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A Brief Assessment of LC2IEDM, MIST and Web Services for use in Naval Tactical Data Management

Anthony W. Isenor

Defence R&D Canada – Atlantic

Technical Memorandum

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Abstract

A single platform, or ownship, typically has many available sensor resources. These sensors provide data to software applications that form tracks, fuse tracks and display results. Other information may also be fused including remote source data such as that from Link 11 transmissions, or a recognized maritime picture. The management of this multitude of potentially replicate data is an important function of the ownship tactical data system. In this report, three developments are assessed for potential use in the tactical data management process; the Land Command and Control Information Exchange Data Model, the Maritime Information Sharing Technology, and Web Services. This assessment indicates that none are presently capable of supporting tactical data management on ownship.

Résumé

Une plate-forme unique, ou navire observateur, possède en général de nombreux capteurs. Ces ressources fournissent des données à des applications logicielles qui produisent des pistes, les fusionnent et affichent les résultats. D’autres informations peuvent aussi être fusionnées, y compris des données de sources éloignées, p. ex. des données provenant de transmissions Link 11 ou d’une image maritime reconnue. La gestion de cette multitude de données susceptibles d’être répliquées est une fonction importante du système de données tactiques du navire observateur. Dans le présent rapport, trois développements sont évalués du point de vue de leur utilisation possible dans le processus de gestion des données tactiques, soit : le modèle de données d'échange d'information de commandement et de contrôle (Terre), la technologie de partage d'information maritime et les services Web. L’évaluation indique qu’aucune de ces technologies ne peut actuellement répondre aux besoins de la gestion de données tactiques à bord d’un navire observateur.

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Executive summary

Introduction

Tactical data may be considered the data originating from a multitude of sensors, tracker applications, and track fusion applications, all of which operate on a single platform called ownship. The organization of these tactical data is important for the sharing of data among the ownship applications, and also potentially for the sharing of data between platforms.

Existing technologies need to be assessed in terms of their applicability to the storage and management of the ownship tactical data. Three technologies are considered in this report, those being the Land Command and Control Information Exchange Data Model, the Maritime Information Sharing Technology and Web Services. This report assesses these three technologies in terms of vendor availability, cost, openness, maturity and evolution potential.

Principal Results

The three technologies are all noted to be effective in the intended developmental scope. However, none are immediately appropriate for use as a data support function for tactical systems.

Significance of Results

Tactical systems on a single platform require a data support function. This function needs to be capable of supporting a multitude of sensors and processing applications for the management of contacts and tracks. Recognising that the three investigated technologies do not support this function is an important step in the developmental process for onboard combat systems.

Future Plans

The results of this report will be incorporated into a larger United Kingdom (UK) effort that is investigating the applicability of these and other technologies to support the data needs of a platform combat system. If the investigation does not identify a suitable technology, a functional requirements and data modelling effort will be undertaken to develop the necessary structure to support a combat system. Such an effort would likely be a collaborative UK-Canada development.

Isenor, Anthony W. 2004. A Brief Assessment of LC2IEDM, MIST and Web Services for use in Naval Tactical Data Management, DRDC Atlantic TM 2004-148, Defence R&D Canada – Atlantic.

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Sommaire

Introduction

Les données tactiques peuvent être considérées comme les données provenant d'une multitude de capteurs, d'applications de poursuite et d'applications de fusion de pistes, qui sont tous exploités à bord d'une plate-forme unique appelée « navire observateur ». L'organisation de ces données tactiques est importante pour le partage de données entre les applications du navire observateur, et peut-être aussi pour le partage de données entre les plates-formes.

Il est nécessaire d'évaluer les technologies existantes du point de vue de leur applicablité au stockage et à la gestion de données tactiques de navire observateur. Trois technologies sont examinées dans le rapport, soit : le modèle de données d'échange d'information de commandement et de contrôle (Terre), la technologie de partage d'information maritime et les services Web. Le rapport évalue ces trois technologies du points de vue de leur disponibilité auprès des fournisseurs, de leur coût, de leur ouverture, de leur maturité et de leur potentiel d'évolution.

Principaux résultats

Les trois technologies se sont avérées efficaces dans le cadre de développement projeté. Toutefois, aucune n'est immédiatement utilisable comme fonction de support de données pour les systèmes tactiques.

Portée des résultats

Les systèmes tactiques sur plate-forme unique nécessitent une fonction de support de données. Cette fonction doit permettre l'exploitation d'une multitude de capteurs et d'applications de traitement aux fins de la gestion de contacts et de pistes. Le fait de constater que les trois technologies étudiées n'assurent pas cette fonction marque une étape importante dans le processus de développement des systèmes de combat embarqués.

Recherches futures

Les résultats du rapport seront intégrés à des travaux de plus grande envergure du Royaume-Uni (R.-U.) portant sur l'applicabilité de ces technologies et d'autres techniques destinées à répondre aux besoins de données d'un système de combat installé sur plate-forme. Si l'étude n'identifie pas une technologie satisfaisante, un effort de modélisation des exigences fonctionnelles et des données sera entrepris afin d'élaborer la structure nécessaire pour les besoins d'un système de combat. Cet effort sera probablement mené en collaboration par le R.-U. et le Canada.

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1. Introduction

A single naval platform typically has many sensor resources. These sensors generate data related to location and states of remote platforms. However, having many sensors at the disposal of the platform can create challenges related to the management of the data emanating from these sensors.

Consider the situation of multiple sonar sensors, all operating and in some fashion analysing the acoustic environment. Suppose the majority of sensors are located on a submarine. Some may not physically be on the submarine, for example, deployable sensors that are dropped from the submarine to the sea bottom.

Each sensor consists of the hardware that makes up the sensor, and application software that inputs the data stream and automatically creates tracks based on the stream. In this context, tracks may be considered consistent and repeated contact with something that forms an identifiable series or "track" for the object (a track in acoustic space rather than the well known track on the ground). Many of these applications, called trackers, use the input stream from a single sensor. Each tracker would use a different algorithm for track generation, thus providing multiple possibilities for the tracks (see Figure 1).

However, the situation quickly becomes complicated because a single real-world object may be responsible for one or more tracks generated from one or more tracker applications. In this case, tracks need to be grouped using grouper applications, to form a single master track based on a collection of primitive individual tracks.

There may also be many grouper applications, again each being distinct because of the algorithm. Thus, multiple grouper applications will provide multiple possible solutions to the grouping problem.

Each grouper application is creating a unique group of tracks that hopefully represents a real-world object. However, other classifier applications examine the grouped track and attempt to class the track as a particular object class (e.g., a ship, a marine mammal). Again, there may be multiple classifiers executing, each unique because of the underlying algorithm or because of the algorithm's use of the input data.

Of course the information available to the submarine may also originate from other sources. For example, incoming information may be obtained via Link 11 or from the Recognized Maritime Picture (RMP). This information must also be accessible to the applications and potentially fused with the submarine sensor data.

In terms of traditional data modelling, which utilizes entity-relationship modelling techniques, the need to organise and manage the multiple outcomes of the situation essentially decomposes to multiple many-to-many table relationships. This is the primary complication in the data modelling exercise associated with this situation. However, before considering the details of any data modelling exercise, we must first assess existing technologies or developments that may already deal with this data management problem.

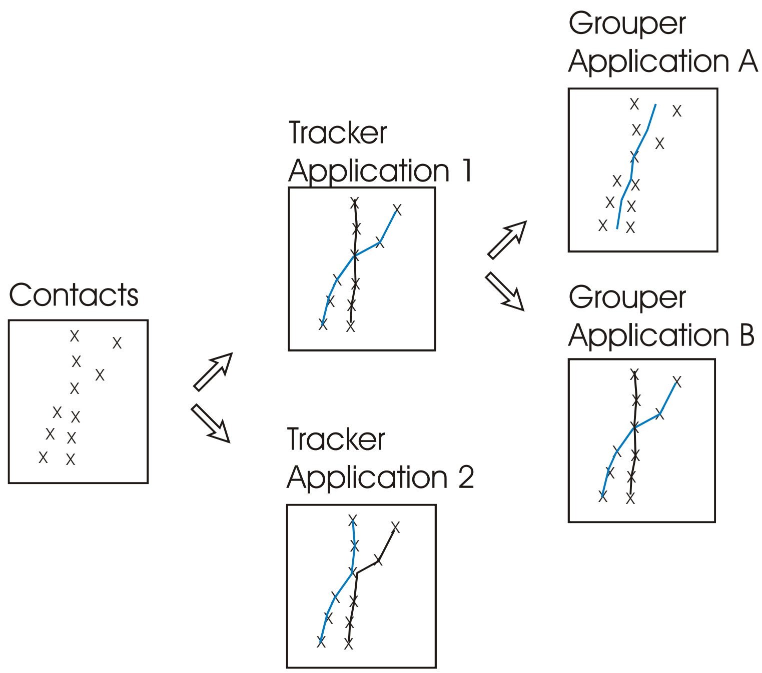

Figure 1. Contacts are shown at the left, as a sequence of X marks. Tracker application 1 produces two tracks based on the contacts (indicated by blue and black lines), while tracker application 2 produces a different set of tracks. Grouper application A and B both act on the output of Tracker Application 1 producing two different groupings. Grouper A and B may also be acting on Tracker Application 2 output (not shown).

The following brief report outlines three potential technologies that may be of use in such a situation. This report, which is a contribution to a larger UK effort assessing similar technologies, considers the Land Command and Control Information Exchange Data Model (LC2IEDM), the Maritime Information Sharing Technology (MIST), and Web Services.

All three technologies are based to some extent on the principle of shared resources. The LC2IEDM was developed for the sharing of operational data that supports situational awareness in a battlespace. LC2IEDM attempts to identify the objects associated with the battlespace, characteristics of these objects, and actions, which collectively are items that contribute to the context of the battlespace.

The MIST system was developed for the operational sharing of contact data originating from sonar. MIST is actually a system, with a developed database and support services. These services utilize web service technologies.

Finally, Web Services are a technical specification for the creation of online services. A service can be considered an online resource that remote applications can access. These services typically perform very specific functions. For example, a service may access a currency exchange system and provide online currency conversion.

Each of the three technologies is assessed by first providing a brief description followed by an examination of vendor support, cost, openness, maturity and the potential for evolution. Vendor support considers the commercial support of the technology. Cost qualitatively considers the costs associated with developing the technology for a tactical data management scenario. Openness examines the accessibility of the technology software or related specifications. Maturity examines the state of the technology in terms of its past development time. Evolution attempts to forecast the potential of the technology for continued development and improvement. Finally, an overall assessment of the technology's usefulness from a tactical data management perspective is made.

2. Land Command and Control Information Exchange Data Model

2.1 Description

The Land Command and Control Information Exchange Data Model (LC2IEDM) [1] is a development that originated in the Multilateral Interoperability Program (MIP) [2]. MIP is not a formal program, but rather is a voluntary activity of supporting nations (see Annex 1). The aim of the MIP is "*to achieve international interoperability of Command and Control Information Systems (C2IS) at all levels from corps to battalion, or the lowest appropriate level, in order to support multinational (including NATO*[1]*), combined and joint operations and the advancement of digitization in the international arena*" [3].

The LC2IEDM has recently been superseded by the Command and Control Information Exchange Data Model (C2IEDM) [3]. The MIP committee approved C2IEDM Edition 6 in November 2003. The data model specification and supporting documentation was made available on the MIP web site [2] in the spring of 2004. The C2IEDM is based on the LC2IEDM, with additional tables for navy and air force specific information. There has also been additional work on clarifying some table descriptions and content to make a more generic structure. However, this report describes the LC2IEDM because the modifications that resulted in C2IEDM are still being examined and understood. However, preliminary examination shows that the navy-specific additions do not impact the assessment contained in this report.

The consideration of the LC2IEDM must first recognize several important terms that relate the LC2IEDM to the larger system. LC2IEDM is a data model, and as such, is not a system but rather a structured set of definitions and relationships that pertain to a database. There is a larger system defined with the LC2IEDM including such things as an automated replication mechanism (ARM) [4]. The ARM specification details the replication of data between instances of the Land Command and Control database (LC2DB, note that for clarity the database is being distinguished from the data model). Several countries including Canada have implemented the ARM specification.

The Operational Context Exchange Service (OCXS, [5]) is a Java software suite that has been developed by the United States (US) Naval Undersea Warfare Center (NUWC) and is used to communicate to and from the LC2DB. The suite was designed to act as a bridge between the LC2DB and outside applications. Note the difference between the OCXS and the ARM. The ARM deals with database instance-to-instance replication, while the OCXS deals with application-to-database communication. These components will be briefly described.

[1] NATO – North Atlantic Treaty Organisation

The OCXS provides a data path between outside applications and the LC2DB. OCXS places data into the LC2DB using the physical model name set expressed in extensible markup language (XML) [6, 7]. All relationships within the LC2DB are dealt with implicitly from the data file. OCXS does not deal with any database relationships. This means that the input XML document must load the LC2DB tables without violating any formal relationships as specified in the LC2IEDM. A schematic of an OCXS message object placing data into the LC2DB is shown in Figure 2.

OCXS also deals with output from the LC2DB. OCXS can request information from the database, with the information being made available to the user as a physical XML tag set.

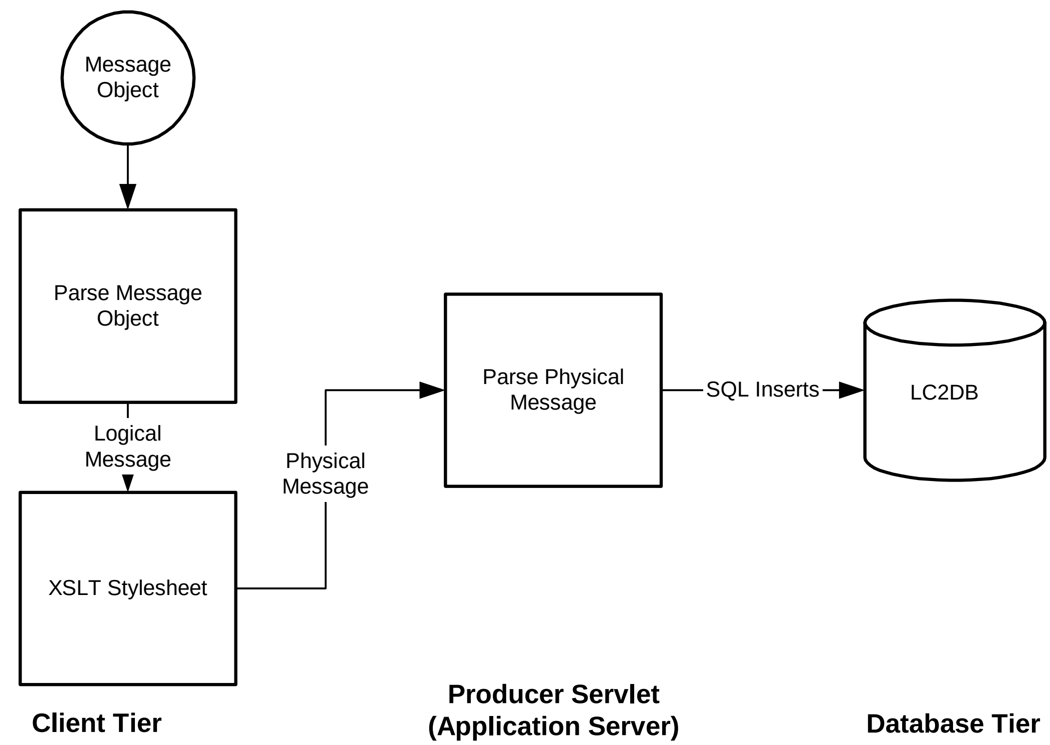

Figure 2. The OCXS uses input message objects in XML, to construct SQL input statements that are used to place data into the LC2DB. Reproduced from [7].

The ARM specification includes the functional requirements of the data replication between LC2DB instances (Figure 3). The ARM consists of a replication database that consists of about 40 tables. These tables are used to coordinate the transport of data from one LC2DB instance to another. In essence, the ARM database identifies nodes in the LC2DB network, protocols between the nodes, data contracts between the nodes, and the actual data contained in the LC2DB instance. In terms of the data, the ARM database holds information on the data value, and the table and column where that data value resides in the LC2DB instance providing the data.

The LC2IEDM specifies the entity/relationship model that forms the central structure of the larger system. The LC2IEDM consists of about 200 tables and supporting relationships. The main model concepts deal with objects that exist at described locations. The model allows the objects to have described capabilities, which leads to the objects conducting certain actions on targets. The objects may also operate in a certain context which may be defined by the reporting of associated objects, capabilities, actions, etc. or through the actions of the objects relative to described rules-of-engagement.

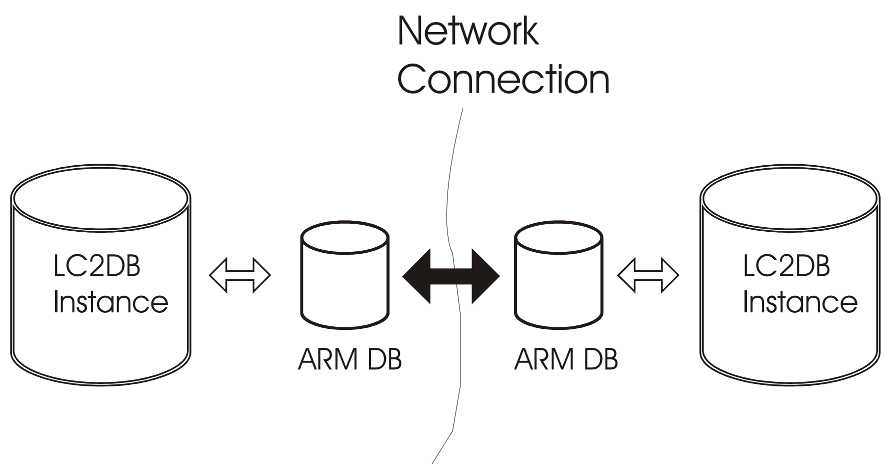

Figure 3. The ARM consists of a database specifically for managing the data replication between two LC2DB instances.

2.2 Vendors

The LC2IEDM development is a result of multinational collaboration, under the auspices of the MIP. Large commercial software vendors do not directly support the LC2IEDM development. However, there are activities to train military contractors in the LC2IEDM. Individual military research laboratories are also producing software that supports LC2IEDM. OCXS is an example of such software.

2.3 Cost

The data model and documentation is free of charge. The creation scripts are available for the Oracle database management system (DBMS). There is a free version of the Oracle DBMS available for download [8], and this is quite adequate for basic research. However, any implementation would likely require the purchased Oracle DBMS product. The small business version of the Oracle DBMS is about $700 US.

Implementation of the ARM specification would be potentially costly. However, both Canada and the UK have ARM implementations. These may be available through national contacts.

There are no applications that are standard with the LC2IEDM system. Again, individual organizations are developing these applications, which may be available through national contacts.

2.4 Openness

The data model description is available as entity-relationship diagrams (for example diagrams see references 6 and 7) produced from ERwin™ [9] software. The diagrams are freely available from the MIP web site [2]. The data model itself is open, as the generation scripts and structures are also available.

The openness of individual software developments to support the database will depend on the specific development. For example, the ARM implementations may be available from national contacts.

2.5 Maturity

The data model has been in the conceptual and development phase for about 20 years. As such, from the perspective of army operations, the model is quite mature. The supporting applications for the model are presently being developed and thus are not as mature.

2.6 Evolution Potential

This model has enormous support in the army, both in terms of human and fiscal resources. Although unproven, it is expected that the model is capable of dealing with high-level objects for the navy. In this regard, the model has great potential.

The model has already gone through various stages of evolution. Initially the model was known as the Generic Hub (GH) and then the LC2IEDM. More recently, the model has evolved to account for air force and navy requirements and has been renamed to the C2IEDM.

The model is also being incorporated into the NATO Technical Architecture. Current plans are underway to define the LC2IEDM as the NATO Reference Model. This means the ideas, objects and structures present in the LC2IEDM will most likely propagate into other NATO models, which are built based on the Reference Model. LC2IEDM is quickly evolving into a recognized standard for the sharing of command and control battlespace data and information.

The MIP is dedicated to the evolution of the LC2IEDM. In this regard, MIP has eight technical working groups and one multi-disciplinary working group dedicated to tasks such as system engineering and architecture, data modelling, test and evaluation, etc. These groups are continually working for the improvement of the model.

It should be noted that the LC2IEDM system is also extensible. The system allows the creation of tables for use within a specific user group. This allows, for example, a group of national assets to create data structures important for national objectives, and to share the data within these tables among themselves.

Overall, the evolution potential of LC2IEDM is considered high. However, it is unlikely that LC2IEDM will evolve into a solution for tactical data management. This is because the tactical data management problem is not a C2IS issue. The MIP aim [2] is to specifically address C2IS interoperability. As well, NATO solutions are directed at the operational and strategic level, while national partners provide tactical level support [10].

2.7 Overall Assessment from a Tactical Data Perspective

The LC2IEDM and supporting specifications were designed to describe the shared information requirements of command and control information systems. As such, the model was not intended as a tactical data management solution. The challenges of tactical data management, as described in the Introduction, cannot be addressed by the present LC2IEDM.

3. Maritime Information Sharing Technology

3.1 Description

The MIST system consists of all developed components required for a functional system. MIST includes a DBMS, client and server software, messaging between the client and server, and a database.

The MIST database is implemented in an open source DBMS named PostGreSQL. PostGreSQL had its beginnings at the University of California, Berkley, in 1986 [11]. The development of PostGreSQL has since evolved into a Global Development Group, consisting of companies and individuals around the world.

The MIST server utilizes open source software developed at The Apache Software Foundation (ASF, formerly known as the Apache Group). ASF is an open source development organization [12] consisting of a community of developers and users. One ASF development is named Tomcat, a sub-project under the Apache Jakarta project.

Tomcat provides the means to execute a service that is provided on the server. Tomcat listens for incoming requests that are in the form of messages. A service is executed when an appropriate message is received.

The messaging used in the MIST system is based on the Simple Object Access Protocol (SOAP). SOAP [13] is a World Wide Web Consortium (W3C) Web Services message specification. One implementation of the W3C specification has been developed under the Apache Web Services Project.

SOAP is described as a lightweight XML-based message protocol used in a distributed environment. In the MIST implementation, SOAP is used as the message protocol to request actions and receive responses from the MIST server. For an introduction to XML-based languages, see [14].

The MIST server [15] provides access to services using Tomcat. As noted above, Tomcat listens for incoming requests. SOAP provides the messaging language for the request. Thus, SOAP is the language being used between the client (performing the request) and Tomcat (receiving the request). SOAP is also the messaging protocol from the server back to the client (Figure 4).

The MIST client and server software [16] also consists of developed Java code. This software represents the services provided by the server and the software for requesting the services, which is on the client. At present, the MIST system supports services for initializing the database, adding and removing contacts from the database, and retrieving contacts and contact history from the database.

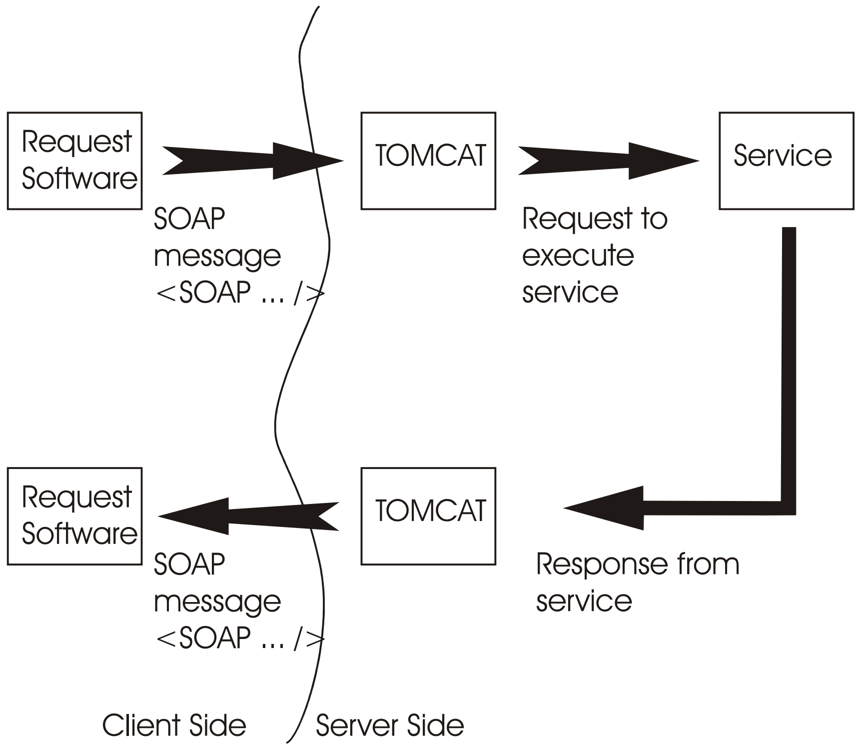

Figure 4. Requesting software sends the request via a SOAP message to a server running Tomcat. Tomcat sends the request to the service, which executes and sends a response back to Tomcat. Tomcat generates a return SOAP message and sends this to the requesting software.

The MIST database is a two-table structure with no formal relationships. One table maintains a list of contacts, while the second table maintains the details of the contact information. The contact information consists of information on the sensor used to determine the contact, the position of the contact (e.g., latitude, longitude, course, speed, bearing and range), contact identification information (e.g., track number, country, domain of operation, unique identifiers and threat level), time stamps, and security information.

The MIST system may be considered a centralized data system. However, the implementation can be as a set of clusters. Each cluster would represent the MIST client-server model, where multiple clients are connected to the central server. Clusters can then be connected to a higher-level central server, thus developing a tree-type architecture.

3.2 Vendors

There is no commercial vendor support for this system. At present, the system is purely a research tool and as such, is only supported by the two primary development labs, NUWC and the UK Defence Science and Technology Laboratory (DSTL).

3.3 Cost

This system is freely available to countries participating in The Technical Cooperation Program (TTCP) and has been released to TTCP Maritime Systems Group. Tomcat and PostGreSQL are also freely available from the referenced websites.

3.4 Openness

MIST utilizes PostGreSQL, an open source DBMS, and Apache Tomcat, an open source servlet container. The data structure is also open to TTCP countries, although no formal data model exists (e.g., ERwin™). The MIST software that supports the SOAP services is also open source to TTCP countries.

3.5 Maturity

The MIST system development was first released to the TTCP community in 2002. As a system, MIST can be considered relatively immature.

3.6 Evolution Potential

MIST is managed by a collaborative effort between NUWC and DSTL. MIST has been assessed in comparison to general navy contact data [6], and was noted to contain many essential elements in a contact record. However, the assessment did uncover various areas of potential improvement for the MIST system. Unfortunately, the MIST management does not appear to be addressing these suggestions. As well, there has been no indicated evolution of the system over the past two years. The evolution potential of MIST is considered low.

3.7 Overall Assessment from a Tactical Data Perspective

In part, MIST was developed as a tool for investigating network sharing of data between platforms. The MIST database deals exclusively with known contact data. These data represent the output of the tactical systems that were described in the Introduction. MIST was not intended as a sharing mechanism for tactical data. Although the central ideas around the MIST development could be useful for a tactical system, MIST in its present form does not meet the requirements of a database system for managing tactical data.

4. Web Services

4.1 Description

Web Services is the term given to a collection of specifications that describe access methods to services over the web. Web Services do not consist of one thing in particular, but rather a collection of specifications.

Access is the key component that is guiding Web Services. Web Services are based on the premise that developed services should not be restricted to specific implementation languages or hardware used to provide the service. Web Services provide the developer with the ability to separate applications into functional components, and to develop those components on different hardware platforms and different languages. The communication between the components is provided by Web Services.

Web Services have their foundation in XML. From the XML development, came the three essential languages that may collectively be called Web Services: SOAP, Web Services Definition Language (WSDL) [17] and Universal Description, Discovery and Integration (UDDI) language [18]. Only SOAP has been described previously (Section 3.1).

In a Web Services environment, developers should not be developing services that already exist. Thus, a service provided over the web needs to have a discovery mechanism that allows the service to be found. The UDDI allows this discovery mechanism by providing a searchable listing of service information. Software can search the UDDI to discover the services identified by the particular listing. This is illustrated in Figure 5.

Once an appropriate service is identified, the client will want to execute the service. To execute the service, the interface requirements must be known. For example, the service may require one or more input parameters. The WSDL for the service provides the interface specification. This specification describes the details of how to interact with the service. Typically, the WSDL describes a SOAP message construct for interacting with the service. By constructing and sending the properly structured SOAP message, one can execute the service and obtain the results of the service.

A WSDL and SOAP example of a web service is provided in Annex 2. A simple web service development is also provided in [6].

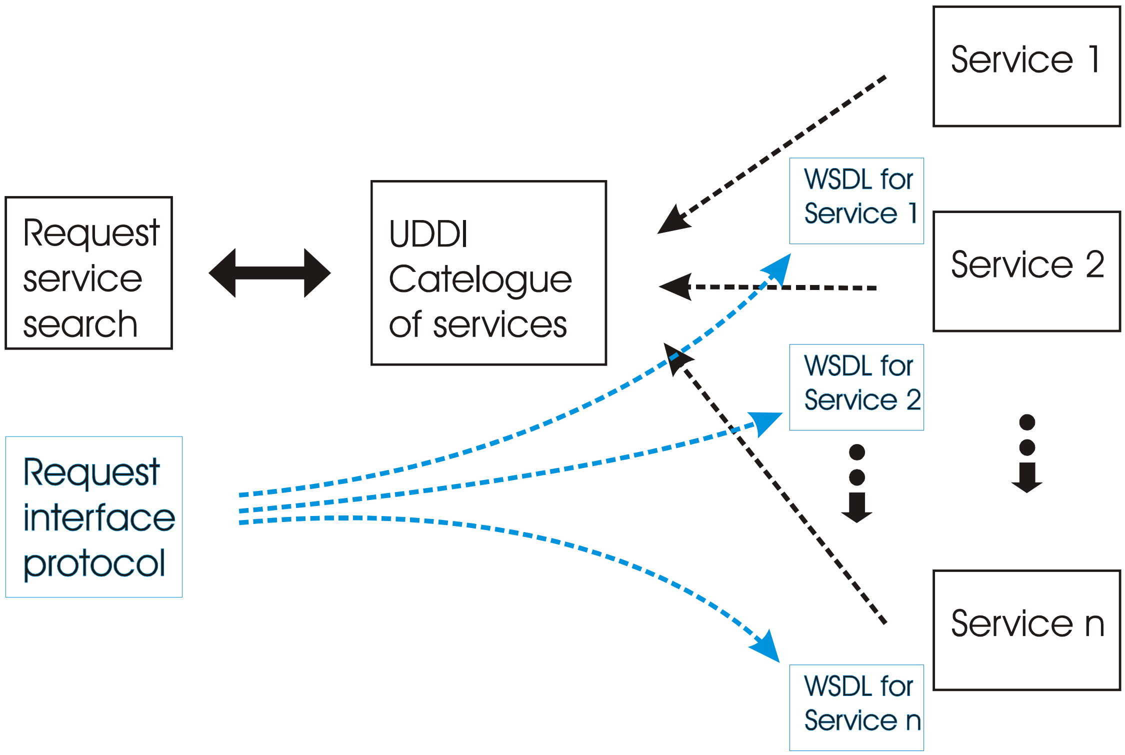

Figure 5. A request is sent to a UDDI catalogue. The catalogue contains a listing of all available Services 1 to n. Once an appropriate service is found, a request is made for the interface protocol from the WSDL listing (shown in blue). After the interface protocol is obtained, a request may be directed to the Service using a SOAP message built according to the interface protocol. This request would be similar to Figure 4.

4.2 Vendors

The UDDI and WSDL specifications are available on the World Wide Web. WSDL was developed as part of the W3C Web Services effort. UDDI was developed by the Oasis Group [19].

Vendors are now supporting these specifications in their particular software products. Currently available products are capable of searching UDDI inventories on keywords, and returning matching services. Using the service definition as described by the supporting WSDL, the software will generate SOAP messages that can then be directed to the service.

4.3 Cost

There is no purchase cost associated with implementing Web Services. However, there will be software development costs incurred to actually develop the services, the UDDI listing, and the WSDL information. All of these costs would be incurred in a tactical data management development.

Commercial software products as described in the Vendor section are available starting at about $200 US.

4.4 Openness

Web Services are driven by open standards. Java packages are also freely available to aid in the construction of the services. Web Services can be considered completely open.

4.5 Maturity

SOAP, WSDL and UDDI represent the core technologies of Web Services. The first UDDI schema specification was created in 1999. The SOAP specification was first introduced in early 2000. Finally, the first working draft of the WSDL specification was April 2002. All can be considered relatively immature technologies.

4.6 Evolution Potential

In a networked environment, Web Services have enormous potential. The ability to create applications by utilizing remote services is similar in concept to a web-based function library accessible by any development environment. However, there are issues that need to be addressed.

The following is a small sample of issues that will need to be considered in the evolution of Web Services. For example, the security of the transactions is presently a problem and represents another layer to the web service. Neither SOAP nor HTTP is capable of dealing with the entire security issue [20]. Also, there is reliability of the service. A mission critical application cannot be constructed using unreliable services. Finally, the management of the service collection may require community organization. If a set of services is to be implemented, who will be responsible for developing which service?

Although there are numerous issues to be addressed, the development community has identified Web Services as an important contributor to the next generation of the World Wide Web. As such, the evolution of Web Services is expected to be high.

4.7 Overall Assessment from a Tactical Data Perspective

Web Services provide the capability to separate applications into functional components, and to develop those components on different platforms, using different languages, and deploy them at different sites. In terms of the management of tactical data on a single asset (e.g., submarine), Web Services provide the ability to integrate disparate tactical systems.

This may have application to legacy components of a tactical system. The concept of a web service wrapper, placed around a legacy system, would open the system to all other web service systems on the local asset. In this regard, Web Services may be useful in integrating between existing disparate tactical systems.

For any new developments involving the integration of multiple tactical systems (i.e., a combat system), it is unlikely that Web Services would play a role. This is primarily because the problems that Web Services were developed to address (i.e., unknown hardware, unknown software languages and unknown interfaces) are not present.

5. Concluding Remarks

The management of tactical data at the single asset level is a complicated problem. Multiple sensors, creating multiple tracks, assembled into a set using multiple grouping algorithms, with the possibility of different classifications, produces an intricate set of relationships between the data items. The management of these data represents a considerable challenge.

A combat system, which here was loosely defined as a collection of integrated tactical systems, requires access to the information generated by all the tactical systems. In this regard, the combat system wants an unambiguous view of the data items, and the history of associations that created these items.

In this brief investigation, three technologies were assessed for applicability to the problem of tactical data management. The LC2IEDM is an army-based development that applies to the sharing of data in the operational battlespace. In this regard, the LC2IEDM is dealing with identified objects. The MIST system also deals with objects as described by the contact information stored in the MIST database. Finally, Web Services provides a model for developing shared service resources in a networked environment, but does not provide immediate benefit to the tactical data management problem.

The three technologies were qualitatively assessed relative to the tactical data management problem as outlined in the Introduction. Unfortunately, none of these three technologies presently provide the needed functionality for tactical data management. As well, there is no indication that the assessed systems intend to evolve into the realm of tactical data.

Based on this assessment, the development of a tactical data management system is a distinct possibility. In this case, it would be advisable for any developed tactical data management system to consider the higher-level data sharing requirements. For example, in a networked scenario there will likely be a requirement to share the object data identified by the tactical systems. Thus, it would be advisable to consider the C2IS level requirements during the development, to ensure some level of compatibility between the tactical and C2IS levels.

6. References

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Annex 1: Multilaterial Interoperability Program Participates

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Annex 2: Web Services Example

As a web service example, consider the Xmethods site located at http://uddi.xmethods.net. Using specialized software, the Xmethods site provides a UDDI interface that may be searched for keywords. Searching the site for keyword "temperature" results in one discovered service. This service is http://developerdays.com/cgi-bin/tempconverter.exe/wsdl/ITempConverter#ITempConverterbinding

The temperature converter service provides a conversion between temperature values in degrees Celsius and degrees Fahrenheit. The WSDL that describes the service is shown in Figure 6. The WSDL provides the specifications for a SOAP message that would be used for interfacing with the service. A few of the key WSDL components will be described. For a more complete description, see [21].

The document element is the <definitions> tag. In the <definitions> tag, is the *name* attribute. The *name* attribute contains the name of the class that implements the service.

The <message> tag is next, and defines the information passed between the client and the server. The <part> tag defines the message parameter using the *name* attribute.

As an example, the "CtoFRequest" message has one parameter defined, that being the <temp> element. This element is defined by the content of the *name* attribute in the <part> element. Similarly, the response has an element <return> defined.

The <porttype> element describes the operations available from the service. The operations are also linked to input and output messages for these operations. In this example, two operations are available as indicated by the two <operation> tags. The available operations are named "CtoF" and "FtoC" as indicated in the operation *name* attribute.

The <binding> element links the defined operations to a specific method. In this way, all the linkages are defined. The specific method is linked to an operation (i.e., via <binding>), the operation is linked to input and output messages (i.e., via <porttype>) and the messages are linked to specific XML element definitions (i.e., via <message>).

The required SOAP message for this service is shown in Figure 7. The <temp> tag encloses the user request, which in this case is "10". The <temp> tag refers to the temperature in degrees Celsius that is to be converted.

Sending the SOAP message to the service results in the execution of the service. The service then returns the SOAP message shown in Figure 8. We see that the return tag encloses the value "50" indicating the returned temperature in degrees Fahrenheit.

```
<?xml version="1.0"?>
<definitions xmlns="http://schemas.xmlsoap.org/wsdl/"
xmlns:xs="http://www.w3.org/2001/XMLSchema"
name="ITempConverterservice"
targetNamespace="http://www.borland.com/soapServices/"
xmlns:tns="http://www.borland.com/soapServices/"
xmlns:soap="http://schemas.xmlsoap.org/wsdl/soap/"
xmlns:soapenc="http://schemas.xmlsoap.org/soap/encoding/">
  <message name="CtoFRequest">
    <part name="temp" type="xs:int"/>
  </message>
  <message name="CtoFResponse">
    <part name="return" type="xs:int"/>
  </message>
  <message name="FtoCRequest">
    <part name="temp" type="xs:int"/>
  </message>
  <message name="FtoCResponse">
    <part name="return" type="xs:int"/>
  </message>
  <portType name="ITempConverter">
    <operation name="CtoF">
      <input message="tns:CtoFRequest"/>
      <output message="tns:CtoFResponse"/>
    </operation>
    <operation name="FtoC">
      <input message="tns:FtoCRequest"/>
      <output message="tns:FtoCResponse"/>
    </operation>
  </portType>
  <binding name="ITempConverterbinding" type="tns:ITempConverter">
    <soap:binding style="rpc"
transport="http://schemas.xmlsoap.org/soap/http"/>
    <operation name="CtoF">
      <soap:operation soapAction="urn:TempConverterIntf-
ITempConverter#CtoF"/>
      <input>
        <soap:body use="encoded"
encodingStyle="http://schemas.xmlsoap.org/soap/encoding/"
namespace="urn:TempConverterIntf-ITempConverter"/>
      </input>
      <output>
        <soap:body use="encoded"
encodingStyle="http://schemas.xmlsoap.org/soap/encoding/"
namespace="urn:TempConverterIntf-ITempConverter"/>
      </output>
    </operation>
    <operation name="FtoC">
      <soap:operation soapAction="urn:TempConverterIntf-
ITempConverter#FtoC"/>
      <input>
```

```
        <soap:body use="encoded"
encodingStyle="http://schemas.xmlsoap.org/soap/encoding/"
namespace="urn:TempConverterIntf-ITempConverter"/>
      </input>
      <output>
        <soap:body use="encoded"
encodingStyle="http://schemas.xmlsoap.org/soap/encoding/"
namespace="urn:TempConverterIntf-ITempConverter"/>
      </output>
    </operation>
  </binding>
  <service name="ITempConverterservice">
    <port name="ITempConverterPort"
binding="tns:ITempConverterbinding">
      <soap:address location="http://developerdays.com/cgi-
bin/tempconverter.exe/soap/ITempConverter"/>
    </port>
  </service>
</definitions>
```

Figure 6. The WSDL that describes the temperature converter service.

```
<?xml version="1.0" encoding="UTF-8" standalone="no"?>
<SOAP-ENV:Envelope xmlns:SOAPSDK1="http://www.w3.org/2001/XMLSchema"
xmlns:SOAPSDK2="http://www.w3.org/2001/XMLSchema-instance"
xmlns:SOAPSDK3="http://schemas.xmlsoap.org/soap/encoding/"
xmlns:SOAP-ENV="http://schemas.xmlsoap.org/soap/envelope/">
   <SOAP-ENV:Body>
      <SOAPSDK4:CtoF xmlns:SOAPSDK4="urn:TempConverterIntf-
ITempConverter" xmlns:xs="http://www.w3.org/2001/XMLSchema">
         <temp>10</temp>
      </SOAPSDK4:CtoF>
   </SOAP-ENV:Body>
</SOAP-ENV:Envelope>
```

Figure 7. A SOAP message used to access and execute a remote web service that converts temperature values. In this example, a temperature of 10°C is input to the service.

```
<?xml version="1.0" encoding='UTF-8'?>
<SOAP-ENV:Envelope xmlns:SOAP-
ENV="http://schemas.xmlsoap.org/soap/envelope/"
xmlns:xsd="http://www.w3.org/2001/XMLSchema"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xmlns:SOAP-
ENC="http://schemas.xmlsoap.org/soap/encoding/">
   <SOAP-ENV:Body>
      <NS1:CtoFResponse xmlns:NS1="urn:TempConverterIntf-
ITempConverter" SOAP-
ENV:encodingStyle="http://schemas.xmlsoap.org/soap/encoding/">
         <return xsi:type="xsd:int">50</return>
      </NS1:CtoFResponse>
   </SOAP-ENV:Body>
</SOAP-ENV:Envelope>
```

Figure 8. An example output from the temperature conversion service. The input shown in Figure 7 is converted to a temperature in Fahrenheit, 50°F.

List of symbols/abbreviations/acronyms/initialisms

ARM	Automated Replication Mechanism
ASF	Apache Software Foundation
ATCCIS	Army Tactical Command and Control Information System
C2IEDM	Command and Control Information Exchange Data Model
C2IS	Command and Control Information Systems
DBMS	Database Management System
DND	Department of National Defence
DRDC Atlantic	Defence R&D Canada – Atlantic
DSTL	Defence Science and Technology Laboratory (UK)
GH	Generic Hub
HTTP	Hypertext transfer protocol
LC2DB	Land Command and Control Database
LC2IEDM	Land Command and Control Information Exchange Data Model
MIP	Multilateral Interoperability Programme
MIST	Maritime Information Sharing Technology
NATO	North Atlantic Treaty Organisation
NUWC	Naval Undersea Warfare Center
OCXS	Operational Context Exchange Service
RMP	Recognized Maritime Picture
SOAP	Simple Object Access Protocol
TTCP	The Technical Cooperation Program

UDDI	Universal Description, Discovery and Integration
UK	United Kingdom
US	United States
W3C	World Wide Web Consortium
WSDL	Web Services Definition Language
XML	eXtensible Markup Language

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A single platform, or ownship, typically has many available sensor resources. These sensors provide data to software applications that form tracks, fuse tracks and display results. Other information may also be fused including remote source data such as that from Link 11 transmissions, or a recognized maritime picture. The management of this multitude of potentially replicate data is an important function of the ownship tactical data system. In this report, three developments are assessed for potential use in the tactical data management process; the Land Command and Control Information Exchange Data Model, the Maritime Information Sharing Technology, and Web Services. This assessment indicates that none are presently capable of supporting tactical data management on ownship.

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