

Using OneSAF to Explore Simulation and JC3IEDM Alignment

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Abstract. OneSAF, the U.S. Army's next generation simulation capability is being distributed and introduced to its training, testing, and analytical users world-wide. In addition to the distributed simulation infrastructure, simulation execution tools, and complement of pre-composed models (entities, units, and associated behaviors) OneSAF also provides front-end scenario development capabilities as well as tools to interface to real-world battle-command systems. This paper centers on efforts to align two OneSAF capabilities with the internationally agreed to data model for information exchange, the Joint Consultation, Command, and Control Information Exchange Data Model (JC3IEDM). OneSAF's XML-based Military Scenario Definition Language (MSDL) defines a standard format for sharing military scenarios between MSDL compliant scenario producers and consumers. Not only is MSDL in use by OneSAF but it is now in the formal product development phase of the Simulation Interoperability Standards Organization (SISO) standards development process with balloting expected by the summer of 2007. After the scenario is loaded and OneSAF is executing, the OneSAF C4I Adapter is used to translate and route message-based products between OneSAF and real-world battle-command devices. Because of its early successes and adaptable architecture, the OneSAF C4I Adapter has been employed as a middleware capability by multiple PEO-STRI projects. This paper focuses on efforts to extend the OneSAF capabilities by aligning the MSDL's electronic order of battle data model and the C4I Adapter's internal data model with the JC3IEDM to provide leap-ahead interoperability between simulations and JC3IEDM conformant C4I devices.

1. INTRODUCTION

Interoperability among multiple digital Battle-Command (BC) devices has always been a key concern within a single military branch and between other national military services. The environment surrounding today's war on terrorism has expanded this even further, to necessitate interoperability among international coalition allies.

Interoperability between simulations and BC devices has been, and remains a key enabler in the training of soldiers and the testing and experimentation of new BC systems and tactics. Ensuring a common method of achieving the interoperability goals among simulations and BC systems at the national and international levels has been a difficult task, is still incomplete, and remains a pressing issue.

At the forefront of interoperability issues, be they Service, National, International, or Global, are the identification of and agreement on common standards supporting consistent understanding of information exchanged between systems. To support a common understanding of military command and control data the Multilateral Interoperability Program (MIP) has defined a data model and associated business rules for interpreting the data model to allow consistent sharing of Command, Control and Situational Awareness data. The current version of this data model is called the Joint

Consultation, Command and Control Information Exchange Data Model (JC3IEDM) version 3.1; dated December 2006. [5]

As the US Army strives to understand JC3IEDM conformance and the issues associated with aligning simulation and its BC systems' data products with the JC3IEDM they have funded a number of projects under the supervision of the Simulation to C4I (SIMCI) Overarching Integrated Product Team (O-IPT). This paper reviews the progress of two such efforts: "Migrating Army M&S Initialization to the JC3IEDM" and "Using the JC3IEDM as an Internal Data Model in the PEO STRI Common C4I Adapter"

Both of these efforts leverage components of the US Army's OneSAF simulation system. The first project intends to align OneSAF's Military Scenario Definition Language (MSDL) with the JC3IEDM. The second aims to develop an internal data model for the C4I Adapter based on the JC3IEDM. The OneSAF system as well as each of these system components will be introduced in more detail in the sections below.

1.1 One Semi-Automated Forces (OneSAF) Simulation

OneSAF is the US Army's next generation, entity-level simulation system. It was officially released as version 1.0 on September 29, 2006 with subsequent releases planned on an annual basis. OneSAF is a government

owned, open-source, (to US DoD, and to Non US Foreign Military Sales users on a case-by-case basis) composable simulation toolkit that includes computer-based simulation pre-exercise, exercise execution, and post-exercise tools [10]. Additionally, a full complement of entities (individual combatants, tanks, rotary and fixed-wing aircraft, etc.), and semi-automated units (teams, squads, platoons, and companies) are also included along with tools allowing the user to develop their own unique entities and units. OneSAF supports both High Level Architecture (HLA) and Distributed Interactive Simulation (DIS) interoperability strategies to interoperate, leverage, and augment existing simulation-based investments.

For this paper we will discuss two OneSAF components in more detail: the Military Scenario Definition Language (MSDL) and the C4I Adapter, as they are fundamental to the JC3IEDM related efforts.

1.2 The Military Scenario Definition Language (MSDL)

MSDL uses the industry standard eXtensible Markup Language (XML) to define an unambiguous schema to hold military scenario information. The goal is to define a military scenario language that can be used by a wide-range of computer-based simulations and/or scenario development tools. Valid MSDL scenarios can be created by tools complying with the MSDL schema and these populated scenarios can then be imported by simulations supporting the MSDL language. [9]

MSDL is currently undergoing a rigorous review and formalized specification development under the direction of a Product Development Group (PDG) chartered by the International Electronic and Electrical Engineering (IEEE's) Society's Simulation Interoperability Standard Organization (SISO). The PDG has international representation and although the initial MSDL product is land warfare focused, the PDG intends to extend the standard as new domains (air, naval, space, etc.) are matured. [9]

1.3 The C4I Adapter

The PEO STRI Common C4I Adapter (C2A) is a software tool used to provide runtime interoperability between simulations and real-world BC devices. In its present form the interactions are limited to U.S. Army BC systems that comprise the Army Battle Command System (ABCS) system of systems. While the C2A is primarily used for data translations between military simulations and military message formats it can also be used as a generic data translator, and currently includes support for generic XML and Java data representations.

The C2A performs two primary tasks. The first is the translation of data between the various formats. The second task is to address and send or receive the reformatted messages. This second step will be ignored in this paper.

1.4 The Joint Consultation, Command and Control Information Exchange Data Model (JC3IEDM)

The JC3IEDM is an internationally defined and managed ontology-oriented set of products defining the range of information to be interchanged between Command and Control (C2) systems [2]. Specifically, the JC3IEDM is owned and managed by MIP and the North Atlantic Treaty Organization (NATO) Management Board. A short history of the formation of this organization follows.

The MIP was initially established in 1998 with representation from Canada, France, Germany, Italy, the United Kingdom and the United States of America with the very specific objective of enabling information exchange between co-operating but independent national C2 systems. Today there are 24 nations actively participating in the MIP program. [7]

As a natural evolution, a union between activities of the Army Tactical Command and Control System programme and MIP led to NATO's endorsement of the MIP activities and products. This union led to a signed Memorandum of Agreement between MIP and the NATO Data Administration Group that encompassed collaborative data modeling efforts which led to the production of the JC3IEDM. [7]

As discussed previously, the JC3IEDM not only provides a data-model, but also a comprehensive set of annexes that describe the attributes, valid domain values associated with attributes, the elements the attributes belong to, the relationship between the elements, and the business rules for using the entities, attributes, and associations [2]. These are all important components to ensure proper use of the JC3IEDM. For the complete set of JC3IEDM documentation please see <http://www.mip-site.org>.

Recognizing the importance of a standardized international coalition-based information exchange data model, the United States Army began officially endorsing the Command and Control Information Exchange Data Model (C2IEDM), the precursor to the JC3IEDM, in 2005. This led to the acceptance and endorsement of the JC3IEDM, in 2006, as the information exchange data model for information passed among the Army's BC systems and for information passed between simulations and BC systems. [8]

1.5 The SIMCI Organization

The US Army's SIMCI organization is co-chaired by PEO-STRI and PEO Command Control Communications Tactical (C3T) with the objective of developing greater interoperability and integration across these two domains. Members of SIMCI include senior representatives from Army Agencies, Combat and Material developers, and academia. SIMCI is playing a key-role and has provided substantial funding to promote interoperability between simulation and C4I

systems and the two projects described in this paper are sponsored by SIMCI FY06 and FY07 funding lines.

The remainder of this paper discusses two SIMCI funded, JC3IEDM-centric projects. Section two describes the alignment of MSDL with JC3IEDM and section three covers the OneSAF C4I Adapter's use of JC3IEDM as an internal data model.

2. ALIGNING MSDL WITH THE JC3IEDM

This FY06, now extending into FY07, project focuses on identifying challenges and gaps as part of the Army's migration of M&S and BC systems to the JC3IEDM.

An analytical and prototyping technical approach is being used to analyze, develop, and migrate the existing MSDL data interchange format currently aligned with US Army and US Joint Standards to the JC3IEDM data model and applicable annexes. To guide and bound the problem area the Electronic Order of Battle (EOB) domain was selected as the starting point for MSDL and JC3IEDM alignment.

To understand the EOB domain and to populate the aligned MSDL structures with relevant data this project is being executed in direct coordination with the Army C4I and Simulation Initialization System (ACSIS) developers, from the Army Research Laboratory – University of Texas. They will help extend and align the MSDL data structures with the JC3IEDM and then populate the resulting data model with ACSIS data. For more information on ACSIS please see [1]. Finally, the OneSAF models and C4I Adapter will be initialized using the MSDL scenario to demonstrate the end-to-end capability.

The expected outcomes of this analysis include:

- Identified gaps and alignment between the ACSIS/Lightweight Directory Access Protocol (LDAP) Data Interchange Format (LDIF) data model, JC3IEDM, and MSDL.
- An initial consensus on a JC3IEDM compliant data model describing the EOB that can be integrated in to MSDL.
- A list of essential and optional EOB data elements necessary to initialize an entity-level simulation using OneSAF as the entity-level simulation.
- A list of essential and optional JC3IEDM data elements necessary to consistently initialize a simulation and C4I Adapter software device.
- A data model and analysis that other simulation federations and the international community can leverage as part of the SISO MSDL standardization process.

Figure 1 provides end-to-end graphic of prototype effort.

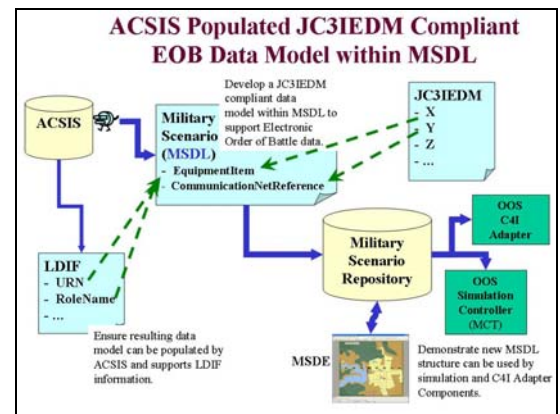


Figure 1: End-to-End Data Flow

2.1 Key Similarities and Gaps

2.1.1 MSDL Network Information

Originally, MSDL contained a very simplistic representation of EOB information within the **CommunicationNetReferences** XML element structure. It allowed for the name or identification of a communication net and a reference from this network identifier to its owning unit. The **CommunicationNetReferences** structure was defined as part of an **EquipmentItem** element. [9]

2.1.2 Proposed Network Extensions to MSDL

To support additional EOB information with the purpose of initializing the simulations and C4I interface components in a consistent manner the following additions to the MSDL were proposed. This structure is currently being evolved as the EOB elements are better understood by the MSDL development team.

As above, the **EquipmentItem** structure within MSDL is the owner of the EOB information. The EOB information now includes: [9]

A **PlatformRoleInstance** structure containing the following data elements:

- **URN** – The Unit Reference Number (URN) of the digital communications device.
- **Role Name** – Name describing the role, Battlefield Functional Area (BFA), and the unit associated with this **PlatformRoleInstance**.
- **IP Address** – The IP address of the role on its associated subnet type network
- **OR Name** – Organizational Role (OR) name used by some systems.
- **Email Address** – Prefix is the host description, suffix is the domain of the owning unit.
- **BFA System Type** – The Army Battle Command System (ABCS) or Force XXI Battle Command for Brigade and Below (FBCB2) Battlefield Functional Area (BFA) system type name.
- **BFA Version** – BFA software version installed on the system device.

- **EPLRS RSID** – If this role is communicating on an Electronic Position Location Reporting System (EPLRS) type network this is the Reporting System ID (RSID) of the EPLRS radio through which the role can communicate.
- **CommunicationsNetReferences** – Structure holding the **CommunicationNetReference** information.
 - **CommunicationNetReference** – The reference to a **CommunicationNetInstance** that the equipment monitors or uses to communicate with a mission.
 - **CommunicationNetType** – The tactical use/purpose of communication network. This element corresponds to the three basic types of communicating network: broadcast, multicast, and subnets.
 - **CommunicationNetID** – The name or ID of the communication net.
 - **UnitOwnerHandles** – A Universally Unique ID reference to the unit that owns a particular item of data as part of the unit’s plan.

2.1.3 JC3IEDM Network Information

On initial inspection the JC3IEDM appears to provide a much more comprehensive definition of a network and the characteristics of the network. Within the JC3IEDM a **Network** is a subtype of **Facility** (subtyped from a general **Object-ITEM**) that provides communication and information services composed of one or more links and nodes. The **Network Facility** has three additional associated object-items carrying important characteristics that may have multiple values for each network:

- **Network-capacity** – How much information can be carried per time unit on the network and the networking protocol used. Both values are defined by predefined coded values. [5, 7]
- **Network-Frequency** – Frequency related information pertaining to the network such as lower and upper frequency bounds, modulation codes, etc. [5, 7]
- **Network-Service** – The type of service provided by the network: i.e. message handling, video, e-mail, etc. [5, 7]

Each **Network** also has one or more associated **electronic addresses** (as a separate Object-Item) to allow access to appropriate people, organizations, or services on the network. [7]

Although within the scope of this project, a comparative analysis of each attribute within the JC3IEDM’s representation of network information has yet to be performed against the proposed MSDL structure. Future status will be provided once the analysis is complete.

2.2 Expected Software Evolution due to Alignment

As new EOB data is introduced and existing data is restructured within the MSDL schema three tools will be enhanced to support the new information: the Military Scenario Development Environment (MSDE), the OneSAF Management and Control Tool (MCT), and the OneSAF C4I Adapter. Each of these will be discussed in turn in the following paragraphs.

Within the OneSAF architecture MSDE provides an easy to use graphical front-end to develop new military scenarios for import into OneSAF for execution. MSDE builds upon Microsoft PowerPoint allowing users to drag-and-drop military organizations onto appropriate coordinate locations. The user can then assign control graphics to the units such as no fire lines, staging areas, avenues of approach, etc. Synoptic weather information can be added as can basic network assignment information. Once the user has completed the scenario development phase an MSDL compliant document is produced containing all of the scenario data. For OneSAF this file is imported by the MCT. As part of this effort MSDE will be extended to support the modified MSDL structure and data.

The OneSAF MCT is used to find, select, import, and enhance an existing MSDL scenario file. On import the geographic location of interest is identified, the entities and units within the MSDL file are mapped to appropriate OneSAF entity and unit compositions and are placed on appropriate locations. Basic attribute values declared within the MSDE and carried within the MSDL, such as network assignment and sides and force relationships, are also applied to the entities and units. The graphical overlays produced in MSDL are loaded and linked to the appropriate organizations. The MCT import capability will necessarily evolve to access more information from the MSDL file to auto-populate the EOB attribution of the OneSAF composed entities and create appropriate communication networks and entity/unit assignments within the simulation.

The OneSAF C4I Adapter, introduced in section 1.3, currently uses a C4I produced data file, the LDIF, to initialize and establish connectivity between the simulation and C4I domains. The objective of this effort is to allow the C4I adapter to initialize using the enhanced MSDL file. The advantage being a single input file for the simulation and the C4I adapter will reduce translations and the errors due to inconsistencies between multiple input sources. The C4I Adapter will have to replace their existing LDIF parser with a compliant XML-based MSDL parser to retrieve the EOB information.

3. JC3IEDM AS IN INTERNAL DATA MODEL

3.1 Background

The Common C4I Adapter (C2A) was designed to be a pass-through data translation system. That means that data of some type is provided as an input to the

software, a transformation is performed, and data of another form is output. There is no “internal” way of storing or defining data.

Recently it became apparent that the lack of an internal data model was proving to be a hindrance to the overall usefulness and reusability of the system. Each simulation that utilizes the services of the C2A must create data mapping files for each of the messages that it intends to send or receive. Depending on the complexity of the tactical message format, these mappings can become increasingly large and complex. The developers of these mappings are experts in their simulation’s data model, but not that of the military message format. This increases the learning curve required to construct the mappings.

The best way to mitigate this is to create an internal data structure that each client can utilize when creating their simulation specific mappings. This allows users to create mappings from their simulation data model to the C2A internal data model. The structure of the C2A’s internal data remains stable, and does not require a military tactical message format expert to assist with the mappings. That expert would still be required to create mappings from the internal model to the tactical format, but that mapping only occurs once, and will generally not require input from the simulation developers. As tactical formats change, the simulation developers will not need to update their mappings to match, instead only the mappings from the internal model to the tactical format would be updated.

It is beneficial to examine the potential savings of this approach.

m = the number of simulation systems

n = the number of messages per simulation

(Assume for this example that each system creates the same number of messages).

The initial development of mappings will require that

$$mn + n$$

mappings be created. The mn represents each system creating a mapping for each message to the internal data model. The second n represents the mapping from the internal model to the tactical format. This initial number of mappings is actually greater than would be required with the current approach, which would be mn .

The savings potential occurs later, when the tactical message format undergoes a version change. In the current approach this would require a complete recreation of all associated mappings, or mn mappings. With the new approach the only mappings that would be recreated would be those that map from the internal data structure to the tactical messages, which equates to n mappings. This is a savings of mn mappings. In the past three years alone the United States Joint Variable Message Format (JVMF) has gone through three versions: DCX2, R5 and 6017. If this pace of change continues the cost savings realized by using the internal data representation will be great. This cost savings will only increase as additional US military and coalition

message formats are utilized by the C2A and simulation.

In addition to cost savings the military’s move to a web-service architecture is also driving the C2A design change. The Army’s web-service architecture for data sharing is founded on a publish/subscribe capability called Publish and Subscribe Services (PASS). It requires each node to store state information to properly manage what it publishes to the server and to appropriately react to subscription events. This contrasts with the message-based approach, currently represented within OneSAF, where messages are passed to specific individual or groups. This transition from discreet message-based interoperability to a publish/subscribe approach requires the C2A to perform additional data management and transformation tasks.

To limit changes to the models within OneSAF, the C2A will interface to PASS to abstract the knowledge sharing approach from the simulation. In effect, the simulation will maintain a message based approach to data sharing, even though the “real world” has converted to the new method.

3.2 Data Model Analysis

There are numerous approaches to selecting a data model that can be used to represent the types of data required for interoperability among military simulations and BC systems. This issue has been thoroughly studied and written about as shown in [3, 4, 6]. The consensus of that research is that there is no “silver bullet” data model for representing simulation and C4I data. There is one distinctive difference between previous efforts and the C2A in that the C2A is only concerned with BC data exchange; therefore, it is not necessary to consider simulation-based data models. The only task of the C2A is to provide for interoperability between a simulation and BC device. If simulation data is not consumable by a BC system it is discarded. This definition of the requirements will allow the C2A to use a BC specific model internally.

An analysis was completed on the practicality of using the C2IEDM as the internal data model. The C2IEDM was developed to fulfill the information exchange requirements of intra Army as well as coalition based forces [2].

Other well known data models were also available that would have adequately fulfilled the requirements. One of them, the Joint Common Database (JCDB) formed the data share backbone for some versions of the US ABCS. The JCDB had also been used for previous simulation and C4I interoperability efforts such as the C4I-M&S Reference Object Model [3]. Its applicability to simulations has also been scrutinized in an analysis with the US Army’s Warfighter’s Simulation [6]. The JCDB’s major deficiency was in its usefulness within the modern coalition environment.

As mentioned earlier, in 2006, the JC3IEDM was released by the MIP. This model expanded on the

already large set of data represented by the C2IEDM, without altering the existing, well understood ontology, making it an even more attractive candidate than its predecessor [8].

3.3 Implementation

The selection of an appropriate data model is an obvious start to this effort, but without a proper implementation of that model into a form usable by software no benefits would be realized. The MIP provides the standard in either an XML schema (XSD) or a relational database format [5]. This makes a useful implementation in either of those formats relatively easy to achieve. Due to the current capabilities of the system, and the US Army's future reliance on a web-service-based architecture the decision was made to proceed using XML.

It is not practical to allow users freedom to create mappings to/from the entire set of data items contained within the schema. If this were allowed some mechanism of verifying the data being mapped remained in compliance with the JC3IEDM business rules would be necessary. Instead, an upfront analysis of the model will be performed with the goal of restricting mappings to a set of message-like, JC3IEDM compliant XML schemas. This implementation will require an analysis on the correlation between data fields in the JC3IEDM and various tactical message formats. The results of this analysis will be a series of new XML schemas that each represents a single tactical message. Version 1.0 release of OneSAF supports the transmission/reception of 28 different Joint Variable Message Format messages, so at a minimum 28 JC3IEDM compliant messages must be created in order to maintain the current capabilities. This number will increase since the C2A provides services to more systems than just OneSAF.

3.4 Potential Problems

One potential problem is with semantic loss while mapping between the various models. This topic was discussed in relation to the C2IEDM previously in [2]. The basic problem is that enumerated values allowed in data fields differ among the simulations, JC3IEDM, and tactical message formats. For instance, the simulation may reference a battlefield entity type as "M1A2," the JC3IEDM's closest match may be "MEDIUM ARMORED VEHICLE" and the tactical format may call it a "TANK." The specificity lost during these translations can lead to ambiguities in the mappings.

This problem is relatively easy to overcome when performing mappings from a specific case to something general. Careful thought when creating the mappings will mitigate any effects of the semantics loss. Where the larger problem arises is when mappings occur in the other direction, from the general to the specific. A common solution to this problem will most likely never be found, as the mappings are highly domain specific. The best approach to ensuring that deficiencies due to

specificity changes are minimized is to include an examination of the mappings during the overarching system's verification and validation process.

4. CONCLUSIONS

This paper has discussed two current efforts that utilize the international JC3IEDM standard in unique ways. The first focuses on consistent simulation and BC initialization and the second concentrates on consistent simulation run-time data exchange.

The JC3IEDM provides a well thought out, well documented, and capable representation of the data required to meet the information exchange requirements of intra and inter-service, national, and international BC devices. For this purpose the JC3IEDM is quite useful to simulations and translation-based middle-ware services in the representations of militarily significant data, such as entity, organizational and electronic order of battle data, which is key when defining a military scenario that will be used to interoperate with command and control devices.

It must be understood that these projects are, at the time of this writing, still in their development stages. Since this paper is not meant to be a chronicle of completed software the final implementations may be slightly different than described here. The ideas expressed in this paper were culled from experiences in the proposal, analysis, design and early implementation phases.

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