Achieving Interoperability through an Information Management Architecture

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Abstract

An information architecture has been conceptualised and demonstrated, to manage and deliver the information necessary for the development of Situation Awareness at all levels of the Command hierarchy in the tactical Land environment. The concept (dubbed the 'infospace') not only achieves the goal of sharing information at the tactical level but also is extendible to provide interoperability through information sharing, between different user applications, to Joint and other echelon elements and even to coalition partners. The system level architecture is based on modern database technologies and the use of well defined client-, server- and middle-tier interfaces to facilitate connection to client applications. Technical level concept demonstrations of the architecture have been produced for several specific military applications including the integration of an Armed Reconnaissance Helicopter into the broader Land Command, Control, Communications, Intelligence, Surveillance and Reconnaissance (C4ISR) system.

1. Introduction

Fundamental to the goal of delivering the requisite understanding of the battlespace to all levels of decision-makers in the Land Force, is the concept of a common shared pool of information, which we have called the virtual information space or 'infospace'. Under this concept, various users can access the 'infospace' to retrieve information and to deposit new or processed information. When such access is available irrespective of the application being used, then interoperability among users is achieved by information sharing rather than direct compatibility of applications.

To support this concept, an Information and Dissemination Architecture (IMDA) has been developed with the requirement that all the information necessary to produce the knowledge required by decision-makers must be made available to them in a timely manner. It is assumed that the decision-makers will be using digitised Situation Awareness (SA) systems, which provide battlespace visualisation, information fusion, and decision support and planning tools. Each user of the SA system will have a particular set of tools for his/her specific task but it is essential that all work with the same basic information.

Another feature of the IMDA is the ability to control the distribution of information. Concepts of 'smart push' and 'user pull' can be readily implemented to tailor information delivery to

individual users. The architecture also easily allows for distributed information fusion, prior to transmission to the user, in order to conserve usually limited transmission bandwidth.

The Land Operations Division (LOD) implementation of the IMDA is known as the Information Management Engine (IME). Different versions of the IME have been used in several demonstrations of the infospace concept through work on the Land C4ISR system over the past two years. The concept demonstrations (described in more detail below) have shown how the architecture can:-

- enable the shared Situation Awareness essential to achieve collaborative planning and decision making; team work in reconnaissance and engagement missions sensor to actor and network centric warfare paradigms;
- achieve interoperability between users of different SA or Command Support Systems (CSS). Users could be at different echelons or in different services or partners in a coalition operation;
- provide a mechanism for integration of a variety of information sources – including raw information sources (real or simulated), and end-user applications (including Geographic Information System (GIS) based visualisation, information fusion algorithms, Order of Battle (ORBAT) repositories and Intelligent Agent based decision support tools).

2. Description of the 'infospace' Concept

Conceptually, the infospace represents a large pool of information and knowledge, from which applications can draw and, in turn, to which they may add. This idea is similar to the traditional federated information systems approach, which assumes the existence of a single consistent global definition of reality. However, in practice such consistency is unobtainable unless using a completely centralised system. Fortunately it is recognised that different parts of a large complex information system will not require the same information all of the time. As a result, requirement for complete consistency between all the information in the infospace may be relaxed under certain circumstances.

Some updates in the information stored in the database will be time-phased through the various command levels, giving priority to the immediate user. Latency in updates under urgent demands can have a detrimental effect on operations, however the latency can be minimised by employing triggered notifications with low bandwidth requirements. Redundancy of information can also be managed across a distributed database structure, while maintaining (as far as practical) the appearance of a centralised database.

Among the components forming the infospace are some that provide database services; these database systems themselves may be centralised or distributed depending upon particular application requirements. Because they implement rigorous transaction semantics, these databases make available to other components robust information collection and dissemination abilities in an environment of inherently and notoriously unreliable communications.

Services required by both sources and consumers of information are facilitated by components hidden behind various kinds of object interface definitions, with the interconnections between clients and servers provided by a backbone of middleware support. In both its design and

implementation, this overall scheme is deliberately consistent with the DSTO EXC3ITE architecture [EXC3ITE 2000]. The overall design is thus characterised by well-defined and standardised interfaces between system components, and explicit provision for future enhancement and alteration.

Different interpretations of the distributed component paradigm, various distributed object standards, as well as older connection mechanisms, may be represented. That is, various parts of the system can be constructed using different middleware platforms, such as Sun Microsystems's Jini™ [Edwards, 1999] and Object Management Group's (OMG) CORBA [Pope, 1998] [OMG, 1999]. Simulations may be built around DIS or according to the newer HLA standard [Seymour *et al*., 2000]. Older legacy systems may expect to communicate using a formatted message language such as OTH-T Gold or ADFORMS [USN, 1996]. In addition, separate domains using the same middleware platform may also be present.

The interconnection of components built around distinct object standards or operating in different object domains is achieved by constructing suitable bridges to relate distinct domains to one another. Legacy systems using older connection technologies can be encapsulated behind more appropriate object interfaces. In fact, these possibilities are intimately related, because the fundamental problem of mapping between different information structures is the same in both cases [Reid, 2000].

Local systems, which might include platforms such as Armed Reconnaissance Helicopters (ARH) and Light Armoured Vehicles (LAV) as well as Company Headquarters, may collect information and store it in local database systems. Some of this information might also be pushed through a bridge and into the broader information system, from where other users can access it. Alternatively, users may access remote information through a pull mechanism, in which they explicitly express their requirements and await their responses [Reid, 2000]. Figure 1 (overleaf) shows a schematic of the concept.

3. Shared Situation Awareness

The main objective of a situation awareness system is the provision of information in the form required and in a manner optimised for assimilation by the decision-makers. Underpinning this must be a well designed IMDA. The information management and dissemination technology used in the recent US Task Force XXI advanced war fighting experiment was found to be the key enabler in providing intelligently presented multimedia data to the tactical operations centres [Orr and Bhatt, 1998].

The design of the IME reported [Kirby et al., 2000] builds on the concept of a virtual information space that was implicit in the old US Battlefield Awareness and Data Dissemination system [Orr and Bhatt, 1998]. LOD has further developed this concept, which has undergone testing at several exercises have been conducted over the past two years involving Synthetic Environments (SE) [Seymour *et al.*, 2000]. Various versions of the IME have been demonstrated at Exercises Phoenix, Roving Ranger and New Talon, which were centred around the ARH capability development. The IME was also important in Operation Loki and Exercise Hydradrive, where the effect of command support systems on the operations of a battle group was examined.

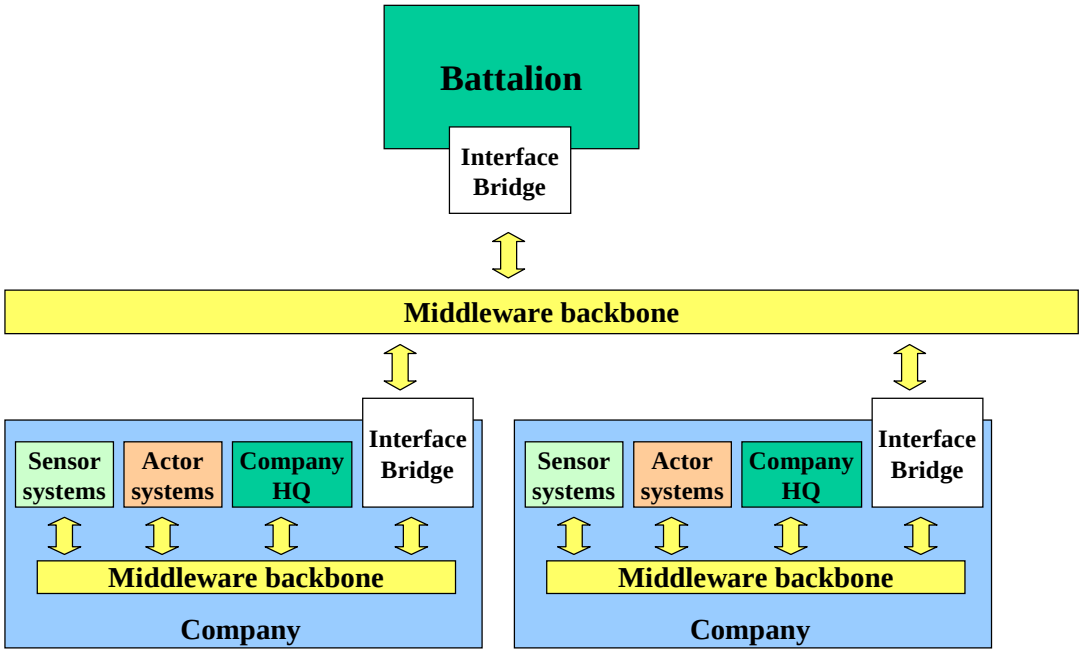

Figure 1: Use of middleware for interoperability

The aims of involving the IME in these demonstrations were to show the following:

- how an increased overall effectiveness of military operations can result from decisions enabled by improved SA (made possible by the IMDA);
- that the architecture designed to support operational needs for better SA can also provide the stimulus (synthesised information) to the 'infospace' as though they were real-world information sources;
- to give insights into ways of achieving teaming in reconnaissance and engagement missions, and illustrations of sensor – actor concepts.

3.1 Exercise Phoenix

A demonstration was fielded during Exercise Phoenix in September 1998 to support army development of operating procedures for an Armed Reconnaissance Helicopter (ARH). The aims of the demonstration were to:

- raise the user awareness of new concepts and potential of SA tools;
- aid the Task Force in developing operating procedures for tasking and conducting missions;
- obtain feedback from users on the utility of SA and priorities for further R&D.

The demonstration was carried out using Distributed Interactive Simulation (DIS). ModSAF was used for constructive simulation forces of forces. Two virtual ARH mission simulators were also part of the DIS network. [Matthews *et al.*, 2000] was used to extract entity positions from DIS and forward them on to other systems.

Situation awareness was provided in the ARH cockpits using a product called Carmen (developed by Maptek). Situation awareness was also provided at the Battalion and Brigade headquarters. Carmen was used for the HQs, in addition to a MapInfo-based product produced by Exa-Min.

The exercise called for consistent depictions of enemy and own force positions across all systems, collaborative planning between remote locations, mission rehearsal, mission monitoring, and the ability to re-task mid mission [Seymour *et al.* 1998]. The IME was the glue that provided the interfaces and interoperability between the visual systems and DICE.

3.2 Exercise Roving Ranger

Roving Ranger was the first Army Exercise to be carried out within the DSTO laboratories. It was conducted jointly by the Army and LOD in March 1999 and involved three 1 Aviation Regiment Iroquois gunship crews, their logistics support, and two ARH mission simulators. The primary aim of the exercise was to examine data collection and analysis methodologies.

As with Exercise Phoenix, situation awareness was provided to the ARH cockpits and the headquarters using Carmen (MapInfo was not used for this exercise). Use of DICE was also abandonded in favour of a new Java process that read the DIS traffic directly. The IME was required to interface the visual components to each other and to this Java process.

3.3 Exercise New Talon

Exercise New Talon was conducted in September 1999, with a focus on specific operations requiring aviation support. It was designed as a follow-up exercise for Roving Ranger, and as such the requirements for information dissemination were very similar to those for Roving Ranger. Again underpinning the need for shared SA was the requirement for a suitable IME.

3.4 Operation Loki

Operation Loki was another Army exercise conducted within DSTO laboratories. It was conducted in August 1999, and used the Janus wargame instead of DIS. DICE was used as an intermediate interface between Janus and BCSS. One of the prime focuses of the operation was to test the effectiveness of the Collection Plan Management System (CPMS) [Haub et al., 2000]. As such the IME was required to interface between the CPMS engine and its accompanying visualisation packages (built by Exa-Min using MapInfo), as well as interfacing to Janus (via DICE).

3.5 Exercise Hydradrive

Exercise Hydradrive was conducted in November 1999 as a follow-up to Operation Loki. ModSAF was used instead of Janus as the stimulus, though CPMS was still a major focus. The IME was again required to interface between these applications and data sources.

4. Interoperability

An approach based on the 'infospace' concept has been proposed for achieving interoperability between coalition partners [Seymour, 1999] [Reid, 2000]. In this proposal information from different national partners is fed directly to a version of the IME through appropriate interfaces. The various national SA systems can then access all of this data via the IME without necessarily knowing which nation had collected it. Knowledge (the result of cognitive processes acting on data) sharing could also occur via the IME given appropriate knowledge representation schemata [Reid, 2000]. A schematic of this proposed architecture is given in Figure 2.

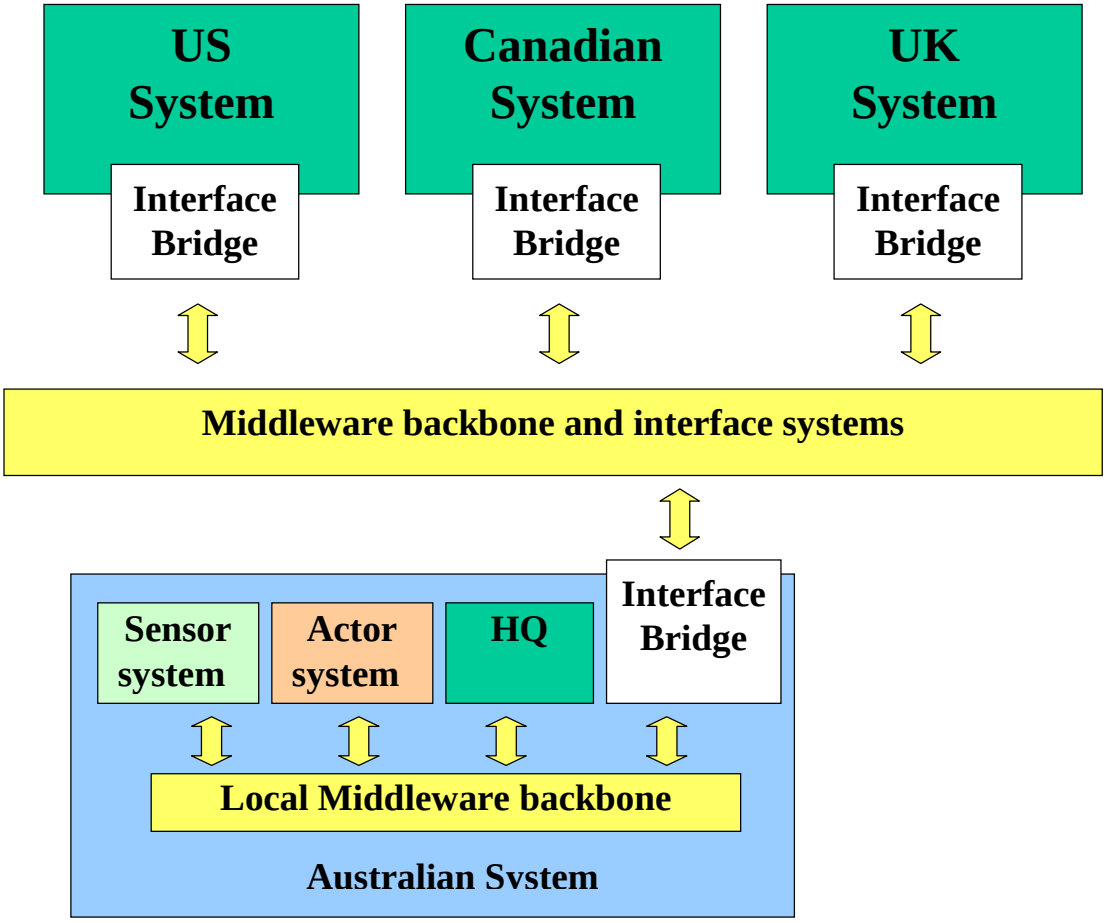

Figure 2: Interoperability between coalition forces.

In addition, technology has been developed [Reid, 2000] to provide a broadly applicable and open solution to problems of achieving interoperability between different systems displaying a host of varied requirements. This approach separates the fundamental issues of semantic differences from those relating to the way in which information is packaged up and conveyed; the results of an analysis of the semantic requirements of different systems are automatically interpreted to produce the desired effect. Individual bridges to different systems operate within a layer providing translators, parsers, composers and other supporting services, all of which interact through a distributed object middleware platform. This open architecture approach

provides an extensible and scalable framework for achieving interoperability between a multitude of dissimilar situational awareness support systems.

5. Integration of Applications

5.1 Types of Interface Available for the IME.

The IME in both its current and previous incarnations consists fundamentally of an SQL database, implemented using Oracle 8i. The principal differences between the two is in the internal table structure of the database itself, which has been extended to provide greater functionality and improved interoperability with other systems. There are many ways to interface to these IMEs (see Figure 3), and the main different types of interface are described in the following sections. Note that this list is by no means limiting – if interoperability requirements demand it, other interfaces can be designed as necessary.

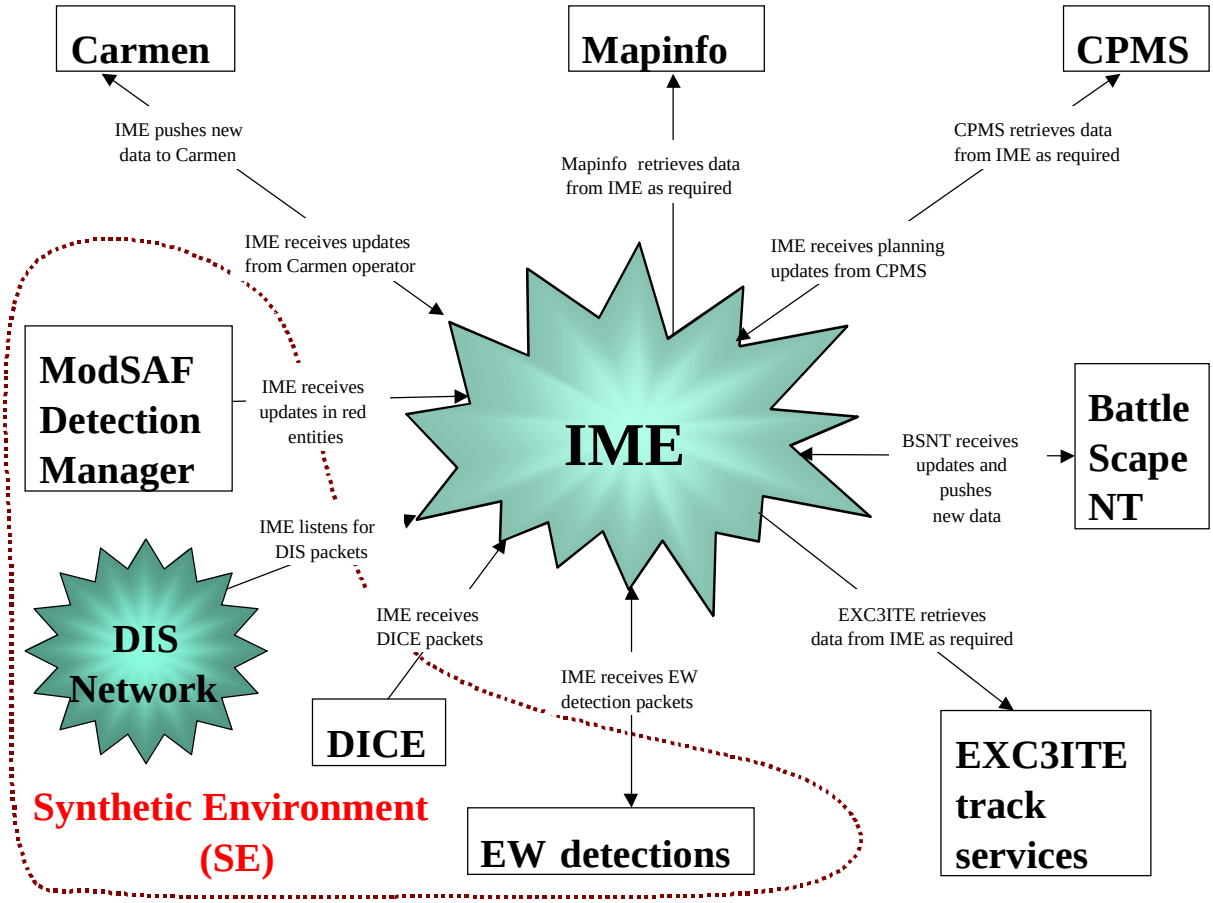

Figure 3: Interfaces to the IME and the applications that use them. The processes within the dotted area are synthetic information sources, the other processes represent real applications.

Clients can communicate with the IME by interfacing directly with the database using the Open Database Connectivity standard (ODBC). With an appropriate knowledge of the database schema, the client can send raw SQL commands to interrogate the IME for information. As this is the level at which the IME is itself implemented, this is the lowest level at which a client can meaningfully interface to the IME. All information is available to the client at this level.

5.1.2 Java and JINI Class Libraries

A Java class library has been written which contains a number of classes for interfacing to the IME database. Due to its tight coupling with the particular database schema, this class library can be considered an integral part of the overall IME. In addition to the basic interfacing ability, the wrapper library also provides a number of helper functions that are useful (though not essential) to clients of the IME – coordinate transformations, automatic notification of incoming updates ("IME push"), etc. Presently this class library deals mainly with entities and detections, but this may be extended in the future.

Future work will aim to extend the functionality of this library using Java's JINI technology, to facilitate dynamic lookup and binding of information services.

5.1.3 The EXC3ITE Track Service and Other CORBA Services

The previous generation of IME also provided a CORBA interface onto the data, in the form of an EXC3ITE track service [EXC3ITE 1999] – providing another means for interfacing with the database. Future work on the current version of the IME will provide it with a similar capability. As with the Java class library, this interface deals exclusively with entities. It lacks much of the functionality of the raw Java library, but is useful as a means of achieving interoperability with clients that support the more generic Track Service interface.

In addition to the EXC3ITE track service, another CORBA interface was provided to facilitate access to the Order of Battle (ORBAT) information in the IME. While it was originally designed for the Collection Plan Management System [Haub *et al*. 2000], this interface is open for other applications to use, and may form the basis of a future EXC3ITE service [EXC3ITE 2000].

5.2 Integrating Applications with the IME

The appropriate choice of interface type for integrating an application with the IME depends strongly on the application in question. In the experimental environment established in LOD and the wider DSTO (Figure 2), all three of the above described interfaces have been used. Examples are listed below:

- *MapInfo* - MapInfo provides in-built support for interfacing to data directly from ODBC data sources, and this is the method that has been used to interface it to previous versions of the IME. Future work on the current version IME will integrate MapInfo with it in the same manner.
- *Autometric's "Battlescape"* – using the Edge Development Option (EDO) libraries, Battlescape can be extended through the use of standard C++ code. To interface Battlescape to the IME, C++ code was used to make ODBC calls on the database (using an ODBC library) to retrieve the data directly.
- *OpenMap* – work in Information Technology Division of DSTO has produced an EXC3ITE Track Service compatible layer that can be displayed in OpenMap – a small, open-source mapping application. This layer interfaces to the IME using its EXC3ITE Track Service interface.

- *Maptek's "Carmen"* – due to the nature of Carmen's development, direct connection to the database and direct access to the Java classes were both not available. Integration with Carmen was achieved by communicating through a socket to a dedicated proxy process. This proxy was implemented using Java, and made use of the IME's Java class library to interface to the IME.
- *CPMS* – as mentioned above (see Section 5.1.3), this was achieved using a CORBA interface designed for ORBAT information [Haub et al., 2000].

5.3 Interfacing Raw Information Sources to the IME

In addition to the end-user applications, the IME needs to interface to raw information sources. In a real environment these would consist of sensors such as GPS receivers for automatic position reporting. In a synthetic environment, they consist of simulations of such sensors. At present only simulations are supported, however there is no reason why real sensors could not be interfaced to the IME in a similar manner. Due to the nature of sensors and their entity-oriented information type, raw information sources are well suited to using the IME's Java class library interface. All current implementations of such sources use this library.

The information sources that have been interfaced to the IME are:

- *DIS* – one or more processes listen to the DIS network traffic and report the positions of the friendly virtual DIS entities. This acts as an automatic GPS position reporting system for simulated (ModSAF) and virtual (ARHs) DIS entities.
- *EWSP system* – an LOD-developed simulation of the virtual ARH's Electronic Warfare Self Protection (EWSP) system. This system forwards detections of missile, radar and laser designation threats to the IME.
- *ModSAF detection manager (MDM)* – a small program that automatically forwards ModSAF's detections of enemy entities to the IME, acting as an automatic enemy reporting system.
- *DICE* – a process connects to the Distributed Interactive C3I Environment (DICE) to receive message updates [Matthews *et al.*, 2000]. Using DICE, the IME can receive messages from any simulation that DICE can interface to – such as Janus.

These information sources were all simulated sources, but were interfaced to the IME in the same way that real information sources would be interfaced. As a result they appeared to other clients of the IME as real information sources would. In this way the IME acted as an interface between the real and synthetic worlds. This ability of the IME was used in all of the exercises discussed in section 3.

6. Conclusion

The concept of maintaining a virtual pool of information and its technical implementation in our concept demonstrator has proven to be a viable, flexible, and open system for integrating diverse force element components in the tactical environment. It allows users with different tasks to share information and hence collaborate in planning, decision-making and engagement. As such, it is an integral component of actualising network-centric warfare principles. The architecture could thus be an enabler for modern war-fighting concepts such as combined arms teams and sensor-actor paradigms.

Extension of the ideas beyond the tactical environment to provide interoperability with operational level information systems and with partners in coalition operations appears straightforward and limited concept demonstrators will be produced in future work.

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