical training and for development of tactics and procedures. There was also a strong belief that a capability as demonstrated in JADE would be a useful tool in the development of NBD. The assertion that a simulation based joint training capability could reduce the amount of live exercises was however more favoured by the respondents at the CRC than at the naval training establishment. This might be related to the fact that the personnel at the CRC conducted the training in their day to day working environment.

The simulations employed in JADE were not developed for integration with other systems. The models had some differences in fidelity, e.g. in the area of weapon and engagement modelling. This did not pose a problem during the training event, and no particular demand for better models of weapons, sensors and voice communication was reported. However, the importance of proper IFF models and functional TDLs were emphasized.

All three groups, users, instructors and observers, believed that a future joint training capability should include additional units and platforms. These included other CRCs and units at higher echelons like combined air operations centres, maritime operations centres and maritime tactical commands. At lower echelons Forward Air Controllers, SAM operations centre and naval helicopters were favoured.

Simple game-based flight simulators were set up in order to investigate whether they could be useful for training fighter control. The game-based flight simulators did not offer an integrated solution to the pilots; having avionics and the tactical picture on different systems made it difficult for the pilots to understand the tactical situation. The lack of a simulated IFF transponder as part of the flight simulator made the task of fighter control hard when the tactical picture became cluttered. The fighter controllers however valued interacting with pilots in stead of distaff, which normally fulfils this role during CRC training events.

5.2 Technical experience

The prototype used in JADE was fairly complex, but was developed during six months by a small team with limited financial resources. From a technical point of view there were several issues that should be investigated further.

Limited bandwidth between sites caused some minor problems during the training event, e.g. occasional network saturation caused loss of simulation attribute updates. Using a single network for all data transport, i.e. simulation data exchange, voice communications and TDLs, is desirable due to flexibility and network configuration management. It does however make it more difficult to prioritise certain types of data exchange.

The TDL system established was complex. It involved several subsystems and needed careful testing and configuration. The use of real TDL equipment also makes it more difficult to relate the tactical picture with simulated data for post experiment analysis. The option of using simulated data links, i.e. the Link 16 Base Object Model (BOM) [18], should be investigated.

The use of VoIP multicast for voice communication between sites was successful. The solution proved robust, scalable and flexible, and no noticeable reduction of voice quality was observed even during network saturation. The solution employed may however be hard to maintain when the number of networks and users increases due to cumbersome configuration and the lack of monitoring tools.

Prior to the experiment a lot of time and resources went into establishing a secure network. The establishment of a permanent secure network between major sites is a prerequisite for cost-effective employment of capabilities as presented in JADE. Distributed simulation technology makes it possible to rapidly adapt existing systems to include new participants, making the establishment of networks a limiting time factor.

6.0   CONCLUSION

This paper has described JADE, a CD&E activity on the feasibility of utilising legacy simulations for joint tactical training. An experiment was conducted as a distributed training event in the joint air defence domain. JADE was a discovery experiment and the main measurement method was questionnaires providing subjective views from the parties involved.

The general opinion of the concept of interconnecting existing training systems was positive. Currently in Norway, joint air defence training involving naval and land based units is only available through live

exercises. A capability as demonstrated in JADE will increase access to such training in addition to serve as a tool for tactics and procedures development. There was also a strong belief among the participants that such a capability could play an important role in order to develop NBD concepts within the domain.

A simulation infrastructure for training and experimentation was used for connecting the existing systems and to provide basic services for distributed simulation. The use of such an infrastructure based on open standards shows promise in developing an evolving capability in the area of both joint training and experimentation. The infrastructure furthermore made it possible to establish the prototype capability for JADE with limited human and financial resources.

7.0 ACKNOWLEDGEMENTS

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