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Executive Summary

Introduction

This document was prepared by the Institute for Defense Analyses (IDA) under Task Order BL-5-3518 "Army Business Information Systems (BIS) Integration Strategy," which is the internal designation for the activity in support of the FY12 Army Study "*Development of a Strategy for Integrating Army Business Information Systems Using the Global Force Management Data Initiative (GFMDI) Baseline.*"

The document constitutes the final report under the task order and addresses the objective of providing initial recommendations on ways for taking advantage of the transformational character of the GFMDI to achieve total asset visibility within the Army Business Information Systems. It presents a proposal for implementing the GFMDI strategy across the Army Business Mission Area (BMA).

The document is organized as follows:

1. Section 2 describes a series of phases for a possible implementation of the GFMDI strategy within the Army BMA.
2. Section 3 identifies specific tasks under each of the phases of the proposed GFMDI strategy implementation plan and highlights applicable technologies for each of the implementation plan objectives.
3. Section 4 presents a summarization of the main analytical results as documented in the previous deliverables under the study plan. These results provide the rationale, as well as the technical underpinnings, for the recommended selection of technologies contained in the proposal.
4. Section 5 summarizes the conclusions of the study and provides recommendations. Attachment 1, Supplemental Materials, is on a CD located on the back inside cover of this document. It contains code snippets and further details referenced in the document.

The IDA team acknowledges the comments and suggestions provided by the task sponsor Mr. John Organek, as well as the inputs provided by Mr. Bruce Haberkamp and Mr. Andrew Schaaf from the Army GFMDI activity.

Scope

As was the case in previous deliverables under this task order, this document does not address the complexities inherent in the policies and procedures embedded in the "as-is" systems that currently may support the description and capture of structured tasks within the BMA, such as depot operations or upgrade and maintenance of major pieces of equipment that are part of typical logistics operations. Instead, it focuses primarily on the specification of data constructs that are both consistent with the models underlying the GFMDI[1] and leverage the use of globally unique enterprise identifiers (EID).[2]

The IDA team believes newly proposed data items that may aid in the extended use of the GFMDI approach within the Army BMA information systems could be easily implemented as additional modules without disrupting the existing baseline systems. This could be implemented, for example, in the same way that all Department of Defense (DoD) financial systems comply with the requirement to populate the 66 elements specified in the Standard Financial Information Structure (SFIS)[3] without necessarily having to modify their existing physical schemata.

Finally, the IDA team reiterates that all analytical results contained in this document pertaining to the issue of how well existing constructs in the models underlying the GFMDI can support the Deploy to Redeploy/Retrograde (D2RR) process represent the IDA team's best effort at interpreting the available documentation since it has not been possible to gain access to the subject matter experts currently developing the D2RR business flows – an analysis being performed by the Army GFMDI activity – due to schedule limitations. The results presented here are intended to highlight areas where additional detail needs to be developed to ensure unambiguous interpretations.

Analytical Approach

The IDA team concentrated on answering the following questions:

- What sequence of phases would be needed for a plan intended to promote the adoption of a GFMDI strategy for the BMA within the Army enterprise?
- What specific tasks should compose the phases of the proposed implementation plan?

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[1] The GFMDI uses the Global Force Management Information Exchange Data Model (GFMIEDM) as the basis for its controlled vocabulary and structured data exchanges. The model is an extended subset of the Joint Consultation, Command, and Control Information Exchange Data Model (JC3IEDM), a data exchange specification developed by the Multilateral Interoperability Programme (MIP).

[2] In this study the term EID is intended to cover the various types of GFMDI globally unique identifiers, e.g., Organization Unique Identifier (OUID), Force Management Identifier (FMID), etc.

[3] http:/dcmo.defense.gov/products-and-services/standard-financial-information-structure/.

- Which technologies could be readily applied to accomplish the tasks within each of the phases that make up the overall implementation plan?
- How can existing data structures in the information models underlying the GFMDI support BMA information requirements?
- What is missing?
- How can the gaps be filled?

Conclusions and Recommendations

The IDA team concludes the following:

- There do not appear to be any insurmountable *technical barriers* to the adoption of a GFMDI strategy for the entire Army BMA. All the tasks identified under the proposed phases of the implementation plan presented in this report lie within the envelope of current know-how and technologies.
- *Cultural barriers* are the most likely obstacle to the adoption of a GFMDI strategy within the Army BMA. To mitigate them will require a long-term commitment – both at the policy level and financially – on the part of the Army leadership. Only then can the necessary socialization of the GFMDI strategy reach the required involvement and support of all the BMA stakeholders.
- Adoption of a GFMDI strategy for the entire Army BMA has a high potential for reducing life-cycle costs associated with bridging the information interoperability and reuse barriers that are caused by the utilization of proprietary enterprise resource planning (ERP) solutions within the current BMA information systems baseline.

The IDA team recommends that the Army:

- Pursue the use of more powerful information modeling languages such as OWL[4] not only for future versions of the models underlying the GFMDI, but also as a means to enhance semantic interoperability between BMA systems and those in the C2 domain;
- Take advantage of recent developments in the commercial world, such as the use of ODM,[5] a profile for graphically modeling ontologies in Unified Modeling Language (UML),[6] which would immediately support the implementation of the Model Driven Architecture (MDA)[7] approach to update and maintain all the

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[4] Web Ontology Language, http://www.w3.org/TR/owl2-overview/.

[5] Ontology Definition Metamodel, http://www.omg.org/spec/ODM/1.0/.

[6] Unified Modeling Language, http://www.omg.org/gettingstarted/what_is_uml.htm.

[7] Model Driven Architecture, http://www.omg.org/mda/.

artifacts needed for GFMDI exchanges, such as XSD's,[8] physical database schemas, application code, WSDLs[9] for SOA[10] solutions, etc.;

- Continue to support the implementation of GFMDI conformant authoritative data sources for managing its materiel and personnel resources;
- Explore semantic technologies for the purpose of enabling dynamic federation of BMA information repositories and support for business intelligence and data mining; and
- Seek to align the suggestions presented in this study with the activities envisioned under the Army Business Management Strategy and Implementation Plan.

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[8] XML Schema Definition Language, http://www.w3.org/TR/xmlschema11-1/.

[9] Web Services Description Language, http://www.w3.org/TR/wsdl.

[10] Service Oriented Architecture, http://en.wikipedia.org/wiki/Service-oriented_architecture.

Contents

Figures

1. General Considerations

A. Introduction

This document constitutes the final report under the FY12 Army Study *"Development of a Strategy for Integrating Army Business Information Systems Using the Global Force Management Data Initiative (GFMDI) Baseline."* It presents a proposal for how to implement the GFMDI strategy across the entire Army Business Mission Area (BMA) and summarizes the previous analytical results documented in the three preceding quarterly reports prepared for the sponsor.

The GFMDI is a key enabler for achieving the Department of Defense (DoD) policy and standard for establishing an electronic, common, and hierarchal representation of force structure data. This standard integrates the enterprise resource planning (ERP) applications, other Army business systems, and warfighting systems in the DoD target environment, and it is particularly important for maintaining *asset visibility* when Army units task organize into organizations different than those in their standard Tables of Organizational Equipment (TOE) document. GFMDI-standardized data and asset visibility form critical components of the DoD Business Enterprise Architecture (BEA), Army BEA, and their target environment.[11]

The implementation plan presented in this report aims to leverage the transformational characteristics of the GFMDI within the Army's BMA systems to achieve total asset visibility and to provide robust support for static and dynamic force structure representations that underlie the major end-to-end (E2E) processes, particularly those within the Deploy to Redeploy/Retrograde (D2RR) activity. The main driver for conducting this study is the realization that the assignment of globally unique Enterprise Identifiers (EID) to all relevant resources managed by Army BMA information systems provides both a realistic path for achieving *total asset visibility*, as well as a technically robust way to ameliorate many of the information interoperability and reuse barriers that plague these systems. In other words, a commonly accepted and understood means of referencing any resource of interest across the entire enterprise can simplify automated resource discovery and enhance the level of machine processability needed to support the tempo and reliability required by modern operations. Full asset visibility is essential for

[11] From a draft version of the *Army Business Management Strategy and Implementation Plan* (FOUO), provided by the sponsor.

supporting a comprehensive assessment capability encompassing multi-functional analysis to aid strategic decision-making.

The report breaks the GFMDI strategy implementation plan into a series of phases and identifies tasks under each of them, together with tools and commercial standards that could be applied to realize the vision of optimal information interoperability and reuse among the BMA systems, reducing therewith their life-cycle cost and increasing their content quality.

This document also contains the final conclusions and recommendations based on the analytical results obtained during the study.

B. Rationale for the Adoption of a GFMDI Strategy and an Overarching Interoperability Vision

1. The Department of Defense Fiscal Reality

Figure 1-1 below shows a recent budget projection for the Department of Defense (DoD).[12]

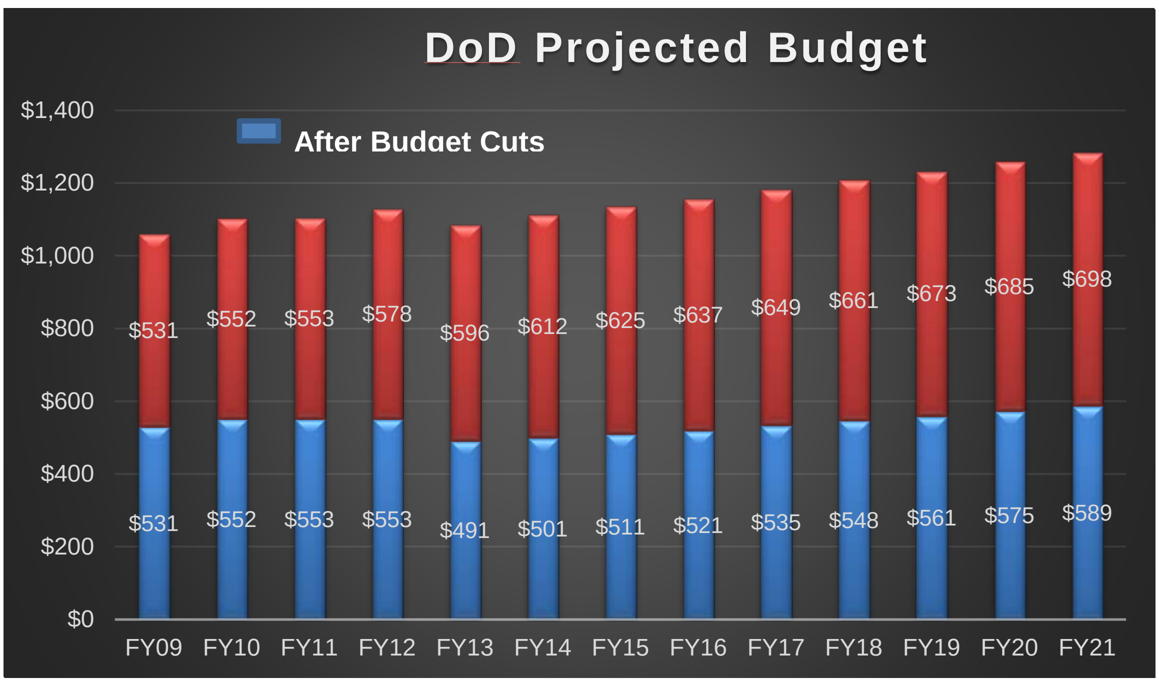

Figure 1-1. DoD Budget Projection

[12] Derived from a briefing by Mark Breckenridge, Deputy Director, Defense Manpower Data Center in Proceedings of the Meeting on Science and Technology Issues for Data-to-Decisions Conference, Institute for Defense Analyses, Alexandria, Virginia, 18 September 2013

Irrespective of whether the actual numbers shown therein will hold in the outer years, the fiscal pressure under which the DoD is likely to operate in the immediate future is an undeniable reality that will affect all its programs, as well as the operations of the military Services and DoD agencies. The Army BMA must, therefore, seek to position itself, through the adoption of adequate strategies, in a situation that will ensure its ability to accomplish its mission with substantially less funding. This means that the costs associated with all its information systems must be reduced while keeping up with the increasing demand for accurate and timely information to support all key decisions.

2. Sources of Increased Costs in Information Systems

Poor data quality and lack of information interoperability and reuse rank high among the main sources of increased costs caused by information systems within the enterprise.

Costs arising from poor data quality are estimated by some practitioners to be as high as 15% to 20% of the operating costs in a typical organization – caused by the required cleanup and rework needed to fix poor data. The combined costs to the economy may be as high as $3.1 trillion which includes both businesses and government.[13]

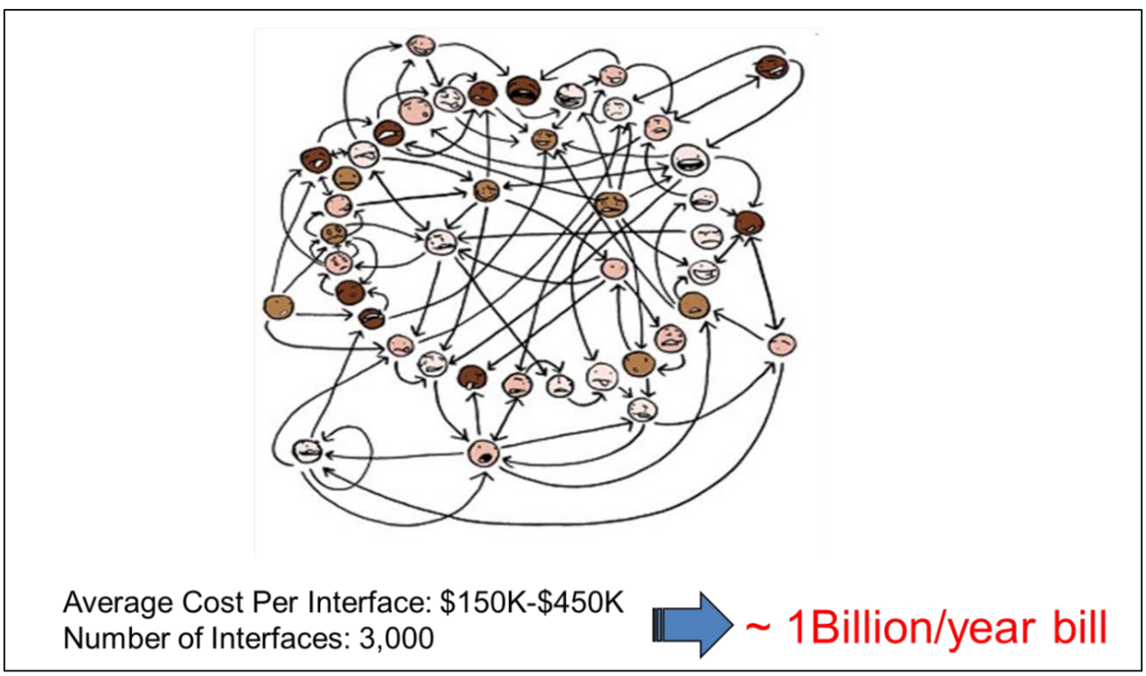

Figure 1-2. Average Interface Maintenance Cost

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[13] http://geospatial.blogs.com/geospatial/2013/05/estimating-the-economic-impact-of-poor-data-quality.html.

Figure 1-2 above depicts a typical situation affecting many of the Army BMA information systems, namely, the so-called *N-Squared Problem*,[14] which arises when an information system cannot exchange and reuse information contained in a different one, leading to the need to create and maintain dedicated interfaces to all the nodes with which it must exchange information. For N totally interconnected systems, the number of interfaces scales as N(N-1)/2 or roughly N^2, which at a yearly cost of $150,000 to $450,000 per interface represents an average annual bill of $1 billion for 3,000 interfaces.[15]

3. Data Quality: Authoritative Data Sources under GFMDI

The data quality issue mentioned in the preceding section can be substantially ameliorated through the adoption of authoritative data sources (ADS). Figure 1-3 below depicts the goal of the GFMDI, namely, the creation of ADSs to handle the three key components of the DoD enterprise: organizations, materiel, and personnel.

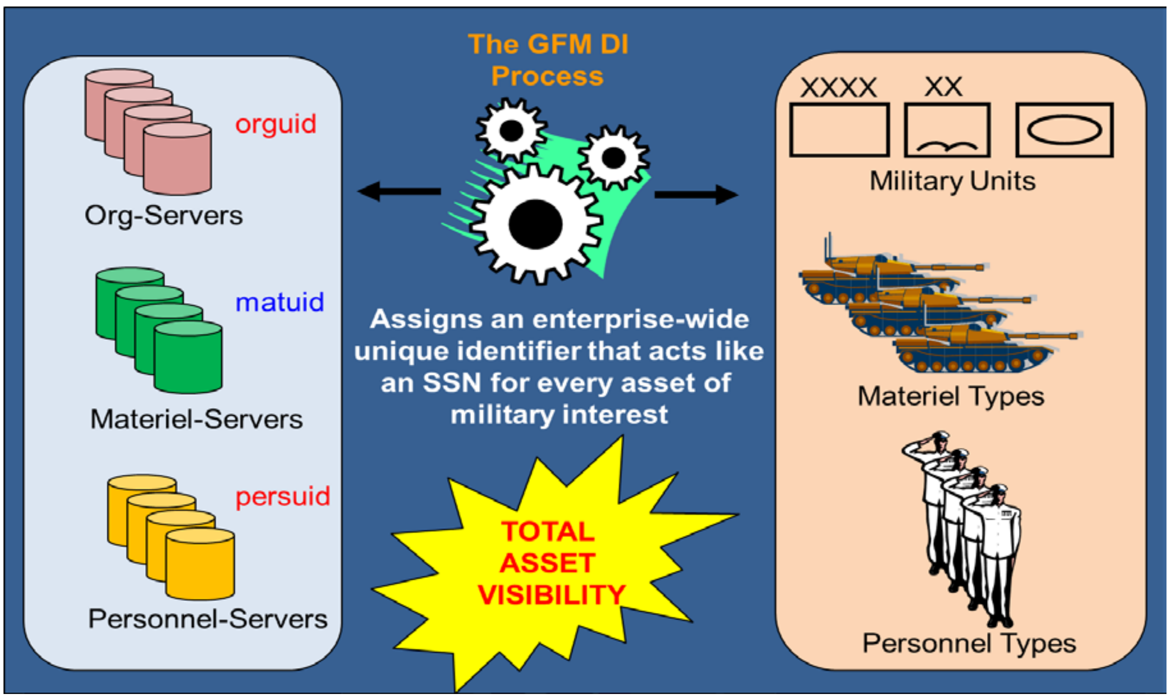

Figure 1-3. Improving Data Quality Through Authoritative Data Sources Developed Under GFMDI

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14 http://www.charteris.com/insight/four-levels-of-data-integration.

15 Cost estimates derived from a USTRANSCOM internal paper provided by the sponsor.

As shown therein, the GFMDI process is expected to assign globally unique identifiers to all pertinent assets within those three areas and to stand up respective servers that can be consulted whenever information systems need such data. Because the GFMDI identifiers provide an unambiguous means of identification for all the assets in question – similar to a ideal social security number (SSN) – any record in any system utilizing them can be correlated with the respective ADS to ascertain the asset nature. Furthermore, because all enterprise systems are expected to use these ADSs, there needs to be only one place where fixes due to either errors or necessary updates have to be carried out to maintain optimal data quality.

4. Information Interoperability: Exchanges Based on Resource Description Framework and Support for Business Intelligence

The Resource Description Framework (RDF) is an industry standard developed by the World Wide Web Consortium (W3C) that provides a general way for expressing data pertinent to a given resource.[16] The key advantage of using RDF for data storage is the enormous simplification it provides in terms of the underlying physical schema required to perform that function. In a data store using RDF, every piece of information, irrespective of its semantics, its origin, or its intended use, is captured in the form of a *triple* consisting of a <subject>, a <predicate>, and an <object>.[17] Once a piece of information is expressed in the form of RDF triples, there is – barring some typographical error or a malformed Universal Resource Locator (URL) snippet in the dataset – an absolute warranty that any RDF data store will be able to ingest those triples.

This enormous interoperability gain is impressive because the likelihood of two randomly selected relational databases to be able take a dataset from the other and load it without any transformation is infinitesimally small. In contrast to this, any two randomly selected RDF triple stores will always be able to load datasets from each other.

For the Army BMA the adoption of RDF as the mechanism for exchanging and reusing data means that information services and business intelligence can be readily supported along the lines of the paradigm depicted in Figure 1-4, namely, through agreed export of the information content in the form of RDF triples.

If in addition one assumes that the enterprise resource planning (ERP) systems in the BMA adopt the GFMDI identifiers, it would also be possible to support exchanges among them with minimal ambiguity regarding the nature of the resources being

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[16] http://www.w3.org/RDF/.

[17] For an explanation of the terms used here see the tutorials at http://jena.apache.org/tutorials/rdf_api.html and http://jena.apache.org/documentation/ontology/.

referenced. Agreements on the metadata required to enable the reuse in the participating systems must be reached to achieve the envisioned end state.

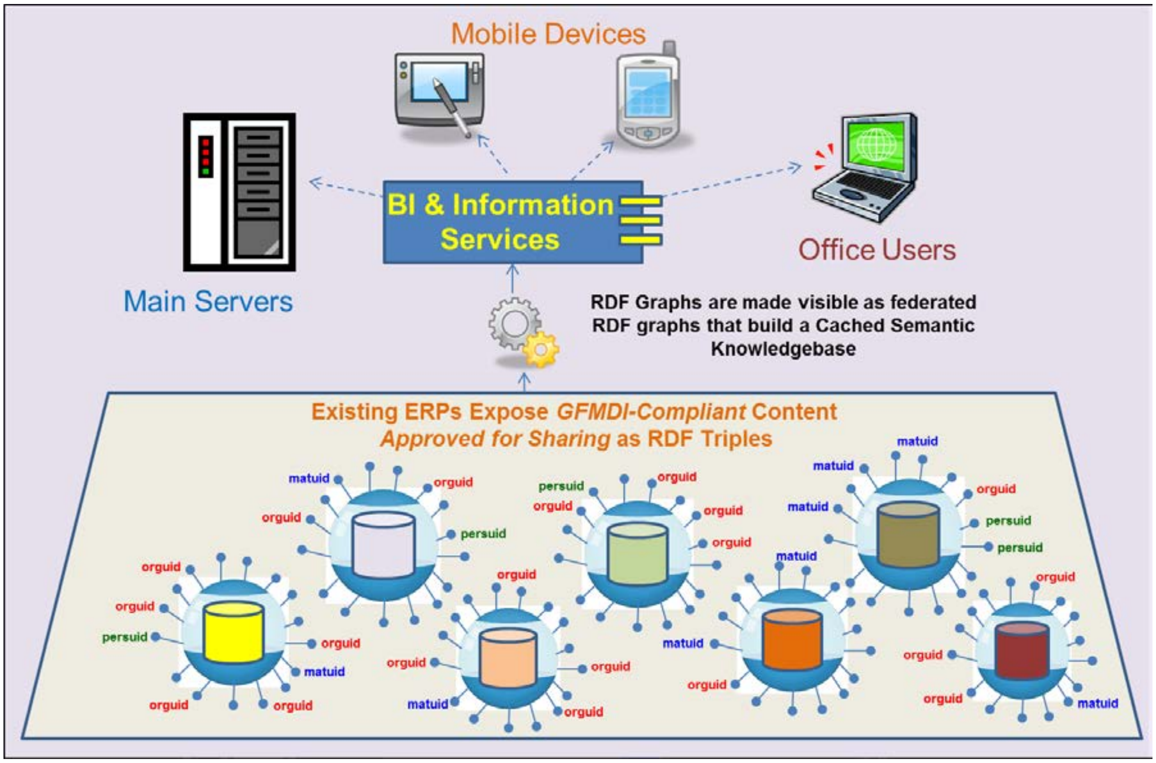

Figure 1-4. ERP Information Interoperability Leveraging GFMDI Identifiers

5. Information Interoperability and Reuse Model for the Army Enterprise

All the elements described in Sections 2.3 and 2.4 are consistent with the guidance provided in the Army Regulation *AR 25-1 Army Information Technology* issued on 25 June 2013 and effective 25 July 2013.[18]

Figure 1-5 summarizes the vision for a comprehensive interoperability and reuse model for the Army enterprise. In addition to the already mentioned foundational blocks represented by the ADSs, and the use of GFMDI identifiers and RDF triples, the model defines Information Exchange Standards Specifications (IESS) as its fourth pillar. IESSs represent the agreed vocabularies of the participating communities of interest. They are essential for achieving information interoperability because they define the semantics of the information to be exchanged and reused. They are also valuable sources of metadata needed for developing advanced solutions that leverage semantic technologies.

[18] http://www.apd.army.mil/pdffiles/r25-1.pdf.

The last point to note with respect to the interoperability and reuse model depicted in Figure 1-5 is that it also calls for an overarching governance – in the form of required policies – of its four pillars to ensure proper harmonization of the underlying activities and to prevent duplication of effort and waste of scarce fiscal resources. The claim that the model makes is that once the four pillars are implemented it will be possible to create fully interoperable network-centric applications to provide Army-wide information services powering the generation of actionable information to the decision makers.

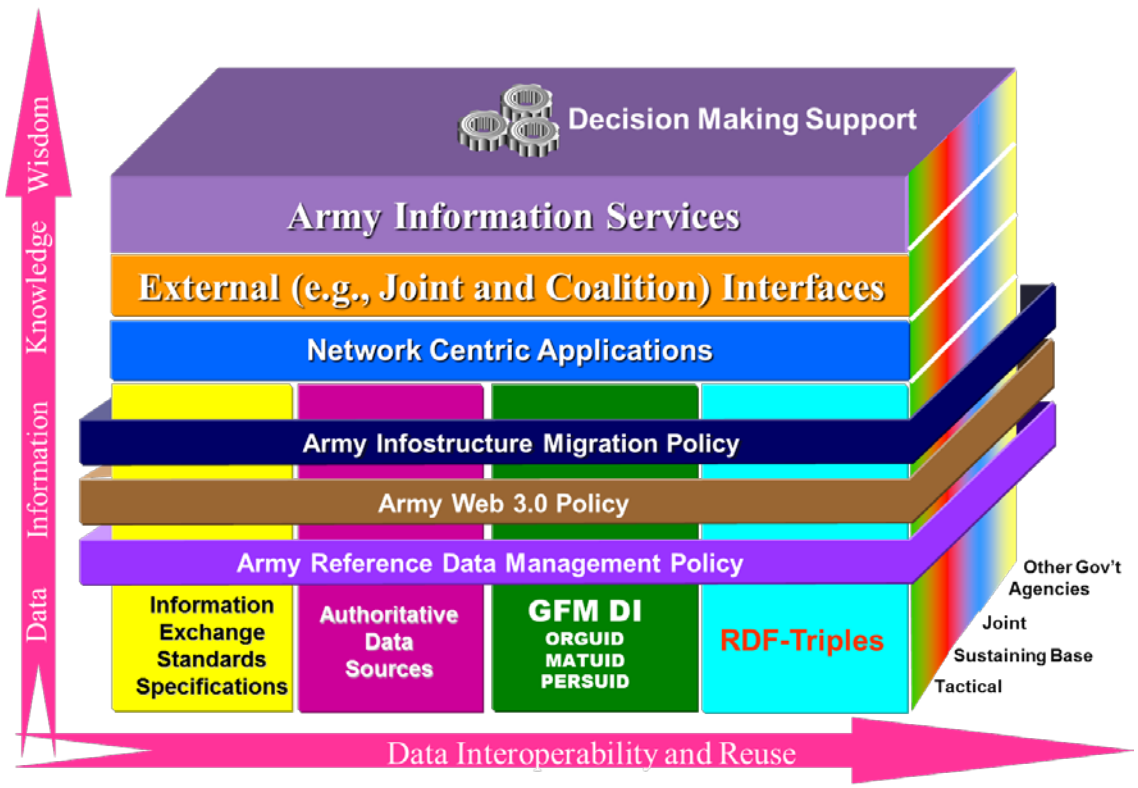

Figure 1-5. Interoperability and Reuse Model for the Army Enterprise

2. Phases of Proposed GFMDI Strategy Implementation Plan

A. Introduction

The background for the GFMDI strategy implementation plan can be summarized as follows:

- The assignment of globally unique identifiers to every Army unit in accordance with the Global Force Management Data Initiative (GFMDI) will make it feasible for all systems that require force structure information to operate from "the same sheet of music," thereby increasing the accuracy of information for decision making, enabling planning capabilities not currently available, and eliminating the need for laborious and expensive re-keying of force structure information, minimizing human error, and reducing processing time and associated costs. Once implemented across the enterprise the GFMDI strategy will support business and war fighting operations in a more effective and efficient manner than what the current BMA systems support.
- Although GFMDI requirements have been approved by the Joint Requirements Oversight Council (JROC), they have not been institutionalized in the Army enterprise.
- The various implementation plans associated with the current Capability Development Documents (CDD) do not cover all the aspects necessary to achieve the desired end state.
- Force structure is currently being produced in multiple systems spread across many organizations that do not conform to any standard. The next challenge is to extend the use of GFMDI-compliant force structure data to systems within the Business Mission Area (BMA) and the Warfighting Mission Area (WMA).
- GFMDI covers uniquely identified organizations, authorized equipment and billets, and the relationships among them, and it is primarily intended to support machine-to-machine exchanges. It does not require elimination of legacy key management and is primarily meant for exchanges across the enterprise.
- The Army has made substantial progress regarding the creation and population of an Army Organization Server (AOS) intended to be the ADS for authorized static and dynamic force structure information.

- The Army has not applied Master Data Management to its force structure information, and the implementation of the GFMDI strategy would provide the standards necessary to implement that capability.

The proposed approach presented here for implementing the GFMDI strategy across the Army BMA, therefore, is to conduct a series of pilots to determine the resources and level of effort required to ensure that typical BMA systems (e.g., selected ERPs) can consume force structure data available at the AOS, and to exchange products keyed to the GFMDI globally unique identifiers created and maintained in the AOS. The information gained from this operation will be used to support Program Objectives Memorandum (POM) 14-18 decisions. An assessment of the pilots is intended to form the basis for enterprise-wise use of a GFMDI-compliant representation of the Army's organizational/ force structure capable of supporting both static and dynamic force structure capabilities.[19]

The overall activity is to be conducted in four phases, and it will provide a roadmap for ensuring use of GFMDI-compliant force structure data in all pertinent BMA systems. The first set of pilots (Phase 1) will concentrate on key end-to-end (E2E) processes, starting with BMA systems that support Deploy-to-Redeploy/Retrograde (D2RR), and then expanding to the Hire-to-Retire (H2R), Budget-to-Report (B2R), and Cost Management (CM) processes. Subsequent pilots will address Procure-to-Pay (P2P), Acquire-to-Retire (A2R), Order-to-Cash (O2C), Plan-to-Stock-Inventory-Management (P2SIM), Concept-to-Product (C2P), Environmental-Liabilities (EL), Service-Request-to-Resolution (SR2R), Service-to-Satisfaction (S2S), Proposal-to-Reward (P2R), Market-to-Prospect (M2P), and Prospect-to-Order (P2O).

B. GFMDI Strategy Implementation Plan: Phase 1

Figure 2-1 depicts the five activities that compose Phase 1 of the proposed GFMDI strategy implementation plan, namely (1) inventory of relevant systems, (2) requirements analysis for the selected systems, (3) documentation of information linkages among systems — under the view that the D2RR systems form the 'core' that must interface with all the other BMA systems, (4) documentation of procedures for achieving interoperability and (5) estimation of resources needed to attain optimal interoperability. As mentioned in the preceding section, the initial focus of the plan is the D2RR process.

To that effect, a representative subset of BMA information systems that support that activity should be identified. Thereafter, said systems should be analyzed in terms of how the D2RR process uses them – in other words, assessing what information they

[19] The phases and specific tasks of the proposal could serve as additional detail for the future Army Business Management Strategy plan (see Footnote 11 above).

provide to the D2RR business flows – which will enable the analysis of dependencies among them. To fully understand the problem space, it is also necessary to ascertain whether there are, or should be, information exchange requirements among the BMA systems being examined. Once this mapping of information requirements and systems is completed, the plan progresses to an activity designed to elaborate how the systems are going to exchange their information making full use of the GFMDI asset identification scheme – that is, the globally unique identifiers assigned to military units, and potentially, to other assets of interest. The Phase 1 pilot concludes with documentation of the level of effort required to carry it out, as well as an assessment of how well the expectations regarding interoperability and reuse have been met.

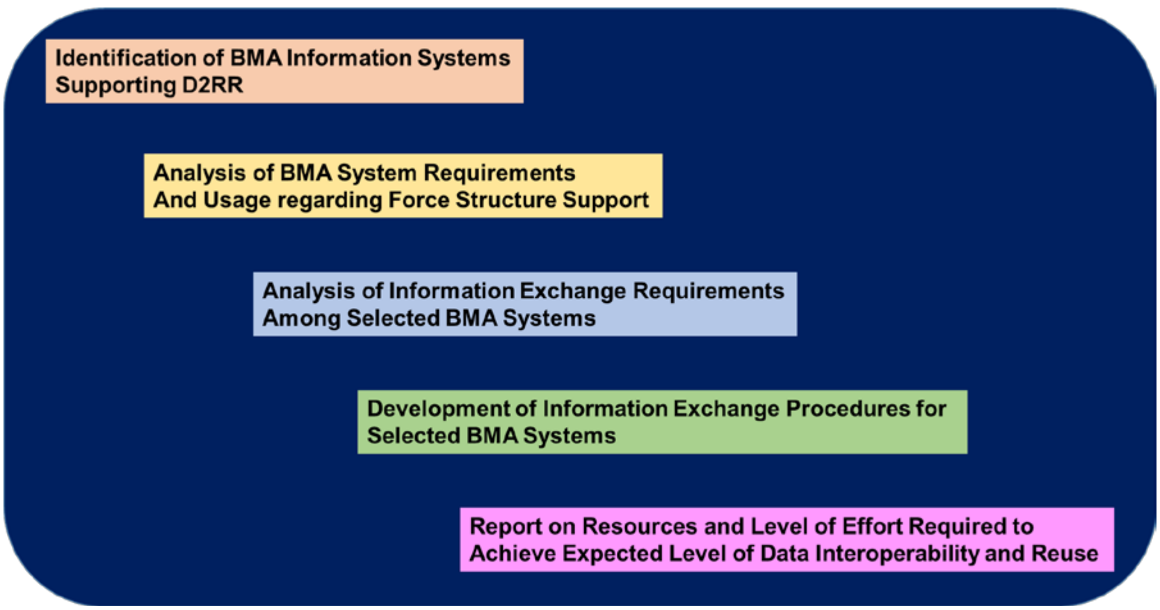

Figure 2-1. GFMDI Strategy Implementation Plan: Phase 1 Activities

C. GFMDI Strategy Implementation Plan: Phase 2

Figure 2-2 depicts the five activities that comprise Phase 2 of the proposed GFMDI strategy implementation plan. By extending the initial approach to three additional E2E processes, namely, Hire-to-Rehire, Budget-to-Report, and Cost-Management, the pilots in this phase are intended to provide a deeper understanding of the level of effort and requirements pertaining to the use of GFMDI globally unique identifiers for the purpose of enabling optimal information interoperability and reuse within the Army BMA systems.

To that effect representative BMA systems should be identified and the results obtained in Phases 1 and 2 assessed regarding their suitability, and, where required, be either extended or modified. This phase concludes with a documentation of the level of effort required to carry it out, as well as an assessment of how well the expectations regarding interoperability and reuse have been met in the additional BMA systems. It should be noted that the selection of E2E processes made for this phase is not intended to be definitive. A different mix could be chosen depending on the circumstances and priorities that may exist when this phase is expected to start. However, irrespective of the systems chosen, Phase 2 is designed to better assess the complexities involved in the implementation of the GFMDI strategy, and to give the decision makers a more detailed picture of the necessary funding and migration schedules for a future operational capability.

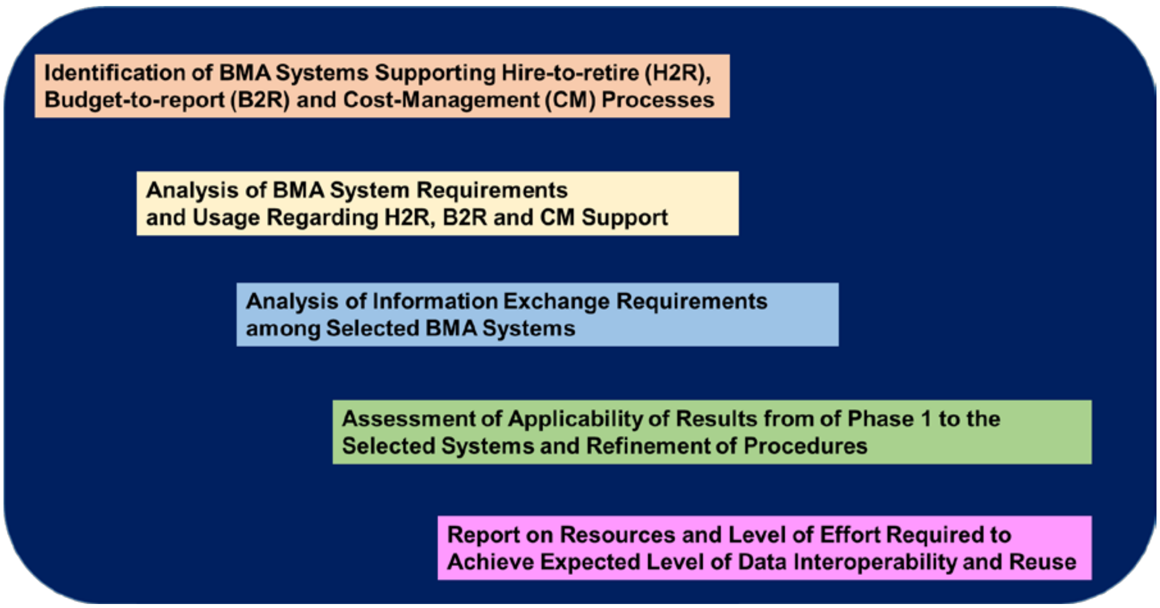

Figure 2-2. GFMDI Strategy Implementation Plan: Phase 2 Activities

D. GFMDI Strategy Implementation Plan: Phase 3

Figure 2-3 depicts the five activities that compose Phase 3 of the proposed GFMDI strategy implementation plan. This phase is intended to explore through appropriate pilots the remaining set of E2E processes and to assess how well the procedures and techniques developed and tested in the pilots from Phase 1 and Phase 2 can be extended to the remaining BMA systems.

As noted in the preceding section, here too the E2E processes chosen for this phase are understood to be subject to change depending on the circumstances and priorities that may exist when this phase is expected to start. The documentation of the lessons learned, as well as the resources and level of effort required should be both comprehensive and sufficiently detailed to enable the formulation of a transition strategy for the BMA systems at the enterprise level.

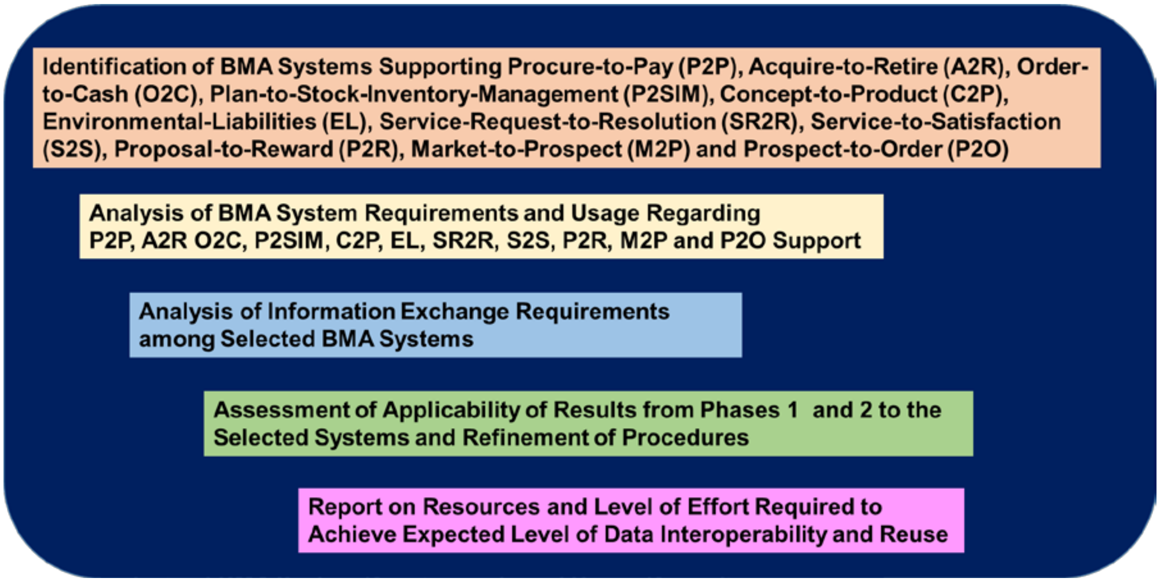

Figure 2-3. GFMDI Strategy Implementation Plan: Phase 3 Activities

E. GFMDI Strategy Implementation Plan: Phase 4

The final phase (shown in Figure 2-4) of the proposed GFMDI strategy implementation plan comprises (1) the development of a schedule specifying dates for initial and final operational capabilities after applying the approach demonstrated in Phases 1, 2, and 3 to all pertinent BMA systems involved in the E2E processes, (2) the assignment of responsibilities for migrating the current baseline to one that conforms with the use of GFMDI globally unique identifiers, and (3) the re-architecting of the Army BMA activities and workflows to leverage the new information interoperability and reuse capabilities.

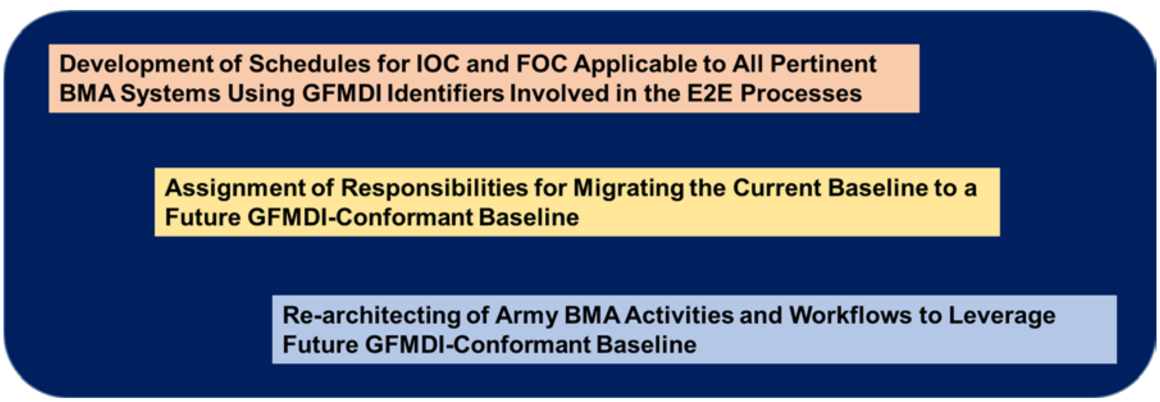

Figure 2-4. GFMDI Strategy Implementation Plan: Phase 4 Activities

3. GFMDI Strategy Implementation Plan: Specific Tasks

A. Introduction

The preceding section described a breakdown of the proposed GFMDI strategy implementation plan in terms of four phases, with the first three comprising pilot demonstrations envisioned to gain the necessary expertise for adopting the use of GFMDI globally unique identifiers to achieve optimal information interoperability and reuse among the BMA information systems that support its fifteen E2E processes.

This section provides specific tasks for each of the phases, and where appropriate highlights applicable technologies that may be applied to carry them out.

B. Specific Tasks for Phase 1

Request that for Phase 1 the Director, Office of Business Transformation (OBT), G-3/5/7 and Forces Command (FORSCOM) in coordination with the Chief Information Officer (CIO/G-6) and the Assistant Secretary of the Army for Acquisition, Logistics, and Technology (ASA (ALT)):

1. Identify representative BMA information systems that both consume and produce data involving force structure and are part of the infrastructure supporting the business flows for the D2RR;
2. Identify technical personnel with the required level of expertise in the respective BMA information systems that will be part of the pilots;
3. Oversee and manage the development of the technical approach selected to demonstrate the ability of the selected BMA systems supporting D2RR to consume and produce data keyed to the GFMDI conformant data structure sets, with particular emphasis in the use of semantic technologies, e.g., RDF-based exchanges, development of exchange information models in OWL, use of the MDA approach for their maintenance and update;
4. Review and modify as required technical proposals generated to conduct the pilot's objectives;
5. Facilitate the resolution of technical issues that may arise during the performance of the pilots;

6. Ensure that the technical experts provide solutions of general applicability both in terms of systems as well as type of E2E processes involved; and
7. Support the overall consolidation of lessons-learned for Phase 1 and provide inputs to be used in the production of the final roadmap for the use of GFMDI-conformant data across the BMA information systems that support critical E2E processes

C. Specific Tasks for Phase 2

Request that for Phase 2 the Assistant Secretary of the Army for Manpower and Reserve Affairs (ASA(M&RA)), the Assistant Secretary of the Army for Financial Management and Comptroller (ASA(FM&C)) in coordination with the Chief Information Officer (CIO/G-6), and the Assistant Secretary of the Army for Acquisition, Logistics, and Technology (ASA (ALT)):

1. Identify representative BMA information systems that both consume and produce data involving force structure and are part of the infrastructure supporting the business flows for the H2R, B2R, and CM;
2. Identify technical personnel with the required level of expertise in the respective BMA information systems that will be part of the pilots;
3. Coordinate the review and incorporation of the lessons-learned from the Phase 1 of the plan;
4. Oversee and manage the development of the technical approach selected to demonstrate the ability of the selected BMA systems supporting H2R, B2R, and CM to consume and to produce data keyed to the GFMDI conformant data structure sets, with particular emphasis in the use of semantic technologies, e.g., RDF-based exchanges, development of exchange information models in OWL, use of the MDA approach for their maintenance and update;
5. Review and modify as required technical proposals generated to conduct the pilot's objectives;
6. Facilitate the resolution of technical issues that may arise during the performance of the pilots;
7. Ensure that the technical experts provide solutions of general applicability both in terms of systems and the type of E2E processes involved; and
8. Support the overall consolidation of lessons-learned for Phase 2 and provide inputs to be used in the production of the final roadmap for the use of GFMDI-conformant data across the BMA information systems that support critical E2E processes.

D. Specific Tasks for Phase 3

Request that for Phase 3 the Assistant Secretary of the Army for Acquisition, Logistics and Technology (ASA(ALT)), the Assistant Secretary of the Army for Financial Management and Comptroller (ASA(FM&C)), the Assistant Secretary of the Army for Installations, Energy and Environment (ASA(IE&E)), and the Assistant Secretary of the Army for Manpower & Reserve Affairs (ASA(M&RA)) in coordination with the Chief Information Officer (CIO/G-6):

1. Identify representative BMA information systems that both consume and produce data involving force structure and are part of the infrastructure supporting the business flows for the P2P, A2R, O2C, P2SIM, C2P, EL, SR2R, S2S, P2R, M2P, and P2O processes;
2. Identify technical personnel with the required level of expertise in the respective BMA information systems that will be part of the pilots;
3. Coordinate the review and incorporation of the lessons-learned from Phases 1 and 2 of the plan;
4. Oversee and manage the development of the technical approach selected to demonstrate the ability of the selected BMA systems supporting P2P, A2R, O2C, P2SIM, C2P, EL, SR2R, S2S, P2R, M2P, and P2O processes to consume and to produce data keyed to the GFMDI-conformant data structure sets, with particular emphasis on the use of semantic technologies, e.g., RDF-based exchanges, development of exchange information models in OWL, use of the MDA approach for their maintenance and update;
5. Review and modify as required technical proposals generated to conduct the pilot's objectives;
6. Facilitate the resolution of technical issues that may arise during the performance of the pilots;
7. Ensure that the technical experts provide solutions of general applicability both in terms of systems as well as type of E2E processes involved; and
8. Support the overall consolidation of lessons-learned for Phase 1 and 2 and provide inputs to be used in the production of the final roadmap for the use of GFMDI-conformant data across the BMA information systems that support critical E2E processes.

E. Specific Tasks for Phase 4

Request that for Phase 4 the Assistant Secretary of the Army for Acquisition, Logistics and Technology (ASA(ALT)), the Assistant Secretary of the Army for

Financial Management and Comptroller (ASA(FM&C)), the Assistant Secretary of the Army for Installations, Energy and Environment (ASA(IE&E)), and the Assistant Secretary of the Army for Manpower & Reserve Affairs (ASA(M&RA)) in coordination with the Chief Information Officer (CIO/G-6):

1. Review the lessons-learned from the previous three phases, the technical solutions developed, and the assessments of level of effort required for the adoption of the GFMDI strategy across the Army BMA;
2. Develop a migration schedule for the Army BMA in coordination with representatives from all pertinent information systems;
3. Create the necessary information for POM 14-18 decisions to achieve the implementation of the GFMDI strategy across the Army BMA.

4. Summarization of Analytical Results

A. Introduction

Under the task order, the IDA team provided to the sponsor three interim reports documenting technical solutions, as well as considerations regarding possible barriers to the adoption of the GFMDI strategy within the Army BMA. This section summarizes the key results presented in those reports. Technical content not included in this summary is provided in Attachment 1, Supplemental Materials, which is on a CD located on the back inside cover of this document.

For the purpose of what will be described in this section, the reader should keep in mind the following. The GFMDI underlying information models are the Global Force Management Information Exchange Data Model (GFMIEDM) and the Joint Consultation, Command, and Control Information Exchange Data Model (JC3IEDM). The GFMIEDM is an extended subset of the JC3IEDM. The latter is developed and maintained by the Multilateral Interoperability Programme.[20] Because many of the data constructs that would apply to the BMA processes are not completely covered in the GFMIEDM, the IDA team, with concurrence from the sponsor, chose to base its technical analysis on the JC3IEDM.

B. Extension and Use of the "Structure" Construct

During the initial phase of the effort, the sponsor requested an analysis of the type of support offered by the JC3IEDM to represent and capture information pertinent to specific logistic requirements, e.g., using the JC3IEDM vocabulary to express the declaration of contents of materiel shipped, the specification components that make up a type of platform, etc.

Upon examination of the JC3IEDM, the IDA team concluded that, with minor modifications, it would be possible to represent the data sets for the above-mentioned logistic requirements using the concept of structure, which the current JC3IEDM applies only to the description of an order of battle (ORBAT). By applying this concept not only to the Organisation subtype under the ObjectItem hierarchy it is possible to create representations for essentially any tree-like dataset, such as the contents of a large box,

[20] https://mipsite.lsec.dnd.ca/Pages/Default.aspx.

containing N medium size boxes, which in turn may contain M small boxes, each of which may have one or more items, e.g., spare parts as shown graphically in Figure 4-1.

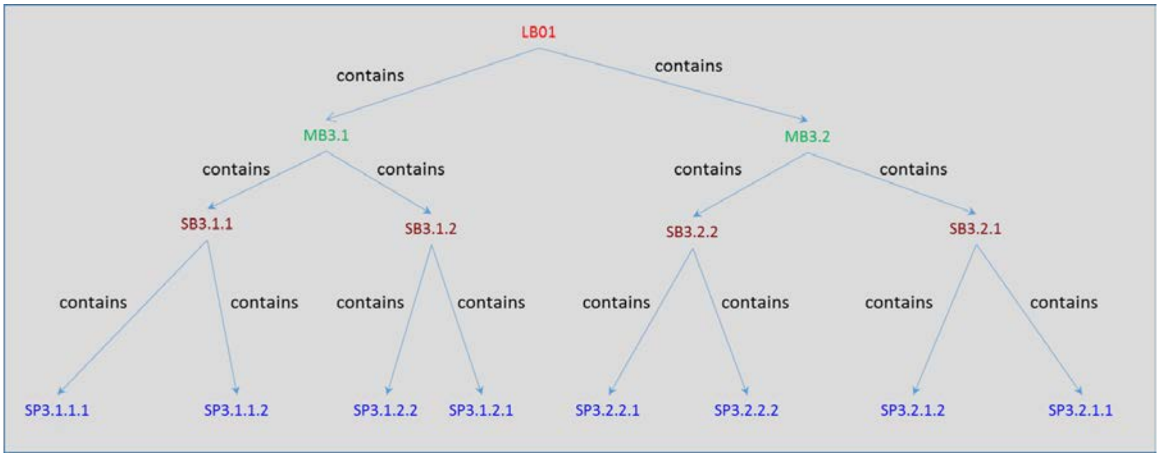

Figure 4-1. Tree-like Decomposition of Container Contents

Figure 4-2 below shows the implementation of extending the basic idea of structure to ObjectItem. The large box in the example above would be an instance of ObjectItem serving as the "root" of the tree. All N medium size boxes, as well as the M small boxes and the individual spare parts would also be instances of ObjectItem.

The relationship between each of the N medium size boxes and the "root" large box instance (e.g., *contains*) would be captured in the ObjectItemAssociation, a construct that serves to link pairwise instances of ObjectItem. Similarly, the relationship between each of the M small boxes and the respective N medium size boxes, as well as the relationship between each of the spare parts and the respective M small boxes they are contained in would be tracked as records in the ObjectItemAssociation table. By assigning to the instance that serves as the "root" of the tree an instance of ObjectItemStructure, it is now possible to list as entries in ObjectItemStructureDetail all the pertinent pairwise associations registered in ObjectItemAssociation.

The traversal of the tree constructed in this way would then read: large box *contains* medium size box N1, N2, … and medium size box N1 *contains* small size box M1, M2 … and medium size box N2 *contains* small size box M3, M4, etc. And finally, small size box M1 *contains* spare part 1, … and so forth, as shown in the graphic above.

A similar extension applied to ObjectType in JC3IEDM would equally allow for the description of tree-like datasets that represent the components of types of platform, e.g., a type of armored vehicle, a type of radio. Figure 4-3 below shows the entity-level depiction of the JC3IEDM subview corresponding to ObjectTypeStructure. With it one can represent the decomposition of platforms like an M1-A1 tank into its gun, turret, threads, etc., each of which could in turn be further decomposed into its subparts to any level of granularity required for a given logistics operation.

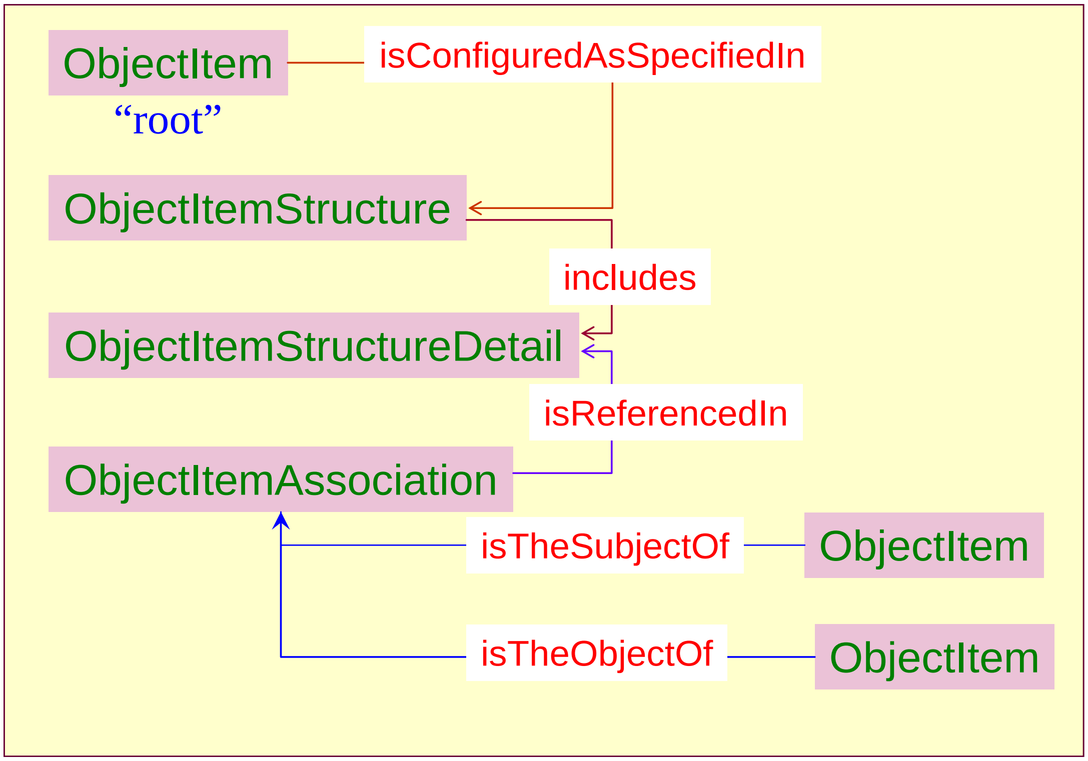

Figure 4-2. The JC3IEDM Extension of Structure for ObjectItem

It should be noted that because these two constructs are extensions to the current JC3IEDM there would be a need to agree to the specific standards for expressing the way in which instances of either ObjectItem or ObjectType are associated with each other under ObjectItemAssociation and ObjectTypeAssociation respectively. For example there would be a need to agree on both the coded domains (*contains*, *has subcomponent*, etc.), as well as the rule that specifies how the code is to be read, e.g., from subject to object. In the same vein, where specialized vocabularies already are in use within a particular community of interest, this usage would need to be reflected in the final specification of the model to minimize ambiguity and facilitate the adoption of the proposed extensions. Aside from these small but important caveats, there do not appear to be any technical limitations.

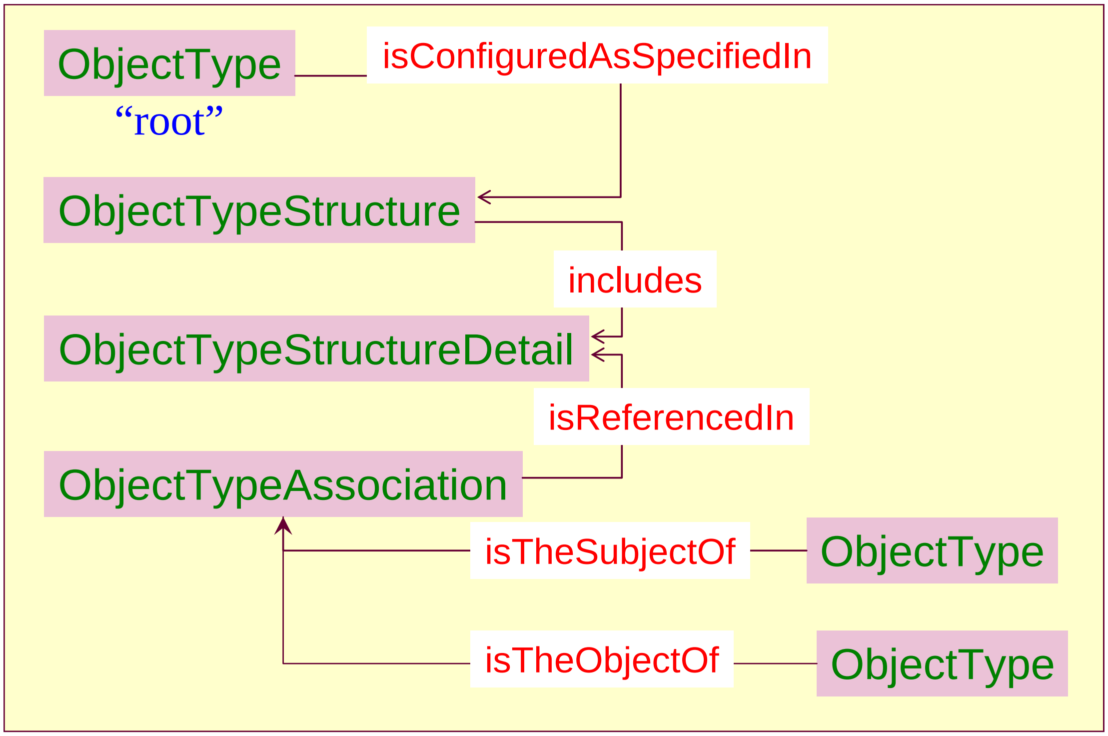

Figure 4-3. The JC3IEDM Extension of Structure for ObjectType

Obviously, each of the instances of ObjectItem and ObjectType used in the specification of the respective tree-like data sets would be identified via a GFMDI-conformant identifier. Finally, it should be noted that ObjectTypeStructure could be used as a replacement for the more limited construct contained in the JC3IEDM, namely, ObjectTypeEstablishment.[21]

C. Support for Courses of Action

In the follow-on phase of the study the sponsor requested an analysis of the type of support offered by the JC3IEDM to represent and capture information pertinent to additional logistic requirements, e.g., using the JC3IEDM vocabulary to express activities pertinent to depot operations, major equipment maintenance and upgrade, courses of action, etc. The sponsor also requested an analysis regarding support in JC3IEDM for the representation of standard architectural products, e.g., activities at nodes, activity models.

[21] For further technical detail concerning the specification and use of the ObjectItemStructure and ObjectTypeStructure extensions in the BMA context, see the first and second deliverables in Attachment 1.

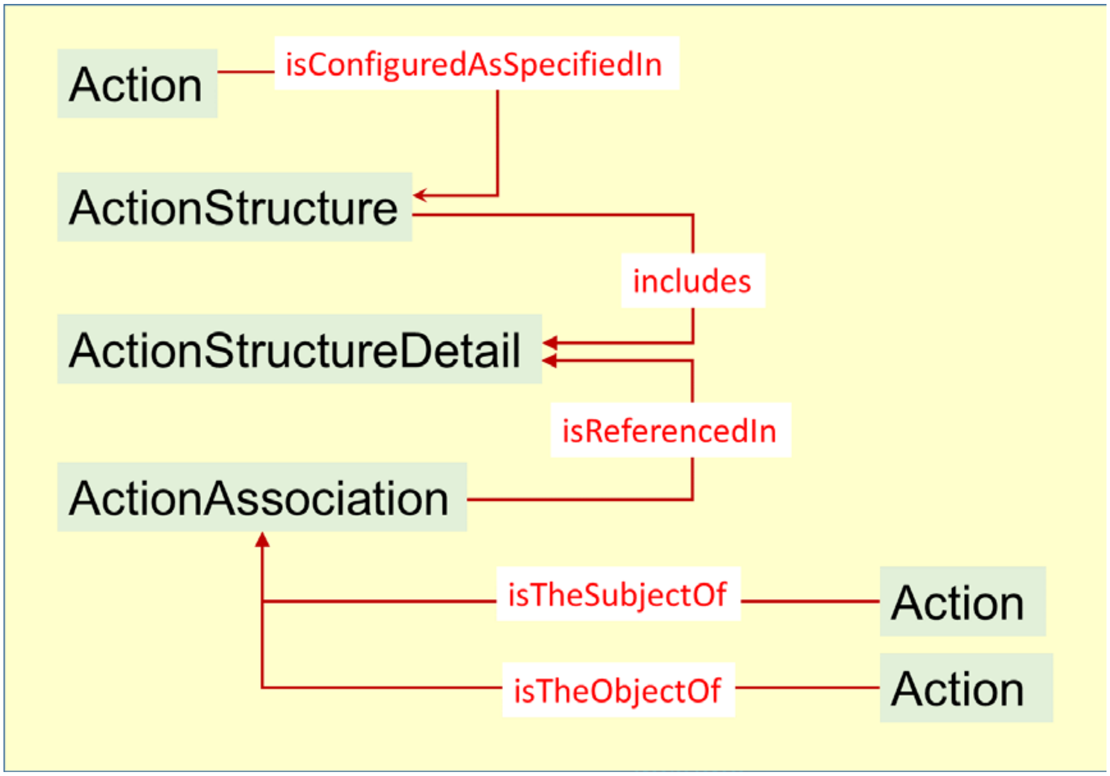

Figure 4-4. The JC3IEDM Extension of Structure for Action

Based on the analytical results obtained in the first phase the IDA team concluded that the concept of structure could be also applied to the JC3IEDM Action construct. Figure 4-4 above shows the specification for ActionStructure built in a manner analogous to that of ObjectItemStructure. The corresponding subview for ActionTypeStructure is shown in Figure 4-6 below.

With these two JC3IEDM extensions the IDA team demonstrated that it is possible to capture tree-like datasets related to either instances of Action or instances of ActionType. Structured activities, i.e., composite activities that break down into specialized subactivities, can be expressed using the ActionStructure in the same manner that composition of instances of ObjectItem is done with ObjectItemStructure, as the reader can easily verify by taking the example described above and replacing "boxes" with "actions" to represent something like scheduled maintenance of a vehicle or delivery of medical supplies by a depot in response to a request from the field.

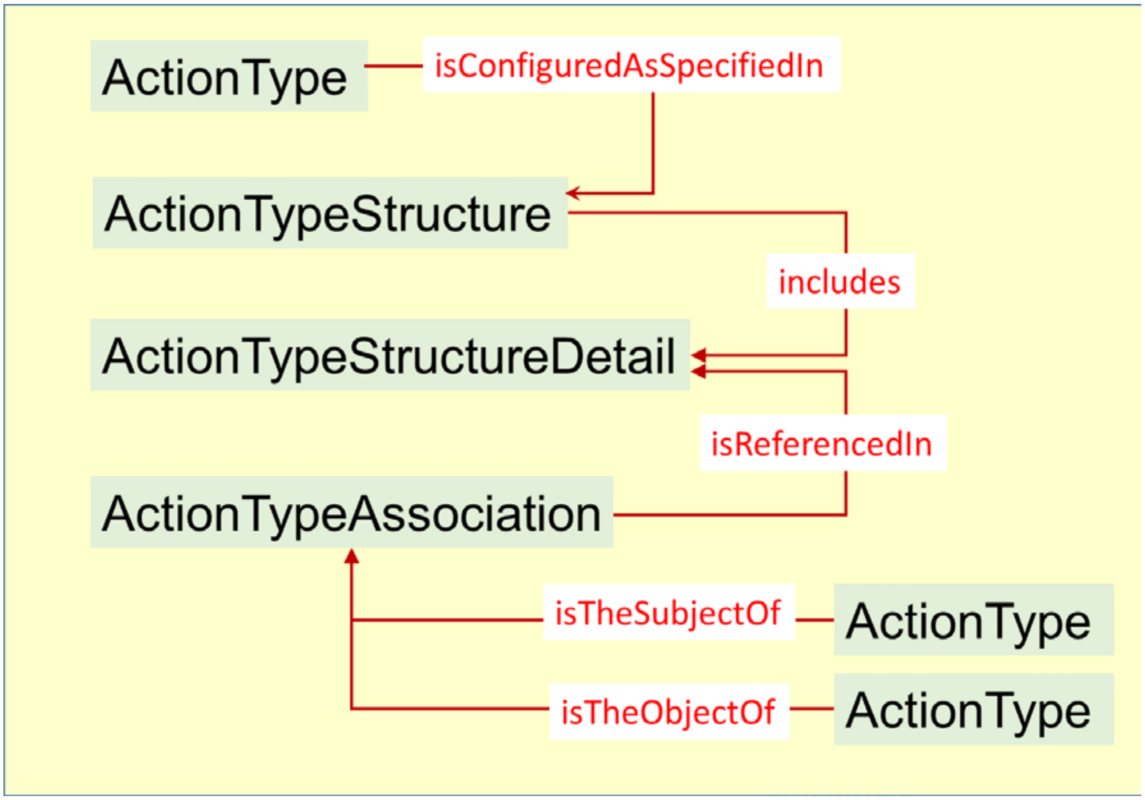

Figure 4-5. The JC3IEDM Extension of Structure for ActionType

Courses of action (COA) can be expressed by assigning separate instances of ActionStructure to the root action for each of the COAs. Each of those instances of ActionStructure corresponding to the respective COAs can then capture the different subactivities under them in the standard manner discussed above. So, for example, if there are three ways in which materiel can be moved from a depot to a ship depending on the maximum capacity of the forklift to be used, then each way would be an instance of ActionStructure corresponding to a combination of actions to move pallets that remains within the maximum lift weight limit of the forklift to be used.

Support in JC3IEDM for the representation of standard architectural products, e.g., activities at nodes, activity models, could be done using ActionStructure with the agreement that only those instances of Action are to be viewed as *types*, which in the JC3IEDM are further specified as instances of ActionTask without a temporal dimension. Because of the advantage that obtains from explicitly separating the semantics of instance and types, the IDA team opted instead to introduce explicitly the concept of ActionType and the corresponding ActionTypeStructure and successfully demonstrated how to use it to capture architecture products such as activity models and operations at nodes (respectively Operational View 5 [OV-5] and Operational View 2 [OV-2] in the DoD

Architecture Framework notation).[22] The technical details are contained on the CD accompanying this document.

It should be noted that whereas the GFMDI strategy explicitly covers and has, or plans to have, appropriate servers to function as authoritative data sources for military units, types of materiel, and personnel, the areas outside those three domains are at present not addressed by the strategy. In the case of activities represented as instances of Action or ActionType there would be a need to stand up analog servers to provide the corresponding GFMDI globally unique identifiers to the systems that want to reference those resources without ambiguity.

Standardized taxonomies already exist, such as the Universal Joint Task List (UJTL)[23] and service-specific extensions, e.g., the Army Universal Task List (AUTL),[24] which could provide the basis for an ADS of types of activities. Further analysis is required to elaborate the procedure for bringing these information sources under the GFMDI umbrella.[25]

D. Applicability of Semantic Technologies

Army Regulation *AR 25-1 Army Information Technology* (see Footnote 17 above) already includes semantic technologies for the architecting of its information systems. With concurrence by the sponsor the IDA team, therefore, undertook an initial assessment of the maturity and applicability of these technologies within the BMA in the context of institutionalizing the GFMDI strategy. Special emphasis was given to the cost benefit that could be derived from their use.

1. Industry Standards with Substantive Cost Savings Potential

The main thrust of the assessment focused on the use information models written in Ontology Web Language (OWL), coupled with the Model Driven Architecture (MDA) approach developed by the Object Management Group.[26] Figure 4-6 below depicts the key components of the MDA cycle as tested by the IDA team. As shown therein, the production process of executable code for any major application starts with the analysis of the problem domain, but unlike the typical cycle, where the requirements are immediately used as the basis for programmers to start writing executable code, in the

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[22] http://dodcio.defense.gov/dodaf20.aspx.

[23] http://www.dtic.mil/cjcs_directives/cdata/unlimit/m350004.pdf.

[24] http://armypubs.army.mil/doctrine/DR_pubs/dr_a/pdf/fm7_15.pdf.

[25] For further technical detail concerning the specification and use of the ActionStructure and ActionTypeStructure extensions in the BMA context see the second deliverable in Attachment 1.

[26] http://www.omg.org/mda/specs.htm.

MDA approach these requirements are captured in the form of a model that abstracts from the particular platform implementation – in other words, it specifies a requirements model without any constraint dictated by the final technology planned for the actual deployment.

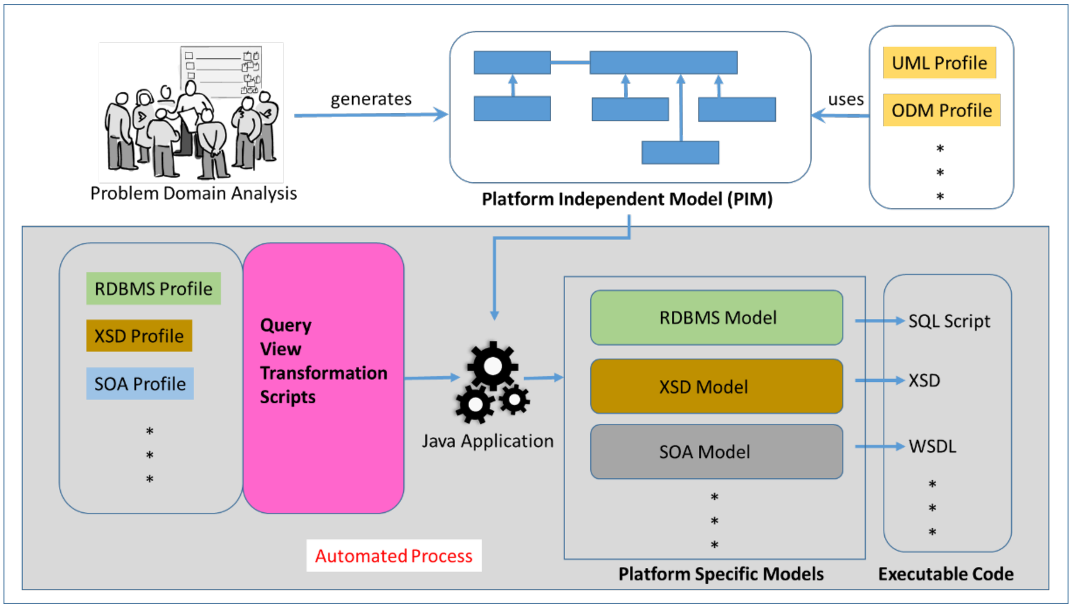

Figure 4-6. The Model Driven Architecture Approach

This type of model is appropriately named a *Platform Independent Model* (PIM), and it can be written in either standard Unified Modeling Language (UML) notation, or in a specific Unified Modeling Language (UML) profile, such as the Ontology Definition Metamodel (ODM) profile, which enables the graphical generation of OWL models using commercially available UML case tools. Under the MDA approach once a PIM written in a specific UML profile is in place it is then possible to use scripts written in the *Query, View, and Transformation* (QVT) language that forms part of the MDA specification to convert it to another model that uses a different UML profile. More specifically, under the MDA approach the QVT scripts are intended to enable the insertion of the necessary platform specific constraints purposefully left out in the PIM to produce a desired *Platform Specific Model* (PSM).

Two things are worth noting. First is the fact that the kinds of PSM models that can be generated out of a single PIM are essentially limited only by the availability of the required QVT scripts. In other words, the same PIM can serve as the basis for multiple implementations based on different technologies.

The second thing to note is that unlike the traditional cycle, where the requirements phase oftentimes includes platform-specific details and, therefore, must be revisited whenever a new technology is envisioned for the deployment phase, within the MDA approach the PIM does not need to be changed to support a deployment based on a different technology.

Furthermore, when new operational requirements are identified, the main component that needs to be updated is the PIM. All the PSMs can then automatically be updated by reapplying the QVT scripts to the new PIM. Because most UML computer aided software engineering (CASE) tools can produce executable code out of a PSM, the application update cycle is also not only faster but is less prone to errors caused by human programmers.

The above-mentioned features of the MDA approach can therefore generate substantive cost savings to the enterprise because of the enhanced traceability from requirements down to executable code, the minimization in human error, and the accompanying reduction in the number of programmers required to maintain and update the application binaries. [27]

2. Motivation for the Use of the Ontology Web Language (OWL)

The IDA team rationale for exploring the use of OWL is three-fold:

- Information modeling techniques based on entity relationship (ER) languages, such as Integration DEFinition for Information Modeling (IDEF1X),[28] are tightly coupled to specific technologies, e.g., relational databases. OWL supports a modeling style that depends less on the specifics of the final implementation.
- ER data models are typically process-oriented (focus on the *how* of object use), i.e., they merge the description of the nature of the objects with the way in which they are employed for a specific process. As a result the attribution of the entities in an ER model is typically a function of the process for which it is built. Since within a given enterprise there are multiple processes involving the same objects, this leads to a proliferation of incompatible (non-interoperable) ER data models. Semantic modeling techniques using OWL, on the other hand, focus on the nature of the objects within the problem domain (the *what* of the object). It is thus easier to explicitly maintain a clean separation between the characterization of the nature of the object and its use within processes, and to elaborate vocabularies applicable across the enterprise.
- OWL is the most popular language for semantic modeling. Extensive tool support for automated reasoning exists for semantic models written in OWL. This

[27] Some parts of the Federal have already begun utilizing the MDA approach for the generation and maintenance of their information exchange specifications, e.g., U.S. Department of Homeland Security and the U.S. Department of Justice for the National Information Exchange Model (NIEM).

[28] http://www.itl.nist.gov/fipspubs/idef1x.doc.

not only facilitates the formalization of applicable business rules, which, as noted above, enhances in turn data quality and reduces costs, but also provides a natural path for the application of well-established methods for solving interoperability issues and enhanced machine-processability of data.

3. Applicability of OWL within the MDA Approach

Given the above-mentioned benefits the IDA team undertook a technical analysis of the feasibility of merging the MDA approach with the use of OWL, so that it could be used by the Army BMA for the maintenance and update of both the information models underlying the GFMDI, as well as any other model within the BMA information systems.

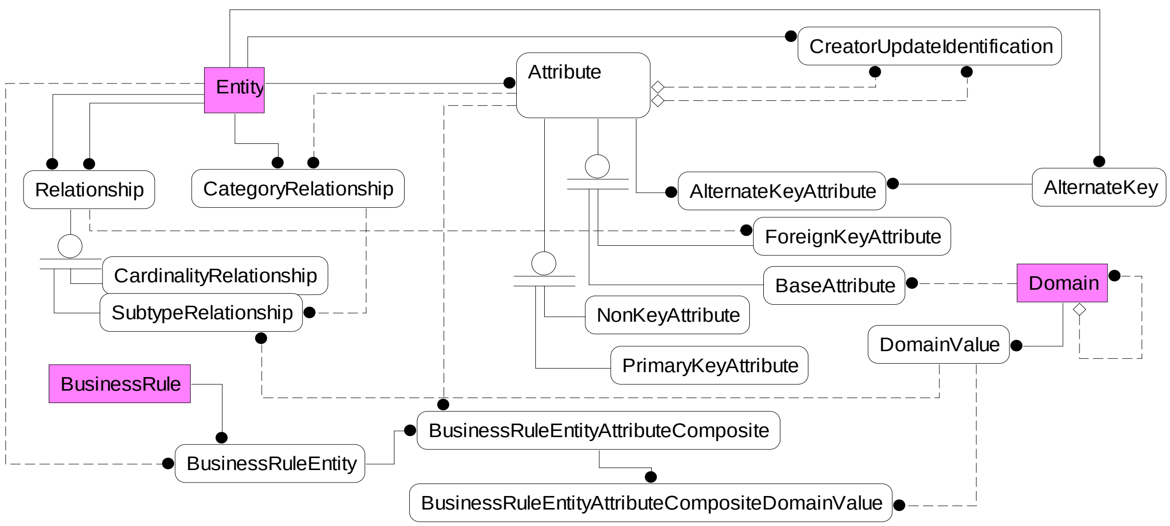

Figure 4-7. MIP Metamodel for the JC3IEDM Information Resource Dictionary

To that effect the IDA team built an OWL model out of the JC3IEDM Multilateral Information Programme (MIP) information resource dictionary (MIRD) using MIRD2OWL, a tool developed in house written in Python. The tool is generic in the sense that it can be used with any information model whose entity relationship specifications are expressed using the MIRD metamodel (see Figure 4-7 above). The resulting OWL specifications were then imported into Sparx Systems Enterprise Architect (Sparx EA),[29] the CASE tool selected in the study for UML modeling.

The import step mentioned above was carried out using OWL2EA, a Java application developed by the IDA team that takes OWL expressions and maps them to the corresponding constructs specified in the Ontology Definition Metamodel (ODM) UML

[29] http://www.sparxsystems.com/.

profile.[30] The ODM profile enables a user to visualize and create OWL models using standard UML modeling tools, such as Sparx EA, eliminating thereby one of the shortcomings of OWL, namely, its lack of a graphical language specification.

Once the JC3IEDM OWL model was loaded into Sparx EA, the IDA team investigated whether it could serve as a PIM on which QVT scripts could be applied to generate the respective PSMs in accordance with the MDA approach. Two such scripts were developed by the IDA team to answer the question, and both were successfully tested.

The first script transforms the JC3IEDM OWL PIM into a PSM corresponding to an ER relational model written with the UML profile for databases implemented in Sparx EA. As shown in Figure 4-6 the final step within the MDA approach is the generation of *executable code*, which, for a relational database specification, means generating an SQL[31] script to create a physical schema in a database server application. Using the DDL[32] generation feature in Sparx EA the IDA team obtained the SQL script from the JC3IEDM PSM and successfully loaded it into MySQL, a commercially available relational database managing system (RDBMS). Annex A below supplies further technical detail on all the steps involved and results obtained.

The second script transforms the JC3IEDM OWL PIM into a PSM corresponding to an XSD model written with the UML profile for XSDs implemented in Sparx EA. Such a model can be used to maintain specifications required for XML-based exchanges consistent with the vocabulary of the JC3IEDM. The IDA team selected this test case in light of the fact that DoD has promulgated policy regarding the use of the National Information Exchange Model (NIEM)[33] for its XML-based exchanges.[34] Due to fiscal and time constraints the QVT script developed by the IDA team did not attempt to cover every aspect of the NIEM specification.

As noted above (see Figure 4-6 above) the final step within the MDA approach is the generation of *executable code*, which, for an XSD specification, means generating the XSD serializations that can be used by an application to validate XML messages. Using the XML serialization feature in Sparx EA, the IDA team obtained the respective XSDs from the JC3IEDM PSM. Appendix B supplies further technical detail on all the steps involved and results obtained.

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30 http://www.omg.org/spec/ODM/1.0/.

31 Structured Query Language.

32 Data Definition Language.

33 https://www.niem.gov/Pages/default.aspx.

34 "Adoption of the National Information Exchange Model within the Department of Defense," Memorandum from Teri Takai, DoD Chief Information Officer, March 28, 2013.

Figure 4-8 shows schematically the components of the solution architecture for the proof-of-principle test described above. The test confirms the feasibility of using OWL as modeling language for a PIM that can then be transformed in accordance with the MDA approach into any number of PSMs using the corresponding QVT scripts.[35]

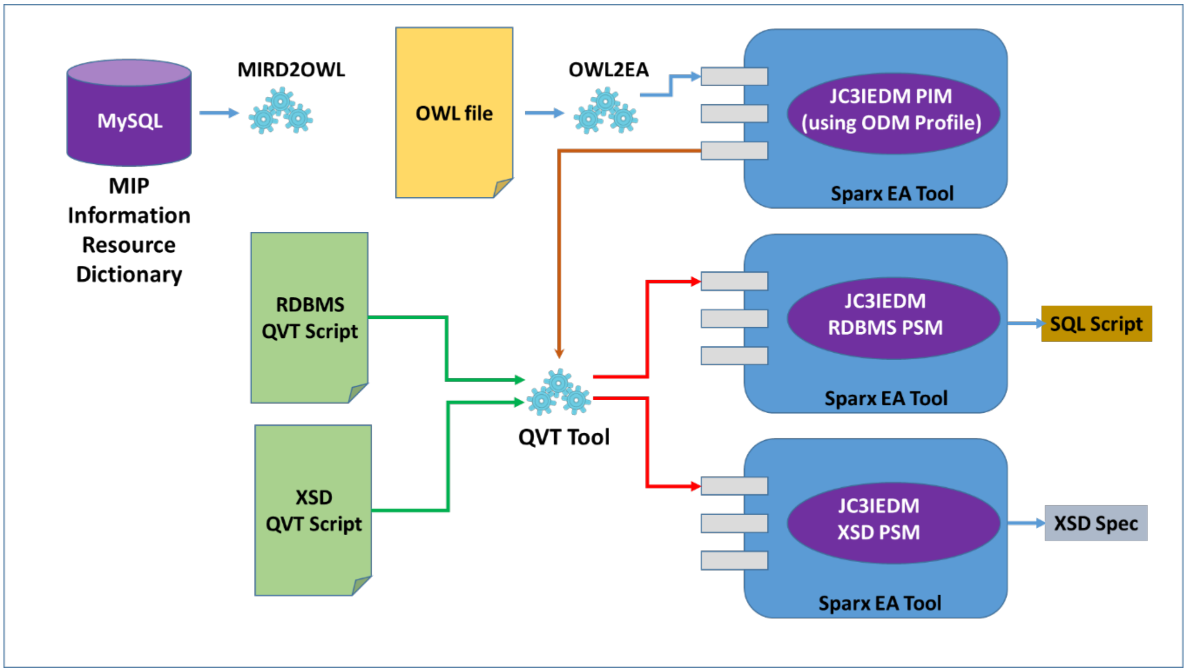

Figure 4-8. Solution Architecture for MDA Proof of Principle

4. RDF-based Exchanges

An additional assessment performed by the IDA team in the area of semantic technologies concerned the feasibility and likely benefits of RDF-based exchanges for Army BMA systems.[36] The focus of this analysis was to determine the potential gains in interoperability and reuse when using RDF triples to encode the types of information exchanges involved in typical logistics operations as described in Sections B and C above, as well as the costs savings that may accrue from the ease of standardizing query code using SPARQL.[37] Upon technical analysis of this issue in the context of examples based on the ObjectItemStructure, ObjectTypeStructure, ActivityStructure and ActivityTypeStructure usage covered in the first two deliverables under the task order, the

[35] A copy of all the software developed for this analysis is provided in Attachment 1.

[36] Resource Description Framework. http://www.w3.org/RDF/.

[37] http://www.w3.org/TR/rdf-sparql-query/.

IDA team concluded with regard to interoperability and reuse that the adoption of RDF-based exchanges offers the following advantages:

- Any RDF triple store is capable of loading any output generated from another RDF triple store, irrespective of the subject matter and vocabulary used. The likelihood of being able to accomplish the same task with two randomly selected relational databases is practically zero.[38]
- Because of the simple storage metamodel use by RDF triple stores, they can be readily federated to implement virtual distributed information systems much easier than when using RDBMS-based storage.
- The semantics associated with any collection of RDF triples (normally referred to as the *Assertion Box* or the *A-Box* of a knowledgebase) contained in an RDF triple store can be formally specified through terminological assertions (the so-called *T-Box*).
- The separation of A-Box and T-Box lets the user control how the instances are to be interpreted for a particular purpose, e.g., through the use of equivalence assertions in the T-Box to merge at run time triples using syntactically different but semantically equivalent vocabularies, without any changes to the content of the A-Box. This is particularly useful in combination with the federation capability offered by RDF triple stores.

With regard to cost savings the adoption of RDF-based exchanges offers the following advantages:

- Open-source support for RDF is quite extensive, and solutions based on RDF-based exchanges offer both scalability and good performance even when the number of RDF triples is large (hundreds of billions of triples).
- Additional technologies, such as intelligent agents, can be readily combined with RDF triple stores to support, for example, data retrieval from and integration of distributed repositories.
- The support offered by the SPARQL query language of variables in a manner similar to Prolog allows the standardization of queries across multiple semantic domains. Specifically, the body for the SPARQL query used to retrieve data sets pertaining to shipped materiel, decomposition of platform types into their subcomponents, or composite actions is almost identical, as shown in Figure 4-9, Figure 4-10, and Figure 4-11.

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[38] This statement assumes that there are no character encoding issues and that the exported RDF triples have not suffered any corruption prior to ingestion into the target system.

```
SELECT ?rootitem ?manifest ?container ?content
WHERE {?t mird:isConfiguredAsSpecifiedIn ?x .
       ?t mird:nameText ?rootitem .
       ?x mird:nameText ?manifest .
       ?x mird:includes ?y .
       ?z mird:isReferencedIn ?y .
       ?w mird:isTheSubjectOf ?z .
       ?w mird:nameText ?container .
       ?r mird:isTheObjectOf ?z .
       ?r mird:nameText ?content .
       }

t = ObjectItem (root)
x = ObjectItemStructure
y = ObjectItemStructureDetail
z = ObjectItemAssociation
w = ObjectItem (association subject)
r = ObjectItem (association object)

mird = qname for <http://mda.ida.org/mird/3.1.4#>
```

Figure 4-9. Example of SPARQL Query to Retrieve Contents of Shipped Materiel Using ObjectItemStructure

```
SELECT ?roottype ?structure ?unit ?subunit ?count
WHERE {?t mird:isConfiguredAsSpecifiedIn ?x .
       ?t mird:nameText ?roottype .
       ?x mird:nameText ?structure .
       ?x mird:includes ?y .
       ?y mird:count ?count .
       ?z mird:isReferencedIn ?y .
       ?w mird:isTheSubjectOf ?z .
       ?w mird:nameText ?unit .
       ?r mird:isTheObjectOf ?z .
       ?r mird:nameText ?subunit .
         }

t = ObjectType (root)
x = ObjectTypeStructure
y = ObjectTypeStructureDetail
z = ObjectTypeAssociation
w = ObjectType (association subject)
r = ObjectType (association object)

mird = qname for <http://mda.ida.org/mird/3.1.4#>
```

Figure 4-10. Example of SPARQL Query to Retrieve Contents of Force Structure Using ObjectTypeStructure

```
SELECT ?rootaction ?structure ?action ?subaction
WHERE {?t mird:isConfiguredAsSpecifiedIn ?x .
       ?t mird:nameText ?rootaction .
       ?x mird:nameText ?structure .
       ?x mird:includes ?y .
       ?z mird:isReferencedIn ?y .
       ?w mird:isTheSubjectOf ?z .
       ?w mird:nameText ?action .
       ?r mird:isTheObjectOf ?z .
       ?r mird:nameText ?subaction .
         }

?t = Action (root)
?x = ActionStructureDetail
?y = ActionStructure
?z = ActionAssociation
?w = Action (subject)
?r = Action (object)

mird = qname for <http://mda.ida.org/mird/3.1.4#>
```

Figure 4-11. Example of SPARQL Query to Retrieve Contents of Composite Actions Using ActionStructure

E. Support for E2E Processes: Deploy to Redeploy/Retrograde (D2RR)

Because of the significance of the D2RR process within the Army BMA, the IDA team undertook a detailed analysis of the data requirements implied by the business flows analyzed by the Army GFMDI cell and the ability to capture them using the vocabularies defined in the underlying models, namely the GFMIEDM and the JC3IEDM.

The specific details of the analyses described in the first two deliverables are provided in Attachment 1. The summary of the results from the first deliverable is as follows:

- A total of 177 activities identified in the current business flows for the D2RR were assessed with regard to the most likely JC3IEDM data constructs that would provide coverage for their data requirements. These assessments were based on the textual description of the nature of the activities. For each of the activities the IDA team also provided an initial estimate of the quality of the coverage. The qualitative values were "excellent," "good," "medium," 'low," "none," and "unknown."
- The table below summarizes the statistics of the estimated coverage quality at the entity level that the current JC3IEDM provides for the D2RR activities. As shown therein, only 14 of the 178 activities, or about 8% of all the cases examined have low coverage or no coverage, or no assessment could be made due

to insufficient information in the narrative associated with the activity. The remaining 92% of the activities have coverage ranging from "medium" to "excellent."

Excellent	Good	Medium	Low	None	Unknown
23	99	32	8	4	2

- According to the assessment, about 77 out of the 299 entities currently defined in the JC3IEDM would be required to capture the information pertaining to the activities within the D2RR business flows.
- Further analysis down to attributes and their coded domains is required to estimate their coverage for specialized concepts used in the D2RR.

For the second deliverable, the IDA team undertook a detailed analysis of a subset of the 177 activities. The approach used assumed an operator attempting to support the activity under analysis using an information system containing the required JC3IEDM entities and the appropriate data fill. Thus, for example, for the activity

> **Marshall Mobilized Elements for Movement**: The process of assembling, holding, and organizing (personnel) supplies and/or equipment, especially vehicles of transportation, for onward movement. (Reference: JP 3-17),

which forms part of the **Mobilize Forces** element under the D2RR, the IDA team conceptualized a scenario in which the operator would be tasked to support a specific tasking, such as

> Assemble, hold, and organize supplies and equipment for onward movement in response to Tank Squad Operational Mission TM-4,

using the above-mentioned information system, and then developed the corresponding workflow comprising the queries that need to be executed to obtain the data necessary to satisfy the objective of the tasking. The complete walk-through for this example is provided in Appendix C.

F. Assessment of Barriers to the Adoption of the GFMDI Strategy

The adoption of a strategy that affects a large number of systems is likely to encounter a number of barriers. The IDA team undertook an analysis of the most likely impediments to the implementation of the GFMDI strategy within the Army BMA and proposed measures that could diminish the risk posed by them. Figure 4-12 shows a taxonomy of the most likely barriers identified by the IDA team.

As shown in Figure 4-12, the *first technical barrier* is the risk arising from the potential inadequacy of concepts in the JC3IEDM for capturing and representing the operational requirements of the D2RR processes. Based on the technical assessments performed during the study, the IDA team concluded that at the entity level there do not appear to be any shortcomings in the way concepts of the JC3IEDM support the D2RR requirements stemming from business flows. However, because the model was designed to support C2 multinational coalition operations, its vocabulary (i.e., domain values) does not necessarily cover all the terms needed for the whole cycle of processes within the BMA. In particular, the model is relatively sparse in the area of personnel, since within multinational coalition operations there is no requirement to exchange detailed personal soldier information.

To mitigate this barrier the needed detail in the Person and PersonType constructs is absent in the current JC3IEDM vocabulary, and needs to be examined and incorporated into the model to support D2RR business flows that deal specifically with personnel information (e.g., Hire-to-Retire).

The *second technical barrier* is the associated risks arising from changes to the "as-is" infrastructure, such as the potential for interruption of services, and negative effects on current workflows, when implementing the GFMDI strategy within the Army BMA.

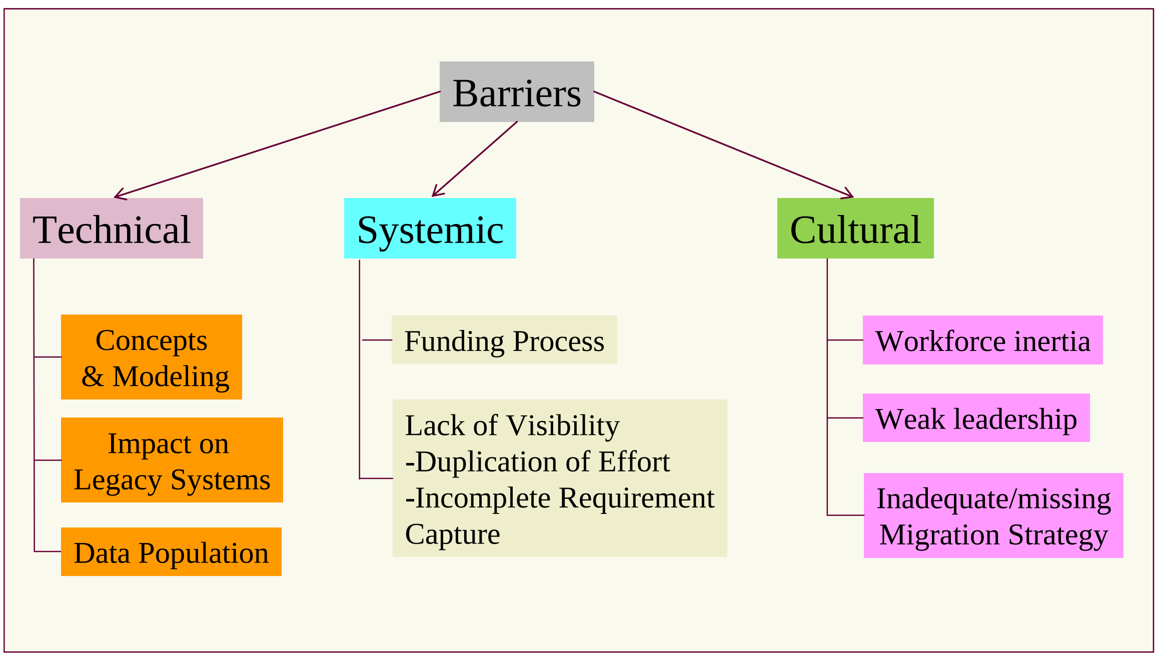

Figure 4-12. Taxonomy of Likely Barriers to the Adoption of the GFMDI Strategy within the Army BMA

This barrier can be mitigated through the adoption of a strict modular approach to the insertion of new data items in the legacy systems along the same lines as the Standard

Financial Information Structure (SFIS),[39] which has been already demonstrated in multiple systems, offers a proven path toward mitigating the potential risks that the adoption of the strategy may entail. In fact, modern technologies developed to handle Big Data (e.g., NoSQL[40]) allow the use of relational and non-relational data side by side, so one could envision a solution that does not even require any alteration of the back-end databases that power the legacy systems. Instead, the new data items could be maintained and populated in a separate module that supports the exchanges, with logical links to the legacy systems as required. At the end-user level, either web interfaces or dashboards can be implemented to make the new functionality available.

The *third technical barrier* is the suboptimal population in the required authoritative data sources (ADSs), i.e., the servers holding the GFMDI identifiers assigned to the resources to be managed by the BMA systems. Without these ADSs the vision of total asset visibility and unambiguous referencing across the enterprise cannot be realized.

For the BMA the GFMDI strategy must consider whether good-quality structured data exists that can be readily converted with typical Extraction, Transformation, and Loading (ETL) techniques. Specifically, the taxonomy of MaterielType currently in use within the logistics community must be analyzed, and the current JC3IEDM constructs modified where necessary, if the intent is to use such a source as part of the data population.

Where no structured data exists, the strategy must consider the applicability of emerging natural language processing techniques, which offer the potential for efficient conversion of unstructured data into data sets that can then be processed with traditional ETL methods to populate the proposed constructs.

The second main category of barriers to the adoption of the GFMDI strategy is systemic impediments. The *first systemic barrier* is the lack of strong incentives and penalties.

This type of impediment can be mitigated by cautious use of waivers to the implementation deadlines and the adoption of a bottom-up approach – rather than to wait for the top-down changes to occur. Specifically, the entities in charge of implementing the strategy should focus on socializing the purpose and expected benefits of the strategy, and work toward obtaining a high degree of buy-in by all the stakeholders involved.

The *second systemic barrier* is the lack of visibility of the GFMDI strategy implementation activities within the enterprise. There is a risk that without adequate dissemination of information about the planned implementation its goals and objectives

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[39] http:/dcmo.defense.gov/products-and-services/standard-financial-information-structure/.

[40] https://en.wikipedia.org/wiki/NoSQL.

may be viewed as either duplicative or overlapping with the goals and objectives of the other efforts, and, therefore, that its enterprise-wide endorsement may stall. Similarly, the perception that the strategy fails to satisfy all enterprise-wide requirements can weaken its chances of successful adoption and implementation.

This barrier can be mitigated through broad exposure and socialization of the GFMDI strategy's objectives and benefits, which coupled with proactive coordination with groups involved in similar/related activities can increase the chances of its adoption and broaden its support. The entities involved in the implementation of the strategy must, therefore, plan for this type of preparatory work to ensure that no major objections remain once the request for funding phase is initiated.

The third main category of barriers to be considered is so-called *cultural barriers*. The *first cultural barrier* to consider is the reluctance on the part of the workforce to change processes with long operational history. The perception by the personnel potentially affected by the strategy is that the current way is acceptable because it is the way it has always been done. More senior personnel may also exhibit a reluctance to learn new technologies since there is a large knowledge base associated with the current baseline, and little or none associated with the to-be infrastructure. The "Why can't I do it with Excel?" syndrome is not a rare occurrence and must be taken into consideration. Finally, in many cases there may be apprehension by managers to upset or alienate their employees by endorsing the new strategy.

To mitigate this type of barrier the formulation of the strategy not only must encompass the technical issues, but must also contain guidelines for managers to address the full complement under DOTMLPF.[41] Specifically, the strategy must include provisions for training of current personnel, pay attention to end-user interface friendliness, and incorporate all pertinent doctrine and leadership aspects.

The *second cultural barrier* is the lack of strong leadership. Managers in charge of the GFMDI strategy implementation may lack the necessary technical background to appreciate their benefits and provide advocacy for their adoption. This situation expresses itself in a degree of unwillingness to disturb the present *steady state* of current operations. There may be also a lack of *enterprise-wide* vision at the management level, which reflects itself in the tendency to operate with very narrow focus, i.e., to address only the local problems without consideration for the possible consequences of their decisions laterally or down the line. The well-known issues regarding the lack of data interoperability have in part their origin in this parochialism. Without a strong push by the management to ensure that their data products will be reusable enterprise-wide, the

[41] Doctrine, Organizations, Training, Materiel, Leadership, Personnel and Facilities under the Joint Capabilities Integration Development System, or JCIDS Process.

default tendency of personnel engaged in data production is to feel that they own the data, instead of viewing it as an enterprise asset.

To mitigate this type of barrier, the GFMDI strategy not only must encompass technical awareness training for managers, but also must plan for adequate socialization of its objectives and benefits (short- and long-term). At the enterprise level there should be an effort to socialize an *enterprise point of view* within all the data production centers to counter any tendencies toward data parochialism. Last but not least, the strategy should consider adding to the management layer personnel with adequate technical background who can provide advice to the decision makers.

The *third cultural barrier* is the lack of an adequate migration strategy for the adoption of the use of GFMDI identifiers across the Army BMA. Because the impact of the GFMDI strategy is likely to affect the full DOTMLPF spectrum, the lack of, or an inadequate, migration strategy, can become a serious obstacle to the strategies' adoption and implementation.

To mitigate this type of barrier the GFMDI strategy must provide an adequate *migration plan,* with appropriate coordination of its time line, and, more importantly, with sufficient consideration for the funding aspects it involves.

5. Summarization of Conclusions and Recommendations

A. Main Conclusions

1. Barriers to Implementation of the GFMDI Strategy Most Likely Cultural

All the technical assessments done for this effort indicate that the information models underlying the GFMDI, as well as the technologies reviewed to leverage the use of GFMDI identifiers, do not represent a risk to their adoption within the entire Army BMA. In fact most technologies considered are already part of the Army's policy regarding information technology (See footnote 18).

This finding is consistent with findings from previous IDA analyses related to the use of globally unique identifiers to ameliorate the lack of information interoperability and reuse.[42] Thus the "data" problems that plague DoD may not be necessarily of technical origin but are most likely cultural in nature. In order to achieve the implementation of the GFMDI strategy the Army leadership must achieve a balanced mixture of technical and *cultural shift* processes within the enterprise.[43] Mitigation of this type of risk requires, therefore, both at the policy level, as well as financially, is a long-term commitment on the part of the Army leadership.

2. Gains in Enhanced Information Interoperability and Reuse Mean Cost Savings

Any technique that reduces both the need for intermediate conversion, as well as the need for cleanup and rework, translates into lower operating costs for an information system. GFMDI identifiers and the enterprise servers hosting them are embodiments of said cost saving techniques.

The development of common vocabularies within the enterprise, coupled with semantic technologies, represents another solution component that both enhances the quality of the information and reduces cost.

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[42] See for example IDA Document D-4004, produced in 2009, on approaches to mitigate ERP interoperability issues using EIDs, and its predecessor IDA Document D-3684, produced in 2008, on the use of EIDs in the context of semi-structured and structured data resources.

[43] IDA Document D-4275, *Development of a Data Quality Framework for Creating and Maintaining Army Authoritative Data Sources*, UNCLASSIFIED, March 2011.

3. Semantic Technologies Offer Concrete Benefits for the Army BMA

Semantic technologies offer clear and substantial benefits not only in terms of information interoperability and reuse but in combination with other industrial standards, also in terms of substantive operating costs reduction.

The information modeling techniques based on languages such as OWL facilitate the separation between the nature of the objects and their use within specific processes, which facilitates the creation and adoption of baseline vocabularies for improved understanding with the BMA.

B. Recommendations

1. Continue Support for GFMDI Servers

From the above it is clear that one of the best ways in which the Army can continue supporting the GFMDI strategy is by vigorously supporting the implementation of GFMDI conformant authoritative data sources for its materiel and personnel resources.

For the mid- and long-term, the Army should consider extending the application of GFMDI identifiers to all the resources essential not only to the BMA but also the WMA. As noted in this document, the vocabulary and constructs needed to capture architecture data already existing in the JC3IEDM. However, no authoritative sources similar to the AOS exist for them.

2. Pursue an Aggressive Schedule for Emerging Technology Insertion

Under the current fiscal climate the Army should aggressively pursue the insertion of technologies offering a high return on investment. Particular attention should be given to semantic technologies, which due to the substantive support they enjoy in the commercial world, are likely to provide reliable solutions to the interoperability and reuse issues confronted by the Army BMA.

3. Ensure Maximum Visibility for the GFMDI Strategy Goals and Objectives

The Army must continue to seek wide dissemination of the benefits expected from the GFMDI strategy implementation. In this manner similar activities can be harmonized minimizing duplication of effort and conflicting objectives.

Appendix A
The Relational Database Platform Specific Model

A. The JC3IEDM OWL Model

Figure A-1 shows the representation of the ObjectItemStructure as it exists in the JC3IEDM PIM obtained from converting the specifications of the MIRD into OWL and mapping them to UML classes stereotyped in accordance with the ODM profile. A brief comparison with the entity-relationship (ER) diagram shown in Figure 4-2 above shows the major differences between the two modeling languages.

Although the ODM profile offers the option for modeling instances of objectProperty in a manner similar to how UML associations are modeled, the IDA team chose to model both objectProperty and dataProperty instances, as well as instances of owlClass and owlRestriction in the form of stereotyped UML classes. The rationale for this choice was the simplification it represented in terms of the cases to be considered when converting and loading the JC3IEDM OWL file into Sparx EA using the OWL2EA tool.

Another advantage of using UML classes stereotyped in accordance with the ODM profile for representing OWL expressions is the higher degree of explicitness it supports when capturing the roles played by each of the portions of an OWL expression. So, for example, it is possible to see which class is the «rdfsDomain» or the «rdfsRange» of a given objectProperty. The downside of this modeling style is the proliferation of graphical objects that are required to represent the equivalent data constructs contained in a typical ER model.[44]

Finally, it is worth noting that standard data ER modeling languages differ from models written in OWL in that the semantics of OWL are strictly set-theoretic, and that OWL reasoners normally operate under the Open World Assumption (OWA).[45] The lack of assertions regarding something of interest does not support assertions stating its falsehood. OWL requires explicit negations of facts before such inferences can be made.

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[44] The JC3IEDM PIM expressed in OWL has an additional source of graphical proliferation, namely, the large number of classes stereotyped «UnionClass», which are needed to keep a one-to-one correspondence between the relationships specified in the original ER model and the corresponding object properties in the OWL analogue.

[45] Open World Assumption: The truth-value of a statement is independent of whether or not it is known by any single observer or agent to be true (http://en.wikipedia.org/wiki/Open_world_assumption).

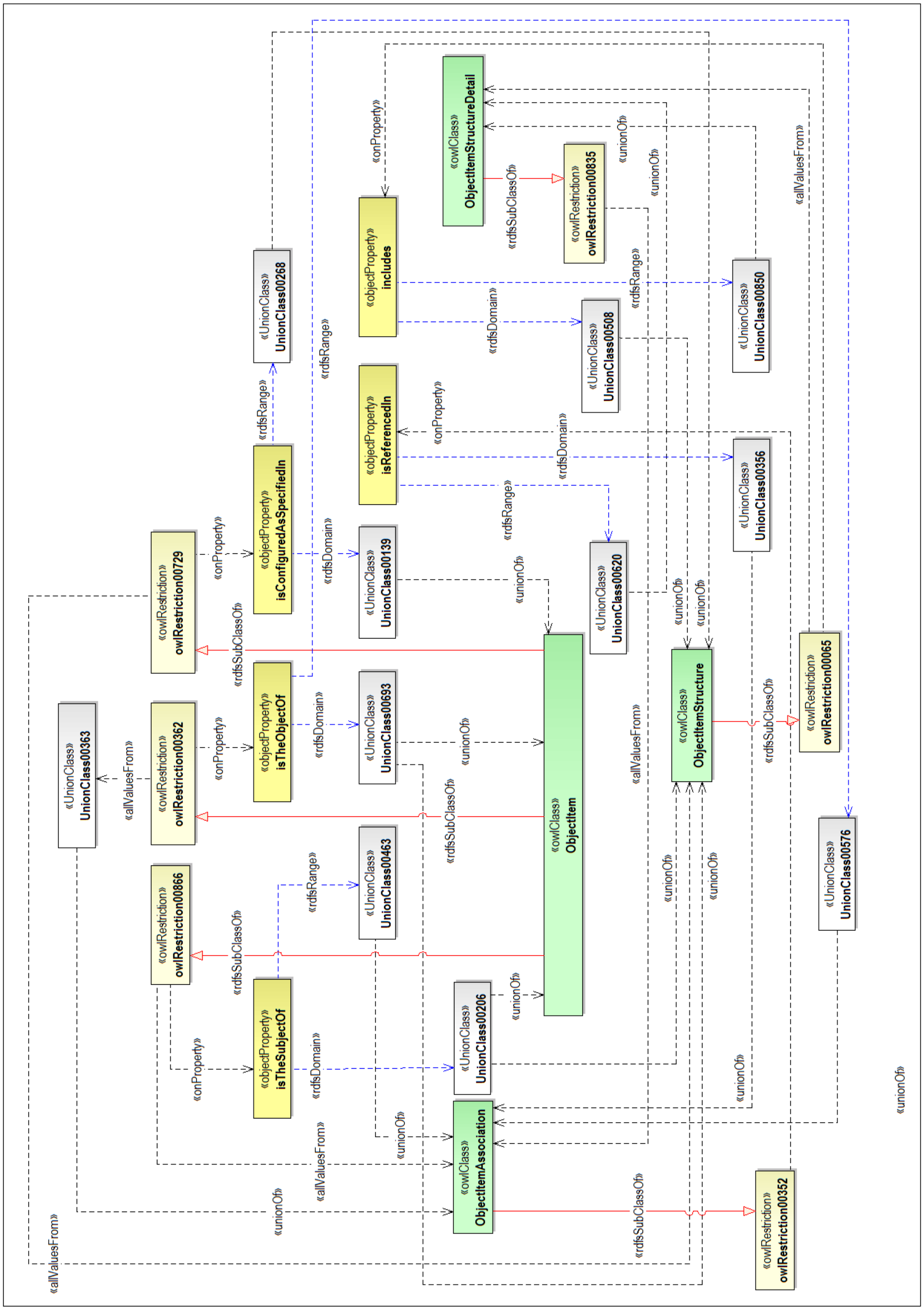

Figure A-1. Representation of the ObjectItemStructure **in OWL**

One of the consequences of the strict set-theoretic semantics of OWL is the rather unique way in which restrictions are modeled. For example, cardinality restrictions such as «allValuesFrom» applied to an instance of objectProperty require not only the specification of the corresponding dependencies – i.e., both a dependency stereotyped as «allValuesFrom» from the owlRestriction to the owlClass that provides all the values of the relation and a dependency from the owlRestriction to the objectProperty stereotyped «onProperty» that points to the objectProperty being restricted – but also the definition of subtype relationships between the owlRestriction and the owlClass that serves as the domain of the objectProperty.

In other words, in OWL restricting an objectProperty such as isConfiguredAsSpecifiedIn with an owlRestriction that states that all its range values are from ObjectItemStructure makes the domain class ObjectItem a subtype of the anonymous class representing the owlRestriction. A slightly more verbose way of saying it is that under OWL one views the world as containing a set of all the things that have the objectProperty named isConfiguredAsSpecifiedIn and whose range is ObjectItemStructure, and then views a cardinality restriction – such as «allValuesFrom» – on said objectProperty as creating a subset made up of all those instances for which the restriction is true. That subset is the class that serves as the domain of the objectProperty, which in this case is ObjectItem.

Figure A-1 shows that in fact all the instances of owlClass, namely, ObjectItem, ObjectItemStructure, ObjectItemStructureDetail and ObjectItemAssociation, are subclasses of the corresponding restrictions imposed of the five instances of objectProperty that make up the specification.

B. Example of a Relational DB Model Generation under MDA

The application of the relational database QVT script to the JC3IEDM PIM written in OWL produces a PSM that expresses the original OWL classes (see Figure A-1 above) as new UML classes stereotyped as database tables – indicated by the icons on the upper right hand corner of each of them (see Figure A-2 below).

In addition, the transformation adds both primary and foreign keys highlighted by the PK and FK adornments prefixed to the corresponding attributes. Finally, the data types for each of the attributes are also added by the QVT script when processing each OWL class.

Inspection of the model shows the following characteristics, all chosen to reduce both the effort required to create the QVT script, as well as the time to carry out the transformation:

- All resulting relational DB classes are modeled as independent entities, i.e., they do not have composite keys arising from identifying relationships. All relationships among the relational DB classes are non-identifying.
- All the names of the relational DB classes and their attributes are identical to those of the corresponding OWL classes and their data properties, with the exception of the primary keys which are generated by adding the string "EID" to the name of the relational DB class.
- The number of data types supported is more limited than in the current JC3IEDM specifications.

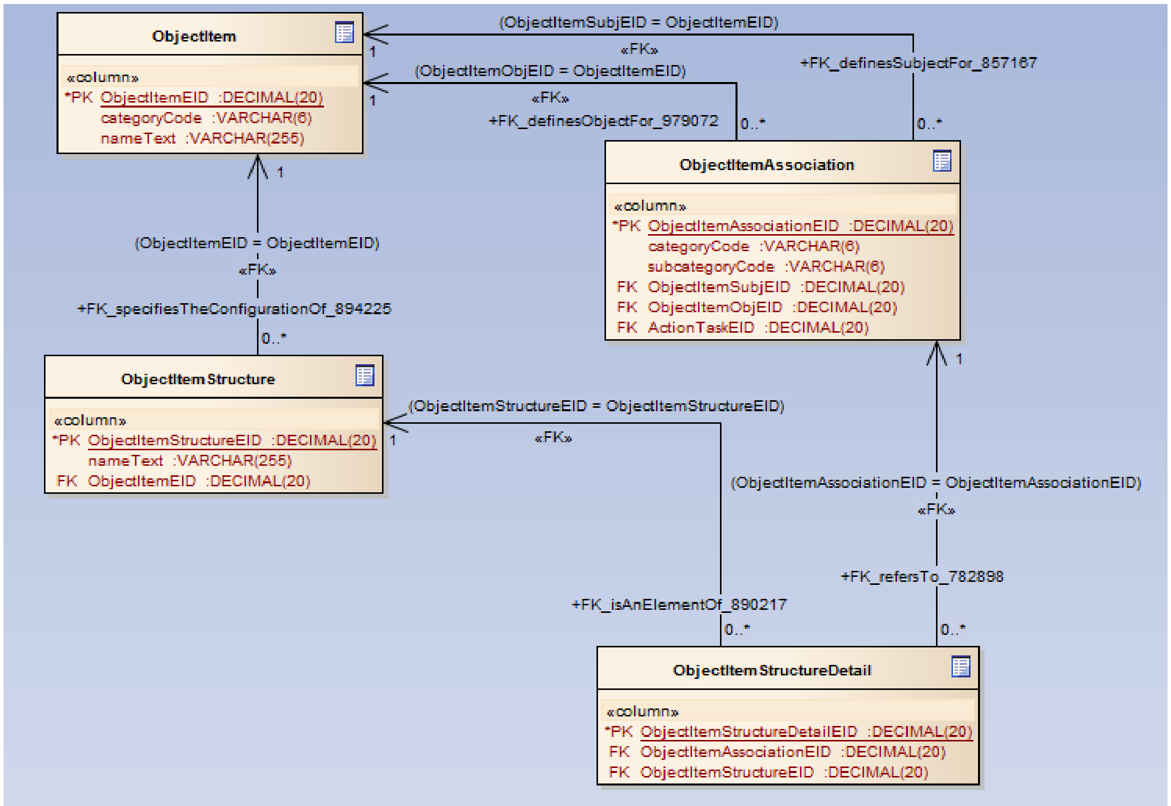

Figure A-2. ObjectItemStructure Subview of the RDBMS QVT Output Model

C. Production of Executable Code under MDA for the Relational DB

The final step in the MDA process is the actual generation of executable code out of the PSM obtained via the transformation carried out by applying the QVT script to the source PIM.

With the UML modeling tool chosen for the analysis, namely, Sparx EA, it is possible, using its Data Definition Language (DDL) capability, to generate the SQL script out of the tables specified in the PSM. Figure A-3 shows the interface that allows the user to control the features to include in the SQL script. In addition to the choice of target servers, the user can also add or remove DROP TABLE statements, have all the tables and attribute names enclosed in quotes to avoid conflict with reserved words used by the target server, and select either all or only specific tables for which to generate the SQL script.

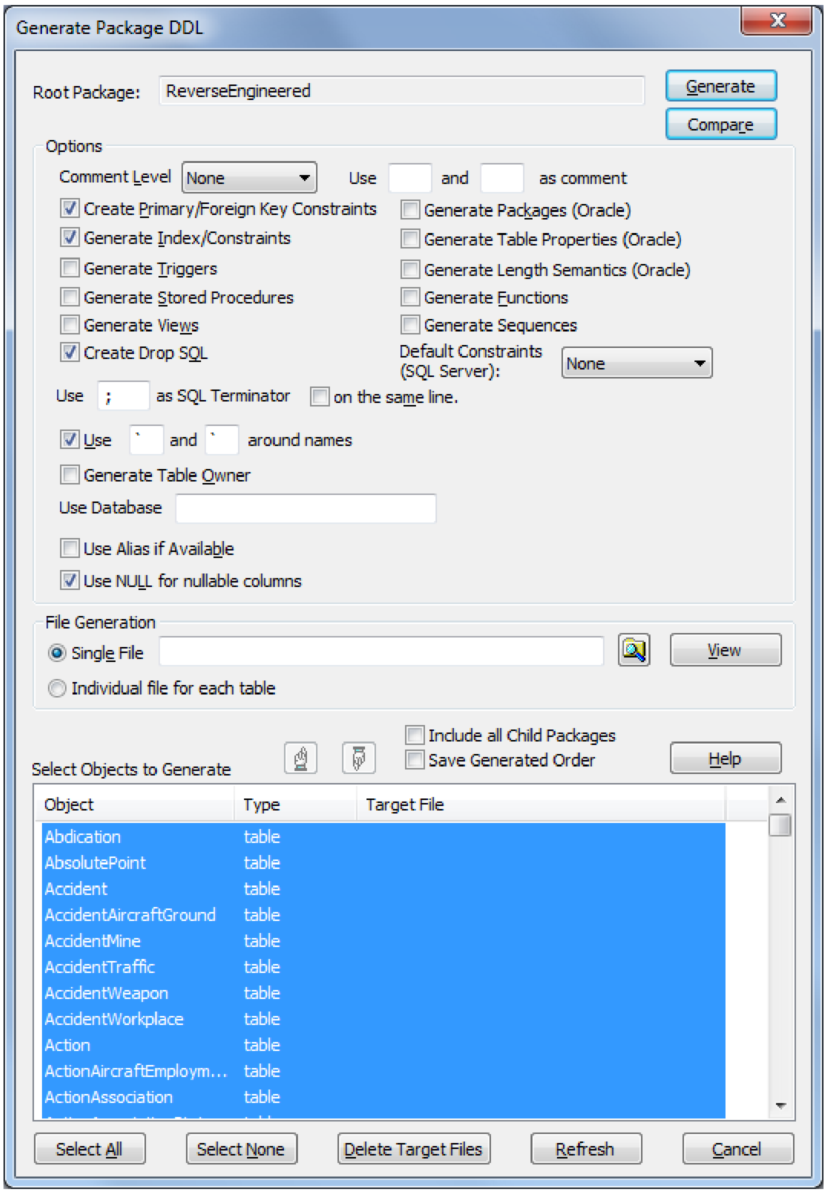

Figure A-3. UML Modeling Tool Interface for DDL Generation

Figure A-4 below shows a portion of the output SQL script for the subview corresponding to ObjectItemStructure specification shown in Figure A-2 above. Running this script in the relational database server MySQL creates the physical schema that enables a user to store and retrieve data conforming to the vocabulary of the JC3IEDM.

```sql
SET FOREIGN_KEY_CHECKS=0;
DROP TABLE IF EXISTS `ObjectItem` CASCADE
;
DROP TABLE IF EXISTS `ObjectItemAssociation` CASCADE
;
DROP TABLE IF EXISTS `ObjectItemStructure` CASCADE
;
DROP TABLE IF EXISTS `ObjectItemStructureDetail` CASCADE
;
CREATE TABLE `ObjectItem`
(
    `ObjectItemEID` DECIMAL(20) NOT NULL,
    `categoryCode` VARCHAR(6) NULL,
    `nameText` VARCHAR(255) NULL,
    PRIMARY KEY (`ObjectItemEID`)
) TYPE=InnoDB
;
CREATE TABLE `ObjectItemAssociation`
(
    `ObjectItemAssociationEID` DECIMAL(20) NOT NULL,
    `categoryCode` VARCHAR(6) NULL,
    `subcategoryCode` VARCHAR(6) NULL,
    `ObjectItemSubjEID` DECIMAL(20) NULL,
    `ObjectItemObjEID` DECIMAL(20) NULL,
    `ActionTaskEID` DECIMAL(20) NULL,
    PRIMARY KEY (`ObjectItemAssociationEID`),
    INDEX `ObjectItemObjEID` (`ObjectItemObjEID` ASC),
    INDEX `ObjectItemSubjEID` (`ObjectItemSubjEID` ASC),
    INDEX `ActionTaskEID` (`ActionTaskEID` ASC)
) TYPE=InnoDB
;
CREATE TABLE `ObjectItemStructure`
(
    `ObjectItemStructureEID` DECIMAL(20) NOT NULL,
    `nameText` VARCHAR(255) NULL,
    `ObjectItemEID` DECIMAL(20) NULL,
    PRIMARY KEY (`ObjectItemStructureEID`),
    INDEX `ObjectItemEID` (`ObjectItemEID` ASC)
) TYPE=InnoDB
;
```

Figure A-4. Portion of the SQL Script for the ObjectItemStructure **Subview Obtained from the Relational DB PSM**

Appendix B
The XSD Platform Specific Model

A precondition for establishing interoperability is deciding on the languages and technologies for exchanging information. XML is a popular language, well supported by technologies such as XSD and by many free, open source tools.

The IDA team decided to define a mapping from the OWL model to an XSD. Such a mapping would help ensure the correctness of JC3IEDM-related messages that a system publishes or receives.

This appendix describes that mapping. It covers the mapping's goals, the use of supporting technologies – in particular, the National Information Exchange Model – the QVT script used to implement the mapping, and the utility of the resulting XSD.

A. Goals

The goals for the XSD PSM may be summarized as follows:

- ***Support interoperability among DoD systems.*** DoD needs technologies that are simple and inexpensive. XML-based message exchanges satisfy both of these needs.
- ***Improve information consistency and correctness.*** Any steps that can be taken toward ensuring that information is transmitted in a format that other systems can recognize and interpret should be seen as positive. Moreover, the ability to determine whether or not a received message is well-formed allows a system to immediately reject invalid data. XSD conformant messages, though not necessarily semantically correct, can still be guaranteed to possess certain properties that a receiving system would otherwise need to check.
- ***Demonstrate the value of Model Driven Architecture in XML-based message exchange.*** Mechanical generation of an XSD from an OWL-based PIM proves that semantic technology-based systems can transmit XML-based messages with relatively low implementation cost.

B. Use of NIEM

The simplest mapping approach would have been to map each OWL class to an XSD element. Class ObjectItem would map to an element something like the following:

```
<xsd:element name="ObjectItem">
    <xsd:complexType>
        <xsd:sequence>
            <xsd:element name="objectItemNameText" type="xsd:string"
                          minOccurs="0" maxOccurs="1"/>
            <xsd:element name="isGeometricallyDefinedThrough"
                          minOccurs="0" maxOccurs="unbounded"
                          type="ObjectItemLocation"/>
            ...
        </xsd:sequence>
    </xsd:complexType>
</xsd:element>
```

However, that would yield an XSD tailored exclusively to JC3IEDM-based exchanges. A schema that used XSD constructs found in schemas used by (or anticipated to be used by) other DoD systems would be more likely to reduce the costs of implementing interoperability, because developers could reuse code for marshaling and unmarshaling those constructs. DoD has decided to pursue NIEM-based message exchanges.[46] NIEM promotes use of a standard set of XSD constructs, which fits in with IDA's view of how best to meet interoperability needs. If the XSD PSM for JC3IEDM uses and extends NIEM constructs, systems that already process those constructs will not need to start from scratch when implementing JC3IEDM-based message transmission.

1. NIEM Naming and Design Rules

The decision to use NIEM immediately introduces a new requirement. NIEM has an extensive set of naming and design rules[47] that dictate how to design and implement NIEM-conformant schemas. The rules, which run to several hundred printed pages, contain more detail than can be presented here; however, it is worth mentioning the following:

- *NIEM does not allow anonymous types*. The fragment presented above would be invalid, because the (complex) type is anonymous. It would have to be rewritten as follows:

  ```
  <xsd:element name="ObjectItem" type="ObjectItemType"/>
  <xsd:complexType name="ObjectItemType"> ... </xsd:complexType>
  ```

- *NIEM does not allow nested elements*. The fragment above, which nests objectItemNameText and isGeometricallyDefinedThrough, would be invalid. The representation of the object item's name would need to be rewritten as:

[46] See http://assets.fiercemarkets.net/public/sites/govit/dodniemmemo2013.pdf.

[47] See https://www.niem.gov/glossary/Pages/naming-and-design-rules.aspx.

```
<xsd:element name="ObjectItem" type="ObjectItemType"/>
<xsd:complexType name="ObjectItemType">
    <xsd:sequence>
        <xsd:element ref="ObjectItemNameText"
                minOccurs="0" maxOccurs="1"/>
        ...
    </xsd:sequence>
</xsd:complexType>
<xsd:element name="ObjectItemNameText" type="xsd:string"/>
```

The referenced element name now begins with a capital letter, consistent with NIEM rules.

- *NIEM encourages extending an existing type*, in particular its ComplexObjectType. Accordingly, a better specification of ObjectItemType would be:

```
<xsd:complexType name="ObjectItemType">
    <xsd:complexContent>
        <xsd:extension base="s:ComplexObjectType">
            <xsd:sequence>
                <xsd:element ref="ObjectItemNameText"
                            minOccurs="0" maxOccurs="1"/>
                ...
            </xsd:sequence>
        </xsd:extension>
    </xsd:complexContent>
</xsd:complexType>
```

ComplexObjectType includes some standard attributes for identification and metadata.

- *NIEM represents associations as extensions of element* Association *and complex type* AssociationType*, the latter being an extension of* ComplexObjectType. The association between ObjectItem and ObjectItemLocation would be expressed as:

```
<xsd:element name="ObjectItemLocationAssociation"
        type="ObjectItemLocationAssociationType"/>
<xsd:complexType name="ObjectItemLocationAssociationType">
    <xsd:complexContent>
        <xsd:extension base="nc:AssociationType">
            <xsd:sequence>
                <xsd:element ref="ObjectItem"
                            minOccurs="0" maxOccurs="1"/>
                <xsd:element ref="ObjectItemLocation"
                            minOccurs="0" maxOccurs="unbounded"/>
                ...
            </xsd:sequence>
        </xsd:extension>
```

```
        </xsd:complexContent>
    </xsd:complexType>
```

2. NIEM Schema Packaging

NIEM is a very large specification. Its core contains hundreds of elements and types. Its domains contain even more elements. No one expects that a single system will recognize every NIEM construct – the implementation effort would be prohibitive. Instead, NIEM includes a schema subset generation tool.[48] This tool extracts exactly those constructs needed to support a particular message exchange. The resulting schema has a manageable size.

When an organization decides to use NIEM to transmit messages, it must determine the messages it wishes to transmit and express them in a standard form. This form has the following components:

- ***Subset schema:*** Constructs from NIEM and its domains; as the name implies the constructs are a subset of those available, specifically the subset needed to support the organization's messaging needs.
- ***Extension schema:*** Constructs that are not in NIEM but which the organization needs. These extend NIEM constructs in the subset schema.
- ***Exchange schema:*** One or more schemas, each of which specifies the constructs in, and format of, a specific message the organization intends to transmit.

C. Use of QVT

The transformation from the OWL PIM to a NIEM conformant XSD is written in QVT. The input is the JC3IEDM OWL PIM, in the format written by the OWL2EA tool. The output is a UML model that uses stereotypes and tagged values from an XSD profile implemented by Sparx EA, the CASE tool selected by the IDA team for the analysis.

The transformation behaves as follows:

- Each class C in the JC3IEDM PIM – that is, a UML element whose stereotype is «owlClass» – is mapped to a pair of UML elements in the target XSD PSM. One element, whose name is C's, is stereotyped «XSDtopLevelElement». The other, whose name is C's suffixed with "Type," is stereotyped «XSDcomplexType» and is the type of the first element. If the only OWL class C extends is MIRDClass, then the type element extends ComplexObjectType. Otherwise, it extends the type established for the supertype.

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48 http://niem.gtri.gatech.edu/niemtools/ssgt/index.iepd.

- Each datatype property D in the PIM – that is, a UML element whose stereotype is «datatypeProperty» – is mapped to a pair of UML elements. One element, whose name is D's with the first letter capitalized, is stereotyped «XSDtopLevelElement». The other, whose name is D's suffixed with "Type," is stereotyped «XSDcomplexType», and is the type of the first element. If D's type is a primitive type (string, decimal, Boolean, or date), the second element extends one of NIEM's complex types for primitive types. If D's type is an enumeration, the second element extends a simple type that is an enumeration of the possible values for D. Furthermore, if the domain of D is the set of classes {C_1 C_2, … }, then each C_i has an attribute whose type is the first element.
- Each object property O in the PIM – that is, a UML element whose stereotype is «objectProperty» – is mapped to a pair of UML elements. One element, whose name is O's with the first letter capitalized, is stereotyped «XSDtopLevelElement». The other, whose name is O's suffixed with "Type," is stereotyped «XSDcomplexType», and is the type of the first element. The first element is substitutable for NIEM's element Association: it has a dependency relationship to Association stereotyped «XSDsubstitutionGroup». The second element extends NIEM's complex type AssociationType.

The QVT is written as five distinct transformations, making use of QVT's "extends" capability for transformation extension and reuse. One of these transformations concerns the JC3IEDM. The other four express NIEM elements and their transformation. The NIEM-related transformations provide only a basic coverage; specifically, they support only those constructs needed to implement the JC3IEDM-related transformation. With additional resources they could be readily expanded to include remaining NIEM constructs.

The transformations were written with schema subset generation in mind. As mentioned above, it is neither desirable nor practical for an exchange schema to include all of NIEM. The transformations are structured such that it is possible to include exactly the set of NIEM elements necessary to support a particular message exchange. Whether the approach used will work in all cases remains to be seen. The NIEM transformations correspond to NIEM namespaces: core, structures, proxy, and appinfo. The schemas for these namespaces use XSD's "import" construct. One schema may import zero or more other schemas, and schema importation may be circular. QVT's extension mechanism, by contrast, allows a transformation to extend at most one other transformation, and it is an error to have a circular transformation structure. It is not known at this time whether the current transformation structure can model all of NIEM.

- The transformation only uses the highest-level NIEM constructs. JC3IEDM-related complex types extend NIEM's ComplexObjectType. There is no use Person/PersonType, Facility/FacilityType, and other constructs that arguably could represent a mapping for JC3IEDM's Person and Facility classes. Resource constraints imposed this limitation. Determining whether a NIEM construct is truly a good match for a data object is not as straightforward as it might seem. Nevertheless, the transformation as implemented does allow for the use of many fundamental NIEM constructs, and the IDA team is of the opinion that it sufficiently demonstrates the validity of the MDA-based approach. The IDA team also believes that, given time and resources, it could perform an analysis of whether PIM elements can be expressed using other NIEM constructs and could use the output of those assessments to build the required element-to-construct mappings in QVT.

D. The Resulting Model

As mentioned above, executing the transformation yields a UML model with stereotypes and tagged values from an XSD profile. The UML model is currently targeted to the Sparx Enterprise Architect tool.

Figure B-1 shows an example of the transformation. The Location class has been transformed into a top-level element and complex type. The complex type extends ComplexObjectType, which has three attributes. As is mandated by NIEM naming and design rules, the attributes are specified by reference to top-level attributes. The referenced attribute is established by the attribute's type (this is Enterprise Architect's standard).

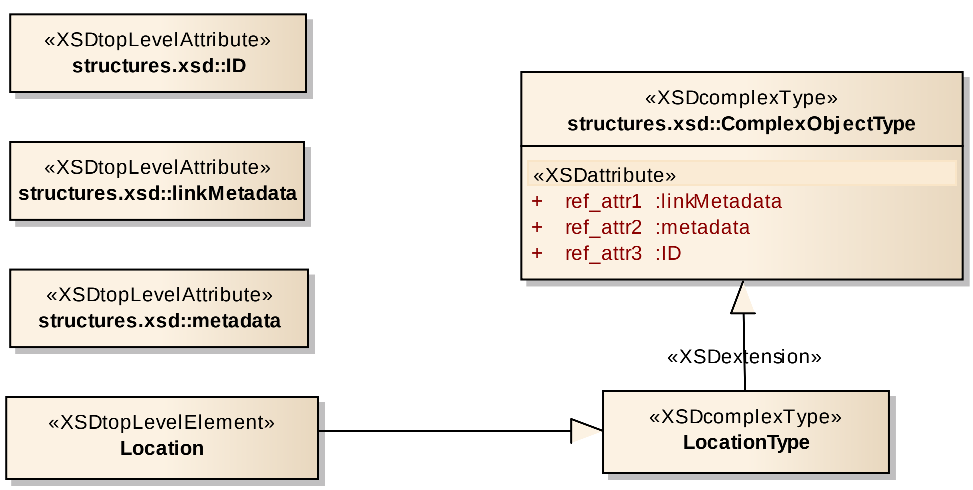

Figure B-1. Transformation of Location Class to XSD PSM

Figure B-2 shows another example. An object property, hasGeometricDefinitionFrom, has been transformed to XSD. Because hasGeometricDefinitionFrom has multiple domains, it is necessary to surround the name with the names of the domain and range in the XSD; that is, the transformation also generates top-level element ActionLocationHasGeometricDefinitionFromLocation. This element has a corresponding type, ObjectLocationHasGeometricDefinitionFromLocation, which extends AssocationType. ObjectLocationHasGeometricDefinitionFromLocation refers to two elements, both of which are of type ReferenceType, another NIEM construct used in associations.

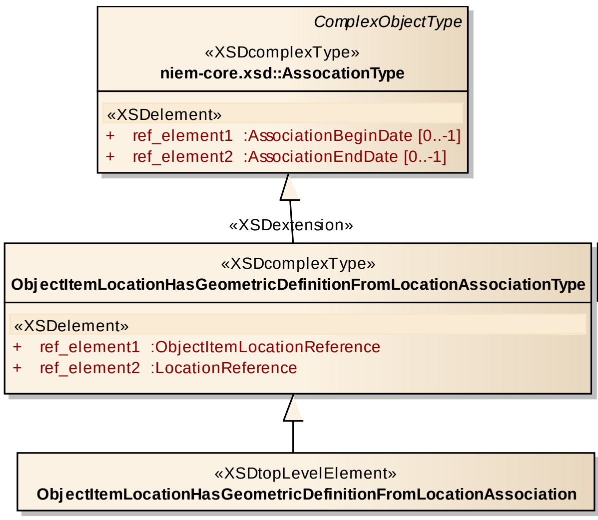

Figure B-2. Transformation of PIM Object Property to XSD PSM

Enterprise Architect can generate an XSD schema from this model. That is, it has the built-in capability to produce a file containing XSD constructs for all the elements in the UML model. Enterprise Architect understands packaging. The QVT transformation generates the package hierarchy shown in Figure B-3. The JC3IEDM-related elements are in package MIRD314. The NIEM-related elements are in subpackages of niem (those stereotyped «XSDschema»). If an element in niem has a relationship to an element in another package (in Figure B-2, LocationReference generalizes ReferenceType in the structures.xsd package), Enterprise Architect generates multiple XSD files, one for each package. In this way it can maintain the import structure used in NIEM.

Enterprise Architect does not implement all features of XSD. As described in Section C of this appendix, the transformation uses substitution groups. Enterprise Architect does not recognize substitution groups. So far, this is the only XSD feature IDA has encountered that Enterprise Architect does not translate. NIEM-conformant schemas sometimes use substitution groups, so users should be aware of their absence.

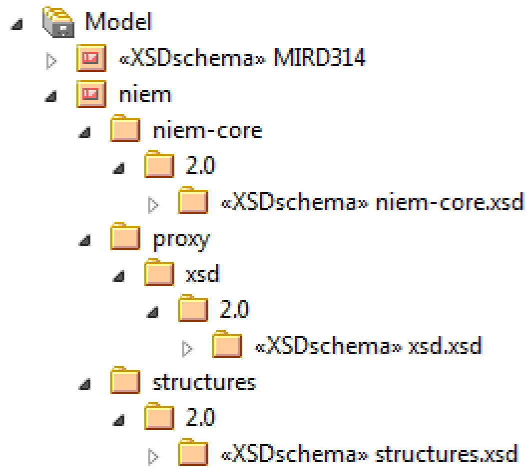

Figure B-3. Package Structure of XSD UML Model

Appendix C
Analysis of Selected D2RR Business Flows

This section explains how a JC3IEDM database could be used to support the activity *"Marshall Mobilized Elements for Movement"* (hereafter referred to as MMEM). As shown in Figure C-1 below, MMEM is a Level III activity.

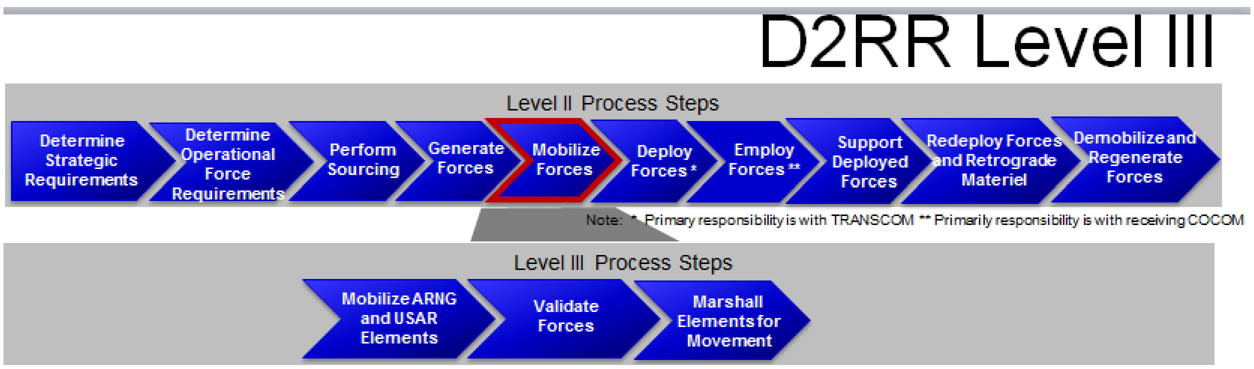

Figure C-1. D2RR Business Flows For Mobilize Forces

MEMM has the following location in the activity hierarchy:

Deploy-to-Redeploy/Retrograde: Encompasses all business functions necessary to plan, notify, deploy, sustain, recall and reset tactical units to and from theaters of engagement.

Mobilize Forces: Mobilization of the Armed Forces includes but is not limited to the following categories:

a. Selective mobilization – Expansion of the active Armed Forces resulting from action by Congress and/or the President to mobilize Reserve Component units, Individual Ready Reservists, and the resources needed for their support to meet the requirements of a domestic emergency that is not the result of an enemy attack.

b. Partial mobilization – Expansion of the active Armed Forces resulting from action by Congress (up to full mobilization) or by the President (not more than 1,000,000 for not more than 24 consecutive months) to mobilize Ready Reserve Component units, individual reservists, and the resources needed for their support to meet the requirements of a war or other national emergency involving an external threat to the national security.

c. Full mobilization – Expansion of the active Armed Forces resulting from action by Congress and the President to mobilize all Reserve Component units and individuals in the existing approved force structure, as well as all retired military personnel, and the resources needed for their support to meet the requirements of a war or other national emergency involving an external threat to the national security. Reserve personnel can be placed on active duty for the duration of the emergency plus six months.

d. Total mobilization – Expansion of the active Armed Forces resulting from action by Congress and the President to organize and/or generate additional units or personnel beyond the existing force structure, and the resources needed for their support, to meet the total requirements of a war or other national emergency involving an external threat to the national security. Also called MOB. Source: JP 4-05.

Marshall Mobilized Elements for Movement: The process of assembling, holding, and organizing (personnel) supplies and/or equipment, especially vehicles of transportation, for onward movement. (Reference: JP 3-17)

Since the context of the analysis is the applicability of the GFMDI to the BMA in general it is assumed that information used during D2RR activities is maintained in a JC3IEDM database. Mission requirements, planning documents, units, their structure, personnel, personnel capabilities, and other information is stored in relational database tables that operational staff may query to assist them as they perform MMEM.

Assume an operational staff member is given the following order:

> Assemble, hold, and organize supplies and equipment for onward movement in response to Tank Squad Operational Mission TM-4.

To execute this order, the staff member needs to know the supplies needed to perform Tank Squad Operational Mission TM-4, in particular the vehicles of transportation.

The following are the steps an operator would perform during the MMEM activity. Each step is described in terms of how the operator interacts with a JC3IEDM database: the tables that contain relevant data, the query executed, and the results returned. The result of the steps is a collection of personnel who should be assigned to the unit. Text in Roman font describes a step an operator would perform. Text in `Courier` font is an

SQL query to execute against the JC3IEDM database. Text in Arial font provides a sample output of a step.

A. Verify that the mission exists in the database

This step requires accessing the tables shown in Figure C-2 below.

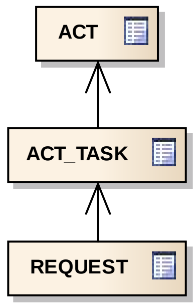

Figure C-2. Tables Accessed to Verify Mission Data

Execute the following query:

```
SELECT act_id,
       act_task.plnd_start_dttm AS PlannedStart,
       act_task.plnd_end_dttm AS PlannedEnd
FROM act INNER JOIN act_task ON act.act_id = act_task.act_task_id
INNER JOIN request ON act_task.act_task_id = request.request_id
WHERE act.name_txt = 'Tank Squad Operational Mission TM-4'
```

If this query returns:

- Zero rows, then the requirement is not recorded.
- Exactly one row, then the requirement is properly recorded in the database and is unique.
- More than one row, then other criteria must be used to determine whether the exercise requirement exists in the database. Apply those criteria; if the desired requirement exists, note its ID. If it does not exist, enter records for it.

For example, suppose a database includes the following fill:

ACT

act_id	cat_code	name_txt
20130221000000000001	Action Task	Tank Squad Operational Mission TM-4

ACT_TASK

act_task_id	cat_code	plnd_start_dttm	plnd_end_dttm
20130221000000000001	Request	2013-04-01 10:00:00.000	2013-04-01 14:15:16.000

REQUEST

request_id	cat_code
20130221000000000001	Not otherwise specified

The query returns:

act_id	PlannedStart	PlannedEnd
20130221000000000001	2013-04-01 10:00:00.000	2013-04-01 14:15:16.000

B. Find the resources needed to accomplish the mission.

This step requires accessing the tables shown in Figure C-3 below.

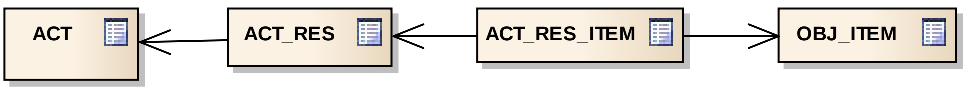

Figure C-3. Tables Accessed to Find Mission Resources

Execute the following query:

```
SELECT
    o.obj_item_id, o.name_txt, o.cat_code
FROM        act a
INNER JOIN  act_res ar        ON a.act_id = ar.act_id
INNER JOIN  act_res_item ari  ON ar.act_res_id = ari.act_res_id
INNER JOIN  obj_item o        ON ari.obj_item_id = o.obj_item_id
WHERE a.act_id = 20130221000000000001
```

For example, suppose a database includes the fill from Step 1, plus the following:

ACT_RES

act_res_id	cat_code	act_id
20130221000000003001	Action Resource Item	20130221000000000001

ACT_RES_ITEM

act_res_id	obj_item_id
20130221000000003001	20121220000000004101

OBJ_ITEM

obj_item_id	cat_code	name_txt
20130221000000005007	Organisation	Tank Squad TS-16

The query returns:

obj_item_id	name_txt	cat_code
20130221000000005007	Tank Squad TS-16	Organisation

C. Find additional resources needed to accomplish the mission

If the query in the previous step yielded only rows whose category code is "Organisation," the results are incomplete. It is necessary to know the materiel and personnel resources that organization comprises. To obtain these resources, query the organisation's structure.

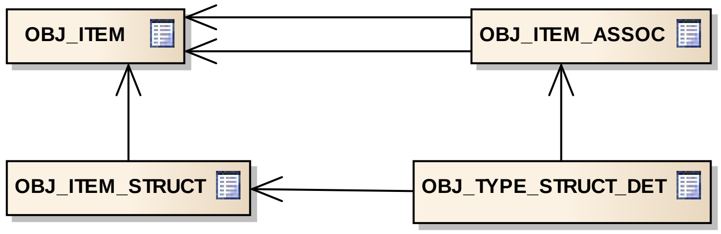

Figure C-4. Tables Accessed to Find Additional Mission Resources

The structure is expressed in the tables shown in Figure C-4 above.

Execute the following query:

```
SELECT
   o.obj_item_id `ObjectID`,
   o.name_txt AS `Name`,
   o.cat_code AS `Type`
FROM       obj_item roi
INNER JOIN obj_item_struct ois
                        ON roi.obj_item_id = ois.root_obj_item_id
INNER JOIN obj_item_struct_det oisd
                        ON ois.obj_item_struct_id =
oisd.obj_item_struct_id
INNER JOIN obj_item_assoc oia
                        ON oisd.obj_item_assoc_id = oia.obj_item_assoc_id
INNER JOIN obj_item o   ON oia.obj_obj_item_id = o.obj_item_id
WHERE roi.obj_item_id = <ObjItemID>
   AND o.cat_code IN ('Person', 'Materiel')
```

Replace `<ObjItemID>` with the obj_item_id from the query result in Step 2.

For example, suppose a database includes the fill from Steps 1 and 2, plus the following:

OBJ_ITEM

obj_item_id	cat_code	name_txt
20130221000000005002	Materiel	TG-001
20130221000000005007	Organisation	Tank Squad TS-16
20130221000000005008	Organisation	Tank TOE-1
20130221000000005009	Organisation	Tank TOE-2
20130221000000005010	Organisation	Tank TOE-3
20130221000000005011	Organisation	Tank TOE-4
20130221000000005012	Person	SSG Washington
20130221000000005013	Person	PVT Adams
20130221000000005014	Person	CPR Jefferson
20130221000000005015	Person	PVT Madison
20130221000000005016	Person	SSG Monroe
20130221000000005017	Person	PVT Adams
20130221000000005018	Person	PVT Jackson
20130221000000005019	Person	PVT Van Buren
20130221000000005020	Person	SSG Harrison
20130221000000005021	Person	CPR Tyler
20130221000000005022	Person	CPR Polk
20130221000000005023	Person	PVT Taylor

obj_item_id	cat_code	name_txt
20130221000000005024	Person	SSG Fillmore
20130221000000005025	Person	PVT Pierce
20130221000000005026	Person	CPR Buchanan
20130221000000005027	Person	PVT Lincoln
20130221000000005028	Materiel	Tank 1
20130221000000005029	Materiel	Tank 2
20130221000000005030	Materiel	Tank 3
20130221000000005031	Materiel	Tank 4

OBJ_ITEM_STRUCT

obj_item_struct_id	root_obj_item_id	name_txt	rptd_id
20130221000000007001	20130221000000005007	Tank Squad TS-16 Structure	20130221000000004001

OBJ_ITEM_ ASSOC

obj_item_assoc_id	subj_obj_item	obj_obj_item_id	cat_code
20130221000000008001	20130221000000005007	20130221000000005008	Command and control
20130221000000008002	20130221000000005007	20130221000000005009	Command and control
20130221000000008003	20130221000000005007	20130221000000005010	Command and control
20130221000000008004	20130221000000005007	20130221000000005011	Command and control
20130221000000008005	20130221000000005008	20130221000000005012	Is under command of
20130221000000008006	20130221000000005008	20130221000000005013	Has as a member
20130221000000008007	20130221000000005008	20130221000000005014	Has as a member
20130221000000008008	20130221000000005008	20130221000000005015	Has as a member
20130221000000008009	20130221000000005009	20130221000000005016	Is under command of
20130221000000008010	20130221000000005009	20130221000000005017	Has as a member
20130221000000008011	20130221000000005009	20130221000000005018	Has as a member
20130221000000008012	20130221000000005009	20130221000000005019	Has as a member
20130221000000008013	20130221000000005010	20130221000000005020	Is under command of
20130221000000008014	20130221000000005010	20130221000000005021	Has as a member
20130221000000008015	20130221000000005010	20130221000000005022	Has as a member
20130221000000008016	20130221000000005010	20130221000000005023	Has as a member
20130221000000008017	20130221000000005011	20130221000000005024	Is under command of
20130221000000008018	20130221000000005011	20130221000000005025	Has as a member
20130221000000008019	20130221000000005011	20130221000000005026	Has as a member
20130221000000008020	20130221000000005011	20130221000000005027	Has as a member
20130221000000008021	20130221000000005008	20130221000000005028	Is authorized to
20130221000000008022	20130221000000005009	20130221000000005029	Is authorized to
20130221000000008023	20130221000000005010	20130221000000005030	Is authorized to
20130221000000008024	20130221000000005011	20130221000000005031	Is authorized to
20130221000000008025	20130221000000005007	20130221000000005002	Is authorized to

OBJ_ITEM_STRUCT_DET

obj_item_struct_det_id	root_obj_item_id	obj_item_assoc_id
20130221000000009001	20130221000000007001	20130221000000008001
20130221000000009002	20130221000000007001	20130221000000008002
20130221000000009003	20130221000000007001	20130221000000008003
20130221000000009004	20130221000000007001	20130221000000008004
20130221000000009005	20130221000000007001	20130221000000008005
20130221000000009006	20130221000000007001	20130221000000008006
20130221000000009007	20130221000000007001	20130221000000008007
20130221000000009008	20130221000000007001	20130221000000008008
20130221000000009009	20130221000000007001	20130221000000008009
20130221000000009010	20130221000000007001	20130221000000008010
20130221000000009011	20130221000000007001	20130221000000008011
20130221000000009012	20130221000000007001	20130221000000008012
20130221000000009013	20130221000000007001	20130221000000008013

obj_item_struct_det_id	root_obj_item_id	obj_item_assoc_id
20130221000000009014	20130221000000007001	20130221000000008014
20130221000000009015	20130221000000007001	20130221000000008015
20130221000000009016	20130221000000007001	20130221000000008016
20130221000000009017	20130221000000007001	20130221000000008017
20130221000000009018	20130221000000007001	20130221000000008018
20130221000000009019	20130221000000007001	20130221000000008019
20130221000000009020	20130221000000007001	20130221000000008020
20130221000000009021	20130221000000007001	20130221000000008021
20130221000000009022	20130221000000007001	20130221000000008022
20130221000000009023	20130221000000007001	20130221000000008023
20130221000000009024	20130221000000007001	20130221000000008024
20130221000000009025	20130221000000007001	20130221000000008025

Using 20130221000000005007 (from Step 2) as the replacement for <ObjItemID>, the query returns:

ObjectID	Object	Type
20130221000000005012	SSG Washington	Person
20130221000000005013	PVT Adams	Person
20130221000000005014	CPR Jefferson	Person
20130221000000005015	PVT Madison	Person
20130221000000005016	SSG Monroe	Person
20130221000000005017	PVT Adams	Person
20130221000000005018	PVT Jackson	Person
20130221000000005019	PVT Van Buren	Person
20130221000000005020	SSG Harrison	Person
20130221000000005021	CPR Tyler	Person
20130221000000005022	CPR Polk	Person
20130221000000005023	PVT Taylor	Person
20130221000000005024	SSG Fillmore	Person
20130221000000005025	PVT Pierce	Person
20130221000000005026	CPR Buchanan	Person
20130221000000005027	PVT Lincoln	Person
20130221000000005028	Tank 1	Materiel
20130221000000005029	Tank 2	Materiel
20130221000000005030	Tank 3	Materiel
20130221000000005031	Tank 4	Materiel
20130221000000005002	TG-001	Materiel

This list represents the personnel and materiel that must be moved.

D. Determine which of the elements retrieved in Step 2 or 3 are transport vehicles

The role of a materiel item as a transport vehicle is contained in the object type hierarchy, as shown in Figure C-5 below.

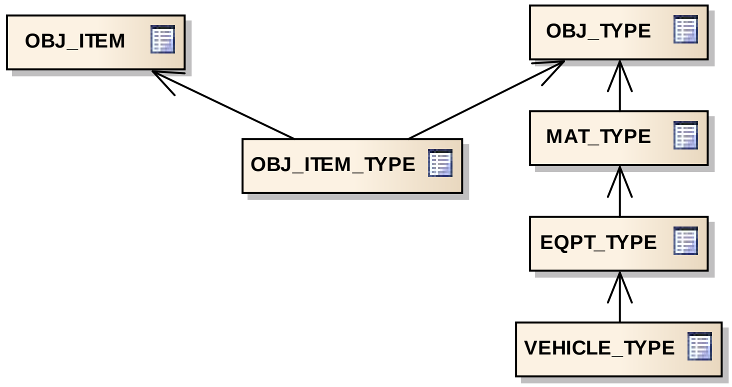

Figure C-5. ObjectType Hierarchy for Vehicles

A transport vehicle is one whose vehicle-type category code is one of “Transporter, general” or “Transporter, tank”.

Execute the following query:

```
SELECT
    o.obj_item_id `ObjectID`,
    o.name_txt AS `Name`,
    vt.cat_code AS `Transporter Type`
FROM        obj_item roi
INNER JOIN obj_item_struct ois
                        ON roi.obj_item_id = ois.root_obj_item_id
INNER JOIN obj_item_struct_det oisd
                        ON ois.obj_item_struct_id =
oisd.obj_item_struct_id
INNER JOIN obj_item_assoc oia
                        ON oisd.obj_item_assoc_id = oia.obj_item_assoc_id
INNER JOIN obj_item o   ON oia.obj_obj_item_id = o.obj_item_id
INNER JOIN obj_item_type oit
                        ON oit.obj_item_id = o.obj_item_id
INNER JOIN obj_type t   ON oit.obj_type_id = t.obj_type_id
INNER JOIN vehicle_type vt
                        ON vt.vehicle_type_id = t.obj_type_id
WHERE roi.obj_item_id = <ObjItemID>
    AND o.cat_code IN ('Person', 'Materiel')
    AND vt.cat_code IN ('Transporter, general', 'Transporter, tank')
```

For example, using the data fill from previous steps, executing this query with 20130221000000005007 substituted for <ObjItemID> yields:

ObjectID	Name	Transporter Type
20130221000000005002	TG-001	Transporter, general

Acronyms and Abbreviations

A2R	Acquire-to-Retire
ADS	Authoritative Data Source
AOS	Army Organization Server
AUTL	Army Universal Task List
B2R	Budget-to-Report
BMA	Business Mission Area
C2P	Concept-to-Product
CASE	Computer-aided software engineering
CD	Compact Disk
CM	Cost Management
D2RR	Deploy to Redeploy/Retrograde
DB	Database
DDL	Data Definition Language
DoD	Department of Defense
DOTMLPF	Doctrine, Organization, Training, Materiel, Leadership and Education, Personnel and Facilities
E2E	End to End
EID	Enterprise Identifier
EL	Environmental-Liabilities
EPC	Event-driven Process Chain
ER	Entity Relationship
ERP	Enterprise Resource Planning
GFMDI	Global Force Management Data Initiative
GFMIEDM	Global Force Management Information Exchange Data Model
H2R	Hire-to-Retire
IDA	Institute for Defense Analyses
IDEF1-X	Integration DEFinition for Information Modeling
JC3IEDM	Joint Consultation, Command and Control Information Exchange Data Model
M2P	Market-to-Prospect
MDA	Model Driven Architecture

MIP	Multilateral Interoperability Programme
MIRD	MIP Information Resource Dictionary
NIEM	National Information Exchange Model
O2C	Order-to-Cash
ODM	Ontology Definition Metamodel
OMG	Object Management Group
OV	Operational View
OWL	Ontology Web Language
P2O	Prospect-to-Order
P2P	Procure-to-Pay
P2R	Proposal-to-Reward
P2SIM	Plan-to-Stock-Inventory-Management
PIM	Platform Independent Model
POM	Program Objectives Memorandum
PSM	Platform Specific Model
QVT	Query, View, Transformation
RDBMS	Relational Database Management System
RDF	Resource Description Framework
S2S	Service-to-Satisfaction
SFIS	Standard Financial Information Structure
SPARQL	SPARQL Protocol and RDF Query Language (a recursive acronym)
SQL	Structured Query Language
SR2R	Service-Request-to-Resolution
UJTL	Universal Joint Task List
UML	Unified Modeling Language
W3C	World Wide Web Consortium
WMA	Warfighting Mission Area
XML	eXtensible Markup Language
XSD	XML Schema Definition

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14. ABSTRACT

This document describes a plan proposal for how to implement the Global Force Management Data Initiative (GFMDI) strategy – namely, the insertion of globally unique identifiers in all relevant information systems across the entire Army Business Mission Area (BMA) – to achieve total asset visibility and optimal information interoperability and reuse. The document also includes analytical results regarding the suitability of the information models underlying the GFMDI to support the information requirements of the Deploy to Redeploy/Retrograde (D2RR) process, and the maturity and applicability of commercial standards and emerging technologies to implement interoperable information exchanges among the BMA systems supporting the D2RR process.

15. SUBJECT TERMS

Global Force Management Data Initiative (GFMDI), Army Business Mission Area (BMA), Deploy to Redeploy/Retrograde (D2RR) process, Model Driven Architecture (MDA), Platform Independent Model (PIM), Platform Specific Model (PSM), Unified Modeling Language (UML), Ontology Web Language (OWL), Ontology Definition Metamodel (ODM), Resource Description Framework (RDF), RDF triple stores, SPARQL, SQL, XML, XSD.

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