



INSTITUTE FOR DEFENSE ANALYSES

A Comparison of the WARSIM Object Model with Army Command and Control Data Models

Brian A. Haugh, Task Leader
Francisco L. Loaiza
Reginald N. Meeson
Richard P. Morton
Steven P. Wartik

Deborah Heystek,
The Aegis Technologies Group, Inc.

Michael R. Hieb, IITRI
Lesley J. Painchaud, IITRI

December 2002

Approved for public release;
distribution unlimited.

IDA Paper P-3740

Log: H 02-002281

This work was conducted under contracts DASW01 98 C 0067/ DASW01 02 C0012, Task BC-5-1943, for the Assistant Secretary of Defense for Command, Control, Communications and Intelligence (C31). The publication of this IDA paper does not indicate endorsement by the Department of Defense, nor should the contents be construed as reflecting the official position of that Agency.

© 2002, 2004 Institute for Defense Analyses, 4850 Mark Center Drive, Alexandria, Virginia 22311-1882 • (703) 845-2000.

This material may be reproduced by or for the U.S. Government pursuant to the copyright license under the clause at DFARS 252.227-7013 (NOV 95).

INSTITUTE FOR DEFENSE ANALYSES

**A Comparison of the WARSIM
Object Model with Army Command
and Control Data Models**

Brian A. Haugh, Task Leader

Francisco L. Loaiza

Reginald N. Meeson

Richard P. Morton

Steven P. Wartik

Deborah Heystek,
The Aegis Technologies Group, Inc.

Michael R. Hieb, IITRI

Lesley J. Painchaud, IITRI

Preface

This document was prepared under the Task Order Object Oriented C2 Models for the Assistant Secretary of Defense for Command, Control, Communications, and Intelligence (C3I), in support of specific requirements identified by Department of the Army, Office of the Chief Information Officer (CIO/G-6). It was performed in response to a task objective to assess the alignment of data representations between representative Army C4I and modeling and simulation (M&S) systems.

The following Institute for Defense Analyses (IDA) research staff members were reviewers of this document: Dr. Richard J. Ivanetich, Dr. Dale E. Lichtblau, Dr. Robert P. McDonald-Walker, Mr. Daniel L. Spar, and Mr. David A. Wheeler. The document also benefited from external review by Dale D. Miller and Melissa E. Nakanishi of the Lockheed Martin Information Systems Advanced Simulation Center under support of the Army Topographic Engineering Center.

Contents

EXECUTIVE SUMMARY.....	ES-1
1. INTRODUCTION.....	1
1.1 PURPOSE OF THE DOCUMENT	1
1.2 INTENDED AUDIENCE	2
1.3 BACKGROUND.....	2
1.4 COMMON DATA/OBJECT MODEL ALIGNMENT	4
1.5 ORGANIZATION OF THIS DOCUMENT	5
2. OVERVIEW OF WARSIM, JSIMS, AND THE TCDM	7
2.1 WARSIM.....	7
2.2 JSIMS FOM	7
2.3 TCDM.....	9
3. OVERVIEW OF THE LC2IEDM.....	11
3.1 BACKGROUND.....	11
3.2 CURRENT STATUS OF THE LC2IEDM.....	11
4. DEFINITION OF ALIGNMENT	13
4.1 BACKGROUND.....	13
4.2 AN INTUITIVE DEFINITION OF ALIGNMENT	14
4.3 DEGREE OF ALIGNMENT.....	16
4.4 RIGOROUS DEFINITION OF ALIGNMENT.....	19
4.4.1 <i>Conceptual Level</i>	19
4.4.2 <i>Entity Level</i>	22
4.4.3 <i>State Level</i>	24
4.4.4 <i>Value Level</i>	27
4.5 SUMMARY OF DIFFERENCES FROM THE AICDM/OMSC STUDY	31
4.5.1 <i>Inheritance</i>	31
4.5.2 <i>Value-Level Alignment Assessments</i>	31
4.5.3 <i>Aligning Complex Data Types</i>	31
4.5.4 <i>Entity-Level Assessment Adjustments</i>	32
4.5.5 <i>Structural Alignment</i>	38
5. PROCESS OF ALIGNMENT	39
5.1 AN OVERVIEW OF THE ALIGNMENT ASSESSMENT PROCESS	39
5.2 THE PROCESS AS A TEMPLATE	41
5.3 ALIGNMENT DIRECTIONALITY	42
5.4 JSIMS FOM-TO-LC2IEDM ASSESSMENT.....	43

5.4.1	Process	43
5.4.2	Level-Specific Details	45
5.5	LC2IEDM-TO-JSIMS FOM ASSESSMENT	52
5.5.1	Process	53
5.5.2	Level-Specific Details	53
6.	WARSIM → LC2IEDM ALIGNMENT ASSESSMENT RESULTS	57
6.1	UNIT AREA	57
6.1.1	Overview of Unit Area Alignments	57
6.1.2	Unit Area Example for Simple Attributes	59
6.1.3	Unit Area Example of an Enumeration Attribute	60
6.1.4	Unit Area Assessments Summary	60
6.2	EQUIPMENT AREA	61
6.2.1	Overview of Equipment Area Alignments	61
6.2.2	Equipment Area Example	63
6.2.3	Equipment Area Assessment Results Summary	64
6.3	ENVIRONMENT AREA	65
6.3.1	Overview of Environment Area Alignments	65
6.3.2	Alignment Example: Infantry Trench	66
6.3.3	Environment Area Assessments Summary	69
6.4	C4I	70
7.	LC2IEDM → WARSIM ALIGNMENT ASSESSMENT RESULTS	73
7.1	UNIT	73
7.2	EQUIPMENT	74
7.3	ENVIRONMENT	76
7.3.1	Example Alignment: Minefield	77
7.3.2	Example Alignment: LC2IEDM Category Codes	78
8.	RECOMMENDATIONS	81
8.1	LC2IEDM ENHANCEMENTS	81
8.1.1	Scope	81
8.1.2	Recommended Changes for Simulation Unit Data	81
8.1.3	Recommended Changes for Simulation Equipment Data	82
8.1.4	Recommended Changes for WARSIM Environment Data	82
8.2	MODELING AND SIMULATION RECOMMENDATIONS	82
REFERENCES		Refs-1
ABBREVIATIONS AND ACRONYMS		Acros-1
APPENDIX A. NOTATION		A-1
APPENDIX B. UNIT ALIGNMENT ASSESSMENTS		B-1
APPENDIX C. EQUIPMENT ALIGNMENT ASSESSMENTS		C-1
APPENDIX D. ENVIRONMENT ALIGNMENT RESULTS		D-1

APPENDIX E. RULES FOR VALUE-LEVEL ASSESSMENTS	E-1
APPENDIX F. WARSIM – JCDB ALIGNMENT ASSESSMENT	F-1

Figures

Figure 1. C4I/M&S Interoperability Components.....	3
Figure 2. Unit Area of WARSIM	8
Figure 3. Equipment Area of WARSIM.....	9
Figure 4. High-Level Depiction of the LC2IEDM Independent Entities	11
Figure 5. Notional Assessment Context	18
Figure 6. LC2IEDM ORGANISATION-ALS19s View	20
Figure 7. LC2IEDM Basic Unit View Used in Alignment Assessment.....	21
Figure 8. Relationship Between Alignment Levels.....	23
Figure 9. JSIMS FOM Class/Type Structure for Speed	26
Figure 10. Mapping the LC2IEDM to a Very Simple Model	32
Figure 11. A more structured general model (in IDEF1X)	33
Figure 12. Non-standard Mappings from the TCDM to the LC2IEDM.....	35
Figure 13. Definition of More Specific Mapping Between Models.....	36
Figure 14. High-Level Depiction of Alignment Assessment Process	40
Figure 15. JSIMS FOM-to-LC2IEDM Alignment Process.....	43
Figure 16. Deep Nesting in JSIMS Complex Data Types.....	44
Figure 17. Potential Attribute Mappings.....	51
Figure 18. Example Table for Value-Level Alignment Analysis.....	54
Figure 19. LC2IEDM to JSIMS FOM Alignment Assessment Process.....	55
Figure 20. Principal LC2IEDM Entity Structure for WARSIM Unit Data.....	58
Figure 21. Example Unit Area Alignment Mapping and Assessments	60
Figure 22. Example Unit Area Alignment Mapping of an Enumerated Attribute.	60
Figure 23. Unit Area Attribute Alignment Assessment Results.....	61
Figure 24. Modeling a JSIMS FOM Equipment Group Using LC2IEDM Entities	63
Figure 25. Example Equipment Area Attribute Alignments	64
Figure 26. Equipment Area Attribute Alignment Assessment Results	65
Figure 27. Relationship Among LC2IEDM Entities that Model an Infantry Trench.....	68
Figure 28. Environment Area Attribute Alignment Assessment Results	70
Figure 29. LC2IEDM Entities in the Unit Area	73
Figure 30. Unit area Reverse Alignment Assessment Results	74
Figure 31. Important LC2IEDM Entities for Modeling Equipment.....	74
Figure 32. Results of Equipment Area Attribute Alignment Assessments	76

Tables

Table ES–1. Summary of Unit Degree of Alignment	3
Table ES–2. Summary of Materiel Concept Degree of Alignment	3
Table ES–3. Summary of Terrain Concept Degree of Alignment.....	4
Table ES–4. Summary of Conceptual Degrees of Alignment.....	4
Table 1. The Four Levels of Alignment	16
Table 2. LC2IEDM Atomic Domains	28
Table 3. JSIMS FOM Atomic Data Types	28
Table 4. TCDM Atomic Types.....	29
Table 5. Example of Mapping Enumeration Literals	30
Table 6. Formulas Used to Calculate Computed Degree of Alignment	52
Table 7. Degrees of Alignment of the LC2IEDM with Respect to WARSIM Concepts	57
Table 8. JSIMS FOM Classes that Model Unit	57
Table 9. Unit Area Entity-Level Assessment Results	61
Table 10. JSIMS FOM Classes that Model Equipment.....	62
Table 11. Summary of Element Assessment Effort for Equipment	62
Table 12. LC2IEDM Entities That Align to Equipment	63
Table 13. Equipment Area Entity-Level Assessment Results.....	64
Table 14. Degree of Alignment of Infantry Trench Attributes.....	69
Table 15. Degree of Alignment by TCDM Coverage	69
Table 16. Degree of Alignment of WARSIM with Respect to LC2IEDM Concepts	73
Table 17. Summary of Element Assessment Effort for Equipment	75
Table 18. JSIMS FOM Classes Used in Aligning the Equipment Area.....	76
Table 19. Degree of Alignment of Minefield Attributes	78
Table 20. Pseudo-Mapping Results	79

Executive Summary

Background

Interoperability between Command, Control, Communications, Computers, and Intelligence (C4I) and Modeling and Simulation (M&S) systems is one of the greatest challenges to the M&S community today. Simulations are a cost-effective component of Army force training, and provide testing environments for new systems. Simulations fill a void created when exercises are impractical, thereby increasing warfighter preparedness. But training on C4I systems requires an interface between these systems and the simulation system. To use simulations with C4I systems, the Army has been developing point-to-point software interfaces. These ad hoc interfaces have failed to yield insights into C4I/M&S interoperability. Lacking such insights, each software interface is a largely independent effort that wastefully re-implements portions of previous interfaces.

In the past 10 years, M&S and C4I standards and development practices have diverged significantly. The two communities now use quite different data models as well as different architectures. M&S uses the High Level Architecture (HLA). C4I uses the Defense Information Infrastructure Common Operating Environment (DII COE). Data model compatibility is a fundamental issue. Major interoperability problems arise when there are data exchange requirements for C4I-M&S interoperation that are not supported by one side of the exchange. Similarly, interoperability problems occur if data representations differ significantly between systems, although these problems are not as bad as those caused by unsupported data exchange requirements.

Organizations should desire data compatibility to the fullest extent possible. General solutions to interoperability problems have not emerged to date, and lack of data compatibility appears to be a principal reason why. Beginning in 1993, with the third Army Tactical Command and Control Systems test, a cottage industry of custom, point-to-point C4I-M&S interfaces has grown up around the Army's family of Command and Con-

trol (C2) systems. Reuse, standardization, and interoperability were seldom key design criteria, so most of these interfaces link a specific simulation to a specific C4I system and typically handle only a small subset of the messages or data the "target"—or stimulated—C4I system can accept and/or the simulation can pass.

Beginning in 1999, the Institute for Defense Analyses (IDA) began studying data compatibility with an eye to determining how to assess and improve it. IDA published a series of reports and papers proposing a methodology for assessing compatibility, and studying it in the context of the Army Integrated Core Data Model and the Army's Object Management Standards Category (OMSC) objects, important U.S. Army models in the C4I and M&S domains, respectively. IDA determined that little data compatibility existed between these two models, and also concluded that the OMSC was unlikely to promote data compatibility with any C4I model. IDA therefore decided to investigate another M&S model.

Purpose

This report extends IDA's previous studies on the issue of aligning data models of Army C4I and M&S systems. It presents a more complete, more general methodology for determining compatibility than has previously been published. Organizations can use this methodology to perform their own studies and thereby improve the prospect of interoperability between C4I and M&S systems they develop or procure.

The real thrust of this report, though, is a case study of compatibility (or extent of alignment) between prominent existing C4I and M&S data models. This study identifies compatibility (or alignment) problems that need to be resolved in order to enable development of systems based on these standard C4I and M&S models. In addition, it makes recommendations on addressing these problems in ways that move C4I and M&S modeling closer to the goal of common modeling standards.

Methodology

The study focuses on important, formally sanctioned data models in the Army C4I and M&S domains. In the C4I domain, this is NATO's Land Command-and-Control Information Exchange Data Model (LC2IEDM). The LC2IEDM is a relational model, and is NATO's proposed data exchange standard for tactical databases. In the M&S domain, the Warfighter's Simulation (WARSIM) will provide simulation tools to Army leaders that they can use to create realistic operational conditions for education, training, and mission rehearsal to meet Title X requirements. WARSIM is to run as a federate of the Joint Simulation System Federation Object Model (JSIMS FOM)¹, which is defined using HLA templates. In this context, WARSIM publishes a set of classes to which other federates can subscribe. It is these classes that form the core of the M&S domain analyzed in this study.

The study performed an analysis of *alignment* to support an assessment of the potential compatibility and interoperability of systems based on the examined data standards. The report defines suitable technical concepts of alignment in order to enable quantitative assessments of alignment between these data models. Roughly speaking, these definitions declare that the LC2IEDM and the JSIMS FOM-published classes of WARSIM are in alignment to the extent that LC2IEDM modeling elements cover the data requirements implicit in the JSIMS FOM classes.

The study assigned each modeling element a *degree of alignment*, the percentage of possible coverage. Ideally, each element in one model ought to have a 100% degree of alignment with an element in the other model, meaning that these elements model the same data, and allowing an LC2IEDM-based system and a WARSIM-based system to interoperate with respect to these elements. But, if a WARSIM element has no counterpart in the LC2IEDM, there is 0% degree of alignment. Or the degree of alignment may be between 0% and 100%, as when the LC2IEDM and WARSIM model similar types of data, but they do not match exactly. Degrees of alignment lower than 100% may indicate a need to modify the models to achieve interoperability (although less-than-perfect alignment may be acceptable).

¹ Hence, it is also known as the Land Component of JSIMS.

The LC2IEDM is a relational data model expressed in the Integrated Computer-Aided Manufacturing Definition 1 Extended (IDEF1X) model, whereas WARSIM has an object-like model in the JSIMS FOM. In this sense, each data model typifies its domain. One challenge of alignment is to compare and contrast these different types of models, accounting for their disparate goals.

Each alignment assessment is unidirectional. It focuses either on the degree to which LC2IEDM modeling elements cover data requirements implicit in WARSIM, or the degree to which JSIMS FOM-published elements of WARSIM cover data requirements implicit in the LC2IEDM. It does not cover both simultaneously. Both perspectives are valuable, however, and IDA therefore undertook two distinct assessments to cover both directions.

WARSIM models terrain characteristics using the Terrain Common Data Model (TCDM). Because terrain characteristics play a central role on any M&S system, we also assess the degree to which the TCDM aligns with the LC2IEDM, and vice-versa. The TCDM is based on features, and IDA undertook an assessment of each attributed feature, identifying LC2IEDM entities and attributes that could model those features. IDA also assessed the degree to which those LC2IEDM entities that can model terrain characteristics—GEOGRAPHIC-FEATURE and FACILITY—can be modeled by TCDM elements.

The LC2IEDM has been developed as a reference data model. However, many developers have requirements to interoperate with the Army Battle Command System (ABCS) which uses the Joint Common Database (JCDB) Data Model (JDM). Hence, IDA performed a separate assessment in which the degree of alignment between WARSIM and the JDM was analyzed.

Findings

Tables ES-1, ES-2, ES-3, and ES-4 summarize the alignment assessments undertaken for this study. These summaries are based on the detailed analyses of alignment between individual entities and classes provided in this report and accompanying databases.

Each table focuses on a particular concept that is central to both M&S and C4I domains. Each table has two sets of columns. The set on the left presents results from WARSIM-to-LC2IEDM alignment; the set on the right presents results

from LC2IEDM-to-WARSIM alignment. Rows show important elements from each area, and the degree of alignment of the element. The final row shows the overall degree of alignment for

the concept. (Table ES-3, which presents the results of terrain assessment, only presents the overall degree of alignment, because of the large number of TCDM features.)

Table ES-1. Summary of Unit Degree of Alignment

WARSIM-to-LC2IEDM Alignment		LC2IEDM-to-WARSIM Alignment	
JSIMS FOM Class	Degree of Alignment to the LC2DM	LC2IEDM Entity	Degree of Alignment to WARSIM
org	84%	COMBAT-UNIT-TYPE	56%
org.land	54%	HEADQUARTERS-UNIT-TYPE	55%
org.land.unit	46%	OBJECT-ITEM	100%
		OBJECT-ITEM-TYPE	25%
		OBJECT-TYPE	50%
		ORGANISATION	83%
		ORGANISATION-ORGANISATION-ASSOCIATION	50%
		ORGANISATION-ORGANISATION-TYPE-ESTABLISHMENT	0%
		ORGANISATION-TYPE	64%
		ORGANISATION-TYPE-ESTABLISHMENT	0%
		ORGANISATION-TYPE-ESTABLISHMENT-ORGANISATION-TYPE-DETAIL	0%
		SUPPORT-UNIT-TYPE	59%
		UNIT	88%
		UNIT-TYPE	56%

Overall Degree of Alignment: 61%

Overall Degree of Alignment: 49%

Table ES-2. Summary of Materiel Concept Degree of Alignment

WARSIM-to-LC2IEDM Alignment		LC2IEDM-to-WARSIM Alignment	
JSIMS FOM Class	Degree of Alignment to the LC2IEDM	LC2IEDM Entity	Degree of Alignment to WARSIM
abstract	88%	CAPABILITY	23%
abstract.land	86%	EQUIPMENT-TYPE	55%
abstract.land.equipment_type	57%	FIRE-CAPABILITY	20%
abstract.land.personnel_type	82%	LAND-MANOEUVRE-CAPABILITY	22%
abstract.land.rotary_wing_type	57%	MATERIEL	57%
org	84%	MATERIEL-STATUS	17%
org.land	54%	MATERIEL-TYPE	69%
org.land.equip_group	53%	OBJECT-ITEM	100%
org.land.supply_cache	52%	OBJECT-ITEM-STATUS	20%
		OBJECT-ITEM-TYPE	38%
		OBJECT-TYPE	50%
		OBJECT-TYPE-CAPABILITY-NORM	75%
		STORAGE-CAPABILITY	20%
		SURVEILLANCE-CAPABILITY	24%

WARSIM-to-LC2IEDM Alignment	
JSIMS FOM Class	Degree of Alignment to the LC2IEDM

LC2IEDM-to-WARSIM Alignment	
LC2IEDM Entity	Degree of Alignment to WARSIM

Overall Degree of Alignment:	70%
------------------------------	-----

Overall Degree of Alignment:	42%
------------------------------	-----

Table ES-3. Summary of Terrain Concept Degree of Alignment

WARSIM-to-LC2IEDM Alignment	
Terrain Degree of Alignment:	41%

LC2IEDM-to-WARSIM Alignment	
Facility Degree of Alignment:	59%
Geographic Feature Degree of Alignment:	63%

Table ES-4. Summary of Conceptual Degrees of Alignment

WARSIM-to-LC2IEDM Alignment	
Conceptual Area	Degree of Alignment
Unit	61%
Equipment	70%
Environment	41%

LC2IEDM-to-WARSIM Alignment	
Conceptual Area	Degree of Alignment
Unit	49%
Equipment	42%
Environment:	
Facility	59%
Geographic-Feature	63%

Ideally, these tables would show 100% alignment. But analysis of these results clearly shows that the Army has a serious problem with data model alignment between the C4I and M&S domains. Even if next generation training and testing simulations are built using standard simulation objects, developers will have to craft interfaces to transform data and, in many cases, create data that is missing from the other domain. The impact for acquisition of systems is significant. Millions of dollars will have to be spent after the systems are developed to interface incompatible models, and additional maintenance costs will be incurred as systems behind the interfaces change. These costs are avoidable to the extent that we can improve the degree of alignment of data prior to implementation.

Recommendations

The recommendations from this study are in two classes: recommendations for LC2IEDM enhancements, and M&S recommendations.

The recommendations for LC2IEDM enhancements are not specific to WARSIM, but rather support requirements from simulation systems. The study found that the structure of the LC2IEDM is generally suited to M&S data, but the LC2IEDM's coded values are not broad enough to support M&S needs. Moreover, the

LC2IEDM's environment model lacks both the breadth and depth necessary for simulations.

The study found that the JSIMS FOM-published classes of WARSIM have substantial limitations in being able to represent C4I information. Army M&S systems can benefit from a reference object model that identifies all relevant C4I data elements within the context of a structure applicable to M&S design. Development of such a model is underway as a natural next step.

1. Introduction

Historically, Command, Control, Communications, Computers, and Intelligence (C4I) and Modeling and Simulation (M&S) have been represented in the services by separate communities with separate backgrounds. C4I comes from the Command and Control (C2) discipline, which is much older than M&S. C2 has a long history that predates computers, and so has not always been strongly influenced by the absolute need for unambiguity that is fundamental to a computer-based implementation. For this and other reasons, C4I data can be difficult to translate into a form acceptable to an M&S system, and vice-versa.

Over the past decade, both communities have begun to recognize the tremendous potential improvements in capability that could be realized if C4I systems and M&S systems could interoperate more effectively. The following examples are often cited as benefits of interoperability:

- Simulation-based acquisition (i.e., requirements development and analysis; testing; and training)
- Development of doctrine and tactics techniques and procedures
- Embedded training (both individual and collective)
- Course-of-action development and analysis
- Mission planning and rehearsal
- Execution monitoring

Unfortunately, there are some fundamental barriers to interoperability in today's state-of-the-practice.

1.1 Purpose of the Document

The purpose of this study is to present investigations into a key area of C4I/M&S interoperability. This area is data/object model alignment: the ability for C4I and M&S systems to share and exchange data based on a shared semantics for the data each system manipulates. A previous study in this area by the Institute for Defense Analyses (IDA) yielded a preliminary methodology for rigorous assessment of data/object model alignment [IDA 2001]. This study refines and extends that methodology to make it better defined and more widely applicable.

This study applies the methodology to assess alignment between two prominent models from the C4I and the M&S domains: NATO's Land Command and Control Information Exchange Data Model (LC2IEDM) [NATO 2000] and the Warfighter's Simulation 2000 (WARSIM), also known as Joint Simulation System (JSIMS) Land Component. The study includes an assessment of alignment of environmental data as represented by the Terrain Common Data Model (TCDM), which is used by JSIMS and WARSIM. This assessment reveals the status of data alignment between representative C4I and M&S mod-

els, identifies changes needed to bring these models into better alignment, and provides a basis for developing a common reference object model capturing both C4I and M&S data requirements to improve future interoperability between C4I and M&S systems.

1.2 Intended Audience

There are 4 intended audiences for this document:

1. LC2IEDM (and other C4I model) designers who want interoperability with M&S systems.
2. WARSIM (and other M&S model) designers who want interoperability with C4I data models.
3. Department of Defense (DoD) officials responsible for establishing directions for C4I and M&S systems.
4. Individuals or organizations conducting alignment studies between disparate data and object models.

The study results highlight some of the issues, choices, and problems involved in translating the data between different models constructed for different purposes, even when they intend to describe the same universe. This information is a prelude to development of a common reference model, and is part of the process of educating those working to improve data interoperability between the C4I and M&S domains. The appendix that assesses alignment between WARSIM and the Joint Data Model (JDM) of the Army Battle Command System (ABCS) may be of special interest to the WARSIM program which is required to interoperate with ABCS. However, the study is not intended as a complete, conclusive or authoritative mapping of the data between these models (WARSIM and the LC2IEDM/ JDM).

This document assumes the reader is familiar with:

- Entity-relationship (ER) modeling concepts in general, and the Integrated Computer-Aided Manufacturing Definition One Extended (IDEF1X) [NIST 1993] notation in particular.
- Object-oriented (OO) modeling concepts in general, and the Unified Modeling Language (UML) [Booch 1996] in particular.
- The concept of a Federation Object Model (FOM) [HLA 2000].

However, the basic notation for IDEF1X and UML diagrams is presented for ease of reference in Appendix A.

1.3 Background

To the extent that C4I/M&S interoperability exists today, it is achieved mainly by *ad hoc* software interfaces established between specific systems. These interfaces typically handle a small subset of the messages or data necessary for interoperability. Significant human intervention is necessary if, for example, realism is to be achieved in a training exercise. M&S systems, for instance, rarely handle free text messages; moreover, they are in-

herently at least partly artificial and therefore do not have the same constraints for message standards, formats, and protocols. Any interface between a C4I system and an M&S system must recognize and overcome these differences. Such interfaces can become complex. They are generally costly to develop and maintain.

In recent years there has been some concerted effort to devise systematic approaches to interoperability. One of these approaches has yielded a framework that lays out several foundational areas in which progress must be made before interoperability goals can be fully achieved [HS 2000]. This framework, shown in Figure 1, identifies a comprehensive solution in terms of the following components:

- **Architectures Alignment**, recognizing that there are many possible solutions. The C4I community has developed the Defense Information Infrastructure Common Operating Environment (DII COE) architectures. The simulation community has the High Level Architecture (HLA) [HLA 2000]. These architectures affect the technical basis upon which C4I and simulation systems are built. Alignment of architectures contrasts and resolves the differences in how architectures compartmentalize the “solution space” of the system(s) or system of systems.
- **Common Data/Object Models**, i.e., the development of models common to both C4I and M&S systems. Having an M&S application use the same or similar model representations as the C4I systems with which it exchanges data minimizes translation and the attendant risks. [HB 1999].
- **Common Standards** to use in applying architectures and common data/object models when constructing interoperable systems. Making sense of where and how to apply standards relies primarily on work being done on the architecture and data/object model alignment. Since little architecture and model alignment work has been done, setting and using meaningful standards to assist interoperability challenges has been difficult to date.
- **Reusable Component Interfaces**, which paradoxically (given the relative lack of activity in the blocks underneath) has been an active research area. One reason is that interfaces can provide short-term solutions that are easy to envision and allow

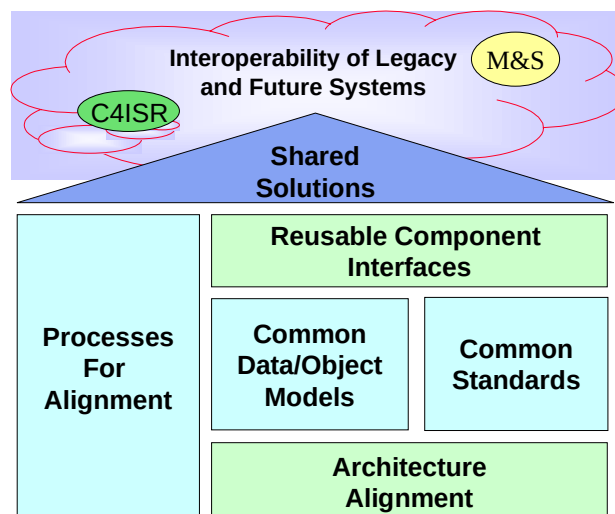


Figure 1. C4I/M&S Interoperability Components

quick successes in a world of disparate systems. Translators in these interfaces help to convert data between systems, but never really remove basic underlying incompatibilities of model representation or architecture misalignment in the original systems.

- ***Processes for Alignment***, providing policies and procedures for evolving the other blocks in Figure 1.

Successes in these foundational areas will lead to ***Shared Solutions*** to C4I/M&S interoperability, the roof of this “house diagram”. This study concentrates on the Common Data/Object Models block, contributing to the understanding of the current state of interoperability in this area.

1.4 Data/Object Model Alignment

Data/object model alignment between C4I and M&S models is the situation where information from the C4I data model can be expressed in the object model of the M&S system without loss of information, and vice versa. Informally, alignment implies that if data from one system is converted to the other and back again, there should be no loss of information.

The objective of data/object model alignment is to create an environment in which a C4I system and an M&S system can share data, unambiguously and without human intervention. In the absence of data/object model alignment, interoperability is costly, slow, or both. If alignment exists, then (for example) an M&S system can obtain formation information from a C4I system and use that information as the basis for simulating troop formation. If alignment does not exist, the M&S system will have to rely on another source (costly) or obtain the formation information from a human (slow).

Data/object model alignment alone does not guarantee interoperability; it is only one component thereof. The aligned models must be applied correctly (Common Standards). Moreover, as the size of this report should make clear, there is great detail in alignment, and unless that detail is properly encapsulated (Reusable Component Interfaces) interoperability will still be complex and costly. Nevertheless, achieving data/object model alignment is a significant step towards interoperability.

The term “data/object model alignment,” as used throughout this paper, is concerned specifically with the alignment of data models used for C4I data and the object models used in M&S systems. However, the methodology in this report has broader application, intending to apply to the alignment of any entity-relationship (ER) model (traditionally used to describe C4I models) with the class diagrams of any Object-Oriented (OO) model (traditionally used in M&S modeling). It also has obvious extensions to alignment between any two models of the same type (ER or OO). The methodology is, as Section 5 will discuss, adaptable to the nuances of the models being studied. This maintains flexibility and lets domain-specific knowledge play a role in alignment.

1.5 Organization of this Document

This document is organized as follows:

- Section 1 (this section) introduces the problems addressed by the study, presents the study's purpose, and its intended audience.
- Sections 2 and 3 provide overviews of the data and object models studied in this report: WARSIM, the JSIMS FOM, the Terrain Common Data Model (TCDM), and the LC2IEDM.
- Section 4 provides a precise definition of what data/object model alignment means.
- Section 5 gives the process used to assess the alignment of the models. It provides enough information to repeat the results of the study, or to extend the results to areas of the models that were not treated in this study.
- Section 6 presents the first part of the results of the study: the degree to which the WARSIM-published elements of the JSIMS FOM align with elements of the LC2IEDM.
- Section 7 presents the second part of the results: the degree to which the LC2IEDM aligns with the WARSIM-published elements of the JSIMS FOM.
- Section 8 states recommendations for how WARSIM and the LC2IEDM should evolve to increase alignment and thereby improve interoperability.

Following the body of this document are six appendices. The first (A) presents the notation used in this document. The second, third, and fourth (B–D) summarize the assessments of all unit, equipment, and environment elements, respectively. The fifth (E) details the rules that were used in performing assessments of data alignment at the level of the specific values supported by data elements. The sixth (F) extends our assessment analysis of WARSIM-C4I data compatibility from the LC2IEDM to the Joint Common Database Data Model (JDM) of the Army Battle Command System (ABCS).

The results reported in this study summarize our detailed assessments of the alignments between the many specific modeling elements of WARSIM and the LC2IEDM. Since the complete details of these assessments are too voluminous to include in this report they are available separately in two different formats: a set of databases (in Microsoft Access format) and a set of spreadsheets (in Microsoft Excel format).

2. Overview of WARSIM, JSIMS, and the TCDM

2.1 WARSIM

WARSIM will provide simulation tools to Army leaders that they can use to create realistic operational conditions for education, training, and mission rehearsal to meet Title X requirements. The program objectives include supporting Total Army and Joint Force events from Battalion through echelons above Corps in scenarios from across the operational continuum while reducing the resources required to prepare, execute, and assess simulation events. WARSIM will support real-time battle command training events such as seminars, Command Post Exercises and Battle Command Training Program events in all type units and schools.

The best documentation of current WARSIM battlefield objects and attributes can be found in the WARSIM managed parts of the JSIMS FOM. Thus, we used WARSIM managed elements in the JSIMS FOM (Version 6.0) [JSIMS 2001] as the primary basis for our assessment of data alignment between WARSIM and the LC2IEDM. However, because such FOMs are designed to document dynamic data that are exchanged by simulations during an exercise using the DoD's High Level Architecture (HLA), the JSIMS FOM does not include all the relevant terrain data. For that reason we also included the JSIMS Terrain Common Data Model (TCDM) [JSIMS 1999] in our alignment assessment.

2.2 JSIMS FOM

JSIMS is a federation of many different simulations, including WARSIM for the Army, the National Air Space Model (NASM) for the Air Force, and Maritime for the Navy [JSIMS 2001]. In order to focus on WARSIM related elements, this alignment assessment is restricted to those object classes (and their attributes) in the JSIMS FOM for which WARSIM has management responsibility. Available resources were insufficient to extend this analysis to all of the object classes to which WARSIM subscribes, or to any of the interaction classes that have WARSIM involvement.

To enable assessment in different modeling areas, we divided the analysis space into four main areas: Unit, Equipment, Environment, and C4I. The Unit area of WARSIM comprises the classes and inheritance relations illustrated in Figure 2. (The figure is drawn using the Unified Modeling Language (UML). See Appendix F for an explanation of the UML notation.) The Equipment area comprises the classes and inheritance relations in Figure 3. Each class has zero or more attributes. An attribute may be atomic (e.g., an integer) or a complex data type (e.g., a 3-d coordinate). There is considerable overlap between the Unit area and the Equipment area classes. This is because all equipment information on platforms is stored in attributes of subclasses of the `org` class (e.g., in `org.land.supply_cache` and `org.land.equip_group`) in this model.

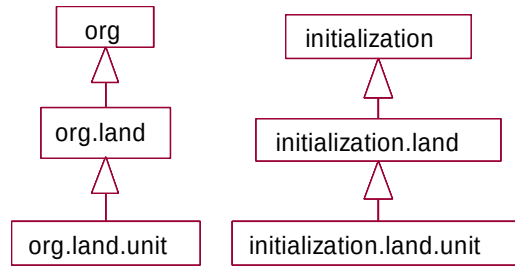
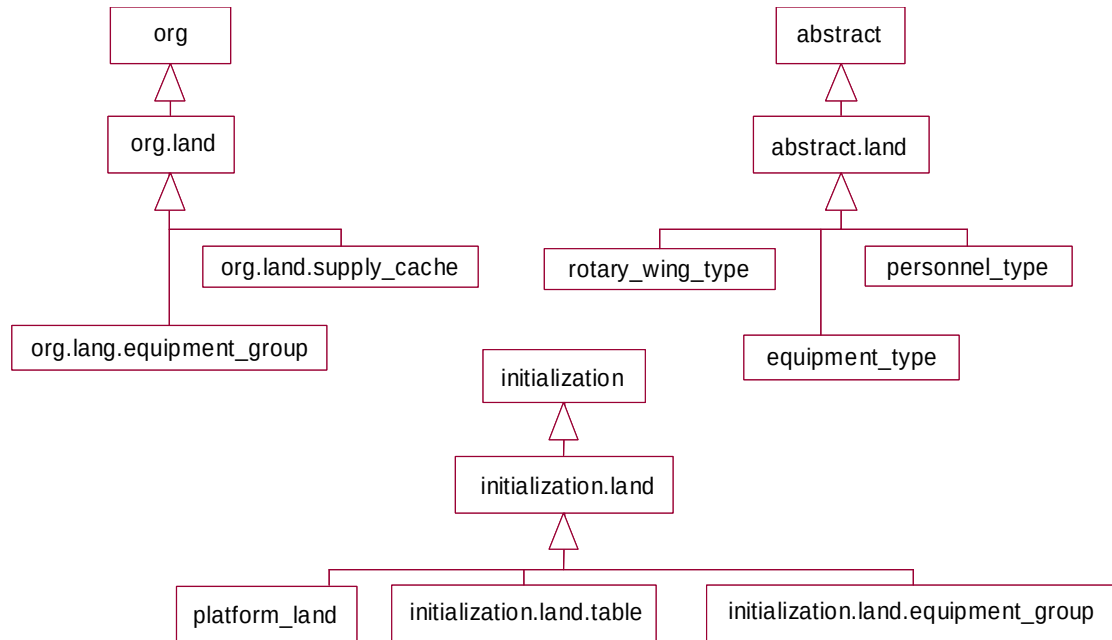


Figure 2. Unit Area of WARSIM

The only Environment area class in the JSIMS FOM that is managed, published, or subscribed to by WARSIM is minefield.land, although many other classes of environmental features are modeled by the TCDM. Hence, minefield.land would ordinarily be the only “dynamic” part of the terrain under HLA rules which require all exchanges of FOM data among federates to occur via its Run-Time Infrastructure (RTI). However, JSIMS and WARSIM are using a separate Synthetic Natural Environment (SNE) federate which models environmental changes through its SNE classes (chem_bio_strike, dynamic_feature, metoc_edit, smoke_strike). Although WARSIM does not subscribe to the SNE classes, we have been informed² that it will accept updates to this FOM data from the SNE federate Application Program Interface (API) in violation of HLA rules. Operator intervention may also change the terrain during execution according to our sources. Hence, some of the terrain elements from the TCDM, which are discussed in the next section, may also change dynamically for WARSIM during a simulation exercise.

The C4I area consists of C4I initialization classes and “C2_artifacts” classes. They were not included in the assessment because they contain only data peculiar to specific C4I system interfaces and do not contain battlefield information.

² Information on dynamic terrain in WARSIM provided by representatives of the Environmental Database Integrated Product Team (EDB IPT).



2.3 TCDM

The TCDM describes the terrain component of the JSIMS SNE. The TCDM includes features that will be represented in the JSIMS Terrain Database. This study used TCDM Revision 1.2a [JSIMS 1999] because this was the most recent version which we were able to obtain at the outset of the study.

The TCDM is a logical data model that addresses both low and medium resolution simulation requirements. It was designed to be extensible to accommodate high-resolution requirements. The TCDM supports both virtual and constructive simulations at the platform and aggregate levels of resolution. The TCDM was built on the Environmental Data Coding Specification (EDCS) [RMFS 2000], and will be used by JSIMS to specify terrain database content requirements, and for the development of the terrain databases.

The design of the TCDM was driven by the needs of the warfighter and military modeler to represent concepts of interest, as well as a requirement for efficient runtime reasoning about the SNE in the context of a military model. These needs implied organizational and representational requirements for the data model.

Analyses based on model resolution, use, consistency, and performance led to the decision to use feature representations rather than geometric representations in the data model. The resulting TCDM is organized into thematic layers, called coverages. Coverages align with how subsets of terrain features would be represented and processed. Within each coverage the data model is flat (except for Surface Areas, which has four subcoverages). The coverages and subcoverages are:

- Surface Areal

- Physiography
- Vegetation
- Urban
- Water
- Point Culture
- Linear and Point Hydrography
- Linear and Areal Terrain Obstacles
- Maritime Trafficability
- Linear Connectivity/Distribution
- Linear and Point Transportation
- Metadata
- Geotile Reference
- Administrative Boundaries
- Battlefield Elements

The Geotile Reference coverage is used only for database generation. It contains elevation profiles along the Geotile Reference System (GTRS) geotile boundaries. The Metadata coverage is used to characterize the data source used in populating Surface Areal regions.

Within a coverage most features share a consistent attribute set. The TCDM specifies the data type for each attribute, the range of allowable values, and in some cases, a default value for an attribute. For enumerated data types a complete set of enumerations is provided.

3. Overview of the LC2IEDM

The version of the LC2IEDM used in this assessment corresponds to the release of 31 March 2000 by the Army Tactical Command and Control Information System (ATCCIS) group. It contains 149 entities, ten of which are independent: ACTION, CANDIDATE-TARGET-LIST, CAPABILITY, CONTEXT, LOCATION, OBJECT-ITEM, OBJECT-TYPE, REFERENCE, REPORTING-DATA, and RULE-OF-ENGAGEMENT. Figure 4 shows the high-level relationships among these entities using the IDEF1X notation [NIST 1993]. The supertype entity OBJECT-ITEM contains the five battlefield objects FACILITY, FEATURE, MATERIEL, ORGANISATION and PERSON, whereas the supertype entity OBJECT-TYPE provides the corresponding hierarchy for their classes, namely FACILITY-TYPE, FEATURE-TYPE, MATERIEL-TYPE, ORGANISATION-TYPE and PERSON-TYPE.

3.1 Background

The LC2IEDM was developed by ATCCIS to support land C2 operations in a multinational environment for echelons to include brigade, corps, and above. It therefore emphasizes the data that national armies would share under such conditions and purposely leaves out those details that may traditionally be handled by national C2 systems, such as personnel-related information. The model also reflects the philosophy that planning documents must be boiled down to the specific actions contained therein, and mapped to WHO does the action, against WHOM, with WHAT, WHERE, and WHEN. In addition, the model permits the specification of contextual data via REPORTING-DATA, REFERENCE, and CONTEXT.

3.2 Current Status of the LC2IEDM

The LC2IEDM is the fourth version of the original ATCCIS model, the Generic Hub (GH). It is, therefore, also referred to as GH4. A fifth version of the Generic Hub model

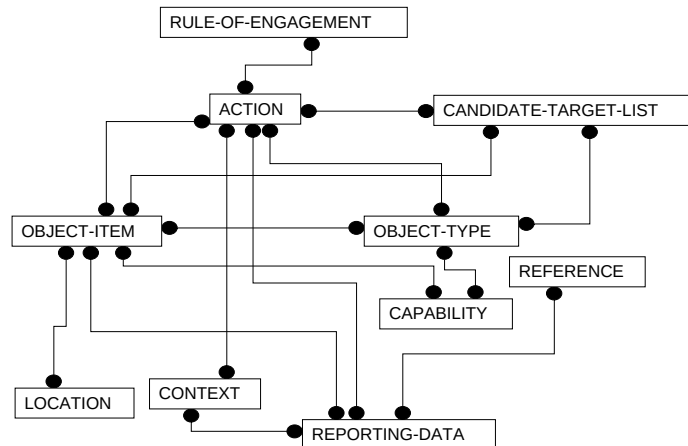


Figure 4. High-Level Depiction of the LC2IEDM Independent Entities

(GH5) was released in the summer of 2002, but as of this writing it has not been adopted by NATO as the basis for the LC2IEDM. The major changes in GH5 with respect to GH4 are additional structures needed to support Military Operations Other than War (MOOTW), as well as extensions to interface with naval and air operations. NATO has adopted the LC2IEDM as the reference model for land C2. In the United States, there are currently initiatives to use the model as the point of departure to support interoperability among services and agencies. The initial version of the Generic Hub (GH) was used in 1993 to develop DoD's C2 Core Data Model (C2CDM), now part of the DoD Data Architecture (DDA). The Army's Joint Common Database (JCDB), currently in version 5.0, was built from the C2CDM, and it incorporated data structures from GH3, as well as from other Army information systems.

4. Definition of Alignment

This section presents the meaning of data/object model alignment between the JSIMS FOM and the LC2IEDM. A clear, precise definition of what data model and object model alignment means is essential. It provides:

- A shared understanding of objectives for an alignment assessment team.
- An unambiguous interpretation of the results of alignment assessment.

The interoperability community generally agrees that data and object models are an important component of interoperability [HB 1999], but has yet to reach more than an informal consensus on what alignment is. Everyone seems to agree that alignment is defined as the ability for systems to share information based on commonality between their data/object models. The ambiguity lies in how one determines commonality. Commonality may stem from syntax, semantics, standards, or other sources, or combinations thereof. Which sources are appropriate depends on factors such as the elements one analyzes from each model and the models' completeness.

In other words, alignment can mean different things, depending on which elements are chosen from the models being aligned. All meanings share certain characteristics, but differ in detail. This section defines four meanings, and explains how they fit into this report.

Note that the definition of data/object model alignment differs from the process used to perform an alignment assessment. Section 5 covers the latter topic.

4.1 Background

The original definition of data/object model alignment came from IDA's study of data/object model alignment between the AICDM and the OMSC [IDA 2001]. The definition in that report was intended to be a general-purpose framework for comparing and contrasting data/object model alignment of an ER-based C4I data model and an OO-based M&S model. However, we recognized that our definition was based on the modeling elements specific to the AICDM and the OMSC, and that we had not fully explored data/object model alignment. We expected to extend the definition of alignment during subsequent alignment assessments.

Our goal is to provide a framework for studying alignment between any ER-based model and any OO-based model. Both the AICDM/OMSC study and the WARSIM/LC2IEDM study began with a complete ER model, its semantics fully specified (i.e., all information necessary to convert the model into a physical database is provided). However, neither the OMSC nor the JSIMS FOM has been a fair representation of an OO model. The OMSC is both syntactically and semantically incomplete. The JSIMS FOM is complete,

but its model is from the High-Level Architecture Object Model Template Specification [DoD 1998b], which uses a subset of OO modeling techniques. For example:

- The JSIMS FOM models attributes but not methods. (An attribute is arguably a shorthand for a set/get method pair, but attributes do not encapsulate behavior to the degree that methods do.)
- The JSIMS FOM uses only single inheritance, not multiple inheritance.
- The data types of all attributes are either atomic or complex data types, or lists thereof. No attribute's data type is a class.³

Until we have performed an alignment assessment including a semantically complete OO model that uses these and other OO constructs, we must regard the definition of data/object model alignment as evolving.

4.2 An Intuitive Definition of Alignment

An alignment assessment is conducted to determine whether ER elements (views, entities, relationships, attributes, and domains) align with OO elements (packages, classes, attributes, and data types), and vice versa, thereby increasing the ease with which an M&S system and a C4I system can interoperate. What, then, does it mean to say elements are or are not aligned?

Intuitively, elements are aligned if data expressed by an element in one model can be translated to the other model, then translated back again with no loss of information—in mathematical terms, if a mapping exists from elements of one model to elements of the other that is one-to-one and “onto”. More precisely, we say that model *B* is fully aligned with an element *E* of model *A* if data expressed by *E* can be translated into model *B* and back again with no loss of information. For example, if system *A* models information about a tank—its weight, current velocity, and current ammunition supply, say—then data/object model alignment implies that there exists a mapping from system *A*'s model to system *B*'s model such that system *B* can record the same three pieces of information. Moreover, the existence of the reverse mapping implies that no translation errors were made: there was no loss of precision or unintentional change in units of measure.

Alignment under this intuitive definition is neither necessary nor sufficient for interoperability. It is not necessary because two systems may not need symmetry: we can conceive of a situation where system *B* takes data from system *A* but does not return it (e.g., logging C4I data generated by an M&S system). We consider this situation unimportant, however, because our interest is in developing and promoting standards for C4I and M&S, and we feel that standards are most useful if they cover the more general case of C4I/M&S two-way interaction.

The intuitive definition is not sufficient because there is no guarantee that the data from *A* translated into system *B* is in a form meaningful to *B*: imagine an ER model set up to store information without regard to semantics (the LC2IEDM has such a schema for ob-

³ However, the data type `id_c` contains a federation object identifier. An attribute whose data type is `id_c` can reference a class instance.

ject types). For example, if B has a single high level object class for any type of object and it has an object type name attribute, then any type of entity from A can be represented in B, although B itself may have no definitions for any objects from A. In such a case, the initial intuitive definition could yield as assessment that B's classes are fully aligned with A's entities, despite the fact that there are no classes defined in B whose semantics are equivalent to the entities of A (see Section 4.5.4 for more detailed discussion of this issue). Symmetric translation may enable the interchange of data, but data/object model interchange is only one part of C4I/M&S interoperability. In the interest of promoting standards, we desire that data/object model alignment account for shared semantics so that data from multiple sources in multiple systems all has the same meaning.

Any explication of semantics depends on the modeling elements used to express it. The LC2IEDM is an ER model. The JSIMS FOM uses OO modeling. One issue in defining alignment is the identification of suitable sets of elements to align. For example:

- We can align entities in an ER model to classes in an object model. Roughly speaking, this concerns matching things that model the same types of physical or virtual objects. For example, the LC2IEDM contains an entity named ORGANISATION, and the JSIMS FOM contains a class named org. To say these two elements align fully is to say that they model the same thing, i.e., that an instance of ORGANISATION models the same information as an instance of org.
- We can align attribute domains in an ER model to data types in an object model. This is a set intersection issue. For example, some LC2IEDM attributes have a domain of NUMBER(15) (an integer of 15 decimal digits), and some JSIMS FOM attributes have a data type of long (a signed 32-bit integer). The possible values type long account for just over 0.002% of the possible values of NUMBER(15).

These two examples imply a correlation between element granularity and alignment rigor. Algebraic theory can be used to determine, rigorously, if an attribute domain and a data type are aligned: a fully faithful (one-to-one and onto) mapping exists between them. But what does it mean to say an entity is aligned with a class? The informal definition above, about representing the same physical or virtual objects, still leaves room for interpretation.

Alignment rigor forms a spectrum. One end is abstract and comprises high-level concepts. The other end is detailed and has mathematical rigor suited to formal reasoning and computer-based implementations. In between are levels of increasing formality.

We therefore partition alignment rigor into a set of discrete levels. The set is drawn from the data elements in the models. We consider all data modeling elements available, and place them along a spectrum in terms of their granularity. The elements in ER and OO models lead us to identify four levels: Conceptual (level 1), Entity (level 2), State (level 3), and Value (level 4). They are summarized in Table 1 (Section 4.4 provides the complete definition). When we speak of alignment, we refer to a particular level if not to whole models.

There is a pattern to the levels: Each alignment level is defined in terms of the next lowest level. In levels 1–3, level i contains a set of names of elements that are the focus of level $i+1$. For instance:

- In level 1, an OO package includes a set of class names. Classes are the focus of level 2 in the OO model.
- In level 2, an ER entity contains attribute names. Attributes are the focus of level 3 in the ER model.

This hierarchical approach has important consequences during alignment assessment.

Table 1. The Four Levels of Alignment

Level	Participating Model Entities	
	OO Model	ER Model
1 CONCEPTUAL: Entities of user perception	Package • Name • Description • Set of class names • Focal class name • Associations (inheritance, composition)	View • Name • Description • Set of entity names • Focal entity name • Relationships
2 ENTITY: Entities of data model	Class • Name • Description • Set of attribute names	Entity • Name • Description • Set of attribute names
3 STATE: Descriptions of entity state	Attribute • Name • Description • Data type name	Attribute • Name • Description • Domain name
4 VALUE: Descriptions of domains	Atomic Data Type • Name • Set of values (discrete or continuous)	Attribute Domain • Name • Set of values (discrete or continuous)

4.3 Degree of Alignment

Simply stating that two models are or are not aligned is not especially useful. If two models are not perfectly aligned—the expected situation—we want to know:

- *Where are they not aligned?* What elements in one model cannot be modeled in the other, either in whole or in part?
- *To what extent are they not aligned?* Will minor changes bring the models into full alignment, or will significant design changes be needed?
- *What changes would improve alignment?* What data elements in each model should be modified? What elements should be added? Are there elements that are not aligned but should be ignored?

To help answer these questions in quantitative terms, we introduce the concept of *degree of alignment*. Degree of alignment is a measure of the percentage of elements of one model that align with elements in another. It gives assessors some idea of how much a model must change to achieve full data/object model alignment. It also helps them under-

stand how a change to a model affects alignment with respect to another: more aligned, less aligned, or not at all.

Alignment assessment can be seen as a process of identifying elements from both models that seem related, and then carefully considering whether one's initial impressions are correct. Degree of alignment is the result of such consideration.

An assessor assigns a degree of alignment to each pairing of ER and OO elements he assesses. The assignment is made with respect to one model or the other. For example, one result of the alignment assessments in the LC2IEDM/JSIMS FOM study is that the JSIMS FOM class `org.land.equip_group` has a degree of alignment of 78% with respect to the LC2IEDM. This means that of all the data elements that make up an equipment group, roughly 22% cannot be modeled by the LC2IEDM. Because software systems are fussy about even small bits of missing data, a degree of alignment of 78% indicates that interoperability between WARSIM and an LC2IEDM-based system is unlikely.

Degree of alignment does not necessarily correlate to the effort needed to improve interoperability. Sometimes alignment can be increased by simply adding an attribute to a class. Other times, increasing alignment requires significant structural changes to a model, changes that might necessitate review by working groups and implementers. Degree of alignment does not account for such distinctions.

A degree of alignment of 100%—known as *perfect* alignment—is not always necessary. An M&S system typically generates huge amounts of state information that a C4I system need not capture, for example. Assessors, on determining the degree of alignment, must decide whether or not it indicates sufficient interoperability.

The methods an assessor uses to assign a degree of alignment depend on the alignment level. The Conceptual level is abstract, leaving an assessor few concrete details with which to reason about alignment; therefore, a degree of alignment assigned to a Conceptual assessment is necessarily done intuitively. The Entity level is slightly less abstract, so the degree of alignment is assigned less intuitively; the State level, even less intuitively. At the Value level, the assessor uses unambiguous methods to assign a degree of alignment. The methods used for the LC2IEDM/JSIMS FOM assessment are presented in Appendix E.

It is desirable, then, to perform Value-level assessments, as they inspire the most confidence that the assessment was done rigorously. Performing Value-level assessments is not always possible or necessary (see [WHLH 2001]), although it was usually practical in the LC2IEDM/JSIMS FOM study.

Entity-, State-, and Value-level assessment are performed in context. A Value-level assessment might compare `NUMBER(15)` and `long`, but this comparison is unenlightening without knowledge of the ER and OO attributes whose domain and data type `NUMBER(15)` and `long` represent. Value-level assessment is therefore performed in the context of a State-level assessment; in fact, as discussed above, alignment levels 1–3 are defined in terms of the next lower level. Each Value-level assessment can be therefore traced to a State-level

assessment, which in turn can be traced to an Entity-level assessment, which in turn can be traced to a Conceptual-level assessment. See Figure 5.

Figure 5 illustrates another concept regarding degree of alignment. When an assessor performs an assessment, the assessor assigns a degree of alignment based on a study of elements relevant to that level. Conceptual-level elements are more abstract than Entity-level elements. A degree of alignment assigned based on Conceptual-level analysis should be less rigorous than a degree of alignment assigned from Entity-level analysis. For analogous reasons, an degree of alignment based on Entity-level analysis is less rigorous than a degree of alignment assigned from State-level analysis, which in turn is less rigorous than a degree of alignment assigned from Value-level analysis. It is desirable to incorporate the rigor of Value-level analysis into Conceptual-level analysis. Therefore, Conceptual-, Entity-, and State-level alignment assessments have a rolled-up degree of alignment that is *computed* from degrees of alignment of lower-level assessments. The rolled-up degree of alignment for an assessment is based on all assessments of which it is the ancestor. In our studies, we have averaged degrees of alignment from child assessments to compute the rolled-up degree of alignment.

The computed degree of alignment is important because it tends to be less subjective than the assigned degree of alignment. The assigned degree of alignment for an element comes from studying the element, but the computed degree of alignment comes from studying what that element comprises; in other words, the computed degree of alignment comes from more detailed, lower level analysis. Furthermore, it is computed from standard formulas, whereas (particularly at higher levels) the assigned degree of alignment comes from intuition. For these reasons, the computed degree of alignment is used as the final value for an alignment assessment.

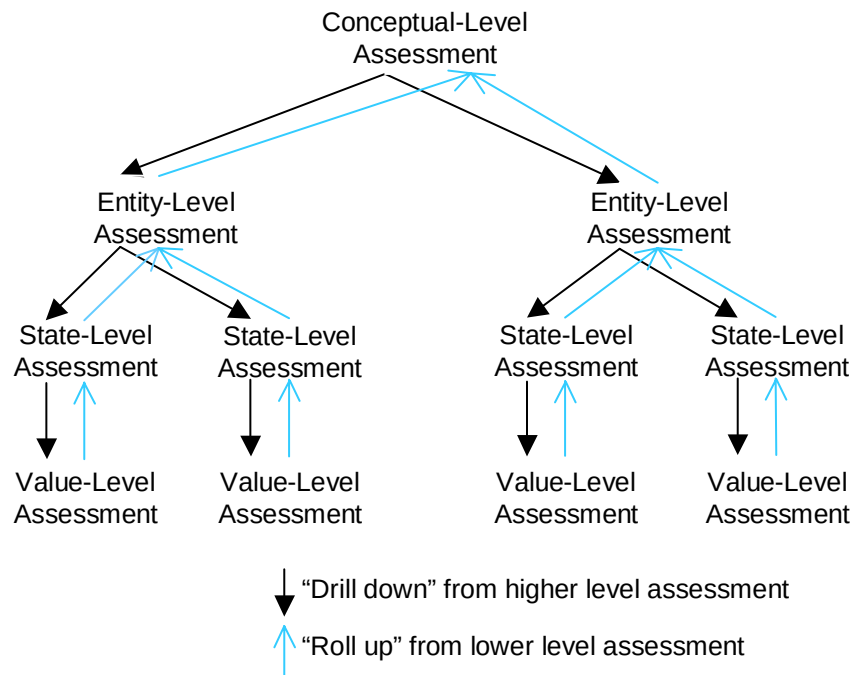


Figure 5. Notional Assessment Context

4.4 Rigorous Definition of Alignment

This section presents the complete definition of data/object model alignment as used in the LC2IEDM/JSIMS FOM study. It covers the meaning of alignment for each of the four levels. Discussion of each level is broken into four parts:

1. *Definition of level:* A conceptual exposition of alignment assessment at the level.
2. *Interpretation in the ER Model:* The ER elements that appear in the level.
3. *Interpretation in the OO Model:* The OO elements that appear in the level.
4. *Meaning of alignment:* What it means to say that the ER model and the OO are aligned with respect to the level.

The details of how an assessor assigns or computes a degree of alignment are process-specific, and are covered in Section 5.

4.4.1 Conceptual Level

4.4.1.1 Definition of Level

A concept is a mental abstraction. The Conceptual level is concerned with the highest level abstractions one uses when thinking about a system, as well as the components of those abstractions. For instance, when someone thinks about an automobile, they think of wheels, a chassis, and an engine. When they think of a military unit, they think of a group of people and equipment. They may also think of properties of the system, such as the velocity of an automobile, and the location of a military unit.

The Conceptual level helps people imagine a system and its concept of operations. They want a general understanding of the elements in the system.

4.4.1.2 Interpretation in the ER Model

An ER model models a concept as a set of entity names, along with the names of the ER relationships that associate them, and an informal (textual) definition of intended semantics. In ER modeling, the usual name for this aggregate is a *view*. A view has a name that suggests what it models.

Typically, one entity in a view is a “focal” entity. It contains the key associations to other entities in the view. Often, its name suggests the whole concept. For example, the LC2IEDM has a view named Unit. This view contains an entity named UNIT. It contains other entities with attributes relevant to modeling a unit, such as ORGANISATION, ORGANISATION-TYPE, and ORGANISATION-STATUS. From the names of these entities, it should be clear that UNIT is the one most central to the view. UNIT, then, is the focal entity of the Unit view.

The LC2IEDM contained many predefined views, but we mostly ignored them. The predefined views partition LC2IEDM entities into sets that focus on something narrower than a Concept, usually those attributes most relevant to a single entity. Typical is the ORGANISATION-ALS19s view, shown in Figure 6. It contains only ORGANISATION entity and its the supertypes and subtypes. Status, association, and type information are partitioned into separate views. The information in Figure 6 shows the rudimentary structure of an organization, but it omits aspects of the concept important to alignment assessment.

We therefore created our own views to perform alignment assessment. These views tended to be broader than the predefined LC2IEDM views. Indeed, they often include elements simply to help them align. As an example, Figure 7 shows the structure of the basic elements of the Unit view actually used in alignment assessment.⁴ Note that the view is named Unit, not Organization, which better reflects what is being assessed. And, the view does not contain POST or CONVOY, these entities being outside the scope of a unit.

In this study, we chose views that correspond to natural divisions of the battlefield objects as well as to the division of labor in the actual analysis, design, and implementation of the WARSIM software. Just as model designers and developers find it useful to organize their models into views or packages (in OO models), it is also useful to have alignment assessment results so organized. The main conceptual level views used are Unit, Equipment, Environment, and C4I, corresponding to areas of WARSIM software development.

4.4.1.3 Interpretation in the OO Model

In an OO model, a concept is a package. A package has a name and a description, and consists of a set of class names, plus the associations among the classes. Each class has a name and an informal (textual) definition. Analogous to the ER model, one class is typically a focal class. For example, the JSIMS FOM concept of a unit is a package that includes a class hierarchy: org, org.land, and org.land.unit. The org.land.unit class is the focal class of the package (see Figure 2 on p. 8).

Not all packages have a focal class. We identified a Terrain package containing TCDM features, but the TCDM has no single feature that connotes a terrain.

A package has associations between its classes: If two classes are part of the same concept, their designer probably considered the structural relationships between them. The JSIMS FOM uses three types of associations:

1. **Inheritance:** Any class can be a superclass of one or more classes. Each subclass

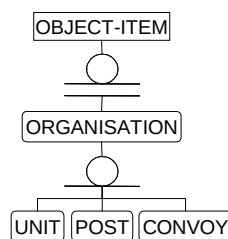


Figure 6. LC2IEDM ORGANISATION-ALS19s View

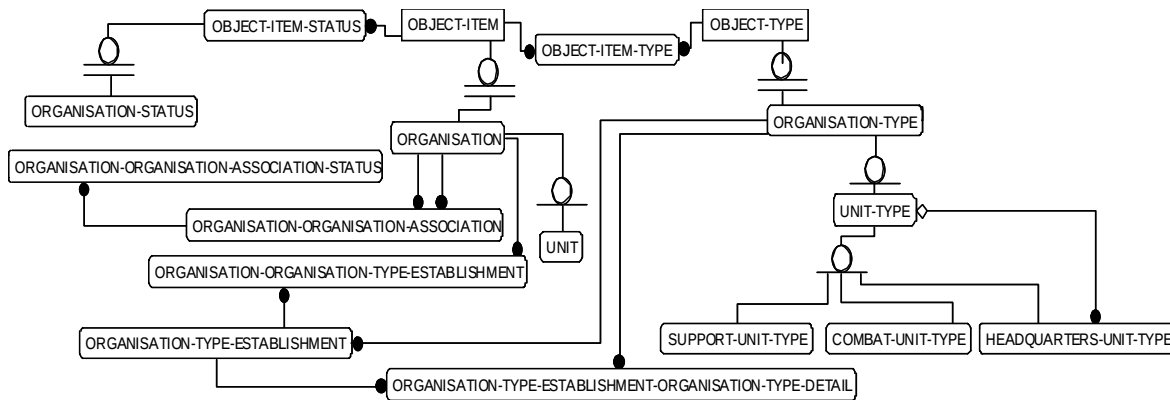


Figure 7. LC2IEDM Basic Unit View Used in Alignment Assessment

inherits all the attributes of its superclass.

2. **Aggregation:** An attribute's data type can be a *complex data type*. A complex data type is identical to a class, except that it can have aggregation relationships but not inheritance relationships.
3. **Federation Object:** Many JSIMS FOM attributes are of type id_c (the “_c” suffix is a naming convention that identifies a data type as a complex data type). This type holds an identifier that is recognized throughout a federation as identifying a JSIMS FOM object instance. A federation permits access to an object instance via this identifier.

Note that the first two associations are static, whereas the third is dynamic. The data type of the object instances represented by an `id_c` cannot be checked until a simulation is executing.

The transitive closure of these associations forms the content of a package defined as follows. If a JSIMS FOM class C is part of a package, then the package must also include the transitive closures of C 's superclass, if any; all complex data types associated with C and its superclasses; and classes referenced by federation object identifiers. (Transitive closure is not generally a good rule for forming a package, but it works in the JSIMS FOM where classes that should be in distinct packages are linked by federation object identifier, not by aggregation or inheritance.)

The JSIMS FOM has no predefined packages. The packages used in alignment assessment were created based on our perception of conceptual similarity.

The TCDM does not explicitly express inheritance among features. Relationships among features are expressed implicitly through coverage membership and military functional use, as discussed in Section 3 of [JSIMS 1999]. Certain features have a Complex Component Identifier attribute that relates features participating in aggregations.

4.4.1.4 Meaning of Alignment

An ER model and an OO model align with respect to a concept to the degree that both can model that concept. A OO concept is modeled as a package, and an ER concept as a

view. To say that the OO model and the ER model align fully with respect to a concept is to say that all of the following statements are true:

- There exist a package and a view that capture the same concept.
- The descriptions of the package and the view indicate that they model identical information.
- For each class in the package, there exists an ER entity (or set of entities) that models the same thing.
- For each entity in the view, there exists a class or complex data type (or set thereof) in the package that models the same thing.
- The associations in the package and the view relate information in identical ways. In other words, information stored in one model can be converted to the other model, then converted back with the original relationships preserved.

As an example, consider aligning the JSIMS FOM and the LC2IEDM with respect to the concept of a unit. A JSIMS FOM package modeling units (i.e., containing classes such as `org.land.unit`) would align with an LC2IEDM view consisting of entities such as `UNIT`. The `org.land.unit` class is the focal class of the Unit package, and `UNIT` is the focal class of the view;⁵ since they both model units, we consider the focal entities aligned. We would also want the JSIMS FOM package to include other classes and complex data types that seem directly related to modeling units (e.g., `org`, `org.land`). Similarly, we need to identify LC2IEDM entities that seem central to the concept of a unit (e.g., `ORGANISATION`, `OBJECT-ITEM`, `ORGANISATION-ORGANISATION-ASSOCIATION`). To determine alignment, we need to see if elements in each model have corresponding elements in the other model. We also need to ensure that these entities have correct relationships (e.g., the relationship between `ORGANISATION` via `ORGANISATION-ORGANISATION-ASSOCIATION` is many-to-many).

4.4.2 Entity Level

4.4.2.1 Definition of Level

At the Entity level, the focus is on the individual entities that make up a concept. Entity alignment resembles Conceptual alignment in that Entity-level elements (classes and entities) are also concepts. However, classes and entities are more narrowly focused concepts than packages and views. Another distinction of the Entity level is that programming and DBMS languages implement operations on Entity-level elements, but not on Conceptual-level elements. A system exhibiting C4I/M&S interoperability is likely to define structures based on Entity-level elements. A software designer may be particularly interested in the degree to which an Entity-level element aligns.

4.4.2.2 Interpretation in the ER Model

In an ER model, an entity (in the general sense of the word) is modeled as an ER entity. The ER entity has a name, suggesting what it models, a description, and a set of attribute names. The attribute names suggest characteristics of the ER entity.

⁵ This example is somewhat simplified. See Appendix B for a full discussion of the LC2IEDM view that is aligned with the Unit package.

4.4.2.3 Interpretation in the OO Model

In an OO model, an entity is modeled as a class or a complex data type. These elements have a name, a description, and a set of attribute names or, for a complex data type, field names.

4.4.2.4 Meaning of Alignment

The definition of alignment is almost the same as for the Conceptual level. An ER model and an OO model align with respect to an entity to the degree that both can model that entity. To say that an ER model and an OO model align fully with respect to an entity means that all of the following statements are true:

- There exist a class or complex data type and an (ER) entity that have the same interpretation. (It is permissible for an element in one model to align with a set of elements in the other.)
- For each attribute in the class (or field in the complex data type), there exists an attribute in the entity that models the same information.
- For each attribute in the entity, there exists an attribute in the class (or field in the complex data type) that models the same information.

If an OO model and an ER model align with respect to some concept, then each class in the concept should align to some set of entities and relationships in the concept, and vice versa. For example, the LC2IEDM UNIT entity aligns with JSIMS FOM `org.land.unit` class at the Entity level. See Figure 8. However, if UNIT were part of another LC2IEDM concept *L* that did not align to the JSIMS FOM Unit concept, then there would be no Entity-level alignment between UNIT and `org.land.unit` in the context of *L*.

The additional information an assessor uses in Entity-level alignment assessment (attribute names) may cause reconsideration of assumptions made during Conceptual-level alignment assessment. For example, the assessor might have inferred alignment based on similar descriptions of a class and an entity, but during Entity-level alignment assessment the assessor may find that a class has attributes the entity lacks, or vice-versa. This information helps the assessor be more precise in an assessment of individual Entity-level elements.

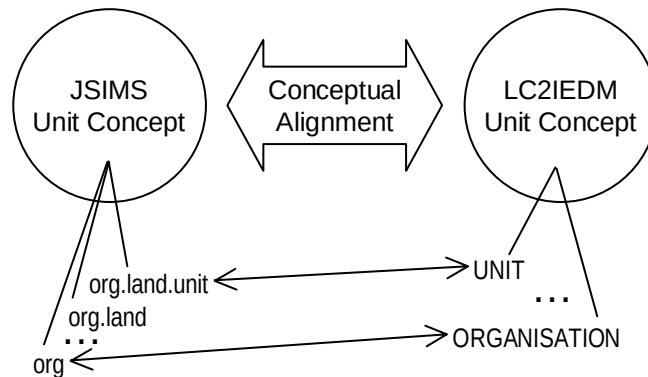


Figure 8. Relationship Between Alignment Levels

Both the LC2IEDM and the JSIMS FOM provide inheritance. A JSIMS FOM class may inherit attributes from a superclass. An LC2IEDM entity may have a supertype. Inheritance has implications for alignment. A JSIMS FOM class cannot be modeled in the LC2IEDM unless the attributes of its superclass can also be modeled; analogously, an LC2IEDM entity cannot be modeled in the JSIMS FOM unless the attributes of its supertype can be modeled. Therefore, an Entity-level element's degree of alignment is influenced by that of its super-element. Section 5 discusses the formula we use.

4.4.3 State Level

4.4.3.1 Definition of Level

The State level considers the properties of entities. State-level alignment means that the information contained in an attribute in one model can be represented by some combination of attributes in the other model.

4.4.3.2 Interpretation in the ER Model

In an ER model, state is modeled using:

- Organic attributes, i.e., attributes that are not migrated from another entity as a foreign key. UNIT-FORMAL-ABBREVIATED-NAME is an organic attribute in the LC2IEDM.
- Attributes from many-to-many relationships between entities that are characterized by uses of associative entities. These attributes fall into three categories:
 1. The foreign keys migrated from parent to child, which record the existence of a relationship between two instances of entities. In the LC2IEDM, the OBJECT-ITEM-TYPE entity, which captures the many-to-many relationship between OBJECT-ITEM and OBJECT-TYPE, includes attributes OBJECT-ITEM-ID and OBJECT-TYPE-ID.
 2. Additional attributes needed to make an associative entity's key unique. In the LC2IEDM, the OBJECT-ITEM-TYPE entity's key also includes OBJECT-ITEM-TYPE-INDEX.
 3. Other attributes of an associative entity, which capture additional information about the relationship. In the LC2IEDM, the ORGANIZATION-FACILITY EFFECTIVE BEGIN CALENDAR DATE-TIME attribute is an example.
- Attributes migrated from a supertype.
- Attributes from many-to-one relationships (e.g., the LC2IEDM attribute REPORTING-DATA-ID).

Attributes from many-to-many relationships often describe temporal properties. That a relationship exists between two entities implies a certain association during a specified period of time. Organic attributes are more often used to describe fundamental, unchanging properties of an individual entity.

The distinction between the categories of attributes from many-to-many relationships is significant because the first and second categories exist as modeling artifacts to implement relationship existence, not to model application data. For instance, an M&S application might want to retrieve the ORGANIZATION-ACTION-ASSOCIATION-EFFECTIVE-DATE at-

tribute's value, but it should not need attributes of ORGANIZATION-ACTION-ASSOCIATION in the first two categories (such as ORGANIZATION-ACTION-ASSOCIATION-INDEX, which exists only to ensure that each record in the ORGANIZATION-ACTION-ASSOCIATION table is unique).

4.4.3.3 Interpretation in the OO Model

In an object oriented model, state is queried or modified using methods. This is true of WARSIM; however, the JSIMS FOM has no methods. Instead, the JSIMS FOM represents the data that object methods can retrieve. Each datum is an attribute. Discussion is limited to this special case.

An attribute has a name, a description, and a data type. The JSIMS FOM uses two kinds of data types: atomic and complex. An atomic data type represents an indivisible datum, i.e., a datum that is not further decomposable through the modeling language. (All LC2IEDM attributes are atomic.)

The JSIMS FOM also offers complex data types. A complex data type is an aggregation of attributes. It is similar to the concept of a record in most high-level programming languages. The components of a complex data type, and the information associated with them, are identical to those of a class.

An attribute's data type may be atomic or a complex data type, but it may not be a class. This characteristic differentiates the JSIMS FOM from most object modeling technologies. However, federation object identifiers provide equivalent, albeit dynamic, modeling capability.

JSIMS FOM attributes also have cardinality. Cardinality specifies how many instances of the attribute are associated with an instance of the class; this information can affect alignment. Example cardinalities include:

- 1: Exactly one instance of the attribute is associated with each class instance.
- 0+: Zero or more instances of the attribute are associated with each class instance. The JSIMS FOM specification states that a 4-byte integer is used to store the number of instances; therefore, the upper bound on the possible number of instances is $2^{31} - 1$.
- 1+: One or more instances of the attribute are associated with each class instance.
- 3: Exactly three instances of the attribute are associated with each class instance.

Some attributes also have units (e.g., meters, kilograms). Units are important in determining whether conversions are necessary or possible in alignment. Conversions can result in loss of precision and therefore can potentially lower degree of alignment (although consideration of this issue occurs during Value-level, not State-level, alignment analysis).

4.4.3.4 Meaning of Alignment

Full alignment at the State level means that any state expressible in one model must be expressible in the other model. An OO model and an ER model align to the degree that an attribute's value can be stored in, and recovered, from the other model.

Usually an atomic attribute in one model aligns to exactly one atomic attribute in the other model. For example, the name attribute of JSIMS FOM class org and the OBJECT-ITEM-NAME attribute of LC2IEDM entity OBJECT-ITEM align.

Sometimes an atomic attribute in one model aligns to several attributes in the other model. This can occur:

- *For an attribute in a complex data type that is used by multiple classes.* Consider the speed attribute of the JSIMS FOM complex data type ground_linear_c. As Figure 9 shows, it does not directly express the speed of a FOM object, but rather expresses that object's speed during a given movement segment. Furthermore, speed can express the segment speed of both an organization (if it is derived from the move_data attribute of class org) or a platform (if it is derived from the platform_move_data attribute of class org.land.unit). In other words, speed can apply to an organization, which is modeled in the LC2IEDM as an instance of ORGANISATION, or it can apply to a platform, which is modeled in the LC2IEDM as an instance of MATERIEL. The LC2IEDM models organization speed using the ORGANISATION-POINT-SPEED-RATE attribute; it models materiel speed using the MATERIEL-POINT-SPEED-RATE attribute. The speed attribute therefore aligns to both LC2IEDM attributes. Of course, if JSIMS FOM data were converted to an LC2IEDM representation, only one of the LC2IEDM attributes would model a given speed.
- *For an attribute whose data type is an enumeration.* Sometimes the enumerated values are split across multiple attributes in the other model. For example, the JSIMS FOM platform_type attribute, of type platform_type_e, aligns to three LC2IEDM attributes: COMBAT-UNIT-TYPE-ARM-CODE, MATERIEL-TYPE-CATEGORY-CODE, and OBJECT-TYPE-CATEGORY-CODE. The reason is that the union of the three LC2IEDM attributes' domains is necessary to cover the values in platform_type_e.

A JSIMS FOM attribute whose data type is a complex data type almost always aligns to multiple LC2IEDM attributes. In fact, because a complex data type is really an entity—it models some physical or virtual object—the attribute's degree of alignment is defined in

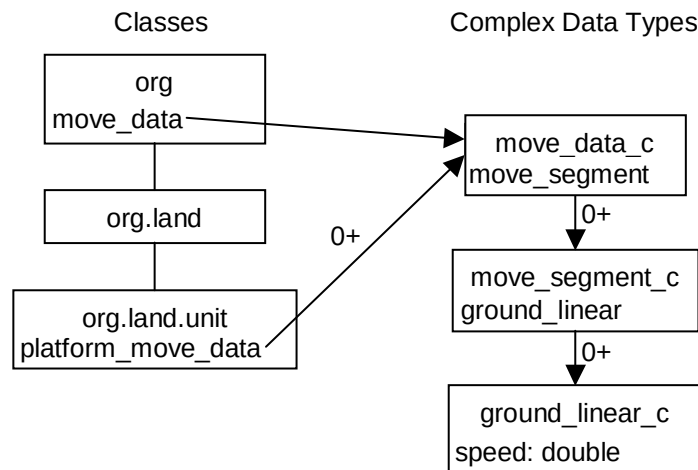


Figure 9. JSIMS FOM Class/Type Structure for Speed

terms of the Entity-level degree of alignment of the complex data type.

As Entity-level alignment is defined with respect to Conceptual-level alignment, so State-level alignment is defined with respect to Entity Level alignment. Attribute A_j of class C and attribute A_i of entity E can only be aligned at the State level if C and E are aligned at the Entity level (more exactly, if E is among the set of entities that are aligned with C).

Some ER attributes align structurally. Their values are expressed by associations, rather than attributes, in the OO model. Structural alignment is characteristic of migrated attributes. For example, the UNIT-ID attribute is migrated from the ORGANISATION entity. Any instance of unit therefore records the information described by the attributes of ORGANISATION. In the JSIMS FOM, this is handled by the fact that class `org.land.unit` is a subclass of `org.land`, which is a subclass of `org`.

4.4.4 Value Level

4.4.4.1 Definition of Level

The Value level considers the overlap of domains. The key issue is the degree to which values from a data type in one model can be mapped to another model. They may map partially, fully, or not at all.

The values in each domain need not be identical. The echelon codes in the JSIMS FOM include Army and Battalion; in the LC2IEDM they include AR and BA. We consider these codes equivalent for the purposes of data/object model alignment because it is possible to define an unambiguous mapping between them.

Permitting alignment via a mapping rather than demanding strict equivalence was a controversial decision. Strict equivalence is preferable; each mapping implies a software development effort must be undertaken. Each such effort introduces possibilities for implementation errors. However:

- Value-level degree of alignment measures domain overlap, and a mapping accounts for overlap.
- Penalizing degree of alignment based on differences in values is difficult; the formulas we proposed seemed to say something about effort, which degree of alignment does not measure.
- Even if two domains have the same set of literals, there is no guarantee that the literals have the same meaning; e.g., two domains modeling terrain might both include “creek” but intend different semantics. Therefore, strict equivalence is not a guarantee of interoperability. There is always some need for human judgment.
- The possibility of implementing a mapping means there is no need to change either of the models to achieve data/object model alignment.

The implication is that degree of alignment measures the potential for alignment rather than the fact. Achieving data/object model alignment to the measured degree may require implementing translation engines.

4.4.4.2 Interpretation in the ER Model

Each ER attribute has a domain. This domain's overlap with a corresponding OO data type is of interest in data/object model alignment. Table 2 lists the types of domains used in the LC2IEDM.

Table 2. LC2IEDM Atomic Domains

Type	Description
NUMBER(n)	An integer of n decimal digits.
NUMBER(15)	An integer of 15 digits. This domain is used throughout the LC2IEDM to record entity identifiers, such as OBJECT-ITEM-ID and REPORTING-DATA-ID.
NUMBER(m,n)	A floating-point value of m decimal digits with precision n .
CHAR(6)	A string of exactly 6 characters. This domain is used to represent values in enumerated domains. In the LC2IEDM, any attribute whose name ends with -CODE (e.g., FACILITY-CATEGORY-CODE) has an enumerated domain.
VARCHAR(n)	A string of up to n characters. This domain is typically used to record descriptive text, either in phrases (where n is fairly small) or large text blocks (where n may be as large as 2000).

4.4.4.3 Interpretation in the OO Model

Each OO attribute (or JSIMS FOM field, or TCDM EAC), has a data type. This data type, which is always atomic, is of interest in data/object model alignment. Table 3 lists the atomic data types used in the JSIMS FOM. Table 4 lists the atomic data types used in the TCDM.

Table 3. JSIMS FOM Atomic Data Types

Type	Description
boolean	A 4-byte integer. An instance of the type may have a value of either 0 or 1, corresponding to the logical values false and true.
char	Not really a domain, but instead indicates a placeholder for future capabilities.
double	An 8-byte IEEE double-precision floating-point number. Its range is $\pm 2^{1023}$, and it has about 17 significant decimal digits.
float	A 4-byte IEEE single-precision floating-point number. Its range is $\pm 2^{127}$, and it has about 7 significant decimal digits.
long	A 4-byte integer in two's complement notation, meaning it can represent values from -2^{31} to $2^{31} - 1$.
octet	A placeholder for buffer data when shuttling values around a FOM in the HLA.
string	A string of up to $2^{31} - 1$ characters (although the length of an instance is fixed).
unsigned long	A 4-byte integer, values of which can range from 0 to $2^{32} - 1$.

Table 4. TCDM Atomic Types

Type	Description
ENUM	An enumerated type, with a list of literals.
FLOAT32	Equivalent to the JSIMS FOM float type.
FLOAT64	Equivalent to the JSIMS FOM double type.
INT16	A two-byte integer in two's complement notation, meaning it can represent values from -2^{15} to $2^{15} - 1$.
INT32	Equivalent to the JSIMS FOM long type.
INT8	A one-byte integer in two's complement notation, meaning it can represent values from -2^7 to $2^7 - 1$.
LEX_STRING	Equivalent to the JSIMS FOM string type.
STRING	Equivalent to the JSIMS FOM string type; differs from LEX_STRING in implementation characteristics that are not relevant here.
UINT16	An unsigned two-byte integer, meaning it can represent values from 0 to $2^{16} - 1$.
UINT32	An unsigned four-byte integer, meaning it can represent values from 0 to $2^{32} - 1$.
UINT8	An unsigned one-byte integer, meaning it can represent values from 0 to $2^8 - 1$.

4.4.4.4 Meaning of Alignment

In theory, full alignment between two domains requires both to have exactly the same data type and domain. It must be possible to represent exactly the same values, to the same degree of precision. If one model represents distances precise to millimeters, then so must the other model—no more and no less.

In practice, it is not necessary to be so stringent. One model might not need all the precision of which the other is capable. Assessors can make assumptions about what a simulation or C2 organization might reasonably model, and these assumptions often translate into relaxed exactness requirements. For example:

- The JSIMS FOM represents coordinates using type double, whereas the LC2IEDM represents them using a NUMBER with various magnitudes (NUMBER(9,6) for latitudes; NUMBER(10,6) for longitudes; NUMBER(12,3) for elevations). A double models both greater magnitude and greater precision than the LC2IEDM domains. However, the LC2IEDM represents coordinates in degrees. A latitude is bounded by ± 90 ; a longitude by ± 180 ; and, until wars use technology located twice as far as the moon, NUMBER(12,3) will suffice for elevations. Also, the LC2IEDM can represent position to within 11 cm. This is precise enough for simulations.
- The JSIMS FOM represents object identifiers using a string, whereas the LC2IEDM represents them using NUMBER(15). A string contains up to $2^{31} - 1$ characters, obviously a larger domain than a 15-digit integer can model. But the likelihood of a simulation or C2 system modeling even 10^{15} unique objects is small.

Two domains are considered fully aligned if an assessor can define a 1:1 mapping between them. They do not have to contain the same elements. For example:

- A JSIMS FOM or TCDM enumerated type can align to an LC2IEDM enumerated domain, even though they contain different literals. An example is the alignment between the TCDM EAC Mine Type Category, whose domain is an enumeration of twelve values, and the LC2IEDM’s MINEFIELD-PURPOSE-CODE attribute, whose domain is an enumeration of seven values. Only two of the twelve Mine Type Category values map to LC2IEDM values, as shown in Table 5. That TCDM and the LC2IEDM do not use the same literals is acceptable for the purposes of alignment.
- A JSIMS FOM coordinate, which is expressed in one of four models—round-earth, earth-centered inertial, earth-centered rotational, or WGS-84 ellipsoidal—can align to an LC2IEDM coordinate, which is always expressed using the WGS-84 ellipsoidal model.
- An enumerated domain can align to a string domain. For example, the JSIMS FOM attribute move_type, whose domain is an enumeration of six values (such as ground_linear and great_circle) aligns to the LC2IEDM attribute ACTION-NAME, whose domain is a 50-character string. One strategy for implementing this alignment is to map the literal values from the TCDM data type to their string representation, storing those representations in ACTION-NAME.

Table 5. Example of Mapping Enumeration Literals

TCDM Value	LC2IEDM Value
Unknown	NKN
Phony / Decoy	PHONEY

Degree of alignment is a function of the percentage of values that overlap. Consider an LC2IEDM domain L and JSIMS FOM domain J . The following situations are possible:

- L and J can map 1:1, in which case the degree of alignment is 100%.
- L can be a proper subset of J , or vice-versa.
- L and J can have a non-empty intersection and a non-empty disjunction.
- L and J can be disjoint, in which case the degree of alignment is 0%.

The general rule is that the degree of alignment of L and J is $|L \cap J|/|L \cup J|$, the cardinality of the intersection of the two domains divided by the cardinality of the union. Degree of alignment is a value between 0 and 1, with 1 being perfect alignment and 0 being no alignment.

Assessors may wish to adapt this rule based on domain-specific knowledge. For example, frequency analysis may reveal that certain values in one model are more likely to occur and hence are more important, in the sense that interoperability would suffer if these values could not be expressed in the other model. The formula for calculating degree of alignment could be tailored based on such knowledge. As another example, the JSIMS FOM and the LC2IEDM both contain enumerated domains with values such as “unknown” and “not otherwise specified”, and sometimes these values are the only ones in a domain that align. In a situation where unknown data equates to failure, it would be appropriate to remove “unknown” from consideration in Value-level alignment analysis.

Appendix E gives the rules for computing the degree of alignment between a JSIMS FOM domain and an LC2IEDM domain, based on the type of domains being aligned. The rules in the appendix systematize the computation of degree of alignment, removing assessor bias, opinion, and interpretation. Therefore, the computed values at higher alignment levels also have unambiguous semantics.

4.5 Summary of Differences from the AICDM/OMSC Study

Data/object model alignment is a new field of study. It may be helpful to explicitly state how its definition has evolved since the AICDM/OMSC study [IDA 2001].

4.5.1 Inheritance

Inheritance is an important feature in OO modeling. The OMSC makes minimal use of inheritance in its standard objects, instead anticipating that M&S developers will create subclasses that inherit from predefined OMSC classes. The JSIMS FOM and the TCDM have extensive inheritance in their class hierarchies, so the LC2IEDM/WARSIM assessment was IDA's first opportunity to study how inheritance affects data/object model alignment.

Inheritance requires extra study from assessors. Section 4.4.3 discussed how assessors must consider all State-level assessments derived from an Entity-level element in order to avoid using an attribute for multiple purposes. Inheritance adds an extra dimension to this consideration. Assessors performing State-level assessments must consider not only the Entity-level element containing the attribute but its ancestor classes (JSIMS FOM) or entities (LC2IEDM).

Inheritance affects degree of alignment. An instance of an Entity-level element implies the existence of instances of its ancestors. In other words, if the ancestors do not align fully, the element itself won't align fully either.

4.5.2 Value-Level Alignment Assessments

IDA developed the principles for Value-level assessments as part of the original model of data/object model alignment. The OMSC seldom has enough detail to make Value-level assessments feasible. The LC2IEDM/WARSIM assessment was our first chance to gain extensive experience with Value-level assessments.

Value-level assessment is supposed to entail rigorous analysis and yield repeatable results. IDA decided to create a set of rules for describing the alignment between two domains. These rules are listed in Appendix E. The degree to which these rules are general-purpose or study-specific remains to be seen.

4.5.3 Aligning Complex Data Types

The original definition of alignment recognized that the focus of a State-level assessment may involve elements from higher levels. The OMSC does not specifically state the parameters or return types of methods, but it was apparent that some methods would use or

return abstractions. The AICDM/OMSC study handled this by assuming that the alignment of a method related to the alignment of the concepts it referenced.

The JSIMS FOM, being a concrete model, provided us opportunities to work with State-level elements (attributes) that were composites. Our assumption that a composite element should relate to a concept turned out to be unworkable. The composite element has a relation not to a Conceptual-level assessment but to an Entity-level assessment.

4.5.4 Entity-Level Assessment Adjustments

The previous definition of alignment at the entity level [IDA 2001] provided a method of calculating the alignment of a model with an entity based solely on the values of the alignments with the entity's attributes. However, in this study, many WARSIM classes were discovered to align well at the attribute level although the semantics of the class itself was not precisely discriminated by the LC2IEDM model. This situation indicated a need to adjust the calculated or "rolled-up" assessment of a class (or entity) by some factor to include the alignment of the semantics of the class/entity itself in addition to the alignment of its attributes.

One general type of this sort of problem occurs when a particular WARSIM class does not have an exact counterpart in the LC2IEDM, although a more general entity (or super-type) may accommodate the data involved. Many examples of this type were found when assessing the TCDM terrain classes (e.g., Amusement Park) used by WARSIM. Many such classes in the TCDM could be mapped into either the FEATURE or FACILITY entities of the LC2IEDM, and their types could be recorded in the OBJECT-TYPE-NAME attribute. But, there is no standard code or entity in the LC2IEDM that is specific to these problem classes. Hence, the LC2IEDM itself provides no standard means of representing such classes, and different systems could map the same type of feature or facility into different object names. Thus, in such cases, the definition of data/object model alignment is qualified so that a lower degree of Entity-level alignment can be assigned, reflecting the absence of a standard means of representing a class.

4.5.4.1 Generic Model Mapping Examples

To motivate this qualification of our definition of data/object model alignment, it may be

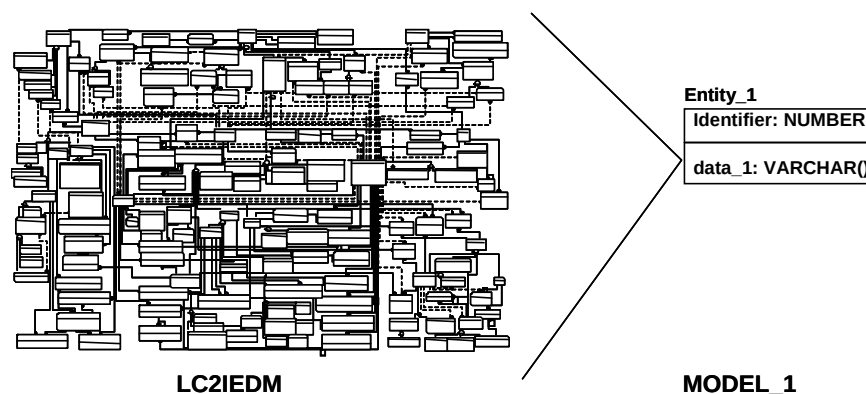


Figure 10. Mapping the LC2IEDM to a Very Simple Model

instructive to consider some very “high-level” models that are capable of representing practically anything. Perhaps the simplest such relational model (call it MODEL_1) is one with a single entity (call it ENTITY_1) and a single data attribute (call it data_1). If data_1 is a variable length character string of sufficiently great length, it could accommodate all of the data of any database model such as the LC2IEDM as illustrated in Figure 10.⁶ Any such data could be added, updated, and deleted (albeit with some difficulty) provided that suitable formatting conventions and translation rules were formulated to specify where different data elements from the other model could be found in this monstrous data string.⁷ While any data model whatsoever could be mapped into this simple model, we would not consider this model well-aligned with any real-world data model of any complexity.

Another example of a simple generic model which could accommodate virtually any other data model is illustrated in Figure 11. This model includes separate entities for objects, their attributes and relations, although it is not specific about any particular kinds of such data elements.

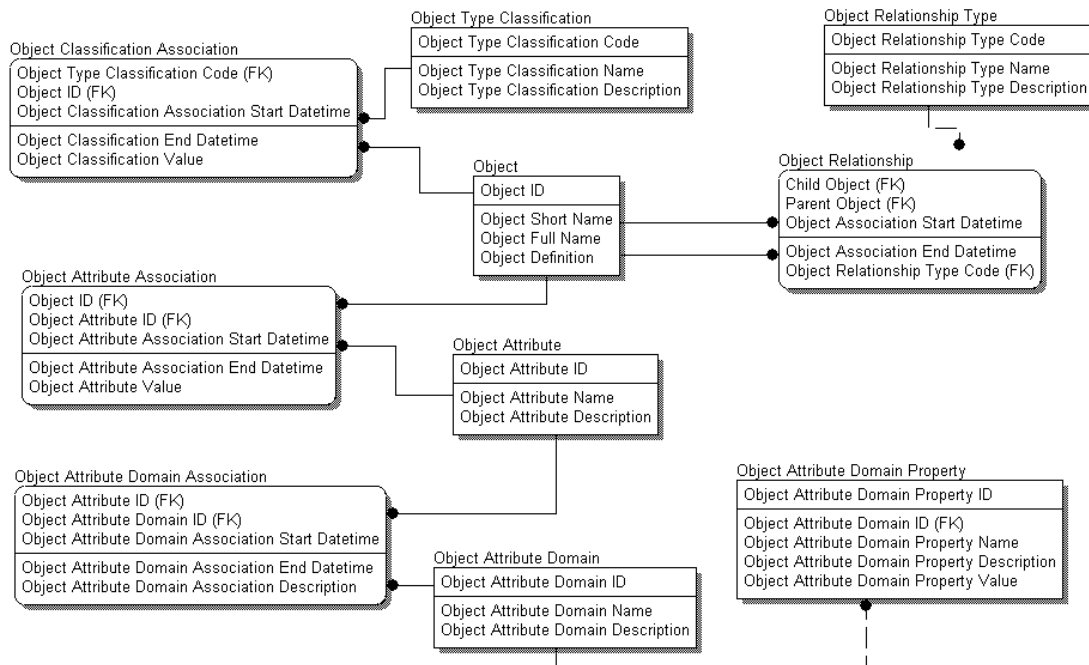


Figure 11. A more structured general model (in IDEF1X)

Part of the reason that generic models like those just illustrated cannot be considered well-aligned with more complex models is that they provide no *standard* means of representing specific data elements such as may be found in ordinary models. There are no entities or attributes which distinguish any specific type of data. In particular, there is no standard means of distinguishing entities such as the five battlefield entities of the

⁶ The illustration of the LC2IEDM in this figure is a greatly reduced copy of the main view of all LC2IEDM classes where each tiny box represents an entity and the lines between them are relations.

⁷ For example, an XML representation of the LC2IEDM model could be used as the value of the data_1 attribute.

LC2IEDM – FACILITY, FEATURE, MATERIEL, ORGANISATION, and PERSON – much less their many attributes and relations. Translation rules may be defined to map other models into such generic models, but those rules are not part of the generic models themselves.

4.5.4.2 Definitions and Principles for Non-Standard Mappings

To clarify our intuitions here, we define the key concept as follows:

A model M has a *standard* means of representing a data element E from model M' if and only if M has a representation R (composed only of its predefined entities/classes, attributes, coded values, and/or relationships/associations) which explicitly captures just (all and only) the same type of information as E .

When a model has no standard means of representing a data element, different users are free to represent its data in different ways. While this can be acceptable if one's only concern is accommodating data, it does not facilitate exchange of data amongst systems. Having different systems placing data into a database using different encoding schemes does not promote data interoperability. In such cases, the data model itself provides no guidance on where to find particular types of data, as such encoding schemes are not part of the model. Since the purpose of our definition of data/object model alignment is to provide a measure of data interoperability of models, models with no standard means of representing certain types of data cannot be considered well aligned with the elements that distinguish that type of data in other models.

The general principle we abstract from this and other examples like it is this:

If a data element E from a model M has no standard representations in a model M^1 , then M^1 has a lower degree of alignment with element E from M , other things being equal, than a model M^2 which does have a standard representation defined for element E .

This principle, which may be more obvious in the extreme case of MODEL_1 (compared to WARSIM) applies equally in less extreme comparisons. Actual examples where this principle applies abound in the data/object model alignment between WARSIM and the LC2IEDM. We have already noted that the Environment area of WARSIM contains many classes (e.g., Amusement Park) from the TCDM that lack a standard representation in the LC2IEDM. Such terrain classes may be distinguished by inserting a name for them in the OBJECT-TYPE-NAME field of the LC2IEDM OBJECT-TYPE entity, but there is no standard way to identify them, so different sources might use different names to represent the same environmental feature or the same name for different features. Since the LC2IEDM itself provides no standard for distinguishing such classes, it is less well aligned with these classes than other environmental classes (e.g., “Built up area”) which have an explicit code (e.g., BUA) in the LC2IEDM to distinguish them.

Although nonstandard representations align less well than standard representations, they do provide a means to represent data, and deserve some lesser degree of alignment. A model that can somehow represent data is at least capable of allowing interoperation (our ultimate interest), whereas one that cannot capture the data of interest does not even allow exchange of that data.

The general principles just explained provide some guidance on assessing the alignment of data elements with no standard representations, but do not prescribe a method for computing such alignment values. To motivate our approach to computing alignment assessment values in such cases, it should help to examine additional cases. Consider the TCDM classes Anchorage and Pier/Wharf/Quay, each of which maps to the FACILITY entity with the associated FACILITY-TYPE-CATEGORY-CODE = HARBUR, which is displayed as “Harbour” (see Figure 12). The problem with this alignment, of course, is that the LC2IEDM model itself provides no standard means of distinguishing an anchorage from a pier/wharf/quay. But, compare this to the situation for the TCDM class Amusement Park. There is no code in the LC2IEDM that is even close to representing this environmental entity, so the best that can be done is to use the FACILITY-TYPE-CATEGORY-CODE = NOS for “not otherwise specified”. However, 22 classes from the TCDM are in a similar situation and map to FACILITY-TYPE = NOS. Thus, this LC2IEDM representation is much less discriminating than that for Anchorage. An anchorage from WARSIM is identified more specifically as a harbour, while an amusement park can only be specified as one of 22 unspecified types of facilities in the LC2IEDM. Hence, the LC2IEDM provides a closer approximation for an anchorage than for an amusement park. It is appropriate to assign a lower degree of alignment to the LC2IEDM’s alignment with Amusement Park than that for Anchorage (other things being equal).

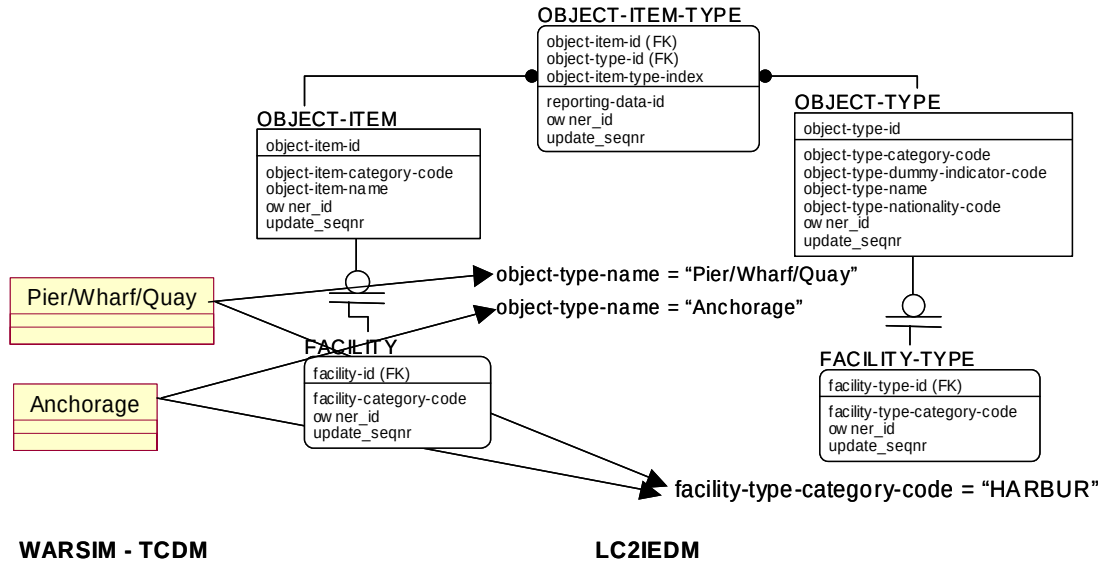


Figure 12. Non-standard Mappings from the TCDM to the LC2IEDM

This example, and others like it, suggest an additional guideline for computing degrees of alignment of non-standard mappings:

If two data elements E_1 and E_2 from a model M have no standard representations in a model M' , but E_1 has a more *specific* mapping to M' than E_2 does, then the degree of alignment of E_1 is greater than that of E_2 , other things being equal.

The concept of specificity used here is an abstraction of the situation in the example wherein the LC2IEDM has a more specific representation (HARBUR) for a WARSIM anchorage than its representation (NOS) for an amusement park. There are different ways such a concept of specificity might be defined. We have elected to use a definition that

allows a complete ordering of specificity relative to any two models whose alignment is being assessed. This is:

A mapping from a data element E_1 in model M to a model M' is *more specific* than a non-standard mapping of E_2 from M to M' if there is a smaller number (m) of data elements from M_1 that map into the same standard parts of a representation (R_1) of E_1 in M' than the number (n) that map from E_2 into a standard representation (R_2) in M' .

This is illustrated in Figure 13 where the elements E_1 and E_2 in model M may be any entity/class, attribute, coded value, or relationship, while the representations R_1 and R_2 in model M' are those entities/classes attributes, relations and coded values of M' that are required to represent E_1 and E_2 , respectively. Elements E_{11} to E_{1m} in the figure illustrate all the other elements in model M which map into the same representation, R_1 , as does E_1 , while elements E_{21} to E_{2n} illustrate those elements which map into R_2 . Naturally, m could be zero, while n must always be greater than zero when the E_1 mapping is more specific than that of E_2 .

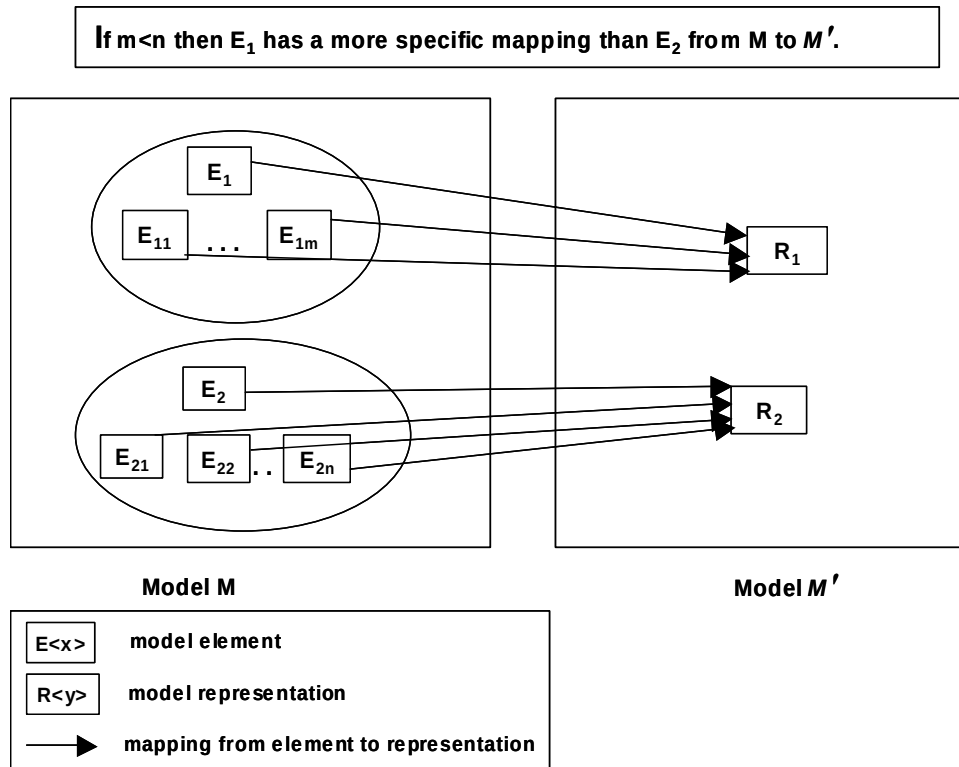


Figure 13. Definition of More Specific Mapping Between Models

Since only two TCDM classes have the same mapping to standard LC2IEDM elements representing an anchorage, the anchorage class in the TCDM has a more specific mapping to the LC2IEDM than does the amusement park class, whose standard representation cannot distinguish twenty-two different TCDM classes. While any of these entities may be discriminated in the LC2IEDM by assigning a distinctive name in the OBJECT-TYPE-NAME attribute (as in Figure 12), such specific names could be composed in any manner and are not standard parts of the LC2IEDM.

4.5.4.3 Calculating Alignment Values for Non-standard Mappings

The principles derived from our examples provide a basis for ordering non-standard alignments but still under-constrain the possible assignment of specific degrees of alignment. While it is clear that a standard alignment should have a higher degree of alignment than a non-standard one, and that a more specific alignment should have a higher degree of alignment than a less specific one (*ceteris paribus*), many options are open as to how to assign actual degrees of alignment. The approach we have taken assigns a certain amount of credit for the minimal capability of having some means of accommodating a data element. That is, credit is given for having a distinguishable means of representing data even if it is non-standard to the model. But, any choice of how much credit to assign for this minimal capability is bound to be somewhat arbitrary. For our assessments, we assign 50% of the credit for this minimal degree of alignment.

The rest of the credit for alignment we determine on a linear scale based on the specificity of the mapping. If there is a one-to-one mapping from one model to another, then data can be moved from one model to the other and back with no loss of information, just using the definitions of the two models. Hence, we give the full balance of 50%, yielding a total of 100% alignment when there is a one-to-one mapping from an entity in one model to a standard representation in the other that covers it. But when multiple data elements map into the same representation, we divide the balance of 50% by the number of such duplicate elements. Thus, the assessment of a non-standard mapping from a class (as distinguished by its definition) in the WARSIM models to the LC2IEDM is calculated by the formula:

$$\text{Credit} = (50\% + (50\% \div (\text{number of indistinguishable classes})))$$

Applying this to the Anchorage class, we get a credit of $(50\% + (50\% \div 2)) = 75\%$, while the Amusement Park class gets a credit of $(50\% + (50\% \div 22)) = 52\%$. This credit is referred to as an adjustment factor in the entity level assessment window found in the accompanying alignment database.

But this is just one part of full assessment of a class' degree of alignment. The alignment of a class or entity also depends upon its attributes (both immediate and inherited)—hence the need for the *ceteris paribus* conditions cited in the assessment principles above. So, for the full entity-level assessment of a class, we use this credit from the class definition mapping as a multiplicative factor to adjust the assessment based on the average assessed values of all of the class' attributes, yielding the equation:

$$\text{Assessment}(\text{Class}) = \text{Credit} \times (\text{average of attribute assessments})$$

This enables the assessment of a class alignment to reflect the extent to which that class is clearly distinguished in the aligned model, as well as the extent to which its attributes are modeled. This formulation is somewhat arbitrary, although it is designed to uniformly reduce the credit for having attributes aligned in proportion to how well a model can distinguish what they are attributes of.

4.5.5 Structural Alignment

If an ER model and an OO model exhibit State-level alignment by virtue of a structural element—relationships between entities in the ER model, and subclass relationships in the OO model—there is *structural alignment*. Structural alignment means that one of the models has an attribute that aligns at the State level through elements other than attributes of the other model. Typically, an assessor identifies the need for structural alignment when performing State-level alignment analysis, then sorts out the details during Value-level alignment analysis.

Consider the problem of determining the JSIMS FOM elements that are aligned with the LC2IEDM attribute EQUIPMENT-TYPE-CATEGORY-CODE. This attribute breaks down equipment types into 31 categories such as “Aircraft, fixed wing” and “Electronics, C3I”. Any LC2IEDM representation of a materiel item may have an associated instance of EQUIPMENT-TYPE, and the value of EQUIPMENT-TYPE-CATEGORY-CODE helps describe that item.

Like the LC2IEDM, the JSIMS FOM class structure models both instances and types. Types are modeled as subclasses of class abstract. That class is an abstract class, i.e., only its subclasses can be instantiated. Therefore, any alignment of the EQUIPMENT-TYPE entity must be to a subclass of abstract. The specific subclass will be determined by the value of EQUIPMENT-TYPE-CATEGORY-CODE. In other words, EQUIPMENT-TYPE-CATEGORY-CODE aligns structurally.

There is no structural alignment of the LC2IEDM with respect to a JSIMS FOM attribute. This is a modeling decision. Structural alignment between a JSIMS FOM attribute and the LC2IEDM would occur when a JSIMS FOM attribute aligns with respect to a relationship between two LC2IEDM entities. This situation occurs frequently. However, the LC2IEDM tables representing entities include foreign keys, i.e., attributes that implement the relationships. We found it more convenient to align JSIMS FOM attributes to these foreign keys than to relationships.

5. Process of Alignment

Section 4 defines alignment between an ER model and an OO model. To use this definition involves following a process for alignment assessment. The process provides:

- *Guidance on where to begin.* The LC2IEDM and the JSIMS FOM contain hundreds of elements. The process helps assessors choose a starting point.
- *Rules for completeness.* Assessors need to know whether an element is considered fully assessed, and if not, what work remains to be done.
- *Methods for assessing alignment.* Insofar as is possible, subjectivity and ambiguity should be absent from an alignment assessment. Thus, when assessing the alignment of two given sets of elements, it is helpful for assessors to have a set of methods to follow.
- *Rules for using the results of alignment assessment.* Alignment assessment aims to identify changes to each model that would improve alignment. The assigned degrees of alignment can help identify such changes, but the results of Value-level analysis are very low-level and do not suggest strategies for improvement.
- *Guidance on documenting results.* The work products yielded by each process step leave a trail that makes alignment assessment understandable and repeatable.

This section presents a process for alignment assessment, specifically that used in the LC2IEDM/JSIMS FOM study. It covers the process steps and the methods used in each step.

5.1 An Overview of the Alignment Assessment Process

The process is based on top-down analysis, proceeding through the four alignment levels. Figure 14 shows an overview. The process can be summarized as follows. The assessors divide each model into Concepts and analyze each Concept for alignment. This analysis entails:

- Identifying Concepts from each model that appear to align, i.e., model the same information.
- Assigning a degree of alignment between the identified Concepts.
- “Drilling down” to Entity-level analysis on each component of the Concepts.

Similarly, Entity-level analysis entails identifying Entity-level elements from each model that appear to align, assigning a degree of alignment between identified elements, then drilling down to State-level analysis for each attribute of the element. State-level analysis consists of identifying attributes from each model that appear to align, assigning a degree of alignment between identified attributes, then drilling down to Value-level analysis for an attribute’s domain. Value-level analysis consists only of identifying domains and assigning a degree of alignment; it is the lowest level, so there is no drilling down.

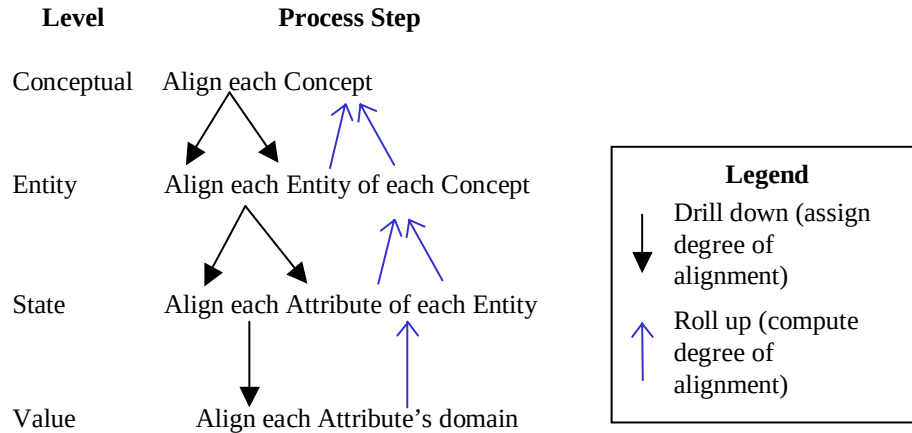


Figure 14. High-Level Depiction of Alignment Assessment Process

The results of Value-level analysis are “rolled up” to provide the State-level computed degree of alignment. The State-level computed degrees of alignment are rolled up to give the Entity-level computed degree of alignment. The Entity-level computed degrees of alignment are rolled up to give the Conceptual-level computed degree of alignment.

Note the use of the phrase “appear to align” rather than “align” in all levels except the Value level. By the definition of alignment in Section 4, these levels concentrate on information that has certain abstract characteristics. In other words, it is not possible to determine alignment with absolute certainty at these levels; the necessary information is found only at the Value level. The top three levels serve as information gathering steps to set the context for Value-level degree of alignment analysis.

In our experience, most interesting alignment assessment results occur during State- and Value-level alignment analysis. This fact should not be taken to mean that Conceptual- and Entity-level alignment assessment can be neglected. The two steps help assessors gather and classify the information needed to interpret their results.

The assessors assign a degree of alignment at each level. At the Value level, the degree of alignment is a quantitative statement of alignment. At other levels, it is a judgment. It provides some guidance as to where a particular assessment is heading. However, the computed degree of alignment can differ (sometimes greatly) from the assigned degree of alignment. Such situations typically reflect studies between the time the degree of alignment was assigned and when it was computed.

There is another reason to assign a degree of alignment at levels other than the Value level. Sometimes an assessor cannot, or need not, drill down. This can happen if:

- *There is no alignment*, i.e., an attribute in one model has no counterpart in the other model. In this case the assessor will assign a 0% the degree of alignment.
- *There is some ambiguity that makes drilling down impossible*. This typically occurs when a model is incomplete or improperly defined. The assessor usually attempts to guess what the model should contain and assigns a degree of alignment accordingly. However, the assessor should not drill down further.

- *An attribute is not modeled but has an invariant value in the context of the assessment.* Consider the ORGANISATION-CATEGORY-CODE attribute of LC2IEDM entity ORGANISATION. This attribute has five possible values: UN (unit), PO (post), CO (convoy), NKN (not known), and NOS (not otherwise specified). An attribute is always assessed in context of a concept, meaning its alignment is being assessed with regard to modeling that concept. Now consider when the JSIMS FOM and the LC2IEDM are being aligned with respect to the Unit concept. In an LC2IEDM model of a unit, ORGANISATION-CATEGORY-CODE will always be UN. Therefore, ORGANISATION-CATEGORY-CODE does not impede alignment, even though the JSIMS FOM has no attribute that models the value.

That an attribute has an invariant value in context is discovered during State-level alignment assessment. The assessor assigns a degree of alignment of 100%.

- *An attribute aligns structurally.* In a relational model, foreign keys define relationships between records. In an object model, some of these relationships are captured using inheritance and composition. Some LC2IEDM foreign keys have no equivalent attribute in the JSIMS FOM, but still align in the sense that the JSIMS FOM provides an inheritance or composition relationship that achieves the same end.

That an attribute aligns structurally is discovered during State-level alignment assessment. The degree of alignment depends upon whether the structures in question fully model the structure conveyed by the attribute.

In these cases, the assigned degree of alignment is used as the computed degree of alignment for the assessment.

5.2 The Process as a Template

The beginning of Section 5 mentioned that the process being described is the one used in the LC2IEDM/WARSIM alignment assessment. That sentence deserves further explanation. The process described below is similar, but not identical to, the one used in the AICDM/OMSC alignment assessment. It differs because:

- *The OMSC is not a complete model.* In the AICDM/OMSC study, we were seldom able to perform Value-level alignment analyses; we usually had to stop with State-level analyses. In the LC2IEDM/WARSIM study, we almost always drilled down to the Value level.
- *The OMSC and the JSIMS FOM use different object models.* As a result, we employed different methods to assess the alignment of OMSC elements to AICDM elements than we used to assess the alignment of JSIMS FOM elements to LC2IEDM elements.

In fact, we expect that every alignment assessment will differ from its predecessors. Assessors will follow a different process each time, based on factors such as those noted above.

We therefore think of Figure 14 (above) as a process template. We expect one of the preliminary steps of any alignment assessment will be to tailor this template according to the

features of the models being assessed. Factors to consider include the object model and the completeness of each model, as just described, as well as:

- Where to start—for example, whether to work strictly top-down.
- Methods to use for determining which elements align to which.
- Methods to use for assigning degree of alignment.
- Formulas to use for computing degree of alignment.

These factors influence the process steps and methods for a given assessment. It is our hope that our work will lead to a process and method library for alignment assessment. Future assessors would select the process that most closely fits their needs, tailor it as necessary, and (insofar as practical) use existing methods to perform their work. Like product lines ([CN 2001]), the implementation of an alignment assessment process template could save substantial effort.

5.3 Alignment Directionality

Section 1 described the need for data/object model alignment along the following lines. Consider an ER model *E* that supports C2 and an OO model *O* that supports M&S. Given data expressed in one model, when that data are converted to the other model and then back again, is the converted data equivalent to the original?

There is a notion of directionality in the last sentence. Either the ER or the OO model is a starting and ending point, in the sense that an assessor verifies alignment against elements of one model or the other. In the LC2IEDM/JSIMS FOM alignment assessment, there are two distinct questions to answer:

1. Can JSIMS FOM data converted to the LC2IEDM be re-converted back to the JSIMS FOM?
2. Can LC2IEDM data converted to the JSIMS FOM be re-converted back to the LC2IEDM?

The alignment assessment process, then, seeks to verify alignment with respect to one model or the other. Section 4 and Figure 14 present alignment without regard to directionality. However, when assessors begin studying model elements, the issue of verification becomes paramount, and it is necessary to choose an alignment direction when following the process. (A complete study of alignment should assess alignment in both directions, if possible.)

The LC2IEDM/JSIMS FOM study really consists of two separate alignment assessments. The first determines the degree to which the LC2IEDM aligns to the JSIMS FOM. The second determines the degree to which the JSIMS FOM aligns to the LC2IEDM. Both assessments share certain characteristics—such as the process in Figure 14—but differ in process and method details. For this reason, Section 5 covers the process for each assessment separately.

5.4 JSIMS FOM-to-LC2IEDM Assessment

This section discusses the alignment assessment process where the issue is the degree to which the LC2IEDM aligns to the JSIMS FOM (question 1 above). It covers the overall process and, for each level, presents the methods used to assign a degree of alignment and the formula used to compute a degree of alignment.

5.4.1 Process

Figure 15 depicts the process for JSIMS FOM-to-LC2IEDM alignment assessment. A comparison of Figure 15 with Figure 14 reveals two differences:

1. Figure 15 shows alignment directionality. The text emphasizes that the assessor aligns LC2IEDM elements with respect to JSIMS FOM elements.
2. Figure 15 contains an alternate drill-down path from State-level assessment. This path leads back up to the Entity level, where it enters a cycle between Entity- and State-level elements.

The alternate path is necessary because some JSIMS FOM attributes have data types that are complex data types. A complex data type is a collection of attributes. It is semantically equivalent to a class, except that it cannot inherit attributes from another class. Because classes are part of Entity-level alignment assessment, it follows that complex data types should be assessed as Entities. The general rules for drilling down from a State-level alignment assessment are therefore:

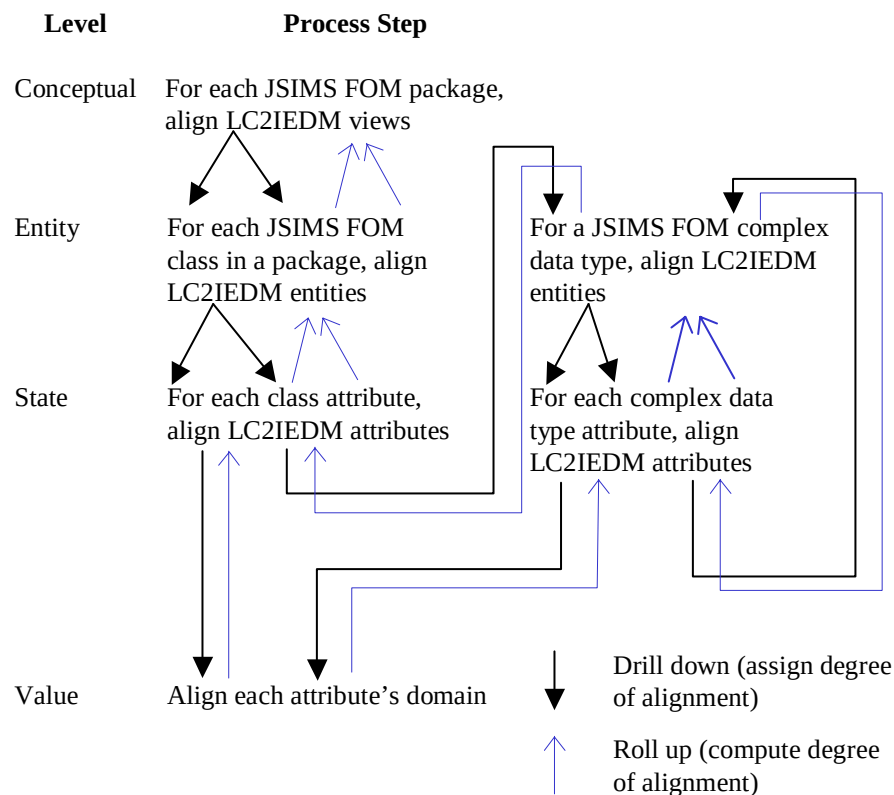


Figure 15. JSIMS FOM-to-LC2IEDM Alignment Process

- If assessing an attribute whose data type is an atomic type (i.e., not a complex data type), drill down to the Value level.
- If assessing an attribute whose data type is a complex data type, perform an Entity-level alignment assessment of the complex data type, and, for each attribute of that type, perform a State-level alignment assessment. Compute the degree of alignment of the complex data type using a formula based on the degrees of alignment of all the complex data type's attributes. Compute the degree of alignment of the original class attribute as the computed degree of alignment of the complex data type that is the attribute's data type.

Sometimes a complex data type contains attributes whose data types are themselves complex data types. An assessor will need to repeat the cycle in Figure 15 multiple times to complete the assessment. Figure 16 shows one of the structures from the JSIMS FOM where repeated Entity-level assessments of complex data types are necessary to resolve an attribute. Ultimately, drilling down terminates either with a Value-level assessment (as shown in Figure 16) or with a higher-level assessment from which drilling down is not possible.

Figure 16 shows assessment nuances worthy of discussion. The attributes head and tail both have data type coordinate_3d_c, which represents a point as a (latitude, longitude, elevation) triple. Because head and tail model the same kind of information, the assessment of coordinate_3d_c is valid for either of them. In other words, it is sometimes possible to reuse alignment assessments. Once an analyst has drilled down from head, there is no need to

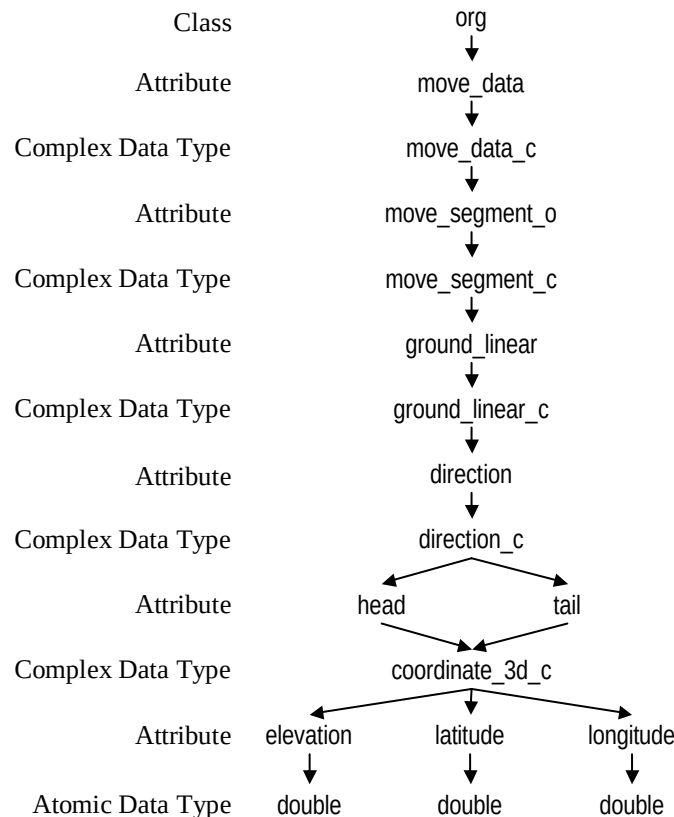


Figure 16. Deep Nesting in JSIMS Complex Data Types

drill down from tail.

Figure 16 also shows a circumstance where an assessment cannot be reused. The attributes elevation, latitude, and longitude are all of type double. But despite their common use of a data type, they do not model the same kind of information. A latitude's domain is bounded by ± 90 . A longitude's domain is bounded by ± 180 . An elevation's domain, which is measured in meters, will be between about -100 and 4000 for land-based operations. An alignment of double shared by the three attributes would overlook their necessarily different ranges.

5.4.2 Level-Specific Details

The following subsections cover the methods, formulas, and heuristics used during each alignment assessment level. The intent is to show the difference types of analysis that occur at different levels.

The material is presented as a rational process, i.e., an idealized description rather than a precise depiction of reality [PC 1986]. A rational process is easier to understand and follow than the chaos of a real process. It can also be summarized more concisely.

5.4.2.1 Conceptual Level

Alignment assessment at the Conceptual level is concerned with revealing the degree to which the highest-level abstractions of the models align. The previous alignment study used an M&S model with “standard objects”, which were a set of classes related by aggregation and inheritance. In that study, standard objects were the focus of Conceptual-level alignment.

In the JSIMS FOM, the highest predefined modeling element is the class. However, a single class is not suited to Conceptual-level alignment. If one considers the essential concepts of M&S (e.g., units, equipment) a little study of the JSIMS FOM shows that sets of classes capture these concepts better than any individual class.

Therefore, we created packages as a first step in Conceptual-level analysis. We reviewed the JSIMS FOM to determine the areas on which we would focus. Each area became a package.

Each package consists of a set of classes and complex data types. One class or complex data type in the package is designated as focal. The guiding principles in determining what to put in a package were as follows:

- If a class is in a package, the transitive closure of its superclass relationships is too.
- If a class has an attribute whose type is a complex data type D , then D is also in the package unless it is the focal element of another package, in which case D will be assessed separately as an independent concept.
- The package includes the transitive closure of complex data types, except as qualified by the rule for focal elements.
- The JSIMS FOM does not model all class composition relationships explicitly.

The last point requires some explanation. The JSIMS FOM object model provides each object instance with a unique identifier. This identifier is of complex data type `id_c`. During execution, the JSIMS FOM provides an object manager that records all currently existing objects, and lets other objects refer to them (i.e., get and set their attributes) through their object identifier. Many JSIMS FOM classes and complex data types contain attributes of type `id_c`. For example, class `org.land.equip_group` contains an attribute `abstract_id_o`, which is a reference to an instance of class `abstract`. This is an implicit composition relationship. The implication for alignment assessment is that the Equipment package, which contains `org.land.equip_group`, also contains `abstract`.

The LC2IEDM has a set of predefined views. It would have been possible to use them, but they were created to illustrate specific LC2IEDM concepts, not for the purposes of alignment. For example, there is no single view that cleanly encapsulates an organization and its related entities. Instead there are views such as:

- ORGANISATION-ALS19s, which depicts an organization, its supertype, and its subtypes.
- ORGANISATION-TYPE-ALS24h, which depicts an organization type, its supertype, and its subtypes.

There is no view that merges the two except the view that includes the entire LC2IEDM.

We therefore decided to introduce our own views, which we deliberately attempted to match with the JSIMS FOM views we created. We used the following principles to create views:

- We looked for LC2IEDM entities with names similar to those of the classes in the JSIMS FOM package to which we were aligning.
- We tried to match JSIMS FOM superclass relationships with LC2IEDM supertype relationships.
- We read class and entity descriptions to look for similarities.
- We studied the relationships among elements in the JSIMS FOM package and included entities in the view if they appeared to have similar relationships. Intermediate entities (e.g., associative entities) were included in the view as necessary.

The real work of Conceptual-level alignment analysis is supposed to begin at this point, with assessors matching up packages and views. The matching principles are in fact more or less the principles used to create views. We therefore found we had completed most of the Conceptual-level alignment analysis already.

What remained was to assign the degree of alignment. At the Conceptual level, the degree of alignment is assigned intuitively. The descriptive information one uses during Conceptual-level analysis (see Table 1) is usually in the form of natural language, and does not facilitate rigor. With only the Conceptual level modeling elements, rigorous analysis is not possible. Computed degree of alignment supplies the necessary rigor by relating Conceptual-level assessments to Value-level assessments.

The formula used was the percent of JSIMS FOM classes in a package that had a matching entity in the corresponding LC2IEDM view. This value was rounded off to one of

five values: 0%, 25%, 50%, 75%, or 100%. The assessor's judgment regarding the structural compatibility of the package and the view could influence the final value assigned.

The work products from Conceptual-level analysis, then, are packages, views, and their alignment. The assessors have classified modeling elements according to their role. They are now ready to begin studies of individual elements.

The true purpose of Conceptual-level analysis, then, is to organize information for subsequent alignment. The partitioning activities that assessors have undertaken give them the foundation for more rigorous work at the lower levels.

5.4.2.2 Entity Level

In Entity-level alignment analysis, the assessor performs one assessment for every component—either a class or a complex data type—of a package. The assessor attempts to find a set of LC2IEDM entities that align to the JSIMS FOM component he is assessing.

In the JSIMS FOM/LC2IEDM study, most of the necessary work for Entity-level alignment analysis was performed during the creation of LC2IEDM views matching JSIMS FOM packages. Part of the assessor's task required looking for entities matching each JSIMS FOM class or complex data type.

In theory, the difference between Conceptual- and Entity-level alignment analysis is that the latter includes consideration of attribute names. In practice, we usually found it necessary to study attribute names in order to intuit the purpose of a class or entity.

Entity-level alignment analysis entails assigning a degree of alignment to each assessment. The general heuristic used is that the degree of alignment is the percentage of attribute in a JSIMS FOM component that have a corresponding attribute in an LC2IEDM entity matching the component. As in Conceptual-level alignment analysis, an assigned degree of alignment is one of five values: 0%, 25%, 50%, 75%, or 100%.

A value of 0% indicates that no LC2IEDM entity exists that can model the information in a JSIMS FOM class or complex data type. Such an assessment is called *terminal*. There is no need to drill down further, because no LC2IEDM attributes would be found to model the attributes of the JSIMS FOM class.

An assessor can also deem a JSIMS FOM class or complex data type irrelevant to alignment analysis. Some classes have attributes that contain simulation-system-specific data, rather than modeling some aspect of the real world. An irrelevant element is not used calculating degree of alignment.

Another way in which the practice of the LC2IEDM/JSIMS FOM alignment study differed from the theory was that we performed most of the Entity-level assessments before formally performing any of the Conceptual-level assessments. In other words, we assessed Entity-level elements without having explicitly defined a context; in particular, we assessed many of the JSIMS FOM classes this way. (We had context for the complex data types because we drilled down to them.) This did not pose a methodological problem be-

cause JSIMS FOM classes are not shared; an attribute's data type can be a complex data type, but not a class. Classes are not likely to be shared between packages. The underlying concept was implicitly known.

We assessed complex data types using almost the same methods as for classes. The only distinction was that we considered the potential for reusing assessments, since complex data types can be shared across classes (see Figure 16). The assessment of a complex data type is derived from an attribute's assessment (see Figure 15).

- Some complex data types (e.g., `coordinate_3d_c`) model values that are independent of the context in which they are used. We wrote assessments of these types to be independent of context. Whenever we needed to assess such a type, we first examined the existing Entity-level assessments. If we found a suitable assessment, we used it as the derivation of the attribute being assessed.
- Other complex data types may depend on context. For example, the values of `id_c`, which models object identifiers, may depend on the type of object being modeled (e.g., there may be naming conventions). For these data types, we always performed separate assessments for each attribute.

The work products of Entity-level alignment analysis are the assessments of individual JSIMS FOM classes and complex data types with respect to LC2IEDM entities. The assessor has identified any JSIMS FOM elements that do not align at all, and has gathered enough information to consider the degree to which individual attributes align.

5.4.2.3 State Level

In State-level alignment analysis, an assessor determines the degree of alignment of each attribute of a class, or field of a complex data type. The assessor attempts to find LC2IEDM attributes that model the information contained in a JSIMS FOM attribute or field.

During Entity-level analysis, the assessor aligned LC2IEDM attributes to JSIMS FOM attributes based mainly on name. During State-level analysis, the assessor starts with the results from Entity-level analysis and adds consideration of:

- *Datatype name.* Similarities or differences in datatypes can enhance or inhibit alignment. It is necessary to know the naming conventions in each model: a JSIMS FOM data type that ends with `_e` contains an enumerated set of values, as does an LC2IEDM attribute whose name ends with `-CODE`. For enumerations, it is also usually necessary to quickly examine each set of values, although a detailed examination can wait until Value-level analysis.
- *Datatype atomicity.* If the JSIMS FOM datatype is an atomic type, such as string or long, then the JSIMS FOM attribute generally aligns to a single LC2IEDM attribute (occasionally more than one; see below). If the JSIMS FOM datatype is a complex data type, it is usual to expect it to align to a larger set of LC2IEDM attributes.

The preferred approach for performing a State-level assessment of an attribute whose data type is complex is to postpone enumerating all of the LC2IEDM at-

tributes that would align to the complex data type. Instead, the assessor should satisfy himself that the LC2IEDM contains at least some viable attributes (if he cannot, he assigns a 0% degree of alignment to the State-level assessment of the JSIMS FOM attribute), then perform an Entity-level alignment analysis of the complex data type. Once he has drilled down from that analysis, he can use the union of the LC2IEDM attributes identified during State-level alignment analyses as the set of LC2IEDM attributes that align to the original JSIMS FOM attribute.

- *Attribute cardinality.* If a JSIMS FOM attribute's cardinality is "1", then there is one instance of that attribute's value per instance of a class. If JSIMS FOM class C contains an attribute A with a cardinality of 1, and if C aligns at the Entity level to LC2IEDM entity E , then E must have an attribute (or perhaps set of attributes) that can model the domain of A . But the situation is more complex if A 's cardinality is not 1.

The usual approach if an attribute's cardinality is other than 1 is to look for an LC2IEDM entity E' that contains attributes that model A , and is related to E by a many-to-one relationship. The LC2IEDM does not place constraints on relationships, so a many-to-one relationship can model cardinalities of 0+, 1+, 2+, 9, and 160 (all of which appear in the JSIMS FOM). However, an assessor seldom finds an E' related directly to E . The more usual case is that E and E' have a many-to-many relationship via an associative entity. This is perfectly acceptable.

Occasionally, cardinality other than one maps to separate attributes rather than a relationship. The JSIMS FOM sometimes uses an array of three double values to represent a coordinate. In the LC2IEDM, this aligns to a single instance of a POINT.

- *Attribute units.* Many JSIMS FOM attributes with atomic data types have units; for instance, latitudes are expressed in degrees. Where available, units should be compared to those of candidate LC2IEDM attributes. Sometimes JSIMS FOM and LC2IEDM attributes share units, making alignment straightforward. Sometimes the attributes have different units, necessitating a conversion algorithm. And sometimes the attributes have incompatible units (e.g., certain capabilities).
- *Class supertype.* If a JSIMS FOM class C has a superclass, then State-level alignment considers whether the attributes of that superclass can be modeled so as to relate 1:1 to an instance of C . The assessor looks in the LC2IEDM for:
 - A supertype entity corresponding to the superclass.
 - Additional attributes in the entity modeling other attributes of C .
 - A relationship from the entity modeling C 's attributes to another entity with attributes that can model the superclass.

The assessor must always consider structure during State-level alignment assessment. If a JSIMS FOM class C has attributes $\{A_1, A_2, \dots, A_n\}$, and the assessor identifies a mapping of this set to LC2IEDM attributes $\{L_1, L_2, \dots, L_m\}$, then there must exist a relationship among all the L_i 's that maintains the cardinality relationship that exists between the A_i 's.

Section 5.4.2.2 discussed the `id_c` complex data type that many JSIMS FOM classes use to identify or reference object instances. The usual name for the attribute that identifies a

class is `id_u`. When assessing a class, the assessor finds the LC2IEDM attribute *L* to which `id_u` aligns. When he assesses other attributes of the class, he first ascertains if the corresponding LC2IEDM attribute relates properly to *A*.

The assessor must be careful not to assign multiple roles to a single LC2IEDM attribute, and must try to match attributes according to purpose. Figure 17 shows hierarchies for units in the two models. Both sets have assorted attributes that can model an organization's name; the issue is which attributes align to which. An assessor might align `org_name` to either of `object-item-name` or `unit-formal-abbreviated-name`. If he chooses `unit-formal-abbreviated-name`, he cannot also align `agg_org_name` to `unit-formal-abbreviated-name`.

Some attributes are irrelevant to alignment. Typically these attributes are simulation-specific. When an assessor finds such an attribute, he should record that fact and not pursue its alignment further.

At the State level, the assessor assigns a degree of alignment based on the factors listed above. As before, the value is 0%, 25%, 50%, 75%, or 100%. There is no specific formula, but the following points should be noted:

- A degree of alignment of 0% is appropriate if the LC2IEDM contains no attribute that can model the same information as the JSIMS FOM attribute in such a way as to be structurally related to the rest of the attributes in the class. If the assessor assigns 0% as a degree of alignment, he does not drill down to the Entity or Value level.
- Some JSIMS FOM attributes translate to different structural representations in the LC2IEDM (e.g., the `location_type` attribute of class `org`). They can be considered terminal.
- The assessor, when assessing a JSIMS FOM attribute whose data type is atomic, has usually studied the attributes fairly closely and bases the degree of alignment on his intuitive perception of the degree to which the attribute domains will overlap. With practice this number tends to be close to that assigned in Value-level assessment.
- When the assessor is considering a JSIMS FOM attribute whose data type is a complex data type, he might base the degree of alignment on whether the LC2IEDM contains an entity with a name similar to that of the complex data type.

Even if the degree of alignment is greater than 0%, an assessor may declare an assessment terminal. This was common in the AICDM/OMSC study [WHLH 2001], because the assessor often found that the OMSC was too vague to facilitate further analysis. It was uncommon in the WARSIM/LC2IEDM study, which is fortunate, because stopping at the State level increases the overall subjectivity of the alignment assessment.

After performing State-level assessments, the assessor has collected the domains to be aligned. He is now ready to compare the domains during Value-level assessment.

5.4.2.4 Value Level

At the Value level, the assessor considers domains and the degree to which they overlap. A Value-level assessment derives from a State-level assessment, in which the assessor is

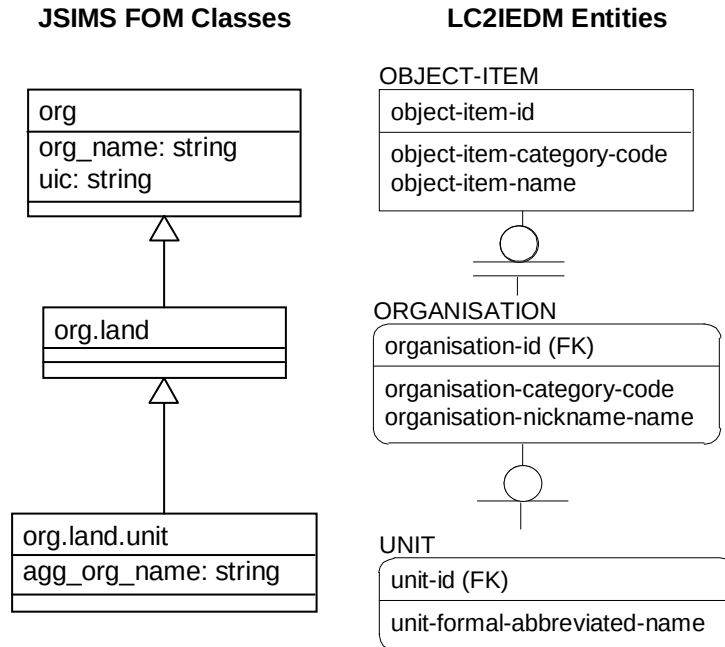


Figure 17. Potential Attribute Mappings

comparing a JSIMS FOM domain such as string or long to a set of LC2IEDM domains. Usually the set of LC2IEDM domains has only one element, but occasionally a JSIMS FOM domain—particularly an enumerated type—aligns to multiple LC2IEDM domains.

Value-level alignment assessments are always terminal and always relevant. There is no rolled-up degree of alignment computed from derived assessments. The assigned degree of alignment is the value used to derive a State-level computed degree of alignment.

Assessors calculate the assigned degree of alignment according to established procedures. The procedures used in the LC2IEDM/JSIMS FOM assessment are in Appendix E. The value is a percentage. The idea is that this percentage expresses the degree to which the LC2IEDM domain (or domains) overlaps the JSIMS FOM domain.

The calculation must account for the expected range of the JSIMS FOM domain. Both the JSIMS FOM and the LC2IEDM store WGS-84 coordinates. The JSIMS FOM stores them using a double. The LC2IEDM uses NUMBER(9,6), NUMBER(10,6), and NUMBER(12,3) to store latitude, longitude, and elevation, respectively. A double can represent quantities of both greater magnitude and greater precision than any of the three LC2IEDM domains. However, the LC2IEDM domains are adequate for all possible magnitudes, and they can model position to within 11 cm, a resolution small enough for WARSIM. We therefore conclude that each domain aligns fully to its respective JSIMS FOM domain.

The approach used to assess domains of enumerated data types was to create a table of the JSIMS FOM values and, for each value, identify which ones had an unambiguous mapping to LC2IEDM values. Figure 18 shows an example table, used in the alignment of a TCDM enumerated domain for the Hydrological Category attribute to the domain of the LC2IEDM GEOGRAPHIC-FEATURE-TYPE-CATEGORY-CODE attribute. The values in the left-

most column are from the TCDM; those in the two right columns are from the LC2IEDM, along with explanations. Of the eleven TCDM values, four are deemed not applicable (N/A) to the alignment assessment. Of the remaining seven, three—Unknown, Data Withheld, and Other—map unambiguously to LC2IEDM values. Three of the other four could map to any of several LC2IEDM values, and one (Not Applicable) has no corresponding value in the LC2IEDM. The degree of alignment is therefore 3/7, or 43%.

5.4.2.5 Computed Degree of Alignment

The completed Value-level analyses provide enough information to calculate the computed degrees of alignment for a Conceptual-level assessment. For any JSIMS FOM element j , let $ADoA(j)$ represent its assigned degree of alignment, and let $CDoA(j)$ represent its computed degree of alignment. We used the formulas shown in Table 6 to calculate $CDoA(j)$. (Relevance means that the assessment is not “not applicable”.)

Table 6. Formulas Used to Calculate Computed Degree of Alignment

Level	Formula
Conceptual	For a JSIMS FOM package P , $CDoA(P) = \text{average}((CDoA(C_i)))$ where C_i is a class that is part of P and the assessment of C_i is relevant.
Entity	For a JSIMS FOM class C whose assessment is relevant, • If the assessment of C is terminal, then $CDoA(C) = ADoA(C)$. • If the assessment of C is not terminal, then $CDoA(C) = \text{average}(CDoA(A_i)) \times f$ where: • A_i is an attribute of C, or an ancestor class of C, whose assessment is relevant. • f is an adjustment factor as defined below.
State	For a JSIMS FOM attribute A whose assessment is relevant, • If the assessment of A is terminal, then $CDoA(A) = ADoA(A)$. • If the assessment of A is not terminal, then $CDoA(A) = \text{average}((CDoA(e_i)))$ where e_i is the data type of A.

Two aspects of Entity-level computed degree of alignment merit further discussion. The first is the adjustment factor for non-standard mappings, discussed in detail in Section 4.5.4. Second, observe that the degree of alignment for a class is computed based on the averages of not only the attributes of that class but of the class’ ancestors, if any. A subclass cannot be instantiated without instantiating its superclass as well. The degree to which a subclass can align therefore depends on the degree to which its superclass can align.

5.5 LC2IEDM-to-JSIMS FOM Assessment

This section discusses the process for alignment where the question is the degree to which the JSIMS FOM can model LC2IEDM elements. The process is similar to that

covered in Section 5.4, but the difference between the JSIMS FOM and LC2IEDM modeling elements changes certain details.

5.5.1 Process

Figure 19 depicts the process for LC2IEDM-to-JSIMS FOM alignment assessment. The process is much closer to the template in Figure 14 than that for JSIMS FOM-to-LC2IEDM assessment in Figure 15. In the LC2IEDM, all attribute domains are atomic, meaning there is no need for cycles between Entity- and State-level alignment assessment.

5.5.2 Level-Specific Details

5.5.2.1 Conceptual Level

By the time the LC2IEDM-to-JSIMS FOM assessment began, the JSIMS FOM-to-LC2IEDM assessment had almost ended. Packages and views had been identified for JSIMS FOM-to-LC2IEDM Conceptual-level analysis. We decided to use them as a starting point for the LC2IEDM-to-JSIMS FOM assessment. The LC2IEDM has some predefined views, but they are tightly focused around a single entity (such as OBJECT-ITEM) and reflect modeling more than domain concerns. The views we had already defined were based on C2 domain elements and seemed more appropriate.

5.5.2.2 Entity Level

The LC2IEDM has some entities that are supertypes of more specific entities. These supertypes tend to be highly abstract, more so than any class that exists in The JSIMS FOM. An example is OBJECT-ITEM. The JSIMS FOM has class org, which maps better to ORGANISATION—a subtype of OBJECT-ITEM.

To the degree that these high-level entities align to anything in the JSIMS FOM, they aligned to several JSIMS FOM classes. Often it was helpful to keep context in mind. When assessing the OBJECT-ITEM entity within the context of the Organization concept, OBJECT-ITEM aligns to class org. Within the context of the Equipment concept, OBJECT-ITEM aligns to classes equipment and platform.

Some LC2IEDM entities exist to provide many-to-many associations between other entities. An example is OBJECT-ITEM-TYPE, which relates OBJECT-ITEM and OBJECT-TYPE. These associative entities have attributes, but to align them means more than just relating their attributes. It is also necessary to consider the entities they relate, and to determine if the JSIMS FOM supports the same structure. (As a rule the JSIMS FOM does not; the JSIMS FOM generally supports one-to-many but not many-to-many relationships.)

5.5.2.3 State Level

The LC2IEDM-to-JSIMS FOM alignment is fundamentally different from the JSIMS FOM-to-LC2IEDM alignment in the need to align attributes that are foreign keys. The JSIMS FOM has a few attributes that serve a similar role (e.g., the `abstract_id_o` attribute associated with many classes), but the prevalence of foreign keys in a relational model demands some new approaches to alignment.

TCDM: Hydrological Category	LC2IEDM: GEOGRAPHIC-FEATURE-TYPE-CATEGORY-CODE	
Unknown	Not known	It is not possible to determine which value is most applicable.
Value Intentionally Left Blank	N/A	
Not Applicable	<i>No match</i>	
Dry	Cliff/escarpment	A steep, vertical, or overhanging face of rock or earth.
	Dry gap	A waterless ravine or mountain pass.
	Mountain	A natural elevation of the earth's surface having considerable mass, generally steep sides, and a height greater than that of a hill.
	Ridge line	Line representation of ridge top.
Value Intentionally Left Blank	N/A	
Value Intentionally Left Blank	N/A	
Non-Perennial / Intermittent / Fluctuating	Ford	A shallow part of a body of water that can be crossed without bridging, boats, or rafts. A location in a water barrier where the physical characteristics of current, bottom, and approaches permit the passage of personnel and/or vehicles and other equipment.
	Mountain pass	A natural route through a low place in a mountain range.
	River/stream	A natural flowing watercourse.
Value Intentionally Left Blank	N/A	
Perennial / Permanent	Ford	
	Lake/pond	A natural body of water surrounded by land.
	Marsh/swamp	A saturated area, at times covered with water, supporting vegetation which may include trees.
	River/stream	A natural flowing watercourse.
	Water (except inland)	An area of water which normally has tidal fluctuations.
	<i>No match</i>	
Data Withheld	Not otherwise specified	The appropriate value is not in the set of specified values.
Other		

Figure 18. Example Table for Value-Level Alignment Analysis

A foreign key describes a structural relationship. If entity E_1 has a foreign key f that is a key of E_2 , a one-to-many relationship exists between E_2 and E_1 . Thus, if E_1 aligns to class C_1 and E_2 aligns to class C_2 , then f aligns if C_2 has an attribute with a cardinality of 0+ whose data type aligns to E_1 (at the Entity level), or to a supertype of E_1 . (Cardinality of

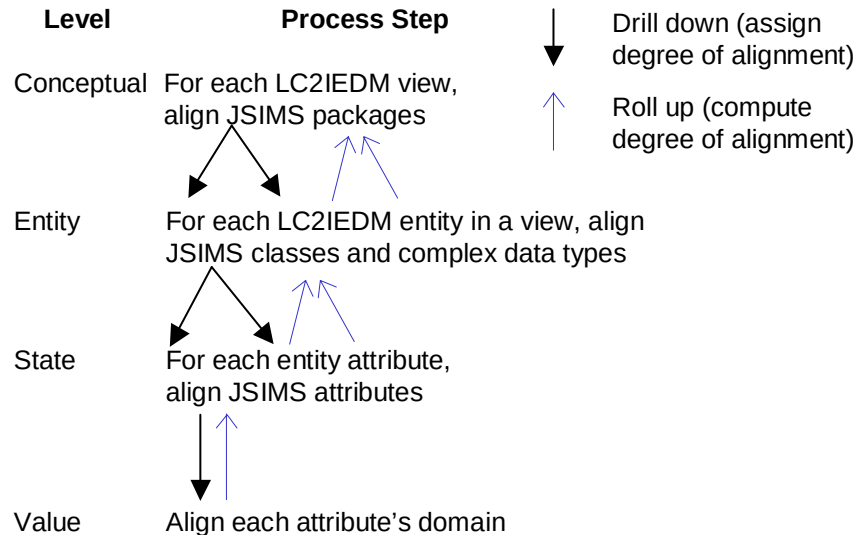


Figure 19. LC2IEDM to JSIMS FOM Alignment Assessment Process

1+ indicates partial alignment. Cardinality of 1 indicates minimal alignment, and must be considered case by case.)

A foreign key can also describe a subtype relationship. If entity E_c has a foreign key f that is migrated from parent entity E_p , and if E_c aligns to C_1 and E_p aligns to C_2 , then f aligns if C_1 is a subclass of C_2 .

A supertype entity E has an attribute whose name has the form E -CATEGORY-CODE. This attribute discriminates a category of instances comprising the subtype. Usually its alignment is obvious from the context of the Conceptual level assessment. In the context of the Unit concept, the value of OBJECT-ITEM-CATEGORY-CODE is always OR (organization). In the context of the Equipment concept, the value of OBJECT-ITEM-CATEGORY-CODE is always MA (materiel).

The LC2IEDM entity CAPABILITY has an attribute CAPABILITY-ID. This attribute is a foreign key in several other entities, including OBJECT-TYPE-CAPABILITY-NORM. Capabilities are expressed in the JSIMS FOM using attributes of class abstract (or its subclasses). The number of capabilities that will be associated with an object type is bounded by the number of capability codes that are relevant to the object type.

In other words, CAPABILITY-ID aligns insofar as the various capability codes can be modeled. Its assessment is therefore entirely dependent on other attributes. It is therefore considered not applicable, because assessing it would duplicate other assessments and skew the computed degree of alignment.

5.5.2.4 Value Level

In general, the issues in performing Value-level alignment were the same as for the JSIMS FOM-to-LC2IEDM direction. The assessment was usually simpler, because JSIMS FOM domains tend to be broader than LC2IEDM domains:

- Where the LC2IEDM uses NUMBER(n), $n \leq 6$, to represent a numeric quantity (as opposed to an entity instance identifier) the JSIMS FOM uses long.
- Where the LC2IEDM uses NUMBER(n) , $n \leq 18$, to represent an entity instance identifier, the JSIMS FOM uses string, which can be as long as $2^{32} - 1$ characters.
- Where the LC2IEDM uses NUMBER(n,m), $n \leq 13$ and $m \leq 6$, to represent a numeric quantity, the JSIMS FOM uses double.
- Where the LC2IEDM uses VARCHAR(n) , $n \leq 2000$, to represent a string, the JSIMS FOM uses string.

The implication is that it is always possible to convert an LC2IEDM domain to a JSIMS FOM domain and back again without loss of precision. The only area where problems might arise is in aligning floating-point domains, because NUMBER(n,m) is a decimal representation and double is a binary representation. However, in the domains we assessed, conversion errors in numeric domains would have resulted in differences that were judged insignificant.

6. WARSIM → LC2IEDM Alignment Assessment Results

This section presents the results of assessing the degree of alignment going from the WARSIM to the LC2IEDM using the process described in Section 5. These results can be summarized for the three main conceptual areas as follows:

Table 7. Degrees of Alignment of the LC2IEDM with Respect to WARSIM Concepts

Conceptual Area	Degree of Alignment
Unit	61%
Equipment	70%
Environment	41%

6.1 Unit Area

6.1.1 Overview of Unit Area Alignments

WARSIM and the LC2IEDM both have explicit entities for representing military units. WARSIM has the `org.land.unit` object class, which corresponds to the UNIT subclass of the ORGANIZATION entity in the LC2IEDM. The WARSIM `org.land.unit` object class is part of a three class hierarchy reflected in its naming structure. Class definitions for these WARSIM Unit area classes are given in Table 8. Although this is a simple hierarchy on the surface, it is greatly enriched by its many complex attributes which support representation of related platforms, crew, and their attributes.

Table 8. JSIMS FOM Classes that Model Unit

JSIMS FOM Class	Definition
<code>org</code>	A collection of personnel and/or equipment and/or supplies.
<code>org.land</code>	Land organizations.
<code>org.land.unit</code>	A collection of personnel, equipment, and supplies having some cognitive behavior. May represent either military or civilian groups.

The LC2IEDM has a much richer entity level representation of units, their attributes, and relationships because its third normal form Entity-Relationship (ER) format imposes modeling constraints that eliminate duplicative information and require all attributes to be simple atomic values. A view of the principal LC2IEDM entities required to represent Unit data from WARSIM is illustrated in Figure 20. This differs from the core LC2IEDM unit view (Figure 7 on p. 21) because the unit entities in WARSIM include much equipment related data. In Figure 20, UNIT is identified as a subtype of ORGANISATION, which is a subtype of OBJECT-ITEM, which is related to the types of unit via the OBJECT-ITEM-TYPE relationship, where the UNIT-TYPE is a subtype of ORGANISATION-TYPE, which is a subtype of OBJECT-TYPE. The WARSIM `agg_org_name` attribute of a unit corresponds to the unit-formal-abbreviated-name attribute of the UNIT entity.

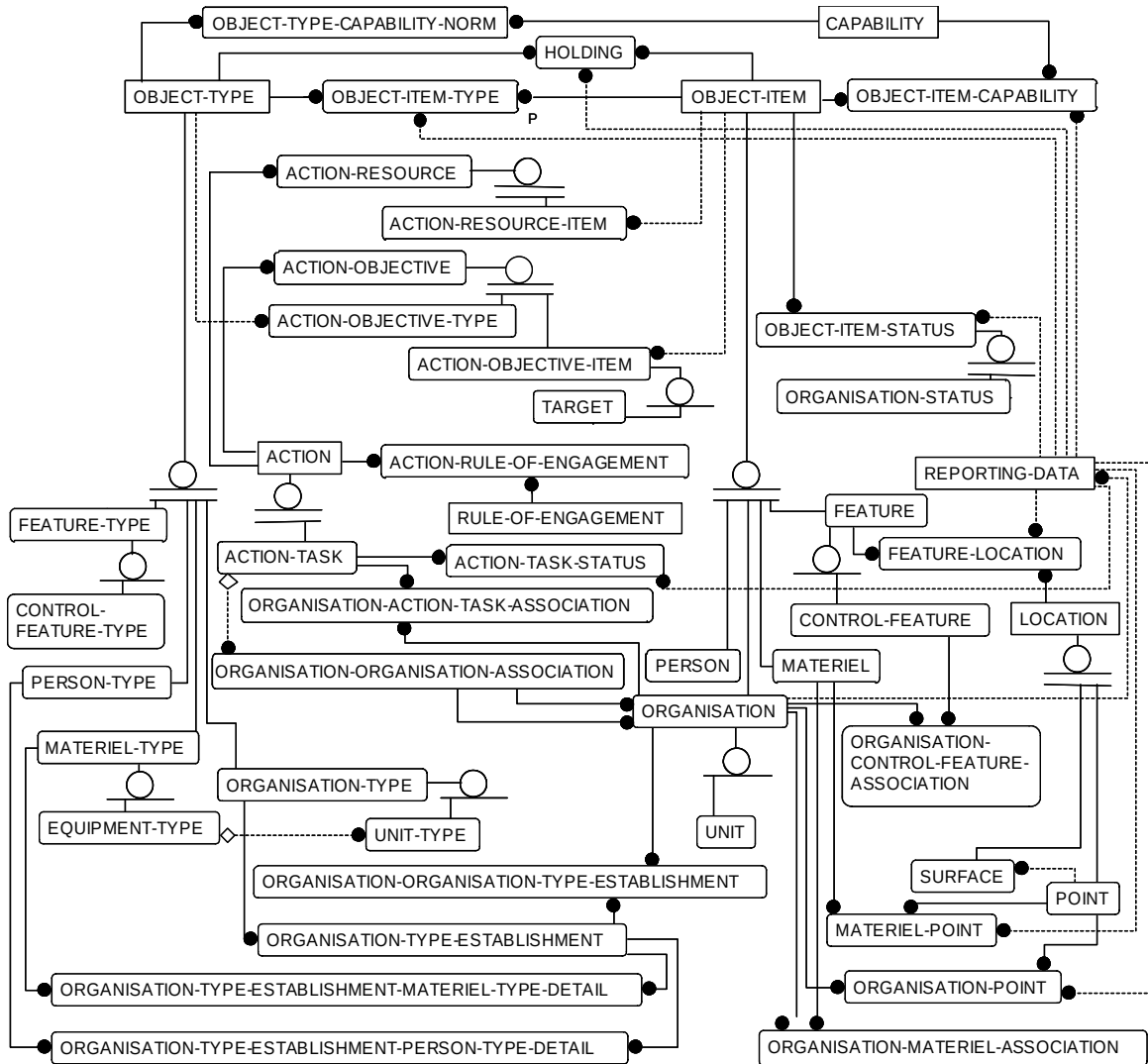


Figure 20. Principal LC2IEDM Entity Structure for WARSIM Unit Data

Authorized levels of equipment and personnel, as modeled in WARSIM, are identified in the LC2IEDM via the ORGANISATION-ORGANISATION-TYPE-ESTABLISHMENT entity, linked to the ORGANISATION-TYPE-ESTABLISHMENT entity which links to ORGANISATION-TYPE-ESTABLISHMENT-MATERIEL-TYPE-DETAIL to list types of authorized equipment (via MATERIEL-TYPE and EQUIPMENT-TYPE) and to ORGANISATION-TYPE-ESTABLISHMENT-PERSON-TYPE-DETAIL to list the types of authorized personnel (via PERSON-TYPE) and their associated authorized quantities.

The WARSIM org.land.unit data on rules of engagement for air and ground (air_rules_of_engagement_o, ground_rules_of_engagement_o) could be mapped into the text field (rule-of-engagement-description-text) of the LC2IEDM RULE-OF-ENGAGEMENT entity. A UNIT is linked to a RULE-OF-ENGAGEMENT through the associations ORGANISATION-ACTION-TASK and ACTION-RULE-OF-ENGAGEMENT. But many specific details of rules of engagement are best represented elsewhere in the LC2IEDM. The engagement and fire restricted areas

specified in WARSIM can be defined geospatially by the SURFACE and POINT subtypes of the LOCATION entity, which is linked to CONTROL-FEATURE by the FEATURE-LOCATION association to specify the type of control. A UNIT may be linked to such a control feature through its ORGANISATION supertype via the ORGANISATION-CONTROL-FEATURE-ASSOCIATION. Alternatively, for rules of engagement restricted to specific tasks, a UNIT can be linked to a suitable control feature through the ACTION-OBJECTIVE-ITEM association for an ACTION-TASK which is associated with the unit through the ORGANISATION-ACTION-TASK-ASSOCIATION.

WARSIM data on fire thresholds and weapon control status (fire_threshold, weapon_control) for a UNIT can be partially captured in the ORGANISATION-STATUS entity of the LC2IEDM. WARSIM's list of a unit's types of air targets is only partially covered by the LC2IEDM via its ACTION-OBJECTIVE-TYPE, EQUIPMENT-TYPE entities which are associated with an ACTION-TASK linked to the UNIT entity via ORGANISATION-ACTION-TASK-ASSOCIATION in the LC2IEDM. WARSIM priorities for a unit on such targets are fully covered via a priority code in the ACTION-OBJECTIVE entity. WARSIM's data on a unit's ground targets is left to a free-form text field, which could be mapped into the free text field of RULE-OF-ENGAGEMENT, or which might be parsed out to the same entities used for air targets.

The types of platforms (platform_midbs_o) which are currently held by a unit are specified by the category and subcategory codes of EQUIPMENT and their amounts (platform_counts) are specified by the HOLDING relationship between OBJECT-ITEM (linked to UNIT as a subtype through ORGANISATION) and OBJECT-TYPE (linked to EQUIPMENT as a subtype through MATERIEL-TYPE).

The link between a unit and other units that are perceived by it (perceived_units) is identified in the LC2IEDM via the REPORTING-DATA entity, which has a special link to the supertype ORGANISATION of UNIT to identify the reporting organization. The location of perceived units is recorded in the LC2IEDM via the link between REPORTING-DATA and ORGANISATION-POINT, which associates the organization with the POINT location where it was perceived. Perceived features have a similar representation mediated via the link between REPORTING-DATA and FEATURE-LOCATION.

These brief descriptions capture the mappings of typical WARSIM unit data to the relevant entities in the LC2IEDM. A few illustrative examples follow of alignment assessments in the Unit area which go down to the state and value level, matching LC2IEDM attributes and values to their corresponding WARSIM data elements.

6.1.2 Unit Area Example for Simple Attributes

An example of mapping Unit area attributes from WARSIM to the LC2IEDM is illustrated in Figure 21. The task attribute of org.land.unit is shown to map directly to the action-name attribute of the ACTION-TASK entity in the LC2IEDM. However, the six other entities shown are required to link the action task to the UNIT entity and to specify the task as in execution and in progress. Nonetheless, the information is fully preserved, so an assessment value of 100% is assigned. The frequency attribute of org.land.unit in WARSIM, in

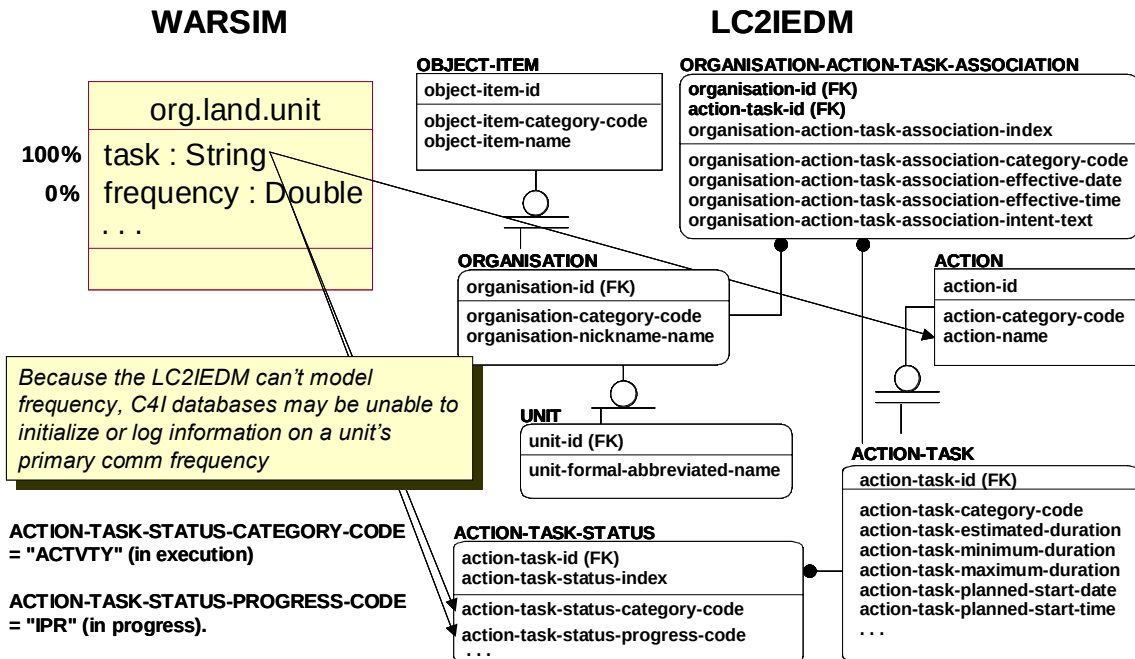


Figure 21. Example Unit Area Alignment Mapping and Assessments

contrast, has no corresponding data element in the LC2IEDM, so it gets a 0% alignment assessment.

6.1.3 Unit Area Example of an Enumeration Attribute

Assessment of enumeration attributes ordinarily just requires computing the ratio of those enumerated values covered by a model over the total number of enumerated values of the attributed. The WARSIM `org_type_e` enumerated attribute has three values (`equip_group`, `supply_cache`, `unit`), of which only one is covered by the LC2IEDM, giving an alignment assessment of 1/3 or 33%, as illustrated in Figure 22.

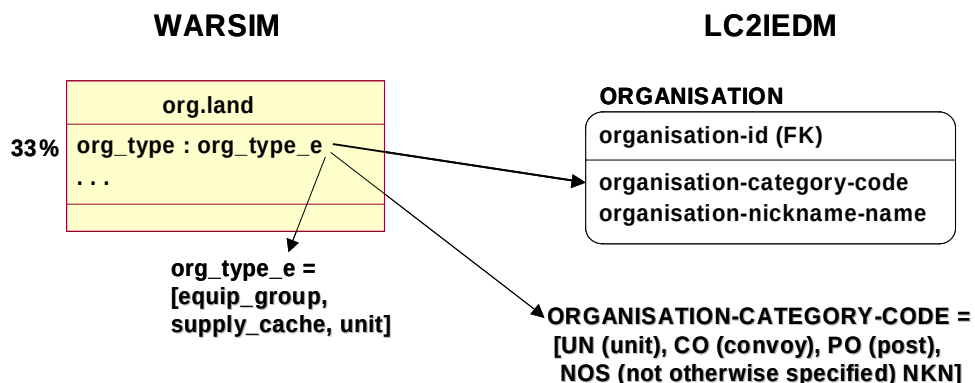


Figure 22 Example Unit Area Alignment Mapping of an Enumerated Attribute.

6.1.4 Unit Area Assessments Summary

Table 9 provides summary assessment results at the Entity-level for the Unit area. The overall degree of alignment of the Unit area of 61% is simply the average of these as-

assessments for org, org.land, and org.land.unit. Greater detail on the aligned classes from the LC2IEDM and the notes explaining the alignment are included in the table of Appendix B. The full details are available in the alignment assessment database.

Table 9. Unit Area Entity-Level Assessment Results

WARSIM-to-LC2IEDM Alignment	
JSIMS FOM Class	Degree of Alignment to the LC2DM
org	84%
org.land	54%
org.land.unit	46%

Figure 23 shows the results of all 146 applicable State-level assessments in the Unit area (12 were identified as not applicable (N/A) due to irrelevance to C4I systems). This graph breaks down the assessment of alignment in the Unit area in terms of ranges of degree of alignment for the attributes. 72, or 49%, of the attributes assessed fully align (at 100%),

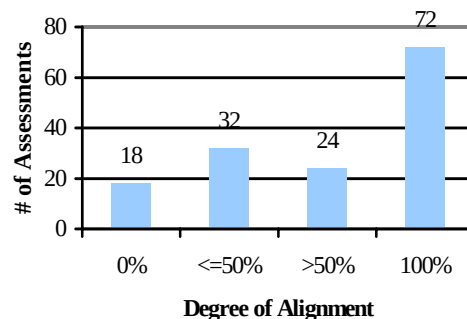


Figure 23. Unit Area Attribute Alignment Assessment Results

while a significant minority (11, or 8%) have no correspondence at all in the LC2IEDM. Complete State-level assessments are available in the alignment assessment database.

6.2 Equipment Area

6.2.1 Overview of Equipment Area Alignments

The Equipment Area of WARSIM’s models comprises nine JSIMS FOM classes published by WARSIM that model materiel. They are summarized in Table 10. (WARSIM does not actually publish classes abstract and org, but as superclasses of WARSIM-published classes it is necessary to consider the alignment of these two classes.) This group of classes overlaps with two classes from the Unit area—org and org.land—because they are superclasses of the org.land.equip_group and org.land.supply_cache classes which represent groups (and “cache’s”) of instances of equipment.

We performed an assessment of the degree to which WARSIM elements of the JSIMS FOM related to materiel align to LC2IEDM elements. We assessed these classes accord-

ing to the process in Section 5.4, drilling down to the Value level, and performing Entity-level assessments of complex data types as necessary.

Table 10. JSIMS FOM Classes that Model Equipment

JSIMS FOM Class	Definition
abstract	Abstract characteristics of objects. Used to consolidate information applicable to many platform objects (e.g., one data set for many of the same model of tank).
abstract.land	Land specific abstract objects.
abstract.land.equipment_type	Static characteristics of equipment types.
abstract.land.personnel_type	Static characteristics of personnel types.
abstract.land.rotary_wing_type	Static characteristics of helicopter types.
org	A collection of personnel and/or equipment and/or supplies.
org.land	Land organizations.
org.land.equip_group	A collection of platforms making up a lower level organization that has reactive but not cognitive behaviors.
org.land.supply_cache	A collection of supplies, TBD.

Table 11 summarizes the effort in terms of number of elements assessed. From the single Conceptual-level assessment that comprises the Equipment concept, we ultimately derived 46 Entity-level assessments. However, only 22 of those assessments were unique. That is, the Equipment concept comprises 22 distinct Entity-level elements (9 classes and 13 complex data types). Some attributes or fields of these elements have the complex data type. Value-level assessments are always relevant and terminal by definition, so values for those cells are not included.

Table 11. Summary of Element Assessment Effort for Equipment

Level	Number of Assessments		Irrelevant Elements	Terminal Elements
	Total	Unique		
Conceptual	1	1	0	0
Entity	46	22	0	0
State	204	136	19	15
Value	127	54		

The JSIMS FOM Entity-level elements related to materiel aligned to many different LC2IEDM entities, as listed in Table 12. No single LC2IEDM entity dominates the modeling of materiel. Because each LC2IEDM entity contains only attributes that are in one-to-one relationship with each other, and because the JSIMS FOM models many characteristics of materiel using one-to-many relationships, it is to be expected that characteristics of materiel would be split across many entities. Note that the MATERIEL and EQUIPMENT-TYPE entities occur often in alignment assessments in relation to most of the other entities.

Elements of the Equipment concept often align to the ORGANISATION entity. This occurs because an ORGANISATION is the LC2IEDM equivalent of a JSIMS FOM equipment group. See Figure 24.

Table 12. LC2IEDM Entities That Align to Equipment

Entity Name	Occurrences	Entity Name	Occurrences
ABSOLUTE-POINT	6	ORGANISATION-MATERIEL-ASSOCIATION	1
CAPABILITY	4	ORGANISATION-ORGANISATION-ASSOCIATION	1
COMBAT-UNIT-TYPE	1	ORGANISATION-POINT	1
CONVOY	1	ORGANISATION-STATUS	1
ELEVATED-ABSOLUTE-POINT	6	ORGANISATION-TYPE	1
EQUIPMENT-TYPE	4	PERSON-STATUS	1
FIRE-CAPABILITY	1	REPORTING-DATA	2
HOLDING	2	REPORTING-DATA-ABSOLUTE-TIMING	4
LOGICAL-NETWORK	1	REPORTING-DATA-RELATIVE-TIMING	1
MATERIEL	3	ROUTE	1
MATERIEL-POINT	1	STORAGE-CAPABILITY	2
MATERIEL-STATUS	1	SUPPORT-UNIT-TYPE	1
MATERIEL-TYPE	1	SURVEILLANCE-CAPABILITY	1
OBJECT-ITEM	5	UNIT	1
OBJECT-TYPE	4	UNIT-TYPE	2
ORGANISATION	4		

6.2.2 Equipment Area Example

Several examples of mapping simple WARSIM attributes from the equipment area into the LC2IEDM are illustrated in Figure 25. The platform name attribute (platform_name_o) for org.land.equip_group from WARSIM maps into the object-item-name attribute of the LC2IEDM, where the object-item-category-code = “MA” for materiel. The total number of platforms (number_of_platforms) belonging to an equipment area is represented in the LC2IEDM by the relationship ORGANISATION-MATERIEL-ASSOCIATION between the ORGANISATION entity representing an equipment group and the MATERIEL entity representing a platform’s equipment. The type of association is probably best represented via organisation-materiel-association-category-code = “CTRL” to indicate that the equipment group

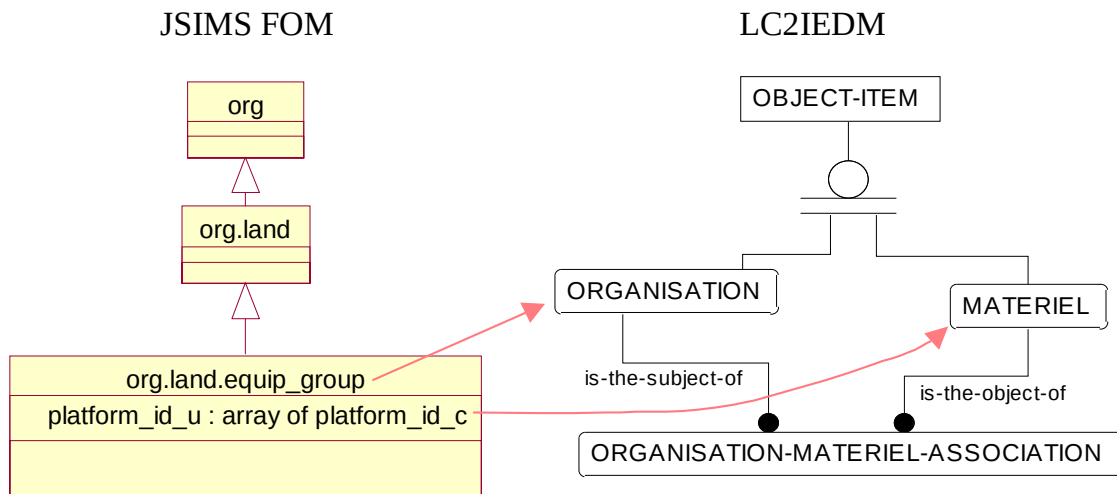


Figure 24. Modeling a JSIMS FOM Equipment Group Using LC2IEDM Entities

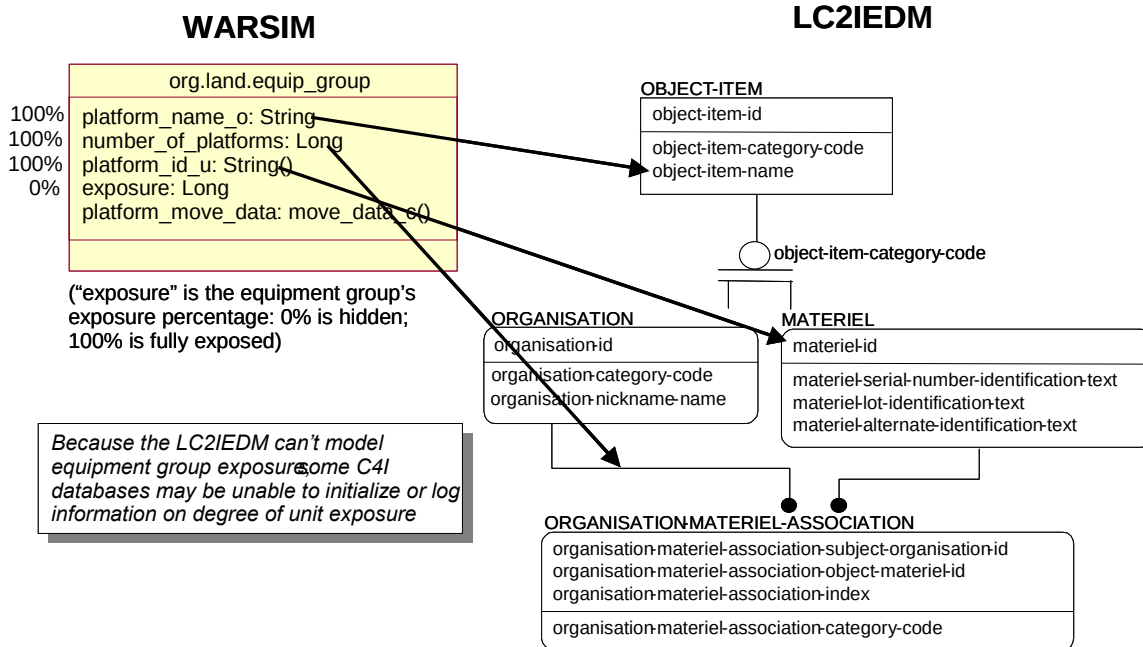


Figure 25. Example Equipment Area Attribute Alignments

controls the platform. A separate instance of this association must be inserted into an LC2IEDM compliant database for each platform type, which are then counted to give the total number. Identifiers for platforms (platform_id_u) in an equipment group are represented in WARSIM via the materiel-id attribute of MATERIEL, which is the same as the object-item-id of OBJECT-ITEM. The platform equipment identified by this WARSIM list of identifiers are the same ones named by the list of platform names, correlated in WARSIM by their position in these lists. The LC2IEDM has 100% alignment with all of these attributes from WARSIM because they can all be perfectly represented and distinguished. But the exposure attribute, which models the percentage of the group's exposure to fire, has no corresponding LC2IEDM element. It has a 0% degree of alignment.

6.2.3 Equipment Area Assessment Results Summary

Table 13 provides summary assessment results at the Entity-level for the Equipment area. The overall degree of alignment of the Equipment area of 61% is simply the average of these assessments for all area classes. Greater detail on the aligned classes from the LC2IEDM and the notes explaining the alignment are included in the table of Appendix C. The full details are available in the assessment database.

Table 13. Equipment Area Entity-Level Assessment Results.

WARSIM-to-LC2IEDM Alignment	
JSIMS FOM Class	Degree of Alignment To the LC2IEDM
abstract	88%
abstract.land	86%
abstract.land.equipment_type	57%
abstract.land.personnel_type	82%
abstract.land.rotary_wing_type	57%

WARSIM-to-LC2IEDM Alignment	
JSIMS FOM Class	Degree of Alignment To the LC2IEDM
org	84%
org.land	54%
org.land.equip_group	53%
org.land.supply_cache	52%

We assessed a total of 22 JSIMS classes and complex types as part of assessing alignment in the equipment area. This included State-level assessments of 136 attributes, of which 117 were deemed relevant. Figure 26 shows that the majority of these attributes had a de-

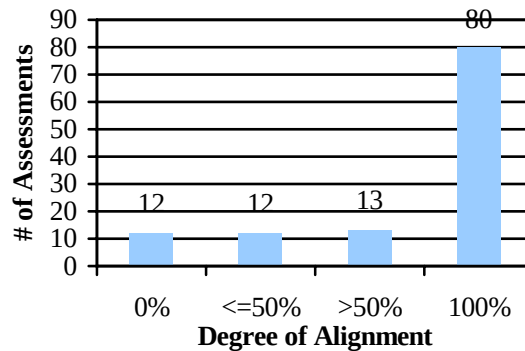


Figure 26. Equipment Area Attribute Alignment Assessment Results
gree of alignment of 100%; however, 12 attributes did not align at all.

6.3 Environment Area

6.3.1 Overview of Environment Area Alignments

An alignment analysis was performed on all the features defined in the TCDM that have attributes. These attributed features represent 167 of the 929 attributes in revision 1.2a of the TCDM. The remaining features were incomplete to the extent that an analysis was not possible. Following the Entity-Level assessment, a State-Level assessment was performed on the 89 attributes associated with features described in the TCDM. Finally, the TCDM data types were evaluated in 60 Value-Level assessments.

Most types of TCDM features were mapped to the LC2IEDM FACILITY-TYPE entity, rather than to a subtype of the FEATURE entity. The rationale for this was that there appeared to be a direct semantic map between types of TCDM features and LC2IEDM FACILITY-TYPES. That is, not only did the LC2IEDM include an entity code for the specific feature under analysis, examination of the attributes of the TCDM feature indicated that the semantics of the feature and the LC2IEDM entity were very close. Examples of these TCDM features include Airport, Infantry Trench, and Minefield.

In some cases, the mapping from TCDM features to LC2IEDM entities was not intuitive. TCDM feature Cleared Way/Cut Line/Firebreak maps to the FACILITY-TYPE entity in LC2IEDM rather than to the CONTROL-FEATURE-TYPE entity because there was an exact entity code. TCDM feature Breakwater/Groin was mapped to FACILITY-TYPE because an entity code exists

for Jetty, which was semantically close. TCDM features Hops and Rice field were also both mapped to the FACILITY-TYPE entity in LC2IEDM because an entity code exists for Crop-land, rather than to the GEOGRAPHIC-FEATURE-TYPE entity, as one might have expected. An even smaller number of TCDM features mapped to the LC2IEDM EQUIPMENT-TYPE entity. These include TCDM features Airport Lighting, Crane, Disk/Dish Antenna, and Nuclear Reactor.

We mapped certain TCDM features to both FACILITY and FEATURE entities. Such TCDM features:

- Tend to have no analog in the category codes of either FEATURE-TYPE or FACILITY-TYPE. In such cases the mapping is not intuitive. The preferred mapping would depend on how an application will use the data.
- Have that attributes are covered by features and facilities in the LC2IEDM. Examples of such features are Built-Up Area and Grandstand.

It should be noted that we originally interpreted Environmental Data Coding System (EDCS) Classification Codes as being part of the TCDM. In fact this is not always the case. During the review of this document, we learned that some of our Value-level TCDM assessments use non-TCDM codes. Unfortunately we did not have the resources to revise the assessments. Some assessments may therefore have a higher degree of alignment than indicated. However, we do not expect that the overall degree of alignment for the Environment area would change significantly if we were to re-conduct these assessments.

6.3.2 Alignment Example: Infantry Trench

This section provides an example to illustrate how the data alignment method was applied in the study. It shows the case where a TCDM feature, Infantry Trench, was mapped exactly to an LC2IEDM category code.

The TCDM feature Infantry Trench was mapped to the LC2IEDM FACILITY-TYPE CATEGORY CODE value TCH (Trench). The TCDM feature is defined as *“trench, typically integrated into a complex obstacle system, to provide cover, concealment, protected fighting positions and communications capability for infantry.”* The LC2IEDM entity is defined as *“a linear excavation dug for defensive purposes.”* At the entity level this mapping received an assigned degree of alignment of 75%. This measure indicates a high degree of alignment, with minor changes to one model resulting in perfect alignment. Following the alignment methodology, the State level assessment was then performed on each of the attributes associated with Infantry Trench. Infantry Trench has five attributes: Damage, General, Depth Below Surface Level, Object Identification Number, Preparation for Destruction Completion, Explosive (Fraction), and Width.

Damage, General was mapped to ACTION-EFFECT-DESCRIPTION-CODE in the LC2IEDM. In the TCDM Damage, General is defined as *“the extent of physical injury/damage in terms of fractional degradation from a healthy state. The following interpretations may be applied: 1/4: Slight Injury/Damage, 2/4: Moderate Injury/Damage, 3/4: Heavy Injury/Damage, 4/4: Fatally Injured or Completely Destroyed.”* In the LC2IEDM ACTION-EFFECT-DESCRIPTION-CODE is defined as *“the specific value that represents or denotes the*

type of outcome of a specific action that is being estimated or recorded.” The mapping was assigned a 100% degree of alignment. Continuing down to the Value level assessment, the range of values represented by the TCDM attribute were assessed with respect to the LC2IEDM. At the Value level a precise degree of alignment is calculated for the attribute. The values that can be represented in the TCDM attribute range from 0 to 100, where zero indicates no damage. Although the LC2IEDM provides 19 enumerations, including captured, burning, illuminated, consumed, and suppressed, it does not include a value representing no damage. Slight, moderate, heavy, and complete damage are included in the LC2IEDM, and map well to the TCDM values. Using the fractional ranges indicated in the TCDM, four out of five values can be represented in the LC2IEDM. Thus, an 80% degree of alignment was assigned for the attribute Damage, General.

Depth Below Surface Level was mapped to ELEVATED-ABSOLUTE-POINT-ELEVATION-DIMENSION in the LC2IEDM. In the TCDM, Depth Below Surface Level is defined as *“distance measured from the highest point at surface level to the lowest point of the object below the surface. Recorded values are positive numbers.”* In the LC2IEDM, ELEVATED-ABSOLUTE-POINT-ELEVATION-DIMENSION is defined as *“the elevation of an absolute point above or below the vertical datum as defined in the World Geodetic System 1984 (WGS 84).”* The mapping was assigned a 75% degree of alignment. The actual degree of alignment was then calculated for Depth Below Surface Level by assessing the range of values representable in the models. In the TCDM, the attribute Depth Below Surface Level is a single-precision floating-point number that can hold values ranging from 0–120,000 decimeters. The attribute ELEVATED-ABSOLUTE-POINT-ELEVATION-DIMENSION in the LC2IEDM is a numeric data type with twelve digits, three following the decimal point. Every value representable in the TCDM can be accommodated within the nine digits provided in the LC2IEDM. Thus, a 100% degree of alignment was assigned for this attribute.

The attribute Object Identification Number in the TCDM was mapped to OBJECT-ITEM-ID in the LC2IEDM. In the TCDM the attribute is defined as *“unique object identification number within a dataset.”* In the LC2IEDM it is defined as, *“the unique value, or set of characters, assigned to represent a specific OBJECT-ID and to distinguish it from all other OBJECT-ITEMs.”* A 100% degree of alignment was assigned for this attribute. Proceeding to the Value level, the data types and the values that can be represented by each attribute were assessed. In the TCDM, the Object Identification Number can assume any value in the range –2147483647 to 2147483647. In the LC2IEDM, OBJECT-ITEM-ID is represented as a numeric data type with fifteen digits. All TCDM attribute values may be represented in the LC2IEDM attribute. A 100% degree of alignment was assigned for this attribute.

The attribute Preparation for Destruction Completion, Explosive (Fraction) in the TCDM was mapped to the attribute ACTION-TASK-STATUS-COMPLETION-FRACTION in the LC2IEDM. Preparation for Destruction Completion, Explosive (Fraction) is defined as *“the degree to which a structure, obstacle, or other object has been prepared for destruction by explosives.”* The LC2IEDM attribute ACTION-TASK-STATUS-COMPLETION-FRACTION is defined as *“the portion of the planned ACTION-TASK that is estimated to have been accomplished.”* The mapping was assigned a 100% degree of alignment. Continuing to the Value level assessment, the data types of the attributes were assessed. The TCDM attribute can represent values in the range of 0–100. The LC2IEDM attribute is represented as a numeric

data type with six digits, three after the decimal point. All of the TCDM attribute values could thus be represented in the LC2IEDM attribute. This mapping was assigned a 100% degree of alignment.

The last attribute of Infantry Trench is Width. Width is defined as “a measurement of the shorter of two linear axes. For a square object, measure either axis. For a round object, width shall be equal to LENGTH_OR_DIAMETER. For a bridge, the width is the measurement perpendicular to the axis between the abutments.” This attribute was mapped to the LC2IEDM attribute REGULAR-AREA-MINOR-DIMENSION which is defined as “the length of the shortest side of the minimum bounding rectangle of a specified regular area.” A 75% degree of alignment was assigned for this mapping. Assessing the data types at the Value level, we see that the TCDM attribute can represent values in the range of 1–300. The LC2IEDM attribute, a data type with twelve digits, three following the decimal point, can represent each of the TCDM values. Thus, a 100% degree of alignment was assigned for this attribute.

Figure 27 shows the relationship between the LC2IEDM entities that model a TCDM infantry trench. The identified OBJECT-ITEM is associated with a FACILITY-TYPE; the specific FACILITY has an associated LOCATION. A non-identifying relationship defines the trench’s damage and preparation for destruction.

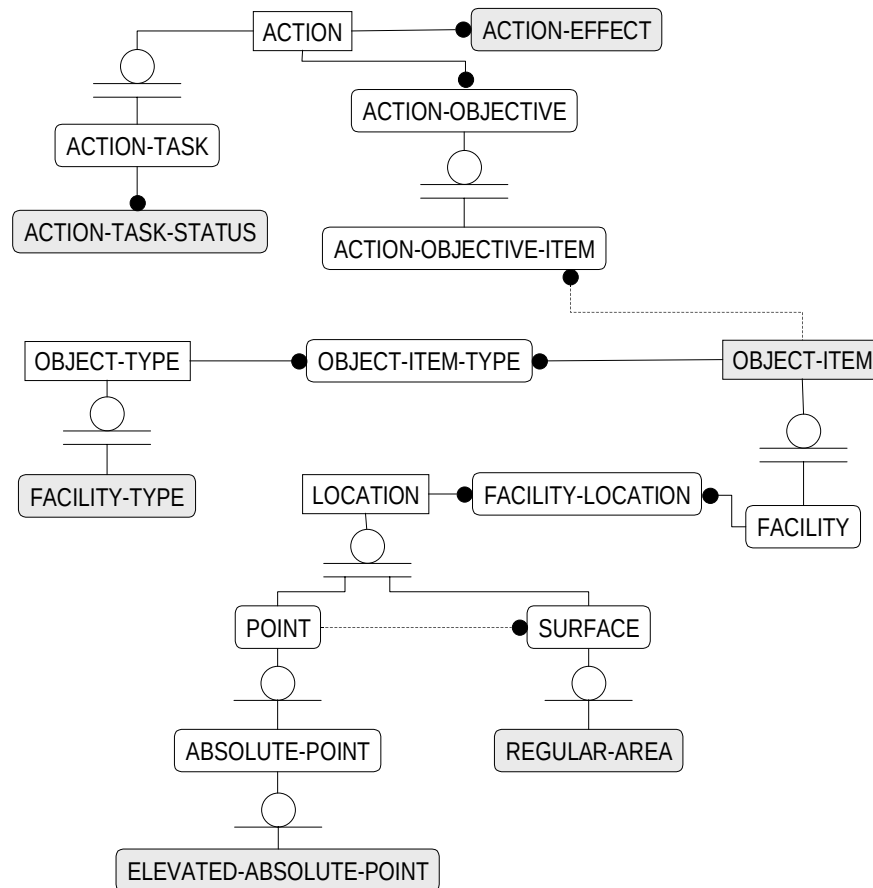


Figure 27. Relationship Among LC2IEDM Entities that Model an Infantry Trench

The results of the State and Value-level assessments are shown in Table 14. The methodology now specifies that the computed degree of alignment values are averaged, or “rolled up”, to provide the entity level degree of alignment. Adding the alignments computed for each of the attributes, and dividing by the number of attributes, resulted in a 96% degree of alignment for the feature Infantry Trench. An adjustment was then applied. Adjustments are used to fine tune the calculated degree of alignment when multiple features in the TCDM are mapped to the same entity in the LC2IEDM. In this case, slightly different data mapped to the same entity would no longer be distinguishable. The adjustment was 100% for this feature as it uniquely maps to the code TCH (Trench) for the LC2IEDM entity FACILITY-TYPE.

Table 14. Degree of Alignment of Infantry Trench Attributes

Infantry Trench Attribute	Assigned Degree of Alignment	Computed Degree of Alignment
Damage, General	100%	80%
Depth Below Surface Level	75%	100%
Object Identification Number	100%	100%
Preparation for Destruction Completion, Explosive (Fraction)	100%	100%
Width	75%	100%

6.3.3 Environment Area Assessments Summary

In accordance with the alignment study method, the degree of alignment of each of the features described in the TCDM is expressed as a percentage. The features and their degree of alignment were then allocated to the appropriate coverage, and an average degree of alignment calculated for the coverage. The results are shown in Table 15. This table shows that the overall degree of alignment of the LC2IEDM with the TCDM is 41%.

Table 15. Degree of Alignment by TCDM Coverage

TCDM Coverage	Degree of Alignment
Surface Areal	
Physiography	24%
Vegetation	21%
Urban	36%
Water	26%
Point Culture	53%
Linear and Point Hydrography	30%
Linear and Areal Terrain Obstacles	42%
Maritime Trafficability	29%
Linear and Point Transportation	46%
Administrative Boundaries	35%
Battlefield Elements	73%
Linear Connectivity	52%

Significantly, the Battlefield Elements coverage provides the highest degree of alignment at 73%. One goal during model development was to represent concepts from the war-fighter’s perspective. Surface Areal represent coverages with a poor degree of alignment

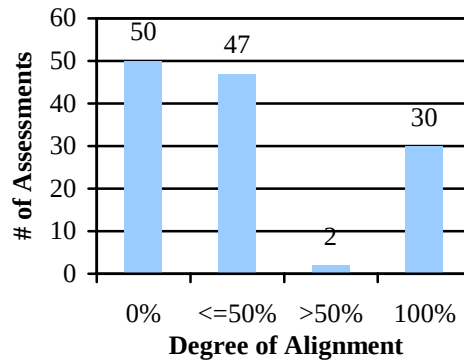


Figure 28. Environment Area Attribute Alignment Assessment Results

with the LC2IEDM. The version of the TCDM used in this study focuses primarily on terrain, and does not yet include features describing a complete Synthetic Natural Environment (SNE).

Figure 28 shows the results of 79 State-level assessments in the Environment area. All were relevant, 58 were terminal, and a majority had 0% alignment.

6.4 C4I

The C4I and C2 object classes published to the JSIMS FOM by WARSIM have no corresponding LC2IEDM data elements. Those C4I/C2 object classes and attributes whose names end with “_p” (for “private”) are used only by WARSIM for initialization. The C4I object classes provide an interface between the simulation and C4I system to translate to/from standard C4I messages using DTD (Document Type Definition), which is a set of rules that defines the elements, and their attributes, in an XML (Extensible Markup Language) document. These objects initialize and hold the state needed by the C4I systems. The LC2IEDM does not contain data related to specific system implementations. Rather, the LC2IEDM represents battlefield objects commonly tracked by (primarily) land-based command and control systems. The following WARSIM C4I/C2 object classes were reviewed:

- c2_artifacts.land: land-specific C2 artifacts
- c2_artifacts.land.state: parent class for data tables required to hold the state needed by the C4I systems. It contains four complex and four atomic attributes in the following two object classes (#complex/#atomic):
 - c4i_handler (2/2): contains the state of the C4I handler.
 - toc_handler (2/2): contains the state of the TOC handler.
- initialization.land.c4i: superclass for data tables required to initialize the C4I systems. It contains 10 complex and 98 atomic C4I attributes in 15 object classes. Examples of these object classes (#complex/#atomic) are:
 - jsims_interaction_manager_p (0/8): C4I handler receives this Federation Object (FO), converts the data to XML format, and sends to CommunicationsManager to write the JSIMSInteractionManager XML data to disk via C4iiRemoteInSim.
 - communications_manager_p (1/3): TOCHandler receives this FO to create CommunicationsManager.

This study did, however, assess WARSIM battlefield objects and attributes related to C4I that were included within the organization/equipment object classes. Examples include org.land.comms_status, org.land.terminal_status, org.land.radio_status, org.land.sensor_status, org.land_type = MSE (mobile subscriber equipment), org.land_type = SIGNAL_CORPS, abstract.land.radio_capability, abstract.land.-terminal_capability, abstract.land.sensor_capability, and org.-land.unit.terminal_address_o.

7. LC2IEDM → WARSIM Alignment Assessment Results

This section presents the results of assessing the degree of alignment going from the LC2IEDM to WARSIM using the process described in Section 5. These results can be summarized for the main conceptual areas as follows:

Table 16. Degree of Alignment of WARSIM with Respect to LC2IEDM Concepts

Conceptual Area	Degree of Alignment
Unit	49%
Equipment	42%
Environment:	
Facility	59%
Geographic Feature	63%

Note that the alignment assessment of the Environment area going in this direction was not completed due to resource constraints. Since only two of the relevant environmental entities were assessed, an overall assessment cannot be assigned.

7.1 Unit

Figure 29 shows the major LC2IEDM entities that participate directly in modeling a unit. Each unit is modeled as an instance of the UNIT entity, a subtype of ORGANISATION, which is a subtype of OBJECT-ITEM. An OBJECT-ITEM has associated type and status information. An ORGANISATION exists in relation to other organizations, via the ORGANISATION-ORGANISATION-ASSOCIATION entity. This view differs from previous views (see Figure 20) of the Unit area because it focuses on how units of all types are represented in the LC2IEDM, independently of the unit data modeled by WARSIM. For example, it includes the subtypes (SUPPORT-UNIT-TYPE, COMBAT-UNIT-TYPE, HEADQUARTERS-UNIT-TYPE) of UNIT-TYPE, which were not needed to represent WARSIM data.

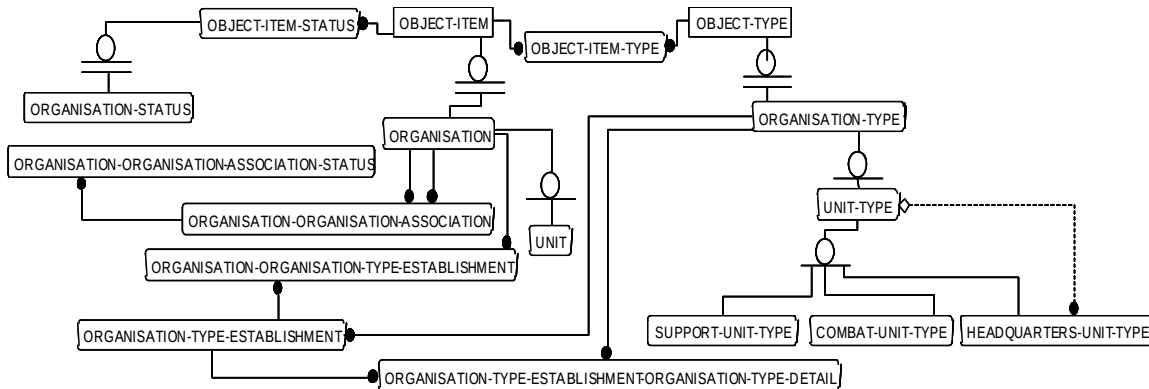


Figure 29. LC2IEDM Entities in the Unit Area

The LC2IEDM’s structure for modeling units is much richer than WARSIM’s. The most significant difference is that WARSIM only models subordinate and supporting units, whereas the LC2IEDM enumerates 45 different types of associations (full control, tactical control, operational control, etc.) between units. Moreover, the LC2IEDM models some organizational capabilities that WARSIM does not. For instance, the ORGANISATION-ORGANISATION-TYPE-ESTABLISHMENT entity lets the LC2IEDM describe nominal organizational composition and strength; WARSIM lacks this capability. A more specific example is the UNIT-TYPE-MOBILITY-CODE attribute, which characterizes a unit’s mobility; WARSIM has no equivalent.

Figure 30 shows the results of the LC2IEDM-to-WARSIM alignment assessment (also called “reverse” alignment) for the Unit area. Of 38 LC2IEDM attributes assessed, half align fully, but 29% do not align at all. The overall degree of alignment of the Unit area of WARSIM with respect to the LC2IEDM is 49%.

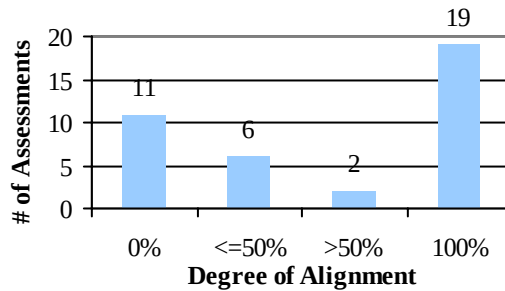


Figure 30. Unit area Reverse Alignment Assessment Results

7.2 Equipment

The LC2IEDM can model each instance of equipment that an organization possesses as an instance of MATERIEL. Figure 31 shows the major LC2IEDM entities that participate in modeling equipment. Each instance of equipment is modeled as an instance of MATERIEL, which is a subtype of OBJECT-ITEM. An OBJECT-ITEM has associations to OBJECT-TYPE, of

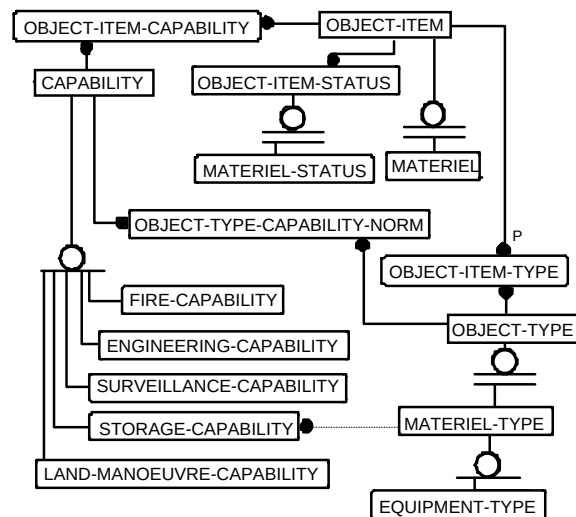


Figure 31. Important LC2IEDM Entities for Modeling Equipment

which MATERIEL-TYPE is a subtype; in other words, an instance of MATERIEL-TYPE models type information about an instance of MATERIEL. (Note that EQUIPMENT-TYPE is a subtype of MATERIEL-TYPE; the attributes of EQUIPMENT-TYPE provide further information that is relevant to modeling equipment, such as dimensions and loaded weight. There is however no LC2IEDM entity EQUIPMENT). Certain other capabilities of materiel and materiel types are modeled in the LC2IEDM as instances of CAPABILITY and its subtypes. Note that an instance of MATERIEL would likely be associated with one instance of MATERIEL-TYPE, and multiple instances of CAPABILITY (each describing a distinct capability).

Status is another important attribute of equipment. The LC2IEDM models equipment status via the MATERIEL-STATUS entity, which is a subtype of OBJECT-ITEM-STATUS. As Figure 31 shows, each instance of MATERIEL has zero or more associated instances of MATERIEL-STATUS. Different instances model status based on observer and observation time.

The JSIMS FOM models instances of equipment (though it more often models equipment groups; see Section 2) as instances of the equipment and platform classes. The JSIMS FOM describes equipment types as instances of class abstract and its subclasses.

Figure 31 clearly illustrates the rich set of equipment modeling relationships that the LC2IEDM provides. The LC2IEDM has specific entities for modeling status and capability. WARSIM, by contrast, has no classes designated for describing status and capability; it only assigns class-specific attributes. Moreover, the LC2IEDM provides (resolved via associative entities such as OBJECT-ITEM-TYPE) many-to-many relationships between major entities (such as OBJECT-ITEM and OBJECT-TYPE), whereas WARSIM's class structure only provides one-to-many relationships.

We assessed these entities according to the methodology in Section 5.5, starting at the Conceptual level and drilling down to the Value level. Table 17 summarizes the effort in terms of number of elements assessed. From the single Conceptual-level assessment that comprises the Equipment concept, we derived 14 Entity-level assessments, 58 State-level assessments, and 19 Value-level assessments. One attribute (CAPABILITY-ID) was judged to be wholly dependent on other attributes and therefore irrelevant. 38 attributes were terminal. Of these, 20 did not align to any JSIMS FOM attribute (i.e., their degree of alignment was 0). Of the remaining 18, several had fixed values (e.g., in the context of equipment, the value of OBJECT-ITEM-CATEGORY-CODE would always be MA (materiel). The rest represent ambiguous knowledge.

Table 17. Summary of Element Assessment Effort for Equipment

Level	Number of Assessments		Irrelevant Elements	Terminal Elements
	Total	Unique		
Conceptual	1	1	0	0
Entity	14	14	0	0
State	58	58	1	38
Value	19	15		

The LC2IEDM equipment area aligns to the JSIMS FOM classes listed in Table 18. The breadth of classes reflects our practice of being willing to choose a JSIMS FOM class if it

contains even one attribute to which an LC2IEDM attribute might align at the State level. For this reason, the superclass equipment is used often: if one of its subclasses is used, then its attributes equipment_name and abstract_id are also used in context to identify the equipment modeled by the subclass.

Table 18. JSIMS FOM Classes Used in Aligning the Equipment Area

Class	Occurrences	Class	Occurrences
abstract	3	equipment.naval_sensor	1
.land	1	.naval_weapon_system	1
.equipment_type	3	.sensor	1
equipment	5	.comint	2
.airborne_sensor	1	.elint	2
.esm	2	.opint	1
.iff	2	.radint	2
.ir	2	.sensor_deck	2
.optical	2	platform	6
.equipment_radiating	0		
.airborne_radar	1		
.ald	1		
.gps	1		
.rf_noise_jammer	1		

LC2IEDM’s comparative wealth of modeling capability in the equipment area suggests it would not align well with WARSIM, a hypothesis borne out by our assessment. We assessed 14 entities and 58 attributes. Figure 32 shows the results. Over one third of the attributes did not align at all, and over two thirds aligned less than 50%. The overall degree of alignment for the equipment area was 42%.

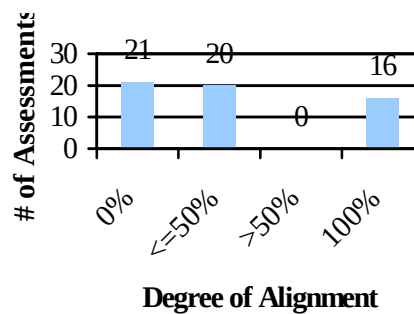


Figure 32. Results of Equipment Area Attribute Alignment Assessments

7.3 Environment

Performing an assessment of the “reverse” alignment between the LC2IEDM and TCDM models proved difficult. The LC2IEDM model provides templates, in the form of -TYPE entities, from which to create specific entity instances. FACILITY-TYPE and FEATURE_TYPE allow a modeler to instantiate a wide variety of entities, using the category codes

(FACILITY-TYPE-CATEGORY-CODE or FEATURE-TYPE-CATEGORY-CODE) to identify them. As a result the model does not contain a large collection of “pre-defined” entities in the form of facilities or features. The LC2IEDM contains only two FACILITY entities, MINEFIELD and BRIDGE. The following sections present an assessment of the MINEFIELD entity, and of category code-based mappings.

It should be noted that we originally interpreted (EDCS) Classification Codes as being part of the TCDM. In fact this is not always the case. During the review of this document, we learned that some of our Value-level TCDM assessments use non-TCDM codes. Unfortunately we did not have the resources to revise the assessments. Some assessments may therefore have a lower degree of alignment than indicated. However, we do not expect that the overall degree of alignment for the Environment area would change significantly if we were to re-conduct these assessments.

7.3.1 Example Alignment: Minefield

The LC2IEDM entity MINEFIELD was mapped to the TCDM feature MINEFIELD. The LC2IEDM entity is defined as “*a FACILITY that is an area of land or water containing mines laid with or without a pattern.*” The TCDM feature is defined as “*an area of land or water throughout which explosive mines have been laid.*” Based on the similarity of these definitions and the range of attributes, a 100% degree of alignment was assigned for this LC2IEDM entity. MINEFIELD has five attributes: MINEFIELD-ID, MINEFIELD-SPACING-DIMENSION, MINEFIELD-PATTERN-CODE, MINEFIELD-PERSISTENCE-CODE, and MINEFIELD-PURPOSE-CODE.

Three of these attributes, MINEFIELD-SPACING-DIMENSION, MINEFIELD-PATTERN-CODE, and MINEFIELD-PERSISTENCE-CODE, have no corresponding attribute in the TCDM. For each of these attributes an assigned and computed 0% degree of alignment was recorded for the State-level assessment.

The LC2IEDM MINEFIELD attribute MINEFIELD-ID is defined as “*The FACILITY-ID of a specific MINEFIELD (a role name for OBJECT-ITEM-ID).*” This attribute was mapped to the TCDM attribute Object Identification Number. Object Identification Number is defined as “*unique object identification number within a dataset.*” While these definitions are not synonymous, an encoding would be possible. For this reason, a 75% degree of alignment was assigned for this attribute. Continuing to the Value-level assessment, the data type of each attribute was evaluated. The LC2IEDM attribute is represented as a numeric value having fifteen digits. In the TCDM, the Object Identification Number can assume any value in the range –2147483647 to 2147483647. This represents only a vanishingly small percentage of the values that can be represented in the LC2IEDM, but in practice it is large enough to represent any set of values that might be used. A 100% degree of alignment was assigned for this attribute.

The LC2IEDM MINEFIELD-PURPOSE-CODE is defined as “*the specific value that represents or de-notes the intended function of a specific MINEFIELD.*” MINEFIELD-PURPOSE-CODE was mapped to the TCDM attribute Mine Type Category. This attribute is defined as “*the type of mine.*” A 50% degree of alignment was assigned for this attribute. Continuing to the Value-level assessment, the data type of each attribute was assessed. Both data types

are enumerations. The LC2IEDM MINEFIELD-PURPOSE-CODE has seven enumerations including heavy tactical, light tactical, medium tactical, nuisance, phony, protective, and unknown. The TCDM Mine Type Category has twelve enumerations including such values as Ocean, Buried, Ocean, Bottom, Mixed, Anti-Tank, Anti-Personnel, Phony/Decoy and Unknown. Only two of the seven LC2IEDM enumerations, Phony/Decoy and Unknown, were mapped to TCDM enumerations. Thus, a 29% degree of alignment was computed for the LC2IEDM attribute MINEFIELD-PURPOSE-CODE.

The results of the State and Value-level assessments are shown in Table 19. Performing a roll up of the computed values for the LC2IEDM MINEFIELD facility, by averaging the computed degree of alignment for the attributes of this entity along with those of its supertypes (not shown), resulted in a 57% degree of alignment at the Entity level. No adjustment factors were applied in the reverse alignment.

Table 19. Degree of Alignment of Minefield Attributes

MINEFIELD Attribute	Assigned Degree of Alignment	Computed Degree of Alignment
MINEFIELD-ID	75%	100%
MINEFIELD-SPACING-DIMENSION	0%	0%
MINEFIELD-PATTERN-CODE	0%	0%
MINEFIELD-PERSISTENCE-CODE	0%	0%
MINEFIELD-PURPOSE-CODE	50%	29%

7.3.2 Example Alignment: LC2IEDM Category Codes

Many of the features and facilities found in the LC2IEDM are represented as category codes within the FACILITY-TYPE or FEATURE-TYPE subtypes, CONTROL-FEATURE-TYPE, GEOGRAPHIC-FEATURE-TYPE, and METEOROLOGIC-FEATURE-TYPE. These category codes are attributes of their FACILITY- and FEATURE-TYPES. In performing an alignment assessment, this portion of the work deviates from the prescribed approach. At the Entity level, the methodology dictates that a single LC2IEDM entity is mapped to zero or more TCDM features. At the State level, a single LC2IEDM attribute is mapped to zero or more TCDM attributes. For the majority of the features and facilities in the LC2IEDM this was not possible. Instead, LC2IEDM attributes, the category codes for the features and facilities, were mapped to TCDM features.

Using this approach we performed a pseudo-mapping for all the features and facilities in the LC2IEDM. The results of that mapping are shown in Table 20. Many of the mappings were exact: LC2IEDM GEOGRAPHIC-FEATURE-TYPE LAK (Lake/pond) was mapped to TCDM feature Lake/pond. Some of the mappings were less exact: LC2IEDM GEOGRAPHIC-FEATURE-TYPE MTN (Mountain) was mapped to TCDM feature Mountainous Region. LC2IEDM FACILITY-TYPE CEM (Cemetery/graveyard/burial ground) was mapped to both TCDM feature Cemetery and TCDM feature Burial Grounds. In some cases precision would be lost though the mapping: LC2IEDM FACILITY-TYPES FORTLN (Fortified Line), FORTPT (Fortified Point), and FRTARE (Fortified Area) all mapped to the TCDM feature Fortification. An adjustment factor would need to be applied to any assigned degree of alignment to account for this. In other cases, additional information would be needed to perform a correct mapping: does LC2IEDM FACILITY-TYPE INDINS (Industrial Installation) map to

TCDM feature Industrial Complex (Heavy), Industrial Complex (Light), Industrial Works, or Industrial Building?

Table 20. Pseudo-Mapping Results

LC2IEDM Category Code	% Mapped to the TCDM
FACILITY-TYPE CATEGORY CODE	51%
CONTROL-FEATURE-TYPE CATEGORY CODE	5%
GEOGRAPHIC-FEATURE-TYPE CATEGORY CODE	83%
METEOROLOGIC-FEATURE-TYPE CATEGORY CODE	0%

Most striking in the results tabulated below is the degree of alignment estimated for the CONTROL-FEATURE-TYPE category codes. The LC2IEDM provides a much richer range of control features than does the TCDM. The fact that no mapping was possible between the LC2IEDM METEOROLOGIC-FEATURE-TYPE category codes and features in the TCDM was expected. The TCDM purposefully omitted all meteorological information in this revision.

Eliminating from consideration the LC2IEDM METEOROLOGIC-FEATURE-TYPE, the overall degree of alignment between the LC2IEDM codes and the TCDM features is 46%.

8. Recommendations

The analysis has led to recommendations on what steps that may be taken to improve the alignment of WARSIM and the LC2IEDM. This section presents these recommendations. Recommendations are stated as categories of change, rather than as suggestions for changes to specific attributes or domains. The alignment assessment databases, and to a lesser extent Appendices B–D, can be used to identify exactly which areas of the models must change to increase alignment.

These recommendations are derived from a study of alignment between the LC2IEDM and WARSIM, but they have broader implications. In our experience, they identify general problems that C4ISR systems have supporting M&S data, and that M&S systems have supporting C4ISR data. Any program that needs C4ISR/M&S interoperability must address the problems raised in this report. The following recommendations are one approach to solving these problems.

8.1 LC2IEDM Enhancements

Several recommendations can be made for enhancements to the LC2IEDM. In creating these recommendations, the study evaluated what changes would be beneficial for the general class of simulations to which WARSIM belongs. Thus, the changes recommended were not specific to WARSIM, but would support requirements from the larger class of constructive simulations.

8.1.1 Scope

Suggested enhancements to the LC2IEDM are organized by the three assessment areas: Unit, Equipment, and Environment.

8.1.2 Recommended Changes for Simulation Unit Data

The enumerations for the types of units in LC2IEDM need to be expanded to reflect more closely the data requirements in simulations. In addition, structures for handling information exchange requirements, such as those that exist in other large standardized models (e.g., the C4ISR Core Architecture Data Model (CADM)) may be needed to handle aspects such as the frequency of the messaging among nodes, the timeliness of the data, its temporal validity, etc. The same is true for those simulation data requirements that express assessments of the unit with respect to its activities, e.g., mission effectiveness and morale, that currently cannot be specified other than as text, e.g., via the LC2IEDM structure CONTEXT. Finally, it may be necessary in LC2IEDM to provide enumerations that reflect assessments in a quantitative form rather than in general terms, e.g., percentage of concealment of a unit, as opposed to the general activity of hiding as part of an action specified for that military unit.

8.1.3 Recommended Changes for Simulation Equipment Data

As in Section 8.1.2, there is a need for enlarging the enumerations in LC2IEDM to handle the numerous equipment types specified in the simulation model, but, perhaps more importantly, for introducing the concept of PLATFORM as an explicit subtype of MATERIEL-TYPE to enable a closer alignment between the two models. The need in LC2IEDM for quantitative enumerations, e.g., as percentages, is also present here. The motion of units in LC2IEDM is primarily along 2-dimensional paths. The model does not support multiple geodetic reference models, expecting every entry to be referenced to the WGS-84 standard. Allowing for different coordinate systems of reference and for 3-dimensional paths would permit the handling of spatial trajectories, orbits, etc., as well as direct upload and download of coordinates without intermediate transformations.

In fairness to the LC2IEDM it should be noted that the domain value level specification in WARSIM elements published to the JSIMS FOM were not sufficiently explicit as to allow unambiguous interpretation of the meanings of those values.

8.1.4 Recommended Changes for WARSIM Environment Data

What has been said with respect to the Unit and Equipment areas in WARSIM applies equally so to the Environment area, namely, that a substantial expansion of the enumerations in LC2IEDM is needed to better support the data requirements of the simulation. On the other hand, it is not clear from the data provided in the TCDM whether all the classes are primarily used as map overlays, and, therefore, ought to be treated simply as instances of the LC2IEDM entity FEATURE-TYPE, or whether in fact those classes that one normally view as instances of facilities or equipment are in fact used as such in the simulation. There is, therefore, in the current alignment assessment a certain amount of uncertainty. While some classes in WARSIM correspond to enumerations in FACILITY-TYPE in LC2IEDM and others appear to map cleanly to enumerations in FEATURE-TYPE, not all cases are easily decided. Thus, we encourage the TCDM developers to draw a stronger distinction between TCDM features that are intended just to support map overlays and those that are treated as genuine facilities.

Last but not least, there is a need to enlarge the set of attributes in LC2IEDM that characterizes either a FEATURE or a FACILITY so that all of the 86 attributes that TCDM specifies for its environment classes can be captured in LC2IEDM, as opposed to only 41 currently.

8.2 Modeling And Simulation Recommendations

WARSIM was found to cover only 61% of the LC2IEDM Unit area data elements, and 70% of its Equipment area data elements. This indicates that WARSIM (as represented by its elements of the JSIMS FOM) has substantial limitations in being able to represent information that is important to effective C2 operations. Some of these limitations are a reflection of using an HLA FOM as the model source, since a FOM cannot represent class associations (such as unit command structure) except for class inheritance hierarchies, even though the underlying simulation may support them. Thus, it would be helpful in assessing a simulation's modeling capabilities and its potential for effective data interop-

erability, to have additional sources of modeling information. Such information could be provided either by maintaining current design and implementation models in addition to a FOM, or by supplementing a FOM with just the neglected associational information.

Even neglecting the absence of association information, the WARSIM data elements fell far short of capturing all the types of data used in C2 interchanges. The mismatches between the models examined indicates that Army M&S systems may benefit from a reference object model which identifies all relevant C4I data elements within the context of a structure that would be applicable to M&S design. Development of such a model is a natural next step.

References

- [Army 2000] *Joint Technical Architecture – Army*, Version 6.0 (May 2000). See <http://arch-odisc4.army.mil/aes/aea/jta-a/jtaa60/html/jtaa60.htm>.
- [Army 2001] Army Operational Data Repository (<http://aodrarch-odisc4.army.mil/>), 2001.
- [Booch 1996] Grady Booch: *Best of Booch: Designing Strategies for Object Technology*, Cambridge University Press, New York, New York (1996).
- [BJRR 1998] Grady Booch, Ivar Jacobson, James Rumbaugh, Jim Rumbaugh: *The Unified Modeling Language User Guide*, Addison-Wesley, Boston, MA (1998).
- [CN 2001] Paul Clements and Linda Northrup: *Software Product Lines: Practices and Patterns*, Addison-Wesley, Boston, MA (2001)
- [DoD 1991] Dod-8320.1, *Data Standardization Procedures*, September 1991. See <http://www-datadmn.itsi.disa.mil/guidance.html>.
- [DoD 1998] DoD-8320.1-M-1, *Data Standardization Procedures*, April 1998. See http://www-datadmn.itsi.disa.mil/8320_1m1.html.
- [DoD 1998b] *High-Level Architecture Object Model Template Specification*, Version 1.3 (February 5, 1998). See <http://www.openskies.net/files/HLA-omt1-3.pdf>.
- [DoD 1999] *Department of Defense Joint Technical Architecture*, Version 3.0, (November 1999). See <http://www-jta.itsi.disa.mil/>.
- [HB 1999] Michael Hieb and James Blalock, “Data Alignment between Army C4I Databases and Army Simulations,” Paper 99S-SIW-034, 1999 Spring Simulation Interoperability Workshop (March 1999).
- [HLA 2000] *IEEE Standard for Modeling and Simulation (M&S) High Level Architecture (HLA)—Framework and Rules*, IEEE, Piscataway, New Jersey (September 2000). See <http://www.dmsi.mil/index.php?page=121>.
- [HS 2000] Michael Hieb and Ron Sprinkle, “Simulation Infrastructure for the DII COE Architecture: The Army Vision,” Simulation Interoperability Workshop, Orlando, FL (September 2000).
- [IDA 2001] Steven Wartik, Brian Haugh, Francisco Loaiza, and Michael Hieb, *Alignment of Army Integrated Core Data Model and Object Management Standards Category*, Paper P-3596, Institute for Defense Analyses, Alexandria, Virginia (September 2001).

- [JSIMS 1999] JSIMS Terrain Common Data Model Revision 1.2a (<http://www.amso.army.mil/terrain/library/tcdm-rev.doc>), July 1999.
- [JSIMS 2001] *Federation Object Model (FOM) and Federation Policies for Joint Simulation System (JSIMS)*, Version 6.0, June 2001.
- [LSCZ 1998] Michael Lightner, J. Schanduaa, D. Cutts, and S. Zeswitz, “The High Level Architecture Command and Control Experiment – Lessons Learned in Designing an Extended Federation”, Paper 98S-SIW-93, 1998 Spring Simulation Interoperability Workshop (March 1998).
- [MHLW 2002] R. Morton, B. Haugh, F. Loaiza, S. Wartik, D. Heystek, and M. Hieb: “Building in Interoperability: A Comparison of the Joint Common Database (JCDB) and the WARSIM Object Model,” Paper 02S-SIW-082, 2002 Spring Simulation Interoperability Workshop, Orlando, FL, March 2002.
- [NATO 2000] NATO STANAG ADatP-32, Edition 2.0: “The Land C2 Information Exchange Data Model,” NATO HQ, Brussels, March 2000.
- [NIST 1993] *Information definition for information modeling (IDEF1X)*, National Institute of Standards and Technology, Gaithersburg, MD, 1993 (FIPS Publication 184).
- [PC 1986] Parnas, D. L. and Clements, P. C. (1986), “A rational design process: How and why to fake it.” *IEEE Transactions on Software Engineering*, 12(2):251–257
- [RMFS 2000] R. Richbourg, D. Miller, P. Foley, and G. Schiavone: “Standardizing the Codification of Environmental Objects: The Environmental Data Coding Specification,” Paper 00F-SIW-071, 2000 Fall Simulation Interoperability Workshop, Orlando, FL, September 2000.
- [WHLH 2001] Steven Wartik, Brian Haugh, Francisco Loaiza, and Michael Hieb, “Building in Interoperability: A Comparison of C4I Data Models and Simulation Object Models,” Paper 01S-SIW-021, Spring 2001 Simulation Interoperability Workshop, Orlando, Florida (March 2001).

Abbreviations and Acronyms

ABCS	Army Battle Command Systems	DDDS	Defense Data Dictionary System
AFATDS	Advanced Field Artillery Tactical Data System	DDM	DoD Data Model
AICDM	Army Integrated Core Data Model	DII	Defense Information Infrastructure
AMSAA	Army Materiel Systems Analysis Activity	DISA	Defense Information Systems Agency
AMSO	Army Model and Simulation Office	DoD	Department of Defense
ATCCIS	Army Tactical Command and Control Information System	DTD	Document Type Definition
C2	Command and Control	EAC	Environment Attribute Code
C2CDM	C2 Core Data Model	EDCS	Environmental Data Coding Standard
C3I	Command, Control, Communications & Intelligence	ER	Entity-Relationship
C4	Command, Control, Communications, and Computers	FO	Federation Object
C4I	Command, Control, Communications, Computers, & Intelligence	FOM	Federation Object Model
C4ISR	Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance	GH4	Generic Hub data model, version 4
COE	Common Operating Environment	GH5	Generic Hub data model, version 5
DB	Database	GTRS	Geotile Reference System
DBMS	Database Management System	HLA	High Level Architecture
DDA	DoD Data Architecture	ICAM	Integrated Computer Aided Manufacturing
		IDA	Institute for Defense Analyses
		IDEF1X	ICAM Definition Method 1 Extended
		IEEE	Institute for Electrical and Electronics Engineers

IITRI	Illinois Institute of Technology Research Insitute	NIST	National Institute of Standards and Technology
JCDB	Joint Common Database	ODISC4	Office of the Director for In- formation Services for C4
JDM	JCDB Data Model	OMSC	Object Management Standards Category
JSIMS	Joint Simulation System	OO	Object Oriented
JTA	Joint Technical Architecture	OOTW	Operations Other Than War
JTA-A	Joint Technical Architecture— Army	SNE	Synthetic Natural Environment
LC2IEDM	Land C2 Information Exchange Data Model	SQL	Structured Query Language
M&S	Modeling and Simulation	STANAG	Standards Agreement
MIDB	Modernized Intelligence Data- base	TCDM	Terrain Common Data Model
MRCI	Modular Reconfigurable C4ISR Interface	UML	Unified Modeling Language
NASM	National Air Space Model	URL	Uniform Resource Locator
NATO	North Atlantic Treaty Organi- zation	WARSIM	Warfighter's Simulation
NGO	Non-Governmental Organiza- tion	WGS	World Geodetic System
		XML	Extensible Markup Language

Appendix A. Notation

This appendix provides a brief description of the IDEF1X and UML notation used in this report. It is intended for reference and not as a tutorial. The reader should consult [NIST 1993] for more details on the IDEF1X, and [BJRR 1998] for more details on UML.

Some figures use shading (or, in the electronic version, color). Shading in diagrams has no semantics in this document. It is used to draw the reader's attention to specific elements of a figure or table. However, in some tables of Appendix F, shading of rows is used to distinguish assessments of entity alignments from separate assessments of their attributes on subsequent rows (as described there).

A.1 IDEF1X Notation

IDEF1X (ICAM Definition 1 Extended [NIST 1993]) is a specification for modeling entities, attributes, and their relationships. The specification includes a standard graphical notation. The following is a brief description of the components of that notation that appear in this report.

A box, with square or rounded corners, denotes an entity. If the box has square corners, it is an independent entity, i.e., an entity that depends on no other for its definition. If the box has rounded corners, it is a dependent entity. Figure A-1 shows the distinction between dependent and independent entities.

Relationships between entities are depicted using lines drawn between the entities. If the line is solid, the relationship is an identifying relationship. If the line is dashed, the relationship is a non-identifying relationship. The presence or absence of black circle at the

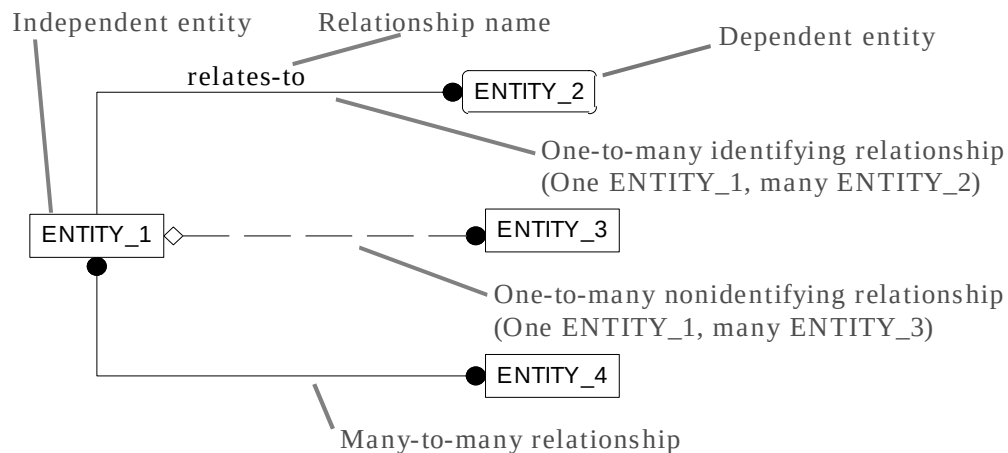


Figure A-1. IDEF1X Entity and Relationship Notation

end of the line specifies a relationship's cardinality. One instance of an entity on an end that has no circle participates in a relationship. Zero or more instances of an entity on an end with a circle participate in a relationship. A diamond on the end of the line for a non-identifying relationship means an instance of the entity at the "many" end need not reference an instance at the "one" end. Figure A-1 shows examples of how these relationships appear.

Some relationships are labeled, such as relationship labeled "relates-to" in Figure A-1. The label is optional. It has no semantic meaning; it merely serves to clarify the relationship's nature.

One entity may be a subtype of another. A subtype relationship is indicated by a circle with one or two lines beneath it. A line from the top of this glyph connects to an entity; that entity is the supertype. One or more lines from the bottom of this glyph each connect to a single entity; that entity is a subtype. Figure A-2 shows both complete and incomplete subtype relationships.

A subtype relationship has a discriminator, which is an attribute from the supertype. The value of a discriminator identifies the type of a subtype. If this attribute specifies all possible subtypes, the subtype relationship is *complete* and its glyph contains a double line (as shown in Figure A-2). If the attribute only describes a proper subset of possible subtypes, the subtype relationship is *incomplete* and its glyph contains a single line. Ordinarily, an IDEF1X diagram view with a complete subtype relation will display all of the subtype entities. However, in our presentation of particular examples, we do not always display all subtype entities due to space limitations and our focus on one or more entities of interest in an example.

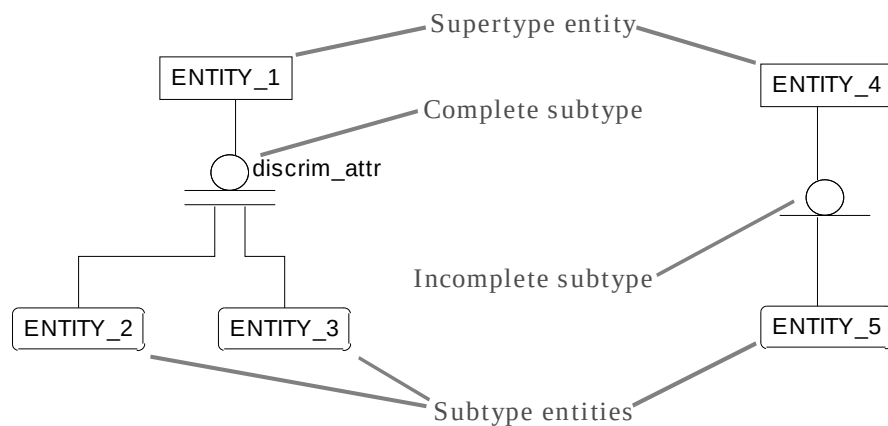


Figure A-2. IDEF1X Subtype Notation

IDEF1X diagrams may depict or omit attributes. The entities depicted in Figure A-1 and Figure A-2 have omitted attributes. An IDEF1X diagram that depicts attributes places the entity name atop the box. Within the box are attributes. Each line shows information on a single attribute. At a minimum, the line shows the attribute's name. It may also show the attribute's data type (after a colon) and that an attribute is a foreign key (indicated by an "(FK)" suffix). Attributes in the top sub-box are primary keys. Figure A-3 shows exam-

ples of entities displaying attributes; the entities are drawn from Figure A-1 and have foreign keys according to the relationships from that figure.

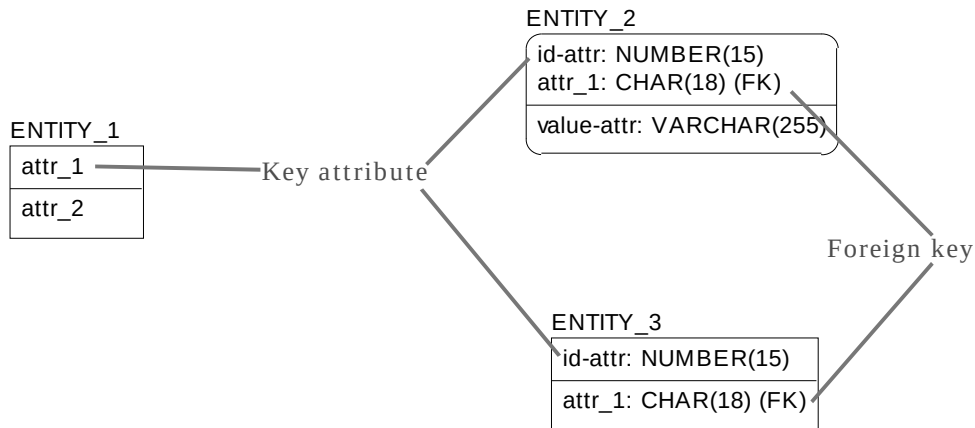


Figure A-3. IDEF1X Display of Attributes

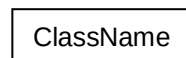
A.2 UML Notation

UML (Unified Modeling Language [BJRR 1998]) is a language for graphically depicting many software development entities. Part of UML includes a model for depicting classes and their associations. This part of the model has been used in this report.

A UML class is depicted as a rectangular box. The name of the class appears inside the box. The left side of Figure A-4 shows how a class is depicted when its attributes are omitted.

A UML diagram may show just a class's name. It may also show the class's attributes and

Class without attributes



Class with attributes

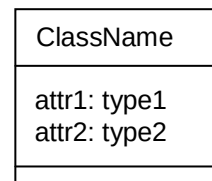


Figure A-4. UML Notation for Depicting Classes

methods, in which case the box is divided into three vertically stacked boxes. The top box contains the class's name. The middle box contains the class's attributes. The bottom box contains the class's methods. The right side of Figure A-4 shows how a class's attributes, including each attribute's data type, are depicted. Because the JSIMS FOM does not associate methods with classes, figures in this report show the bottom as empty.

One class may be a superclass of another. The first class is said to *generalize* the second class. Generalization is depicted by an upward arrow. See Figure A-5.

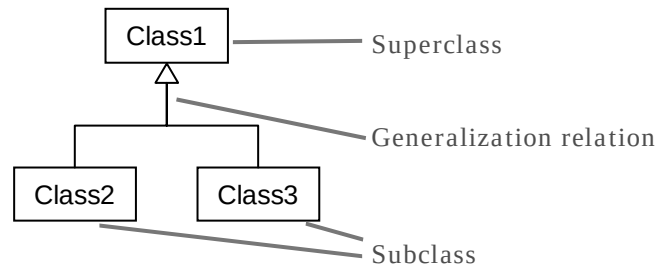


Figure A-5. UML Notation for Depicting Generalization Relationships

Appendix B. Unit Alignment Assessments

This appendix presents the Entity-level assessments related to the Unit concept. It is divided into two sections. Section B.1 gives the assessments for the degree to which WARSIM unit-related classes can be represented in the LC2IEDM. Section B.2 gives the assessments for the degree to which LC2IEDM unit-related entities can be represented in WARSIM.

Each section consists of a table. This table is broken into the individual Entity-level alignment assessments. Each assessment contains:

- The assessment's signature, of the form:

$$element \rightarrow \{e_1, e_2, \dots, e_n\}$$

The interpretation is that *element* in one model aligns to, i.e., can be represented by, the set of elements from the other model.

- Notes made by assessors during the alignment.
- The computed degree of alignment. This value has been computed from lower-level assessments, using the formulas discussed in the body of this study.
- Indications if the assessment is not applicable or terminal.

B.1 WARSIM→LC2IEDM Alignment

Table B-1. Unit Assessment Summaries: WARSIM→LC2IEDM Alignment

org→{ORGANISATION}	
Notes	A JSIMS org class aligns to an LC2IEDM ORGANISATION . 6 items map to ORGANIZATION (236, 237, 238, 296, 150036, 150102) We can distinguish a simple org object (whose WARSIM subclass is not assigned) from all other WARSIM unit class types – org.land.unit, org_perceived_unit_c and extended_perceived_unit_c – using the ORGANISATION-TYPE-CATEGORY-CODE which is set to "UN" for units. A simple org object can be distinguished from org.land and its subclasses because they are all either Units with a UNIT-TYPE-SERVICE-CODE set to "A" for Army or they have an ORGANISATION association to such a unit. The LC2IEDM OBJECT-TYPE-NAME might also be used to support this distinction, although there are no standard LC2IEDM names for such WARSIM classes
Computed Degree of Alignment:	84

org.land→{CAPABILITY, COMBAT-UNIT-TYPE, CONVOY, FIRE-CAPABILITY, HOLDING, MATERIEL-STATUS, OBJECT-ITEM, ORGANISATION-ORGANISATION-ASSOCIATION, ORGANISATION-STATUS, PERSON-STATUS, SUPPORT-UNIT-TYPE, UNIT-TYPE}	
Notes	6 items can map to land (Army) ORGANISATIONs (236, 238, 296, 150044, 150036, 150102). We can distinguish a simple org.land object (whose WARSIM subclass is not assigned) from an org.land.unit, org_perceived_unit_c and extended_perceived_unit_c – since its ORGANISATION-TYPE-CATEGORY-CODE will not be “UN” for unit. The org_perceived_unit_c and extended_perceived_unit_c WARIM objects can also be distinguished by the absence of a REPORTING-DATA-REPORTING-ORGANISATION-ID set to a unique ID chosen to distinguish ground truth. Org.land data is considered WARSIM ground truth, while perceived data is not. But, we don't see a way to distinguish org.land.equip_group and org.land.supply_cache from a simple org.land object. Hence, there is an adjustment factor ($50 + 50/3 = 67$). Although the LC2IEDM OBJECT-TYPE-NAME can be used to support this distinction, there are no standard LC2IEDM names for such WARSIM classes .
JSIMS Notes:	For Unit and Equipment areas
LC2IEDM Notes:	Used to associate an org.land object with an Army organization if it is not identified as a unit (which contains the UNIT-TYPE-SERVICE-CODE).
Computed Degree of Alignment: 54	
org.land.unit→{ORGANISATION, UNIT, OBJECT-ITEM, OBJECT-ITEM-TYPE, OBJECT-TYPE, OBJECT-TYPE-CAPABILITY-NORM, OBJECT-ITEM-CAPABILITY, HOLDING, OBJECT-ITEM-STATUS, ORGANISATION-STATUS ORGANISATION-ORGANISATION-ASSOCIATION, ACTION-TASK, ACTION-TASK-STATUS, ACTION, ACTION-RULE-OF-ENGAGEMENT, RULE-OF-ENGAGEMENT, ACTION-OBJECTIVE, ACTION-OBJECTIVE-TYPE, ACTION-OBJECTIVE-ITEM, TARGET, ACTION-RESOURCE, ACTION-RESOURCE-ITEM, ORGANISATION-ORGANISATION-TYPE-ESTABLISHMENT, ORGANISATION-TYPE-ESTABLISHMENT, ORGANISATION-TYPE-ESTABLISHMENT-MATERIEL-TYPE-DETAIL, ORGANISATION-TYPE-ESTABLISHMENT-PERSON-TYPE-DETAIL, MATERIEL-TYPE, EQUIPMENT-TYPE, UNIT-TYPE, ORGANISATION-TYPE, PERSON-TYPE, ORGANISATION-CONTROL-FEATURE-ASSOCIATION, CONTROL-FEATURE, FEATURE, FEATURE-TYPE, CONTROL-FEATURE-TYPE, FEATURE-LOCATION, LOCATION, SURFACE, POINT, MATERIEL-POINT, ORGANISATION-POINT, ORGANISATION-MATERIEL-ASSOCIATION, REPORTING-DATA, PERSON}	
Notes	4 items map to UNIT (299, 150044, 150036, 150102). Two other types of units – org_perceived_unit_c and extended_perceived_unit_c – can be distinguished by the absence of a REPORTING-DATA-REPORTING-ORGANISATION-ID set to a unique ID chosen to distinguish ground truth. Data in org.land.unit is interpreted to be WARSIM ground truth, unlike the merely perceived units. The LC2IEDM OBJECT-TYPE-NAME can be used to support this distinction, although there are no standard LC2IEDM names for such WARSIM classes .
LC2IEDM Notes:	Some JSIMS units are more general than LC2IEDM UNITs. Therefore this parent entity is needed for some mappings. LC2IEDM UNITs appear to be more narrowly defined than JSIMS units.
Computed Degree of Alignment: 46	

B.2 LC2IEDM→WARSIM Alignment

Table B-2. Unit Alignment Summaries: LC2IEDM→WARSIM Alignment

COMBAT-UNIT-TYPE→{org.land}	
Notes	The org.land class has an attribute, type, with values that align at least in part to the various codes specifiable by attributes of COMBAT-UNIT-TYPE.
LC2IEDM Notes:	From the Unit view.
Computed Degree of Alignment:	56
HEADQUARTERS-UNIT-TYPE→{org.land}	
Notes	The org.land class has an attribute, type, with values that align at least in part to the various codes specifiable by attributes of HEADQUARTERS-UNIT-TYPE.
LC2IEDM Notes:	From the Unit view.
Computed Degree of Alignment:	55
OBJECT-ITEM→{org}	
Notes	Within the context of modeling a UNIT, the important attribute is OBJECT-ITEM-NAME. The org_name attribute of the org class models a name.
LC2IEDM Notes:	From the Unit view.
Computed Degree of Alignment:	100
OBJECT-ITEM-TYPE→{}	
LC2IEDM Notes:	From the Unit view.
Computed Degree of Alignment:	25
OBJECT-TYPE→{org.land.unit}	
Notes	JSIMS does not have an attribute that represents nationality using standard designators as the LC2IEDM does. The intent attribute of the org.land.unit class might capture the OBJECT-TYPE-NAME attribute – although that one was also to be used for UNIT-TYPE attributes.
LC2IEDM Notes:	From the Unit view.
Computed Degree of Alignment:	50
ORGANISATION→{}	
Notes	I don't think JSIMS has any attributes that can model a nickname.
LC2IEDM Notes:	From the Unit view. The principal attribute to model is the nickname.
Computed Degree of Alignment:	83

ORGANISATION-ORGANISATION-ASSOCIATION→{org.land}	
Notes	The org.land class has some attributes that can specify relationships to other organizations.
LC2IEDM Notes:	From the Unit view.
Computed Degree of Alignment:	50
ORGANISATION-ORGANISATION-TYPE-ESTABLISHMENT→{}	
Notes	I don't think this entity aligns. JSIMS models concrete associations between organizations, not allocations of organization types.
LC2IEDM Notes:	From the Unit view.
Computed Degree of Alignment:	0
Assessment is terminal.	
ORGANISATION-TYPE→{}	
Notes	This one aligns by default – its attributes are fixed.
LC2IEDM Notes:	From the Unit view.
Computed Degree of Alignment:	64
ORGANISATION-TYPE-ESTABLISHMENT→{}	
Notes	I don't think this entity aligns. JSIMS models concrete associations between organizations, not allocations of organization types.
LC2IEDM Notes:	From the Unit view.
Computed Degree of Alignment:	0
Assessment is terminal.	
ORGANISATION-TYPE-ESTABLISHMENT-ORGANISATION-TYPE-DETAIL→{}	
Notes	I don't think this entity aligns. JSIMS models concrete associations between organizations, not allocations of organization types.
LC2IEDM Notes:	From the Unit view.
Computed Degree of Alignment:	0
Assessment is terminal.	
SUPPORT-UNIT-TYPE→{org.land}	
Notes	The org.land class has an attribute, type, with values that align at least in part to the various codes specifiable by attributes of SUPPORT-UNIT-TYPE.
LC2IEDM Notes:	From the Unit view.
Computed Degree of Alignment:	59
UNIT→{org,org.land.unit}	
Notes	The JSIMS org.land.unit class seems to most closely capture the intent of a UNIT. The org class has the equivalent concept of an ID.
LC2IEDM Notes:	From the Unit view.
Computed Degree of Alignment:	88

UNIT-TYPE→{org.land,org.land.unit}

Notes

Two JSIMS classes – org.land.unit and org.land – have attributes that can describe a unit's type. The relevant attribute of org.land.unit is an arbitrary string. This attribute could be used to model any of the attributes of UNIT – or all, I suppose, if one wanted to create some complex encoding scheme.

The relevant attribute of org.land enumerates a set of possible unit types. It remains to be seen if these unit types overlap the unit types expressed by attributes of UNIT-TYPE.

LC2IEDM Notes:

From the Unit view.

This entity describes more than just a unit's type. Its attributes also characterize size, service, and mobility, among other things.

JSIMS Notes:

The “unit_type” attribute may be relevant.

Actually this is the “type” attribute

The “intent” attribute may be able to capture information equivalent to that of a unit type.

Computed Degree of Alignment: 56

Appendix C. Equipment Alignment Assessments

This appendix presents the Entity-level assessments related to the Equipment concept. It is divided into two sections. Section C.1 gives the assessments for the degree to which WARSIM materiel-related classes can be represented in the LC2IEDM. Section C.2 gives the assessments for the degree to which LC2IEDM equipment-related entities can be represented in WARSIM.

Each section consists of a table. This table is broken into the individual Entity-level alignment assessments. Each assessment contains:

- The assessment's signature, of the form:

$$element \rightarrow \{e_1, e_2, \dots, e_n\}$$

The interpretation is that *element* in one model aligns to, i.e., can be represented by, the set of elements from the other model.
- Any notes made by assessors during the alignment.
- The computed degree of alignment. This value has been computed from lower-level assessments, using the formulas discussed in the body of this study.
- Indications if the assessment is not applicable or terminal.

C.1 WARSIM→LC2IEDM Alignment

Table C-1. Materiel Alignment Summaries: WARSIM→LC2IEDM Alignment

abstract→{CAPABILITY}	
Computed Degree of Alignment: 88	
abstract.land→{EQUIPMENT-TYPE, ORGANISATION-TYPE, SURVEILLANCE-CAPABILITY, UNIT-TYPE}	
Computed Degree of Alignment: 86	
abstract.land.equipment_type→{CAPABILITY, EQUIPMENT-TYPE, OBJECT-TYPE, STORAGE-CAPABILITY}	
Notes	3 items map to EQUIPMENT-TYPE (only) (only) (301, 303, 150099).
Computed Degree of Alignment: 57	
abstract.land.personnel_type→{}	
Computed Degree of Alignment: 82	
abstract.land.rotary_wing_type→{CAPABILITY, EQUIPMENT-TYPE, OBJECT-TYPE, STORAGE-CAPABILITY}	
Notes	3 items map to EQUIPMENT-TYPE (only) (only) (301, 303, 150099).
LC2IEDM Notes:	The EQUIPMENT-TYPE-CATEGORY-CODE attribute has a value AIRRW for modeling rotary wing aircraft.
Computed Degree of Alignment: 57	

org→{ORGANISATION} Notes	A JSIMS org class aligns to an LC2IEDM ORGANISATION . 6 items map to ORGANIZATION (236, 237, 238, 296, 150036, 150102) We can distinguish a simple org object (whose WARSIM subclass is not assigned) from all other WARSIM unit class types – org.land.unit, org_perceived_unit_c and extended_perceived_unit_c – using the ORGANISATION-TYPE-CATEGORY-CODE which is set to “UN” for units. A simple org object can be distinguished from org.land and its subclasses because they are all either Units with a UNIT-TYPE-SERVICE-CODE set to “A” for Army or they have an ORGANISATION association to such a unit. The LC2IEDM OBJECT-TYPE-NAME might also be used to support this distinction, although there are no standard LC2IEDM names for such WARSIM classes
Computed Degree of Alignment: 82	
org.land→{CAPABILITY, COMBAT-UNIT-TYPE, CONVOY, FIRE-CAPABILITY, HOLDING, MATERIEL-STATUS, OBJECT-ITEM, ORGANISATION-ORGANISATION-ASSOCIATION, ORGANISATION-STATUS, PERSON-STATUS, SUPPORT-UNIT-TYPE, UNIT-TYPE} Notes JSIMS Notes: LC2IEDM Notes: Computed Degree of Alignment: 54	6 items can map to land (Army) ORGANISATIONS (236, 238, 296, 150044, 150036, 150102) . We can distinguish a simple org.land object (whose WARSIM subclass is not assigned) from an org.land.unit, org_perceived_unit_c and extended_perceived_unit_c – since its ORGANISATION-TYPE-CATEGORY-CODE will not be “UN” for unit. The org_perceived_unit_c and extended_perceived_unit_c WARIM objects can also be distinguished by the absence of a REPORTING-DATA-REPORTING-ORGANISATION-ID set to a unique ID chosen to distinguish ground truth. Org.land data is considered WARSIM ground truth, while perceived data is not. But, we don't see a way to distinguish org.land.equip_group and org.land.supply_cache from a simple org.land object. Hence, there is an adjustment factor ($50 + 50/3 = 67$). Although the LC2IEDM OBJECT-TYPE-NAME can be used to support this distinction, there are no standard LC2IEDM names for such WARSIM classes . For Unit and Equipment areas Used to associate an org.land object with an Army organization if it is not identified as a UNIT (which contains the UNIT-TYPE-SERVICE-CODE).

org.land.equip_group→{HOLDING, MATERIEL, MATERIEL-TYPE, OBJECT-ITEM, OBJECT-TYPE, ORGANISATION, ORGANISATION-MATERIEL-ASSOCIATION}	
Notes	In JSIMS, an equipment group represents a collection of platforms. The LC2IEDM would model an equipment group as an ORGANISATION, with associated MATERIEL. Alternately, it might model an equipment group as an ORGANISATION holding a certain quantity of MATERIEL-TYPE. 6 items map to ORGANIZATION (236, 237, 238, 296, 150036, 150102) . These groups are the materiel part of Army units ranging from a single platform to a battalion. In order to capture the Army service affiliation of an equipment group it would either have to be identified with a Unit in the LC2IEDM or associated with a Unit through an ORGANISATION-ORGANISATION-ASSOCIATION . An org.land.equip_group object is clearly distinguishable from simple org in the LC2IEDM via the UNIT-TYPE-SERVICE-CODE (=“A” for Army for ORG.LAND) . But, An org.land..equip_group cannot be clearly distinguished from an org.land object or from an org.land.supply_cache object by LC2IEDM data if an equipment group is not modeled as a u
LC2IEDM Notes:	MATERIEL is the object of ORGANISATION-MATERIEL-ASSOCIATION; ORGANISATION is the subject of ORGANISATION-MATERIEL-ASSOCIATION. MATERIEL-TYPE is a subtype of OBJECT-TYPE; OBJECT-TYPE is used as a classification for OBJECT-ITEM-TYPE; OBJECT-ITEM is classified as OBJECT-ITEM-TYPE; OBJECT-ITEM is a supertype of ORGANISATION. OBJECT-ITEM is a supertype of ORGANISATION. OBJECT-TYPE is used as a classification for OBJECT-ITEM-TYPE; OBJECT-ITEM is classified as OBJECT-ITEM-TYPE; OBJECT-ITEM is a supertype of ORGANISATION. ORGANISATION is the subject of ORGANISATION-MATERIEL-ASSOCIATION.
Computed Degree of Alignment:	53

org.land.supply_cache→{EQUIPMENT-TYPE, MATERIEL, ORGANISATION}	
Notes	A JSIMS supply cache is a type of organization. It would be modeled in LC2IEDM as an ORGANISATION . 6 items map to ORGANIZATION (236, 237, 238, 296, 150036, 150102) ., An org.land.supply_cache can be distinguished from other Army organizations which are units because it is not, although it should be associated with an Army UNIT ORGANISATION in the LC2IEDM. It is distinguished from a simple org by this association. An org.land.supply_cache cannot be clearly distinguished from an org.land object or from an org.land.equip_group object by LC2IEDM data if an equipment group is not modeled as a unit. Hence the adjustment factor of $(50 + 50/3 = 67)$ The LC2IEDM OBJECT-TYPE-NAME can be used to support this distinction, although there are no standard LC2IEDM names for such WARSIM classes .
LC2IEDM Notes:	EQUIPMENT-TYPE is a subtype of MATERIEL-TYPE; MATERIEL-TYPE is a subtype of OBJECT-TYPE; OBJECT-TYPE is used as a classification for OBJECT-ITEM-TYPE; OBJECT-ITEM is classified as OBJECT-ITEM-TYPE; OBJECT-ITEM is a supertype of ORGANISATION. MATERIEL is the object of ORGANISATION-MATERIEL-ASSICATION; ORGANISATION is the subject of ORGANISATION-MATERIEL-ASSOCIATION.
Computed Degree of Alignment: 52	

C.2 LC2IEDM→WARSIM Alignment

Table C-2. Materiel Alignment Summaries: LC2IEDM→WARSIM Alignment

CAPABILITY→{}	
Notes	The CAPABILITY entity describes general characteristics of capabilities. Some attributes probably won't align. CAPABILITY has a attribute for specifying units of measure; JSIMS attributes' units are fixed. CAPABILITY can distinguish between day-time and nighttime; I don't think JSIMS can. CAPABILITY itself aligns to nothing. However, it's the parent of several classes. Those classes will probably align better.
LC2IEDM Notes:	From the Equipment view.
Computed Degree of Alignment: 23	

EQUIPMENT-TYPE→{abstract,abstract.land.equipment_type}	
Notes	There is some similarity between EQUIPMENT-TYPE and abstract.land.equipment_type: Both model cargo dimensions, for example. The abstract class (superclass of abstract.land.equipment_type, conveniently) models an ID. I'm not immediately sure how to model EQUIPMENT-TYPE-FIRE-GUIDANCE-INDICATOR-CODE, EQUIPMENT-TYPE-MOBILITY-CODE. Not clear if there's a JSIMS way to model the is-main-equipment-of association to UNIT-TYPE. The org.land class has a unit_kind attribute, but using that would be modeling the inverse of the association.
LC2IEDM Notes:	From the Equipment view.
Computed Degree of Alignment: 55	
FIRE-CAPABILITY→{abstract.land,equipment,platform}	
Notes	To model fire capability, JSIMS must be able to record a) that equipment can fire a projectile, and b) what type projectile the equipment fires. This information can probably be modeled through the MIDB that's associated with platforms and equipment.
LC2IEDM Notes:	From the Equipment view.
Computed Degree of Alignment: 20	
LAND-MANOEUVRE-CAPABILITY→{equipment,platform}	
Notes	I haven't found anything in JSIMS that correlates platform mobility to terrain types. Possibly the MIDB associated with platforms and equipment will provide that information.
LC2IEDM Notes:	From the Equipment view.
Computed Degree of Alignment: 22	
MATERIEL→{equipment,platform}	
Notes	The platform class aligns to MATERIEL, in that a platform represents an object with physical properties. Platform has lots of subtypes. Maybe most of them align. Does the LC2IEDM consider things like a surface ship (surface_ship is a subclass) as MATERIEL? The equipment class would also align to MATERIEL.
LC2IEDM Notes:	From the Equipment view.
Computed Degree of Alignment: 57	

MATERIEL-STATUS→{equipment.airborne_sensor.esm, equipment.airborne_sensor.iff, equipment.airborne_sensor.ir, equipment.airborne_sensor.optical, equipment.equipment_radiating.airborne_radar, equipment.equipment_radiating.ald, equipment.equipment_radiating.gps, equipment.equipment_radiating.rf_noise_jammer, equipment.naval_sensor, equipment.naval_weapon_system, equipment.sensor.comint, equipment.sensor.elint, equipment.sensor.radint, equipment.sensor.sensor_deck,platform}	
Notes	JSIMS has many classes with attributes that can represent materiel status. However, they are spread throughout the class hierarchy, rather than centralized in super-classes. It's difficult to assign a degree of alignment right now; that will have to wait until lower levels of analysis. An important problem will be determining whether JSIMS can model status of as wide a range of materiel as the LC2IEDM can.
LC2IEDM Notes:	From the Equipment view.
Computed Degree of Alignment:	17
MATERIEL-TYPE→{abstract}	
Notes	The MATERIEL-TYPE entity appears to align in principle to the abstract class. That class' parent has an MIDB-designating attribute. Through the MIDB, I believe many of the attributes of MATERIEL-TYPE can be modeled.
LC2IEDM Notes:	From the Equipment view.
Computed Degree of Alignment:	69
OBJECT-ITEM→{equipment, platform}	
Notes	The equipment class can model the name and ID of an OBJECT-ITEM. The CATEGORY-CODE attribute would be fixed.
LC2IEDM Notes:	From the Equipment view.
Computed Degree of Alignment:	100
OBJECT-ITEM-STATUS→{equipment, platform}	
Notes	The important attribute in OBJECT-ITEM-STATUS is the hostility code. The JSIMS classes listed have a faction ID attribute. At least in the case of “platform”, the faction ID is one of a fixed set of values that don't entirely map to the hostility codes in the LC2IEDM.
LC2IEDM Notes:	From the Equipment view.
Computed Degree of Alignment:	20
OBJECT-ITEM-TYPE→{}	
Notes	OBJECT-ITEM-TYPE expresses the concept of an M:N relationship between OBJECT-ITEM and OBJECT-TYPE. It's not clear that JSIMS can model an M:N relationship. Our assumption is that class “abstract” and its subclasses model OBJECT-TYPE. Although one instance of “abstract” can be shared by many instances of “equipment”, one instance of “equipment” can only have one instance of “abstract”.
LC2IEDM Notes:	From the Equipment view.
Computed Degree of Alignment:	38

OBJECT-TYPE→{abstract}	
Notes	The OBJECT-TYPE entity appears to align in principle to the “abstract” class. That class has an MIDB-designating attribute. Through the MIDB, I believe many of the attributes of OBJECT-TYPE can be modeled. The nationality-code attribute is questionable, however.
LC2IEDM Notes:	From the Equipment view.
Computed Degree of Alignment: 50	
OBJECT-TYPE-CAPABILITY-NORM→{abstract.land.equipment_type}	
Notes	Given the breadth of capabilities that have to be modeled, there probably isn't a good way to align this entity to JSIMS. A lot of separate cases will need to be considered (one for each subtype of CAPABILITY).
	At least one type of capability can be modeled, namely storage capability. The class abstract.land.equipment_type has the necessary attributes.
LC2IEDM Notes:	From the Equipment view.
Computed Degree of Alignment: 75	
STORAGE-CAPABILITY→{abstract.land.equipment_type}	
Notes	STORAGE-CAPABILITY just records the capability to store. The actual amount is held in OBJECT-TYPE-CAPABILITY-NORM. Therefore, the alignment of STORAGE-CAPABILITY won't involve aligning to attributes of abstract.land.equipment_type, just structural alignment.
LC2IEDM Notes:	From the Equipment view.
Computed Degree of Alignment: 20	
SURVEILLANCE-CAPABILITY→{equipment.airborne_sensor, equipment.airborne_sensor.esm, equipment.airborne_sensor.iff, equipment.airborne_sensor.ir, equipment.airborne_sensor.optical, equipment.sensor, equipment.sensor.comint, equipment.sensor.elint, equipment.sensor.opint, equipment.sensor.radint, equipment.sensor.sensor_deck}	
Notes	The SURVEILLANCE-CAPABILITY probably will be modeled structurally rather than through attributes of the listed JSIMS classes.
LC2IEDM Notes:	From the Equipment view.
Computed Degree of Alignment: 24	

Appendix D. Environment Alignment Results

This appendix summarizes the assessment of the alignment between the TCDM and the LC2IEDM. Only Conceptual- and Entity-level assessments are shown; the underlying State- and Value-level assessments are omitted in the interests of brevity. The reader interested in the State- and Value-level assessments can find them in the alignment assessment database.

Each assessment follows a standard format. It presents a combination of the following items:

- The assessment “signature”, which is of the form $a \rightarrow \{e_1, e_2, \dots, e_n\}$. Its interpretation is that element a in one model aligns to elements $e_1, e_2, \dots, e_n$ in the other model. If the set $\{e_1, e_2, \dots, e_n\}$ is empty, then a does not align.
- Notes, which show comments the assessor made. Notes can be general (labeled just “Notes”), or specific to TCDM or the LC2IEDM.
- The Computed Degree of Alignment, which is the rolled-up value calculated to be the degree to which element a aligns.
- An indication if the assessment is terminal or not applicable to alignment.

Not all of these items need be present for a given assessment. An entry is shown only if the assessor provided information on it.

D.1 TCDM-to-LC2IEDM Level Alignment

This section presents the results of determining the degree to which the TCDM aligns to the LC2IEDM. The following entries were made for Conceptual-level alignment:

Conceptual-Level Alignment of Terrain	
Notes:	Roughly speaking, the JSIMS concept of terrain, as expressed through the TCDM, is modeled by the LC2IEDM notion of geographic features. The Geographic Feature view comprises terrain characteristics. The TCDM includes man-made entities (e.g., amusement parks). Terrain therefore aligns to the Facility view as well.
Computed Degree of Alignment:	41

The following table gives the assessment of each Entity-level element (TCDM feature) that was assessed as part of Conceptual-level alignment.

Table D-1. TCDM Feature Assessment Summaries

Administrative Area→{CONTROL-FEATURE}	
LC2IEDM Notes:	no category code exists
Computed Degree of Alignment:	42

Administrative Boundary→{CONTROL-FEATURE-TYPE}	
Notes	To load all data pertaining to this class may require using both CONTROL-FEATURE-TYPE and CONTROL-FEATURE, since the LOCATION-related portion can only be accessed using FEATURE-LOCATION. In addition, the LINE, SURFACE and SURFACE-REGION tables also may be required. 7 items map to BDYPOA (60001, 60010, 60026, 60042, 60060, 60061, 60073).
LC2IEDM Notes:	mapped to "Boundary, political/administrative". ECC: BDYPOA 1000075
Computed Degree of Alignment: 23	
Aerial Cableway Lines / Ski Lift Lines→{CONTROL-FEATURE-TYPE}	
Notes	This Environmental Class may also be viewed as EQUIPMENT-TYPE. The current assessment assumes that the user is not interested in the operation of the conveyor system, but only wants to track it on a display, overlay, or map.
LC2IEDM Notes:	no ECC exists.
Computed Degree of Alignment: 76	
Airport / Airfield→{FACILITY-TYPE, GEOGRAPHIC-FEATURE-TYPE}	
Notes	There exists a FACILITY-TYPE-CATEGORY-CODE for airport in LC2IEDM. 4 items map to AIR (60003, 60004, 60129, 60146).
LC2IEDM Notes:	Maps to AIR, Airfield/airport/airstrip 1000037.
Computed Degree of Alignment: 33	
Airport Lighting→{EQUIPMENT-TYPE}	
Notes	The current assessment is based on the definition which appears to focus on the equipment nature of the class. Airport equipment is also included in the definition for FACILITY-TYPE = Airport, so could be considered a subset of airport/airstrip. If the user only wants to depict this class in a display, overlay or map, then it could be handled as a CONTROL-FEATURE-TYPE. 4 items map to AIR (60003, 60004, 60129, 60146).
LC2IEDM Notes:	mapped to "Beacon". ECC BEACON 1000178
Computed Degree of Alignment: 35	
Amusement Park→{FACILITY-TYPE, GEOGRAPHIC-FEATURE-STATUS}	
Notes	No ECC exists. Can use FACILITY-TYPE = "NOS". The current assessment is based on the definition which appears to focus on the facility nature of the class. If the user only wants to depict this class in a display, overlay or map, then it should be handled as a CONTROL-FEATURE-TYPE. 22 items map to FACILITY-TYPE = NOS (60005, 60006, 60007, 60047, 60051, 60054, 60055, 60056, 60062, 60066, 60070, 60083, 60084, 60089, 60094, 60098, 60099, 60108, 60109, 60136, 60141, 60147).
LC2IEDM Notes:	No ECC exists.
Computed Degree of Alignment: 29	
Anchorage→{FACILITY-TYPE}	

Notes	There exists a FACILITY-TYPE-CATEGORY-CODE for Harbour in LC2IEDM, thus the primary mapping is to FACILITY-TYPE. To load all data pertaining to this Environment Class may require using both CONTROL-FEATURE-TYPE and CONTROL-FEATURE, since the LOCATION-related portion can only be accessed using FEATURE-LOCATION. In addition, the LINE, SURFACE and SURFACE-REGION tables also may be required. 2 items map to HARBUR (60006, 60097). LC2IEDM Notes: Maps to HARBUR, Harbour 1000167. Computed Degree of Alignment: 30
Apron / Hardstand→{FACILITY-TYPE, GEOGRAPHIC-FEATURE-STATUS}	
Notes	The current assessment is based on the definition which appears to focus on the facility nature of the class. If the user only wants to depict this class in a display, overlay or map, then it should be handled as a CONTROL-FEATURE-TYPE. To load all data pertaining to this Environment Class may require using both FACILITY-TYPE and FACILITY, since the LOCATION-related portion can only be accessed using FACILITY-LOCATION. In addition, the LINE, SURFACE and SURFACE-REGION tables also may be required. 22 items map to FACILITY-TYPE = NOS (60005, 60006, 60007, 60047, 60051, 60054, 60055, 60056, 60062, 60066, 60070, 60083, 60084, 60089, 60094, 60098, 60099, 60108, 60109, 60136, 60141, 60147). LC2IEDM Notes: No ECC exists. Computed Degree of Alignment: 21
Aqueduct→{FACILITY-TYPE}	
Notes	No ECC exists for Aqueduct. The current assessment is based on the definition which appears to focus on the facility nature of the class. To load all data pertaining to this Environment Class may require using both FACILITY-TYPE and FACILITY, since the LOCATION-related portion can only be accessed using FACILITY-LOCATION. In addition, the LINE, SURFACE and SURFACE-REGION tables also may be required. 22 items map to FACILITY-TYPE = NOS (60005, 60006, 60007, 60047, 60051, 60054, 60055, 60056, 60062, 60066, 60070, 60083, 60084, 60089, 60094, 60098, 60099, 60108, 60109, 60136, 60141, 60147). TCDM Notes: A pipe or artificial channel used to transport water from a remote source, usually by gravity. LC2IEDM Notes: maps to either "Canal" (ECC CANAL 1000112) or "Bridge" (ECC BRG). Aqueducts are often used as part of a water delivery system that includes canals. They are often constructed as arched bridges that carry the water over areas where the canal cannot be dug. In appearance and structure, they may be a bridge (ECC BRG). Either mapping is appropriate, depending on whether the functional or physical attributes need to be represented. Computed Degree of Alignment: 15
Aqueduct Centerline / Nexus→{CONTROL-FEATURE-TYPE}	

Notes	No ECC exists. The purpose for this line is usually not related to military operations, but is used for charting, mapping, hydrographic surveys. Thus, it would not likely be a CONTROL-FEATURE. On an overlay, it can simply be represented as a LOCATION. It can be associated with the Aqueduct Facility thru FACILITY-LOCATION.
LC2IEDM Notes:	mapped to Bearing Line, ECC BEARING LINE 1000109.
Computed Degree of Alignment:	26
Armistice Line→{CONTROL-FEATURE-TYPE}	
Notes	To load all data pertaining to this Environment Class may require using both CONTROL-FEATURE-TYPE and CONTROL-FEATURE, since the LOCATION-related portion can only be accessed using FEATURE-LOCATION. In addition, the LINE, SURFACE and SURFACE-REGION tables also may be required. 7 items map to BDYPOA (60001, 60010, 60026, 60042, 60060, 60061, 60073).
LC2IEDM Notes:	mapped to Boundary, political/administrative, ECC BDYPOA 1000074.
Computed Degree of Alignment:	28
Assembly Plant→{FACILITY-TYPE}	
Notes	The current assessment is based on the definition which appears to focus on the facility nature of the class. If the user only wants to depict this class in a display, overlay or map, then it should be handled as a CONTROL-FEATURE-TYPE. To load all data pertaining to this Environment Class may require using both FACILITY-TYPE and FACILITY, since the LOCATION-related portion can only be accessed using FACILITY-LOCATION. In addition, the LINE, SURFACE and SURFACE-REGION tables also may be required. 7 items map to INDINS (60011, 60013, 60026, 60106, 60107, 60120, 60130).
LC2IEDM Notes:	mapped to Industrial Installation, ECC INDINS 1000110.
Computed Degree of Alignment:	35
Bamboo / Cane→{GEOGRAPHIC-FEATURE-TYPE}	
Notes	No ECC exists. Closest mapping is to "Tree" ECC TRE. 15 items map to GEOGRAPHIC-FEATURE-TYPE = NOS (60012, 60015, 60052, 60076, 60096, 60100, 60115, 60116, 60131, 60136, 60137, 60140, 60144, 60146, 60153, 60160).
TCDM Notes:	A site of woody and/or tree-like grasses of the tropical or temperate regions that have jointed hollow stems with solid nodes.
LC2IEDM Notes:	No ECC exists. Most closely maps to "Tree" ECC TRE, woody perennial plants having a self-supporting stem or trunk. Can also use "NOS" and use OBJECT-ITEM-NAME to specify "bamboo/cane".
Computed Degree of Alignment:	12

Blast Furnace→{FACILITY-TYPE}	
Notes	The current assessment is based on the definition which appears to focus on the facility nature of the class. If the user only wants to depict this class in a display, overlay or map, then it should be handled as a CONTROL-FEATURE-TYPE. To load all data pertaining to this Environment Class may require using both FACILITY-TYPE and FACILITY, since the LOCATION-related portion can only be accessed using FACILITY-LOCATION. In addition, the LINE, SURFACE and SURFACE-REGION tables also may be required. 7 items map to INDINS (60011, 60013, 60026, 60106, 60107, 60120, 60130).
LC2IEDM Notes:	mapped to Industrial Installation, ECC INDINS 1000110.
Computed Degree of Alignment: 48	
Bluff / Cliff / Escarpment→{GEOGRAPHIC-FEATURE-TYPE}	
Notes	To load all data pertaining to this Environment Class may require using both CONTROL-FEATURE-TYPE and CONTROL-FEATURE, since the LOCATION-related portion can only be accessed using FEATURE-LOCATION. In addition, the LINE, SURFACE and SURFACE-REGION tables also may be required. 2 items map to CLF (60014, 60071).
LC2IEDM Notes:	mapped to “Cliff/escarpment”, ECC CLF 1000010.
Computed Degree of Alignment: 38	
Bottom Characteristics→{CONTROL-FEATURE-TYPE}	
Notes	No ECC exists. Maps best to GEOGRAPHIC-FEATURE-TYPE = “Water”, ECC WAT, an area of water which normally has tidal fluctuations. 15 items map to GEOGRAPHIC-FEATURE-TYPE = NOS (60012, 60015, 60052, 60076, 60096, 60100, 60115, 60116, 60131, 60136, 60137, 60140, 60144, 60146, 60153, 60160).
TCDM Notes:	Designations used on surveys and charts to indicate the consistency, colour, and classification of the sea floor, as determined by sampling methods.
LC2IEDM Notes:	no ECC exists.
Computed Degree of Alignment: 13	
Boundary Line→{CONTROL-FEATURE-TYPE}	
Notes	2 items map to BDYOR (60016, 60031).
LC2IEDM Notes:	mapped to “Boundary, organization” ECC BDYOR 1000073 or to “Boundary, political/administrative” ECC BDYPOA 1000074.
Computed Degree of Alignment: 75	
Assessment is terminal.	
Breach Point / Lane→{CONTROL-FEATURE-TYPE}	
Notes	Linked to LOCATION thru FEATURE-LOCATION
TCDM Notes:	A gap made in a fortification, wall, or obstacle.
LC2IEDM Notes:	mapped to “Obstacle Gap” ECC OBSGAP 1000135
Computed Degree of Alignment: 97	

Breakwater / Groin→{FACILITY-TYPE}	
Notes	no FACILITY-TYPE-CATEGORY-CODE exists for this in LC2IEDM. Possibly maps to Dam/Wier which does have a FACILITY-TYPE-CATEGORY-CODE. 3 items map to DAM (60016, 60041, 60075).
LC2IEDM Notes:	mapped to “Dam/Weir” ECC DAM 1000117
Computed Degree of Alignment: 31	
Bridge / Overpass / Viaduct→{FACILITY-TYPE}	
Notes	There exists a FACILITY-TYPE-CATEGORY-CODE for bridge/Overpass/Viaduct in LC2IEDM. This is the primary mapping. 4 items map to BRG (60019, 60020, 60027, 60049).
LC2IEDM Notes:	Maps to BRG, Bridge/overpass/viaduct 1000039.
Computed Degree of Alignment: 44	
Bridge Span→{FACILITY-TYPE}	
Notes	4 items map to BRG (60019, 60020, 60027, 60049).
LC2IEDM Notes:	maps to “Bridge/overpass/viaduct” ECC BRG 1000039.
Computed Degree of Alignment: 51	
Building→{FACILITY-TYPE}	
LC2IEDM Notes:	maps to “Building” ECC BLD 1000038
Computed Degree of Alignment: 55	
Built Up Area→{FACILITY-TYPE}	
Notes	There is a FACILITY-TYPE-CATEGORY-CODE for Built Up Area in LC2IEDM.
LC2IEDM Notes:	Maps to BUA, Built-up area 1000111.
Computed Degree of Alignment: 59	
Canal→{FACILITY-TYPE, GEOGRAPHIC-FEATURE-STATUS}	
LC2IEDM Notes:	maps to “Canal” ECC CAN 1000112
Computed Degree of Alignment: 30	
Canal Centerline / Nexus→{CONTROL-FEATURE, GEOGRAPHIC-FEATURE-STATUS}	
Notes	Can be associated with Canal through FACILITY-LOCATION.
LC2IEDM Notes:	maps to “Bearing line” ECC BERLIN 1000109.
Computed Degree of Alignment: 26	
Cart Track→{FACILITY-TYPE, GEOGRAPHIC-FEATURE-STATUS}	
Notes	2 items map to RD (60025, 60123).
LC2IEDM Notes:	maps to “Road” ECC RD 1000058
Computed Degree of Alignment: 20	
Catalytic Cracker→{EQUIPMENT-TYPE}	
Notes	7 items map to INDINS (60011, 60013, 60026, 60106, 60107, 60120, 60130).
LC2IEDM Notes:	no ECC exists.
Computed Degree of Alignment: 48	

Causeway→{FACILITY-TYPE}	
Notes	4 items map to BRG (60019, 60020, 60027, 60049).
LC2IEDM Notes:	maps to “Bridge/overpass/viaduct” ECC BRG 1000039
Computed Degree of Alignment: 42	
Cease Fire Line→{CONTROL-FEATURE-TYPE}	
Notes	7 items map to BDYPOA (60001, 60010, 60026, 60042, 60060, 60061, 60073).
LC2IEDM Notes:	maps to “Boundary, political/administrative” ECC BDYPOA 1000074
Computed Degree of Alignment: 28	
Chimney / Smokestack→{FACILITY-TYPE}	
LC2IEDM Notes:	maps to “Chimney/smokestack” ECC CHM 1000113.
Computed Degree of Alignment: 85	
Cistern→{FACILITY-TYPE}	
Notes	No ECC exists. May use “Water Tower” or “Reservoir”, depending on elevation of the cistern with respect to the ground. 2 items map to FACILITY-CODE = NOS, STORAGE-CAPABILITY = WAT (60030, 60164).
TCDM Notes:	A man-made container used for collection or storage of rain water.
LC2IEDM Notes:	No ECC exists. May map to “Water Tower” ECC WTW 1000070. May more closely map to “Reservoir” ECC RES if not elevated. Cisterns may be underground, on the ground, or be open reservoirs.
Computed Degree of Alignment: 35	
Claim Line→{CONTROL-FEATURE-TYPE}	
Notes	2 items map to BDYOR (60016, 60031).
LC2IEDM Notes:	maps to “Boundary, organization” ECC BDYOR 1000073
Computed Degree of Alignment: 38	
Cleared Way / Cut Line / Firebreak→{FACILITY-TYPE, GEOGRAPHIC-FEATURE-STATUS}	
LC2IEDM Notes:	maps to “Cleared way/firebreak” ECC CWY 1000114.
Computed Degree of Alignment: 25	
Coastline / Shoreline→{GEOGRAPHIC-FEATURE-TYPE}	
Notes	2 items map to BCH (60033, 60056).
LC2IEDM Notes:	mapped to “Beach” ECC BCH 1000002. (admittedly a poor map)
Computed Degree of Alignment: 25	
Communication Building→{FACILITY-TYPE}	
LC2IEDM Notes:	mapped to “Communications Building” ECC COB 1000042.
Computed Degree of Alignment: 69	
Communication Tower→{FACILITY-TYPE}	
Notes	2 items map to COT (60035, 60079).
LC2IEDM Notes:	mapped to “Communications Tower” ECC COT 1000043.
Computed Degree of Alignment: 64	

Control Tower→{FACILITY-TYPE}	
LC2IEDM Notes:	mapped to “Control Tower” ECC CTT 1000044.
Computed Degree of Alignment:	85
Cooling Tower→{FACILITY-TYPE}	
Notes	2 items map to TOW (only) (only) (60037, 60150).
LC2IEDM Notes:	mapped to “Tower (noncommunications)” ECC TOW 1000124
Computed Degree of Alignment:	64
Crane→{EQUIPMENT-TYPE}	
LC2IEDM Notes:	maps to “Construction Equipment” ECC CONEQP 1000164
Computed Degree of Alignment:	76
Cropland→{FACILITY-TYPE}	
Notes	There is a FACILITY-TYPE-CATEGORY-CODE for this in LC2IEDM. 3 items map to CRP (60039, 60069, 60119).
LC2IEDM Notes:	Maps to CRP, Cropland 1000115.
Computed Degree of Alignment:	11
Cross Country Barrier→{FACILITY-TYPE}	
Notes	dragon teeth, beam post obstacle maps to 2 different codes
LC2IEDM Notes:	mapped to “Dragon Teeth” ECC DGT 1000047 or to “Beam post obstacle” ECC BPSOBS 1000126.
Computed Degree of Alignment:	69
Dam / Weir→{FACILITY-TYPE}	
Notes	3 items map to DAM (60016, 60041, 60075).
LC2IEDM Notes:	mapped to “Dam/Weir” ECC DAM 1000117.
Computed Degree of Alignment:	47
Defacto Boundary→{CONTROL-FEATURE-TYPE}	
Notes	7 items map to BDYPOA (60001, 60010, 60026, 60042, 60060, 60061, 60073).
LC2IEDM Notes:	mapped to “Boundary, political/administrative” ECC BDYPOA 1000074.
Computed Degree of Alignment:	23
Defensive Position→{CONTROL-FEATURE-TYPE}	
Notes	2 items map to DEFPOS (60043, 60104).
LC2IEDM Notes:	mapped to “Defensive Position” ECC DEFPOS 1000068.
Computed Degree of Alignment:	59
Demilitarized Zone→{CONTROL-FEATURE-TYPE}	
Notes	3 items map to CONTROL-FEATURE-TYPE = NOS (60044, 60059, 60157).
LC2IEDM Notes:	mapped to “Area of Interest” ECC AOI 1000003 or to “No Fire Area” ECC NFRARE 1000132.
Computed Degree of Alignment:	42
Depot (Storage)→{FACILITY-TYPE}	
Notes	2 items map to DEPOT (60045, 60143).
LC2IEDM Notes:	mapped to “Depot, not otherwise specified” ECC DEPOT 1000046.
Computed Degree of Alignment:	46

Disk / Dish Antenna→{EQUIPMENT-TYPE}	
LC2IEDM Notes:	mapped to “Communications antenna” ECC COMANT 1000171 or to “Early Warning/acquisition radar” ECC EWARAD 1000181 or to air traffic control radar or to fire control radar.....
Computed Degree of Alignment: 85	
Drydock→{FACILITY-TYPE}	
Notes	No ECC exists for drydock. The closest concept is Maintenance Facility, ECC MAINTF. Ship maintenance facilities are usually located at major ports, and often include a drydock for hull repairs. 22 items map to FACILITY-TYPE = NOS (60005, 60006, 60007, 60047, 60051, 60054, 60055, 60056, 60062, 60066, 60070, 60083, 60084, 60089, 60094, 60098, 60099, 60108, 60109, 60136, 60141, 60147).
TCDM Notes:	A structure providing support for a vessel, which has a means of removing water so that the bottom of the vessel can be exposed.
LC2IEDM Notes:	no ECC exists for drydock. Closest mapping is to MAINTF, maintenance facility.
Computed Degree of Alignment: 35	
Embankment / Fill→{GEOGRAPHIC-FEATURE-TYPE}	
LC2IEDM Notes:	mapped to “Embankment/fill” ECC EMB 1000023
Computed Degree of Alignment: 50	
Engineering Bridge→{FACILITY-TYPE}	
Notes	4 items map to BRG (60019, 60020, 60027, 60049).
LC2IEDM Notes:	mapped to “Bridge/overpass/viaduct” ECC BRG 1000039
Computed Degree of Alignment: 42	
Exposed Bedrock→{GEOGRAPHIC-FEATURE-TYPE}	
Notes	2 items map to RST (60050, 60125).
LC2IEDM Notes:	mapped to “Rock strata/rock formation” ECC RST 1000052.
Computed Degree of Alignment: 35	
Extraction Mine→{FACILITY-TYPE}	
Notes	22 items map to FACILITY-TYPE = NOS (60005, 60006, 60007, 60047, 60051, 60054, 60055, 60056, 60062, 60066, 60070, 60083, 60084, 60089, 60094, 60098, 60099, 60108, 60109, 60136, 60141, 60147).
LC2IEDM Notes:	no ECC exists
Computed Degree of Alignment: 23	
Fault→{GEOGRAPHIC-FEATURE-TYPE}	
Notes	15 items map to GEOGRAPHIC-FEATURE-TYPE = NOS (60012, 60015, 60052, 60076, 60096, 60100, 60115, 60116, 60131, 60136, 60137, 60140, 60144, 60146, 60153, 60160).
LC2IEDM Notes:	no ECC exists.
Computed Degree of Alignment: 26	

Ferry Crossing→{FACILITY-TYPE}	
Notes	mapped to “Crossing, railway/river” ECC XRR
TCDM Notes:	A route in a body of water where a ferry crosses from one shoreline to another.
LC2IEDM Notes:	mapped to “Crossing, railway/river” ECC XRR
Computed Degree of Alignment: 33	
Filtration Beds / Aeration Beds→{FACILITY-TYPE, GEOGRAPHIC-FEATURE-STATUS}	
Notes	22 items map to FACILITY-TYPE = NOS (60005, 60006, 60007, 60047, 60051, 60054, 60055, 60056, 60062, 60066, 60070, 60083, 60084, 60089, 60094, 60098, 60099, 60108, 60109, 60136, 60141, 60147).
LC2IEDM Notes:	no ECC exists
Computed Degree of Alignment: 25	
Fish Hatchery / Fish Farm / Marine Farm→{FACILITY-TYPE, GEOGRAPHIC-FEATURE-STATUS}	
Notes	22 items map to FACILITY-TYPE = NOS (60005, 60006, 60007, 60047, 60051, 60054, 60055, 60056, 60062, 60066, 60070, 60083, 60084, 60089, 60094, 60098, 60099, 60108, 60109, 60136, 60141, 60147).
LC2IEDM Notes:	no ECC exists
Computed Degree of Alignment: 16	
Flare Pipe→{FACILITY-TYPE}	
Notes	22 items map to FACILITY-TYPE = NOS (60005, 60006, 60007, 60047, 60051, 60054, 60055, 60056, 60062, 60066, 60070, 60083, 60084, 60089, 60094, 60098, 60099, 60108, 60109, 60136, 60141, 60147).
LC2IEDM Notes:	no ECC exists
Computed Degree of Alignment: 44	
Ford→{GEOGRAPHIC-FEATURE-STATUS, GEOGRAPHIC-FEATURE-TYPE}	
LC2IEDM Notes:	mapped to “Ford” ECC FRD 1000026
Computed Degree of Alignment: 36	
Foreshore→{GEOGRAPHIC-FEATURE-STATUS, GEOGRAPHIC-FEATURE-TYPE}	
Notes	2 items map to BCH (60033, 60056).
LC2IEDM Notes:	mapped to “Beach” ECC BCH 1000002
Computed Degree of Alignment: 21	
Geographic Information Area→{GEOGRAPHIC-FEATURE-TYPE}	
Notes	3 items map to CONTROL-FEATURE-TYPE = NOS (60044, 60059, 60157).
Assessment is N/A.	
Grain Bin / Silo→{FACILITY-TYPE}	
Notes	Maps to FACILITY-TYPE “Tower (non-communications)” ECC TOW, enhanced by STORAGE-CAPABILITY. 2 items map to TOW, enhanced by STORAGE-CAPABILITY (60060, 60061).
LC2IEDM Notes:	mapped to “Tower (non-communications)” ECC TOW 1000124
Computed Degree of Alignment: 62	

Grain Elevator→{FACILITY-TYPE}	
Notes	Maps to FACILITY-TYPE “Tower (non-communications)” ECC TOW, enhanced by STORAGE-CAPABILITY. Does not include the concepts of grain processing, loading, or unloading. 2 items map to TOW, enhanced by STORAGE-CAPABILITY (60060, 60061).
TCDM Notes:	A tall structure, equipped for loading, unloading, processing, and storing grain.
LC2IEDM Notes:	mapped to “Tower (non-communications)” ECC TOW 1000124
Computed Degree of Alignment:	60
Grandstand→{FACILITY-TYPE}	
Notes	22 items map to FACILITY-TYPE = NOS (60005, 60006, 60007, 60047, 60051, 60054, 60055, 60056, 60062, 60066, 60070, 60083, 60084, 60089, 60094, 60098, 60099, 60108, 60109, 60136, 60141, 60147).
LC2IEDM Notes:	no ECC exists
Computed Degree of Alignment:	31
Grassland→{GEOGRAPHIC-FEATURE-STATUS, GEOGRAPHIC-FEATURE-TYPE}	
LC2IEDM Notes:	mapped to “Grassland” ECC GSL 1000030
Computed Degree of Alignment:	19
Ground Surface Element→{GEOGRAPHIC-FEATURE-STATUS, GEOGRAPHIC-FEATURE-TYPE}	
Notes	Maps to GEOGRAPHIC-FEATURE-STATUS, which includes 9 enumerated values for GEOGRAPHIC-FEATURE-STATUS-SURFACE-CONDITION.
TCDM Notes:	The surface soil characteristics of the terrain.
LC2IEDM Notes:	no ECC exists
Computed Degree of Alignment:	25
Gully / Gorge→{GEOGRAPHIC-FEATURE-TYPE}	
LC2IEDM Notes:	mapped to “Gully (gorge)” ECC GUL 1000030
Computed Degree of Alignment:	44
Hardened Aircraft Shelter→{FACILITY-TYPE}	
LC2IEDM Notes:	mapped to “Shelter, surface” ECC SHLSUR 1000069
Computed Degree of Alignment:	76
Hedgerow→{GEOGRAPHIC-FEATURE-TYPE}	
Notes	Mapped to FACILITY-TYPE “Fence”, a man-made barrier of relatively light structure used an enclosure or boundary. Could alternatively be mapped to CONTROL-FEATURE-TYPE “Obstacle Line”, ECC OBSLIN, a single line of natural or man-made obstacles.
TCDM Notes:	A continuous growth of shrubbery planted as a fence, a boundary, or a windbreak.
LC2IEDM Notes:	mapped to “Scrub/brush” ECC SCR 1000055
Computed Degree of Alignment:	67
Heliport→{FACILITY-TYPE}	
LC2IEDM Notes:	mapped to “Heliport” ECC HPT 1000052
Computed Degree of Alignment:	52
Hops→{FACILITY-TYPE}	

Notes	Although no FACILITY-TYPE-CATEGORY-CODE exists for Hops in LC2IEDM, it is mapped here as something that is man-made and managed or controlled, much like Cropland, which does have a FACILITY-TYPE-CATEGORY-CODE. 3 items map to CRP (60039, 60069, 60119).
LC2IEDM Notes:	Maps to CRP, Cropland.
Computed Degree of Alignment:	20
Hydrographic Lock→{FACILITY-TYPE}	
Notes	22 items map to FACILITY-TYPE = NOS (60005, 60006, 60007, 60047, 60051, 60054, 60055, 60056, 60062, 60066, 60070, 60083, 60084, 60089, 60094, 60098, 60099, 60108, 60109, 60136, 60141, 60147).
LC2IEDM Notes:	no ECC exists.
Computed Degree of Alignment:	43
Ice Cliff→{GEOGRAPHIC-FEATURE-TYPE}	
Notes	2 items map to CLF (60014, 60071).
LC2IEDM Notes:	mapped to “Cliff/escarpment” ECC CLF 1000010.
Computed Degree of Alignment:	38
Infantry Trench→{FACILITY-TYPE}	
Notes	There exists a FACILITY-TYPE-CATEGORY-CODE for Trench in LC2IEDM, so the primary mapping is to FACILITY-TYPE. An alternative mapping could be to CONTROL-FEATURE: To load all data pertaining to this Environment Class may require using both CONTROL-FEATURE-TYPE and CONTROL-FEATURE, since the LOCATION-related portion can only be accessed using FEATURE-LOCATION. In addition, the LINE, SURFACE and SURFACE-REGION tables also may be required.
LC2IEDM Notes:	Maps to TCH, Trench 100065.
Computed Degree of Alignment:	96
International Date Line→{CONTROL-FEATURE-TYPE}	
Notes	No ECC exists. On a map overlay, may be shown simply as a location line and given the name “International Date Line”. Might also be used as an administrative CONTROL-FEATURE for purposes of time-keeping. LOCATION is linked to CONTROL-FEATURE thru FEATURE-LOCATION and FEATURE. 7 items map to BDYPOA (60001, 60010, 60026, 60042, 60060, 60061, 60073).
LC2IEDM Notes:	Maps to “Boundary, political/administrative” ECC BDYPOA
Computed Degree of Alignment:	28
Irrigation Ditch→{FACILITY-TYPE}	
Notes	Exactly the same definitions in both TCDM and LC2IEDM: “A channel constructed for the purpose of irrigation or drainage”.
LC2IEDM Notes:	mapped to “Ditch” ECC DCH 1000118.
Computed Degree of Alignment:	75

Jetty→{FACILITY-TYPE}	
Notes	3 items map to DAM (60016, 60041, 60075).
LC2IEDM Notes:	mapped to “Dam/Weir” ECC DAM 1000117
Computed Degree of Alignment: 31	
Lagoon / Reef Pool→{GEOGRAPHIC-FEATURE-STATUS, GEOGRAPHIC-FEATURE-TYPE}	
Notes	15 items map to GEOGRAPHIC-FEATURE-TYPE = NOS (60012, 60015, 60052, 60076, 60096, 60100, 60115, 60116, 60131, 60136, 60137, 60140, 60144, 60146, 60153, 60160).
LC2IEDM Notes:	no ECC exists
Computed Degree of Alignment: 13	
Lake / Pond→{GEOGRAPHIC-FEATURE-STATUS, GEOGRAPHIC-FEATURE-TYPE}	
LC2IEDM Notes:	mapped to “Lake/Pond” ECC LAK 1000039
Computed Degree of Alignment: 37	
Lake / Pond Centerline / Nexus→{GEOGRAPHIC-FEATURE-STATUS, GEOGRAPHIC-FEATURE-TYPE}	
Notes	Associate the LOCATION Line with the Lake thru FEATURE-LOCATION, FEATURE, and GEOGRAPHIC-FEATURE, which links back to GEOGRAPHIC-FEATURE-TYPE.
LC2IEDM Notes:	mapped to “Bearing Line” ECC BERLIN 1000109
Computed Degree of Alignment: 34	
Lighthouse→{FACILITY-TYPE}	
Notes	2 items map to COT (60035, 60079).
LC2IEDM Notes:	mapped to “Communications Tower” ECC COT 1000043 (not a great mapping)
Computed Degree of Alignment: 64	
Mandate Line / Convention Line→{CONTROL-FEATURE-TYPE}	
Notes	7 items map to BDYPOA (60001, 60010, 60026, 60042, 60060, 60061, 60073).
LC2IEDM Notes:	mapped to “Boundary, political/administrative” ECC BDYPOA 1000074
Computed Degree of Alignment: 28	
Maritime Limit Boundary→{CONTROL-FEATURE-TYPE}	
Notes	Maps primarily to LOCATION-CATEGORY-CODE = LN (Line), a one-dimensional location that is defined by 2 or more points connected by straight line segments in an ordered sequence. If the first and last point are the same, it creates a boundary. Loosely maps to ECC RELL, “Release Line”, A Phase Line used in river-crossing operations that delineates a change in headquarters controlling movement. 7 items map to BDYPOA (60001, 60010, 60026, 60042, 60060, 60061, 60073).
TCDM Notes:	A line where on either side certain activities or factors of significance to navigation and/or operation apply.
LC2IEDM Notes:	No ECC exists, partially maps to “Release Line” ECC RELL
Computed Degree of Alignment: 28	

Maritime Mole→{FACILITY-TYPE}	
Notes	2 items map to TRANSF (60062, 60092).
LC2IEDM Notes:	mapped to “Transloading Facility” ECC TRANSF 1000026
Computed Degree of Alignment:	34
Maritime Platform→{FACILITY-TYPE}	
Notes	22 items map to FACILITY-TYPE = NOS (60005, 60006, 60007, 60047, 60051, 60054, 60055, 60056, 60062, 60066, 60070, 60083, 60084, 60089, 60094, 60098, 60099, 60108, 60109, 60136, 60141, 60147).
LC2IEDM Notes:	no ECC exists
Computed Degree of Alignment:	44
Maritime Wreck→{CONTROL-FEATURE-TYPE}	
Notes	No ECC exists. Might be mapped to FACILITY-TYPE = DMDBR5 (demolition debris) – the debris left over from the demolition of an object. Alternatively, one could use FACILITY-TYPE – RUI (Ruins) – a site or location where remains of ancient civilization or human activity have been discovered. It could possibly be a CONTROL-FEATURE, if there were any military, political, or administrative significance, or if the area of the wreck posed a hazard to navigation, etc. 22 items map to FACILITY-TYPE = NOS (60005, 60006, 60007, 60047, 60051, 60054, 60055, 60056, 60062, 60066, 60070, 60083, 60084, 60089, 60094, 60098, 60099, 60108, 60109, 60136, 60141, 60147).
TCDM Notes:	The ruined remains of a vessel.
LC2IEDM Notes:	mapped to “Point of Interest” ECC PTINT or to “No-Go Area” ECC NGA.
Computed Degree of Alignment:	28
Marsh / Swamp→{GEOGRAPHIC-FEATURE-TYPE}	
LC2IEDM Notes:	mapped to “Marsh/swamp” ECC MSH 1000041.
Computed Degree of Alignment:	32
Military Area→{CONTROL-FEATURE-TYPE}	
LC2IEDM Notes:	mapped to “Named area of interest” ECC NAMAIN 1000063
Computed Degree of Alignment:	70
Minefield→{FACILITY-TYPE}	
LC2IEDM Notes:	mapped to “Minefield, not otherwise specified” ECC MINEFD 1000078.
Computed Degree of Alignment:	57

Miscellaneous Obstacle→{CONTROL-FEATURE-TYPE}	
Notes	No ECC exists. Could use “Tetrahedron” to represent the area or volume, which can be further described using LOCATION and GEOMETRIC VOLUME codes. Use FACILITY-LOCATION to link the location with the facility. 22 items map to FACILITY-TYPE = NOS (60005, 60006, 60007, 60047, 60051, 60054, 60055, 60056, 60062, 60066, 60070, 60083, 60084, 60089, 60094, 60098, 60099, 60108, 60109, 60136, 60141, 60147).
TCDM Notes:	Obstacle which is of a minor nature and which is not included in amore specific characterization.
LC2IEDM Notes:	almost maps to “Obstacle restricted area” or to “Obstacle Belt” or “Obstacle Lane” or “Obstacle Zone”.
Computed Degree of Alignment: 30	
Native Settlement→{CONTROL-FEATURE-TYPE, GEOGRAPHIC-FEATURE-STATUS}	
Notes	22 items map to FACILITY-TYPE = NOS (60005, 60006, 60007, 60047, 60051, 60054, 60055, 60056, 60062, 60066, 60070, 60083, 60084, 60089, 60094, 60098, 60099, 60108, 60109, 60136, 60141, 60147).
LC2IEDM Notes:	no ECC exists. Could map to “Named area of interest” or many other things depending on how it was being used.
Computed Degree of Alignment: 29	
Navigation Aids (Aeronautical)→{EQUIPMENT-TYPE}	
LC2IEDM Notes:	mapped to “Air-Traffic Control Radar” ECC ATCRAD 1000177
Computed Degree of Alignment: 80	
Nuclear Reactor→{EQUIPMENT-TYPE}	
Notes	3 items map to SITPWR (60091, 60101, 60145).
LC2IEDM Notes:	no ECC exists
Computed Degree of Alignment: 57	
Offshore Loading Facility→{FACILITY-TYPE}	
Notes	transloading facility? 2 items map to TRANSF (60062, 60092).
LC2IEDM Notes:	maps to “Transloading Facility” ECC TRANSF 1000026
Computed Degree of Alignment: 58	
Oil / Gas Facilities→{FACILITY-TYPE, GEOGRAPHIC-FEATURE-STATUS}	
Notes	maps to 3 different codes
LC2IEDM Notes:	mapped to “Depot, POL” ECC DEPPOL 1000007. or to “POL point” ECC POLPT 1000017
Computed Degree of Alignment: 35	
Oil / Gas Field→{FACILITY-TYPE, GEOGRAPHIC-FEATURE-STATUS}	
Notes	22 items map to FACILITY-TYPE = NOS (60005, 60006, 60007, 60047, 60051, 60054, 60055, 60056, 60062, 60066, 60070, 60083, 60084, 60089, 60094, 60098, 60099, 60108, 60109, 60136, 60141, 60147).
LC2IEDM Notes:	no ECC exists
Computed Degree of Alignment: 23	

Orchard / Plantation→{FACILITY-TYPE}	
Notes	2 items map to ORD (60095, 60159).
LC2IEDM Notes:	Maps to ORD, Orchard/plantation 1000119.
Computed Degree of Alignment: 16	
Pack Ice→{GEOGRAPHIC-FEATURE-TYPE}	
Notes	15 items map to GEOGRAPHIC-FEATURE-TYPE = NOS (60012, 60015, 60052, 60076, 60096, 60100, 60115, 60116, 60131, 60136, 60137, 60140, 60144, 60146, 60153, 60160).
LC2IEDM Notes:	no ECC exists.
Computed Degree of Alignment: 13	
Pier / Wharf / Quay→{FACILITY-TYPE}	
Notes	harbor or port 2 items map to HARBUR (60006, 60097).
LC2IEDM Notes:	mapped to “Harbour” ECC HARBUR 1000167
Computed Degree of Alignment: 38	
Pile / Piling / Post→{FACILITY-TYPE}	
Notes	22 items map to FACILITY-TYPE = NOS (60005, 60006, 60007, 60047, 60051, 60054, 60055, 60056, 60062, 60066, 60070, 60083, 60084, 60089, 60094, 60098, 60099, 60108, 60109, 60136, 60141, 60147).
LC2IEDM Notes:	no ECC
Computed Degree of Alignment: 24	
Pipeline / Pipe→{FACILITY-TYPE}	
Notes	22 items map to FACILITY-TYPE = NOS (60005, 60006, 60007, 60047, 60051, 60054, 60055, 60056, 60062, 60066, 60070, 60083, 60084, 60089, 60094, 60098, 60099, 60108, 60109, 60136, 60141, 60147).
LC2IEDM Notes:	no ECC exists
Computed Degree of Alignment: 28	
Polar Ice→{GEOGRAPHIC-FEATURE-TYPE}	
Notes	15 items map to GEOGRAPHIC-FEATURE-TYPE = NOS (60012, 60015, 60052, 60076, 60096, 60100, 60115, 60116, 60131, 60136, 60137, 60140, 60144, 60146, 60153, 60160).
LC2IEDM Notes:	no ECC exists
Computed Degree of Alignment: 13	
Power Plant→{FACILITY-TYPE}	
Notes	3 items map to SITPWR (60091, 60101, 60145).
LC2IEDM Notes:	mapped to “Industrial Installation” ECC INDINS 1000110.
Computed Degree of Alignment: 41	
Power Transmission Line→{FACILITY-TYPE}	
Notes	2 items map to PTL (60102, 60103).
LC2IEDM Notes:	mapped to “Power Transmission Line” ECC PTL 1000120.
Computed Degree of Alignment: 52	
Power Transmission Pylon→{FACILITY-TYPE}	
Notes	2 items map to PTL (60102, 60103).
LC2IEDM Notes:	no ECC exists.
Computed Degree of Alignment: 64	

Prepared Defensive Positions Area→{CONTROL-FEATURE-TYPE}	
Notes	2 items map to DEFPOS (60043, 60104).
LC2IEDM Notes:	mapped to “Defensive position” ECC DEFPOS 1000068.
Computed Degree of Alignment:	72
Prepared Defensive Region→{FACILITY-TYPE}	
Notes	fortified area
LC2IEDM Notes:	mapped to “Defence zone” ECC DEFZ 1000078
Computed Degree of Alignment:	100
Processing Plant / Treatment Plant→{FACILITY-TYPE}	
Notes	7 items map to INDINS (60011, 60013, 60026, 60106, 60107, 60120, 60130).
LC2IEDM Notes:	mapped to “Industrial Installation” ECC INDINS 1000110
Computed Degree of Alignment:	35
Pumping Station→{FACILITY-TYPE}	
Notes	7 items map to INDINS (60011, 60013, 60026, 60106, 60107, 60120, 60130).
LC2IEDM Notes:	mapped to “Industrial Installation” ECC INDINS 1000110
Computed Degree of Alignment:	43
Quarry→{FACILITY-TYPE, GEOGRAPHIC-FEATURE-STATUS}	
Notes	22 items map to FACILITY-TYPE = NOS (60005, 60006, 60007, 60047, 60051, 60054, 60055, 60056, 60062, 60066, 60070, 60083, 60084, 60089, 60094, 60098, 60099, 60108, 60109, 60136, 60141, 60147).
LC2IEDM Notes:	no ECC exists.
Computed Degree of Alignment:	30
Race Track→{FACILITY-TYPE}	
Notes	22 items map to FACILITY-TYPE = NOS (60005, 60006, 60007, 60047, 60051, 60054, 60055, 60056, 60062, 60066, 60070, 60083, 60084, 60089, 60094, 60098, 60099, 60108, 60109, 60136, 60141, 60147).
LC2IEDM Notes:	no ECC exists.
Computed Degree of Alignment:	27
Railroad→{FACILITY-TYPE}	
Notes	1 item maps to RWY
LC2IEDM Notes:	mapped to “Railway/railroad” ECC RWY 1000061.
Computed Degree of Alignment:	31
Railroad Siding / Railroad Spur→{FACILITY-TYPE}	
Notes	2 items map to RAIL (60112, 60113).
LC2IEDM Notes:	no ECC exists. (just for Railway/railroad).
Computed Degree of Alignment:	26
Railroad Yard / Marshalling Yard→{FACILITY-TYPE, GEOGRAPHIC-FEATURE-STATUS}	
Notes	2 items map to RAIL (60112, 60113).
LC2IEDM Notes:	no ECC exists. (just for Railway/railroad).
Computed Degree of Alignment:	43
Railroad Yard / Marshalling Yard Centerline / Nexus→{CONTROL-FEATURE-TYPE}	
Notes	Associated with the railroad yard FACILITY thru FACILITY-LOCATION

LC2IEDM Notes:	mapped to “Bearing Line” ECC BERLIN 1000109.
Computed Degree of Alignment:	48
Railroad in Built-Up Area Centerline / Nexus→{CONTROL-FEATURE-TYPE}	
Notes	No ECC exists. Can associate the LOCATION of the line with the railroad FACILITY thru FACILITY-LOCATION.
LC2IEDM Notes:	mapped to “Bearing Line” ECC BERLIN 1000109.
Computed Degree of Alignment:	26
Rapids→{GEOGRAPHIC-FEATURE-STATUS, GEOGRAPHIC-FEATURE-TYPE}	
Notes	15 items map to GEOGRAPHIC-FEATURE-TYPE = NOS (60012, 60015, 60052, 60076, 60096, 60100, 60115, 60116, 60131, 60136, 60137, 60140, 60144, 60146, 60153, 60160).
LC2IEDM Notes:	no ECC exists.
Computed Degree of Alignment:	24
Reef→{GEOGRAPHIC-FEATURE-TYPE}	
Notes	15 items map to GEOGRAPHIC-FEATURE-TYPE = NOS (60012, 60015, 60052, 60076, 60096, 60100, 60115, 60116, 60131, 60136, 60137, 60140, 60144, 60146, 60153, 60160).
LC2IEDM Notes:	no ECC exists.
Computed Degree of Alignment:	19
Reservoir→{FACILITY-TYPE, GEOGRAPHIC-FEATURE-STATUS}	
Notes	1 item maps to RES
LC2IEDM Notes:	mapped to “Reservoir” ECC RES 1000121.
Computed Degree of Alignment:	37
Reservoir Centerline / Nexus→{CONTROL-FEATURE-TYPE, GEOGRAPHIC-FEATURE-STATUS}	
Notes	Associated with the reservoir FACILITY thru FACILITY-LOCATION.
LC2IEDM Notes:	mapped to “Bearing Line” ECC BERLIN 1000109.
Computed Degree of Alignment:	34
Rice Field→{FACILITY-TYPE}	
Notes	Although there is no FACILITY-TYPE-CATEGORY-CODE for Rice Field in LC2IEDM, it was mapped to FACILITY-TYPE as it similar to Cropland and Orchard/Plantation – which do have a FACILITY-TYPE-CATEGORY-CODE (both man made and managed or controlled). Adding GEOGRAPHIC-FEATURE-STATUS-SURFACE-CONDITION-CODE = FLODNG (Flooding), it gives a good representation of a flooded cropland. 3 items map to CRP (60039, 60069, 60119).
LC2IEDM Notes:	Maps to CRP, Cropland 1000115 or ORD, Orchard/plantation 1000119.
Computed Degree of Alignment:	17
Rig / Superstructure→{EQUIPMENT-TYPE}	
Notes	7 items map to INDINS (60011, 60013, 60026, 60106, 60107, 60120, 60130).
LC2IEDM Notes:	no ECC exists.
Computed Degree of Alignment:	43
River / Stream→{GEOGRAPHIC-FEATURE-STATUS, GEOGRAPHIC-FEATURE-TYPE}	
LC2IEDM Notes:	mapped to “River/stream” ECC RIV 1000051.

Computed Degree of Alignment: 30	
River / Stream Centerline / Nexus→{CONTROL-FEATURE-TYPE, GEOGRAPHIC-FEATURE-STATUS}	
Notes	The LOCATION line can be associated with the river thru FEATURE-LOCATION, FEATURE, and GEOGRAPHIC-FEATURE.
LC2IEDM Notes:	mapped to “Bearing Line” ECC BERLIN 1000109.
Computed Degree of Alignment: 26	
Road→{FACILITY-TYPE, GEOGRAPHIC-FEATURE-STATUS}	
Notes	2 items map to RD (60025, 60123).
LC2IEDM Notes:	mapped to “Road” ECC RD 1000058.
Computed Degree of Alignment: 27	
Road in Built-Up Area Centerline / Nexus→{CONTROL-FEATURE-TYPE}	
Notes	The LOCATION line is associated with the road thru FACILITY-LOCATION and FACILITY.
LC2IEDM Notes:	mapped to “Bearing Line” ECC BERLIN 1000109.
Computed Degree of Alignment: 33	
Rock Strata / Rock Formation→{GEOGRAPHIC-FEATURE-TYPE}	
Notes	2 items map to RST (60050, 60125).
LC2IEDM Notes:	mapped to “Rock strata/Rock formation” ECC RST 1000052.
Computed Degree of Alignment: 36	
Route (Maritime)→{CONTROL-FEATURE-TYPE}	
LC2IEDM Notes:	mapped to “Route” ECC ROUTE 1000050.
Computed Degree of Alignment: 44	
Route (Maritime) Centerline / Nexus→{CONTROL-FEATURE-TYPE}	
LC2IEDM Notes:	mapped to “Bearing Line” ECC BERLIN 1000109.
Computed Degree of Alignment: 50	
Ruins→{FACILITY-TYPE}	
Notes	There is a FACILITY-TYPE-CATEGORY-CODE for this in LC2IEDM.
LC2IEDM Notes:	Maps to RUI, Ruins 1999122.
Computed Degree of Alignment: 56	
Runway→{FACILITY-TYPE, GEOGRAPHIC-FEATURE-STATUS}	
Notes	airstrip 4 items map to AIR (60003, 60004, 60129, 60146).
LC2IEDM Notes:	mapped to “Airfield/airport/airstrip” ECC AIR 1000037.
Computed Degree of Alignment: 39	
Salt Evaporator→{FACILITY-TYPE}	
Notes	7 items map to INDINS (60011, 60013, 60026, 60106, 60107, 60120, 60130).
LC2IEDM Notes:	mapped to “Industrial Installation” ECC INDINS 1000110.
Computed Degree of Alignment: 14	
Salt Pan→{GEOGRAPHIC-FEATURE-TYPE}	
Notes	15 items map to GEOGRAPHIC-FEATURE-TYPE = NOS (60012, 60015, 60052, 60076, 60096, 60100, 60115, 60116, 60131, 60136, 60137, 60140, 60144, 60146, 60153, 60160).
LC2IEDM Notes:	no ECC exists.
Computed Degree of Alignment: 12	

Sand Dune / Sand Hills→{GEOGRAPHIC-FEATURE-TYPE}	
LC2IEDM Notes:	mapped to “Sand dune/sand hill” ECC SND 1000057.
Computed Degree of Alignment: 24	
Scrub / Brush / Bush→{GEOGRAPHIC-FEATURE-TYPE}	
LC2IEDM Notes:	mapped to “Scrub/brush” ECC SCR 1000055.
Computed Degree of Alignment: 27	
Seawall→{FACILITY-TYPE}	
Notes	2 items map to WALL (60161, 60134).
LC2IEDM Notes:	mapped to “Wall” ECC WALL 1000087.
Computed Degree of Alignment: 38	
Sebkha→{GEOGRAPHIC-FEATURE-TYPE}	
Notes	2 items map to DPR (60135, 60149).
LC2IEDM Notes:	mapped (poorly) to “Depression” ECC DPR 1000022.
Computed Degree of Alignment: 18	
Settlement→{CONTROL-FEATURE-TYPE}	
Notes	22 items map to FACILITY-TYPE = NOS (60005, 60006, 60007, 60047, 60051, 60054, 60055, 60056, 60062, 60066, 60070, 60083, 60084, 60089, 60094, 60098, 60099, 60108, 60109, 60136, 60141, 60147).
LC2IEDM Notes:	mapped (vaguely) to “Area of Interest” ECC AOI 1000003
Computed Degree of Alignment: 29	
Settling Basin / Sludge Pond→{GEOGRAPHIC-FEATURE-STATUS, GEOGRAPHIC-FEATURE-TYPE}	
Notes	15 items map to GEOGRAPHIC-FEATURE-TYPE = NOS (60012, 60015, 60052, 60076, 60096, 60100, 60115, 60116, 60131, 60136, 60137, 60140, 60144, 60146, 60153, 60160).
LC2IEDM Notes:	no ECC exists.
Computed Degree of Alignment: 21	
Snow Field / Ice Field→{GEOGRAPHIC-FEATURE-STATUS, GEOGRAPHIC-FEATURE-TYPE}	
Notes	15 items map to GEOGRAPHIC-FEATURE-TYPE = NOS (60012, 60015, 60052, 60076, 60096, 60100, 60115, 60116, 60131, 60136, 60137, 60140, 60144, 60146, 60153, 60160).
LC2IEDM Notes:	no ECC exists.
Computed Degree of Alignment: 14	
Snow Shed / Rock Shed→{FACILITY-TYPE}	
Notes	A hut is a small simple or crude house or shelter. It is distinguished from the term shed, which is used for storage. The definition of snow shed/ rock shed implies it is used to shelter people or things from falling debris.
LC2IEDM Notes:	mapped to “Hut” ECC HUT
Computed Degree of Alignment: 76	
Spring / Water Hole→{GEOGRAPHIC-FEATURE-TYPE}	
Notes	15 items map to GEOGRAPHIC-FEATURE-TYPE = NOS (60012, 60015, 60052, 60076, 60096, 60100, 60115, 60116, 60131, 60136, 60137, 60140, 60144, 60146, 60153, 60160).
LC2IEDM Notes:	no ECC exists.
Computed Degree of Alignment: 24	
Stadium / Amphitheatre→{FACILITY-TYPE, GEOGRAPHIC-FEATURE-STATUS}	

Notes	22 items map to FACILITY-TYPE = NOS (60005, 60006, 60007, 60047, 60051, 60054, 60055, 60056, 60062, 60066, 60070, 60083, 60084, 60089, 60094, 60098, 60099, 60108, 60109, 60136, 60141, 60147).
LC2IEDM Notes:	no ECC exists.
Computed Degree of Alignment:	31
Storage Bunker / Storage Mound→{FACILITY-TYPE}	
LC2IEDM Notes:	mapped to “Bunker” ECC BUNKER 1000023
Computed Degree of Alignment:	68
Storage Tank→{FACILITY-TYPE}	
Notes	2 items map to DEPOT (60045, 60143).
LC2IEDM Notes:	mapped (roughly) to “Depot, not otherwise specified” ECC DEPOT 1000046.
Computed Degree of Alignment:	57
Submerged Rock→{GEOGRAPHIC-FEATURE-TYPE}	
Notes	15 items map to GEOGRAPHIC-FEATURE-TYPE = NOS (60012, 60015, 60052, 60076, 60096, 60100, 60115, 60116, 60131, 60136, 60137, 60140, 60144, 60146, 60153, 60160).
LC2IEDM Notes:	no ECC exists.
Computed Degree of Alignment:	32
Substation / Transformer Yard→{FACILITY-TYPE}	
Notes	3 items map to SITPWR (60091, 60101, 60145).
TCDM Notes:	A structure or group of structures, along a power line route, in which electric current is transformed and/or distributed.
LC2IEDM Notes:	Mapped to “Site, Power” ECC SITPWR, a power production or distribution installation.
Computed Degree of Alignment:	46
Taxiway→{FACILITY-TYPE, GEOGRAPHIC-FEATURE-STATUS}	
Notes	4 items map to AIR (60003, 60004, 60129, 60146).
LC2IEDM Notes:	mapped to “Airfield/airport/airstrip” ECC AIR 1000037.
Computed Degree of Alignment:	25
Telephone Line / Telegraph Line→{FACILITY-TYPE}	
Notes	22 items map to FACILITY-TYPE = NOS (60005, 60006, 60007, 60047, 60051, 60054, 60055, 60056, 60062, 60066, 60070, 60083, 60084, 60089, 60094, 60098, 60099, 60108, 60109, 60136, 60141, 60147).
LC2IEDM Notes:	no ECC exists.
Computed Degree of Alignment:	40
Terrain Cut→{GEOGRAPHIC-FEATURE-TYPE}	
Notes	15 items map to GEOGRAPHIC-FEATURE-TYPE = NOS (60012, 60015, 60052, 60076, 60096, 60100, 60115, 60116, 60131, 60136, 60137, 60140, 60144, 60146, 60153, 60160).
LC2IEDM Notes:	no ECC exists.
Computed Degree of Alignment:	26
Terrain Depression→{GEOGRAPHIC-FEATURE-TYPE}	
Notes	2 items map to DPR (60135, 60149).

LC2IEDM Notes:	mapped to “Depression” ECC DPR 1000022.
Computed Degree of Alignment:	30
Tower (Non-communication)→{FACILITY-TYPE}	
Notes	2 items map to TOW (only) (only) (60037, 60150).
LC2IEDM Notes:	mapped to “Tower, non-communication” ECC TOW 1000124.
Computed Degree of Alignment:	57
Trail→{CONTROL-FEATURE-TYPE, GEOGRAPHIC-FEATURE-STATUS}	
LC2IEDM Notes:	no ECC exists.
Computed Degree of Alignment:	27
Trees→{GEOGRAPHIC-FEATURE-TYPE}	
LC2IEDM Notes:	mapped to “Tree” ECC TRE 1000064.
Computed Degree of Alignment:	22
Tundra→{GEOGRAPHIC-FEATURE-TYPE}	
Notes	15 items map to GEOGRAPHIC-FEATURE-TYPE = NOS (60012, 60015, 60052, 60076, 60096, 60100, 60115, 60116, 60131, 60136, 60137, 60140, 60144, 60146, 60153, 60160).
LC2IEDM Notes:	no ECC exists.
Computed Degree of Alignment:	10
Tunnel→{FACILITY-TYPE}	
Notes	There is a FACILITY-TYPE-CATEGORY-CODE for this in LC2IEDM.
LC2IEDM Notes:	Maps to TUN, Tunnel 1000067.
Computed Degree of Alignment:	78
Tunnel Shelter→{FACILITY-TYPE}	
Notes	2 items map to SHLUND (60155, 60156).
LC2IEDM Notes:	mapped to “Shelter, underground” ECC SHLUND 1000071.
Computed Degree of Alignment:	72
Underground Bunker→{FACILITY-TYPE}	
Notes	2 items map to SHLUND (60155, 60156).
LC2IEDM Notes:	mapped to “Shelter, underground” ECC SHLUND 1000071.
Computed Degree of Alignment:	57
Underwater Danger / Hazard→{CONTROL-FEATURE-TYPE}	
Notes	3 items map to CONTROL-FEATURE-TYPE = NOS (60044, 60059, 60157).
LC2IEDM Notes:	no ECC exists.
Computed Degree of Alignment:	25

Vehicle Barrier→{FACILITY-TYPE}	
Notes	Can be mapped to 5 different codes within FACILITY-TYPE; ROADBL “Roadblock” (a barrier or obstacle (usually covered by fire) used to block, or limit the movement of, hostile vehicles along a route), ABATIS (a vehicular obstacle constructed by felling trees), DGT “Dragon Teeth” (regular spaced concrete or metal barriers laid in a single or multiple rows to prevent vehicular movement), ANTOBS “Anti-Tank Obstacle”, (no definition given), BPSOBS “Beam Post Obstacle” (a squared-off log or a large, oblong piece of timber, metal, or stone inserted in the ground to obstruct movement.)
TCDM Notes:	A permanent or semi-permanent obstruction placed across a route to prevent vehicular traffic.
LC2IEDM Notes:	maps best to “Roadblock” ECC ROADBL. could also map to “Anti-tank Obstacle” ECC ANTOBS 1000132. Or to “Beam post obstacle” ECC BPSOBS 1000126. Or to “Abatis” ECC ABATIS. Or to “Dragon Teeth” ECC DGT.
Computed Degree of Alignment: 94	
Vineyards→{FACILITY-TYPE, GEOGRAPHIC-FEATURE-STATUS}	
Notes	2 items map to ORD (60095, 60159).
LC2IEDM Notes:	Maps to ORD, Orchard/plantation 1000119.
Computed Degree of Alignment: 25	
Volcanic Dike→{GEOGRAPHIC-FEATURE-TYPE}	
Notes	15 items map to GEOGRAPHIC-FEATURE-TYPE = NOS (60012, 60015, 60052, 60076, 60096, 60100, 60115, 60116, 60131, 60136, 60137, 60140, 60144, 60146, 60153, 60160).
LC2IEDM Notes:	no ECC exists.
Computed Degree of Alignment: 26	
Wall→{FACILITY-TYPE}	
Notes	2 items map to WALL (60161, 60134).
LC2IEDM Notes:	mapped to “Wall” ECC WALL 1000087.
Computed Degree of Alignment: 45	
Water (Except Inland)→{GEOGRAPHIC-FEATURE-STATUS, GEOGRAPHIC-FEATURE-TYPE}	
LC2IEDM Notes:	mapped to “Water (except inland)” ECC WAT 1000069.
Computed Degree of Alignment: 38	
Water Tower→{FACILITY-TYPE}	
LC2IEDM Notes:	mapped to “Water tower” ECC WTW 1000070.
Computed Degree of Alignment: 85	
Well→{FACILITY-TYPE}	
Notes	2 items map to FACILITY-CODE = NOS, STORAGE-CAPABILITY = WAT (60030, 60164).
LC2IEDM Notes:	no ECC exists.
Computed Degree of Alignment: 35	
Windmill→{FACILITY-TYPE}	
LC2IEDM Notes:	Maps to WML, Windmill 1000125.
Computed Degree of Alignment: 85	

Zone of Occupation→{CONTROL-FEATURE-TYPE}	
Notes	Zone of Occupation would be a geographic subset of, and included within, the LC2IEDM's "Area of Interest".
TCDM Notes:	An area temporarily held and controlled by a foreign military force.
LC2IEDM Notes:	Maps to "Area of Interest" ECC AOI, A CONTROL-FEATURE-TYPE with an area location which denotes that area of concern to the commander, including the area of influence, and extending into enemy territory to the objectives of current or planned operations. This area also includes areas occupied...
Computed Degree of Alignment: 67	

D.2 LC2IEDM-to-TCDM Alignment Results

This section presents results of assessing the degree to which the LC2IEDM aligns to the TCDM. The LC2IEDM has two entities that model terrain concepts: GEOGRAPHIC-FEATURE and FACILITY. Because these are distinct entities with individual attributes, we opted to assess terrain alignment by modeling each as a separate concept. We therefore performed two Conceptual-level alignment assessments with respect to terrain. Each is presented in a separate section.

D.2.1 Geographic Feature

This section presents results of assessing the degree to which LC2IEDM entities related to geographic features align to the TCDM. The following notes were made on Conceptual-level alignment:

Notes:	The JSIMS terrain view is somewhat broader than necessary. It includes man-made features, which aren't part of geographic features. But better too much than too little.
	The attached document describes how LC2IEDM terrain data maps to the TCDM.
Computed Degree of Alignment: 63	

The following table presents the results of Entity-level assessment for each LC2IEDM entity of the Geographic Feature concept.

Table D-2. Geographic Feature Assessment Summaries

CONTROL-FEATURE→{}	
Notes	It would seem that TCDM offers several ECCs that relate to the various control features that the LC2IEDM can model. However, the ECCs have no attributes that identify them as related; the alignment will be structural, based on relationship of an ECC name to a category code.
LC2IEDM Notes:	From the Geographic Feature view.
Computed Degree of Alignment: 75	
CONTROL-FEATURE-GEOGRAPHIC-FEATURE-ASSOCIATION→{}	
Notes	The CONTROL-FEATURE-GEOGRAPHIC-FEATURE-ASSOCIATION entity describes the relationship between a control feature

and a geographic feature.	
The TCDM cannot model this type of relationship. The TCDM can model limited kinds of relationships between control features (e.g., a BRIDGE can consist of multiple BRIDGE SPANs). Even that capability is very limited in comparison to the LC2IEDM's.	
LC2IEDM Notes:	From the Geographic Feature view.
Computed Degree of Alignment:	0
Assessment is terminal.	
FEATURE→{} Notes	
In the context of the Geographic Feature view, the nature of a FEATURE entity is constrained to modeling geographic features.	
LC2IEDM Notes:	From the Geographic Feature view.
Computed Degree of Alignment:	83
FEATURE-TYPE→{} Notes	
In the context of the Geographic Feature view, this entity has no particularly significant attributes; they're either fixed or migrated.	
LC2IEDM Notes:	From the Geographic Feature view.
Computed Degree of Alignment:	67
GEOGRAPHIC-FEATURE→{Beach, Bluff / Cliff / Escarpment, Contour Line (Land), Embankment / Fill, Ford, Forest, Grass / Scrub / Brush, Grassland, Gully / Gorge, Hill, Island, Lake / Pond, Landslide, Marsh / Swamp, Mountain Pass, Mountainous Region, Ridge Line, River / Stream, Rock Strata / Rock Formation, Sand Dune / Sand Hills, Spot Elevation, Terrain Depression, Trees, Valley Bottom Line, Water (Except Inland)}	
Notes	
A GEOGRAPHIC-FEATURE entity basically just denotes a specific kind of OBJECT-ITEM. It will align to the same degree as an OBJECT-ITEM can be uniquely identified.	
LC2IEDM Notes:	From the Geographic Feature view.
Computed Degree of Alignment:	86
GEOGRAPHIC-FEATURE-TYPE→{} Notes	
It would seem that TCDM offers several ECCs that relate to the various geographic feature types that the LC2IEDM can model. However, the ECCs have no attributes that identify them as related; the alignment will be structural, based on relationship of an ECC name to a category code.	
LC2IEDM Notes:	From the Geographic Feature view.
Computed Degree of Alignment:	60
OBJECT-ITEM→{} Notes	
An OBJECT-ITEM representing a geographic feature would store minimal information about that feature, leaving its subtypes to record the details.	
LC2IEDM Notes:	From the Geographic Feature view.
Computed Degree of Alignment:	72
OBJECT-ITEM-TYPE→{} Notes	
The OBJECT-ITEM-TYPE entity models many-to-many relationships between OBJECT-ITEM instances and OBJECT-TYPE instances. In the context of the Geographic Feature view, it	

	means that one geographic feature type can be the type of multiple geographic features. It may also denote that one geographic feature has multiple types, although that relationship seems unlikely.
LC2IEDM Notes:	The TCDM does not easily model even the 1:n mapping. From the Geographic Feature view.
Computed Degree of Alignment:	50
OBJECT-TYPE→{}	
Notes	In the context of the Geographic Feature view, OBJECT-TYPE doesn't play much role. Rather, its subtype GEOGRAPHIC-FEATURE is used to model various kinds of terrain features.
LC2IEDM Notes:	From the Geographic Feature view.
Computed Degree of Alignment:	75

D.2.2 Conceptual-Level Alignment of Facility

This section presents results of assessing the degree to which LC2IEDM entities related to facilities align to the TCDM. The following notes were made on Conceptual-level alignment:

Notes:	The JSIMS terrain view is somewhat broader than necessary. It includes geographic (natural) features, which aren't part of facilities. But better too much than too little.
	The JSIMS Facility view models man-made facilities. It probably overlaps with the Terrain view.
	The attached document describes how LC2IEDM facility data maps to the TCDM.
Assigned Degree of Alignment:	100

The following table presents the results of Entity-level assessment for each LC2IEDM entity of the Facility concept.

Table D-3. Facility Assessment Summaries

BRIDGE→{Bridge / Overpass / Viaduct, Bridge Span}	
Notes	A BRIDGE is a subtype of FACILITY. The degree of alignment of BRIDGE depends upon the degree to which FACILITY aligns.
	Both the LC2IEDM and the TCDM include the concept of a bridge. In the TCDM a bridge is a complex type.
Computed Degree of Alignment:	64

FACILITY→{Aircraft Maintenance Shop, Airport / Airfield, Airstrip, Barracks, Bridge / Overpass / Viaduct, Building, Built Up Area, Bunker, Burial Grounds, Camp, Canal, Cemetery, Chimney / Smokestack, Cleared Way / Cut Line / Firebreak, Communication Building, Communication Tower, Control Tower, Cropland, Crossing, Dam / Weir, Decontamination Pad, Depot (Storage), Ditch and/or Berm, Engineered, Dragon Teeth, Early Warning Radar Site, Fence, Ferry Site, Fort, Fortification, Gate, Harbour, Helicopter Landing Pad, Heliport, Hospital Building, Hut, Industrial Building, Industrial Complex (Heavy), Industrial Complex (Light), Industrial Works, Infantry Trench, Interchange, Military Trench, Minefield, Miscellaneous Obstacle, Missile Site, Offshore Loading Facility, Orchard / Plantation, Parking Garage, Port Facility, Power Transmission Line, Prepared Raft or Float Bridge Site, Railroad, Refugee Compound, Reservoir, Revetment (Shore Protection), Road, Ruins, Shed, Station, Steeple, Terrain Crater, Terrain Cut, Tower (Non-communication), Tunnel, Underground Bunker, Wall, Water Tower	
Notes	Each LC2IEDM instance of a facility will be represented as some TCDM ECC. The degree of alignment depends upon how many types of facilities can be modeled by TCDM ECCs. Deb identified the following ECCs that aren't in the TCDM DB: Tower (non-communications), Watering Place, Wire Obstacle.
LC2IEDM Notes:	From the Facility view.
Computed Degree of Alignment:	88
FACILITY-STATUS→{}	
Notes	FACILITY-STATUS aligns to the degree that the TCDM can record status information about a facility.
LC2IEDM Notes:	From the Facility view.
Computed Degree of Alignment:	13
FACILITY-TYPE→{Airport / Airfield, Bridge / Overpass / Viaduct, Building, Built Up Area, Canal, Chimney / Smokestack, Cleared Way / Cut Line / Firebreak, Communication Building, Communication Tower, Control Tower, Cropland, Dam / Weir, Depot (Storage), Heliport, Infantry Trench, Minefield, Miscellaneous Obstacle, Offshore Loading Facility, Orchard / Plantation, Power Transmission Line, Railroad, Reservoir, Road, Ruins, Terrain Cut, Tunnel, Underground Bunker, Wall, Water Tower, Windmill}	
Notes	The FACILITY-TYPE entity describes the type of facility and therefore aligns closely to the TCDM ECCs, albeit structurally.
LC2IEDM Notes:	From the Facility view.
Computed Degree of Alignment:	78
MINEFIELD→{Minefield}	
Computed Degree of Alignment:	57
OBJECT-ITEM→{}	
Notes	In the context of the Facility view, an OBJECT-ITEM instance represents the information about a facility that is independent of facility-specific characteristics. The degree of alignment of an OBJECT-ITEM depends upon the degree to which the TCDM models this same type of information.
LC2IEDM Notes:	From the Facility view.
Computed Degree of Alignment:	80
OBJECT-ITEM-STATUS→{}	
Notes	OBJECT-ITEM-STATUS records general status information. The TCDM does not model this type of information well.
LC2IEDM Notes:	From the Facility view.
Computed Degree of Alignment:	20
OBJECT-ITEM-TYPE→{}	

Notes	In the context of the Facility view, the OBJECT-ITEM-TYPE entity models the many-to-many relationships that can exist between facilities and facility types. The TCDM does not model these many-to-many relationships well. At best, it can model one-to-many relationships.
LC2IEDM Notes:	From the Facility view.
Assigned Degree of Alignment:	50
OBJECT-TYPE→}	
Notes	In the context of the Facility view, the OBJECT-TYPE entity records type information that is not specific to a facility.
LC2IEDM Notes:	From the Facility view.
Computed Degree of Alignment:	80

Appendix E. Rules for Value-Level Assessments

This appendix presents the rules assessors followed to perform Value-level alignment assessments. The rules were introduced to codify procedures and techniques. The intent was to ensure that degrees of alignment were uniformly and repeatably derived.

E.1 Background

Value-level alignments describe relationships between atomic domains in JSIMS and LC2IEDM. In this context, “atomic” means indivisible. No JSIMS attribute whose value is a complex data type is included. All LC2IEDM attributes are atomic.

E.2 JSIMS Atomic Domains

In JSIMS, there are two kinds of atomic domains: predefined and user-defined. The predefined domains used in JSIMS are those based on existing data types from number theory and programming languages, and standardized through the External Data Representation (XDR) standard. The following is a list of the predefined types used in the JSIMS Version 6 FOM:

boolean	A 4-byte integer. An instance of the type may have a value of either 0 or 1, corresponding to the logical values false and true.
char	Not really a domain, but instead indicates a placeholder for future capabilities.
double	An 8-byte IEEE double-precision floating-point number. Its range is $\pm 2^{1023}$, and it has about 17 significant decimal digits.
float	A 4-byte IEEE single-precision floating-point number. Its range is $\pm 2^{127}$, and it has about 7 significant decimal digits.
long	A 4-byte integer in two’s complement notation, meaning it can represent values from -2^{31} to $2^{31} - 1$.
octet	A placeholder for buffer data when shuttling values around a FOM in the HLA.
string	A string of arbitrary length (although the length of an instance is fixed).
unsigned long	A 4-byte integer, values of which can range from 0 to $2^{32} - 1$.

There are no attributes published by WARSIM whose type is float, octet, or unsigned long.

The atomic user-defined JSIMS domains are the enumerated data types. An enumerated data type is represented as a 4-byte integer. It can therefore have up to $2^{32} - 1$ distinct values.

E.3 LC2IEDM Atomic Domains

In the LC2IEDM, every attribute includes a specification of its representation in a physical database. This is its domain. Unlike JSIMS, then, all attributes have atomic domains.

The domains used in the LC2IEDM are drawn from the ANSI SQL specification. They are as follows:

CHAR(6)	A string exactly six characters long, i.e., when stored in the database it occupies 6 characters' worth of space. This domain is used to store the attributes whose names end in "-CODE", i.e., domains that correspond to enumerated codes.
NUMBER(<i>d</i>)	An integer with <i>d</i> decimal digits, i.e., between $-10^d + 1$ and $10^d - 1$. This domain is used to store quantities (e.g., number of items held). It is also used to store entity identifiers: NUMBER(12), NUMBER(15), and NUMBER(18) are the characteristic declarations for an attribute whose name ends with "-ID".
NUMBER(<i>d</i> , <i>s</i>)	A fixed-point number with <i>d</i> decimal digits, <i>s</i> of which are after the decimal point. This domain is typically used to store physical measurements. For example, a latitude, which is measured in degrees, is stored as NUMBER(9,6). That means a latitude stored using the LC2IEDM can be resolved to about 11 cm. The LC2IEDM stores all real quantities as fixed-point numbers. No LC2IEDM attributes have a floating-point domain.
VARCHAR(<i>n</i>)	A string that may be up to <i>n</i> characters long, i.e., when stored in the database it occupies no more than <i>n</i> characters' worth of space, and less if its length is less than <i>n</i> . This domain is typically used to record descriptive text, either in phrases (where <i>n</i> is fairly small) or large text blocks (where <i>n</i> may be as large as 2000).

E.4 Rules for Performing Value-Level Alignment Assessments

This section describes how to perform a Value-level alignment assessment. The subsections are organized by the types of domains used in JSIMS. The key questions for assessors to keep in mind as they perform a Value-level assessment are:

1. Can the LC2IEDM represent data that a JSIMS federate might generate?
2. Can a JSIMS federate restore its state using that data?

A Value-level assessment is derived from a State-level assessment. When an assessor performs a Value-level assessment, he has already determined that there exists JSIMS attribute j_a of type j_t and that j_a is aligned with an LC2IEDM attribute l_a whose type (representation in physical database) is l_t .¹ Knowledge of j_a and its purpose is often vital in performing Value-level assessments. For example, if j_a stores a latitude, its value is limited to ± 90 .

E.4.1 Rules for Enumerated Domains

If j_t is an enumerated type (e.g., `country_codes_enum_e`), then there must exist a mapping from each element of the enumeration to an LC2IEDM attribute value. The following rules apply.

3. If j_a aligns to exactly one LC2IEDM attribute whose domain is l_t , and l_t is also an enumerated type, then the degree of alignment is the percent of JSIMS values that have LC2IEDM equivalents. To calculate this quantity:

- a) Define, insofar as possible, an unambiguous mapping from j_t to l_t . The enumerated values do not have to be the same in both types; it is only necessary that a mapping exist.

For example, consider the JSIMS type `country_codes_enum_e`. During State level assessment, we may find that some JSIMS attribute j_a of type `country_codes_enum_e` aligns to the LC2IEDM attribute `OBJECT-TYPE-NATIONALITY-CODE`. To derive a Value level assessment from j_a , we study the overlapping values between and `OBJECT-TYPE-NATIONALITY-CODE`. As it happens, `country_codes_enum_e` has only one value: `cntry_unknown`. `OBJECT-TYPE-NATIONALITY-CODE` has 273 values. One of these values is `NOS` (Not Otherwise Specified, meaning not in the known list of countries), which conveys the same information as `cntry_unknown`.

- b) Compute the degree of alignment as the number of items in the mapping divided by the number of items in j_t .

Continuing our example, the degree of alignment between `country_codes_enum_e` and the values of `OBJECT-TYPE-NATIONALITY-CODE` is 1/1, or 100%.

4. Sometimes j_a aligns to multiple LC2IEDM attributes. The Value-level degree of alignment is still the percent of JSIMS enumerated values that can be mapped to LC2IEDM attribute values, but the analysis is more complicated because of the need to determine (and document!) dependency relationships.

For example, the JSIMS attribute `comms_status_receive`, which is of type `equipment_sensor_status_e`, aligns to 2 LC2IEDM attributes: `MATERIEL-STATUS-OPERATIONAL-STATUS-CODE` and `MATERIEL-STATUS-USAGE-STATUS-CODE`. The value of the second attribute depends on the value of the first.

To calculate the Value level degree of alignment requires understanding these dependencies. The `equipment_sensor_status_e` type has 4 values: `damaged`, `jammed`, `off_status`, and `on_status`. Table E-1 describes relationships between these values and the LC2IEDM `MATERIEL-STATUS-OPERATIONAL-STATUS-CODE` values.

¹ This is simplified. There are some counterexamples below.

Table E-1. Equipment Status Enumerations Mapping

JSIMS Value	LC2IEDM Values	Notes
damaged	• NOP (not operational) • MOPS (marginally operational)	It seems logical that damaged equipment would be considered marginally operational.
jammed	<i>None</i>	LC2IEDM does have a TNOPS (temporarily not operational) value. But it does not seem sufficient to model jamming.
off_status	• OPR (fully operational) • SOPR (substantially operational)	• OPR and SOPR do not exactly model off_status or on_status. They only model the capability for the equipment to be on or off. • The LC2IEDM provides no precise definition of “substantially operational”. I assume it means the equipment can still be turned on and off, and that it does not qualify as damaged.
on_status		

If the equipment is damaged, jammed, or off, then the value of the MATERIEL-STATUS-USAGE-STATUS-CODE attribute will be DEACTV (deactivated). If the equipment is on, then the attribute’s value will be ACTIVE (activated).

We have mapped three out of the four values of equipment_sensor_status_e. We therefore compute the degree of alignment to be 75%.

Note that the mapping is not 1:1 or even n:1. We have identified two possible values for damaged. To implement this mapping, we would choose one (since JSIMS lacks the resolution of LC2IEDM). If a JSIMS federate wanted to store data about damaged communication equipment, it would use (say) NOP. If it wanted to recover data from an LC2IEDM database, it would translate both NOP and MOPS to damaged.

E.4.2 Rules for Boolean Domains

The LC2IEDM has no attributes with Boolean domains. This does not mean that Boolean JSIMS attributes cannot be aligned, just that the alignment never consists of a direct mapping of true/false values.

Here are strategies for alignment assessments derived from a State-level assessment of a Boolean JSIMS attribute j_a :

1. Suppose the State-level assessment determines that j_a aligns to a LC2IEDM attribute l_a . There are two ways to represent the true/false value for l_a :
 - a) Partition the domain of l_d into two sets of values, one of which denotes “true” and the other “false”.
For example, if l_a represents a quantity and l_d is an integer domain, then 0 might correspond to false and all positive values to true.
 - b) The existence of a value for l_d may be sufficient to denote truth. In other words, “true” maps to “non-null” and “false” maps to “null”.

In both cases, if an assessor can establish a mapping, the Value-level degree of alignment is 100%. If he cannot establish a mapping, the Value-level degree of alignment is 0%.

2. Sometimes j_a is modeled in the LC2IEDM by the presence or absence of entities and relationships. If so, the assessor does not have to perform a Value-level alignment assessment. Instead, assess the State-level alignment. If the presence or absence can be modeled unambiguously, the degree of State-level alignment is 100%. Otherwise, the degree of State-level alignment is 0%.

In all cases, the degree of alignment for a boolean-valued JSIMS attribute is either 0% or 100%.

E.4.3 Rules for Integer Domains

Integer JSIMS quantities are represented using 4 bytes, which means they can range from -2^{31} to $2^{31} - 1$. If an integer-typed JSIMS attribute j_a maps to an integer-typed LC2IEDM attribute (i.e., one whose representation is NUMBER(n)), then the degree of alignment depends on whether n decimal digits can store all the values j_a can hold. The rule is that the Value-level degree of alignment is the percent of possible JSIMS values that can be stored by the LC2IEDM attribute.

For some LC2IEDM attribute whose domain is NUMBER(n), $n < 10$ (10 being the number of digits in $2^{31} - 1$) does not automatically imply the domain of j_a aligns less than 100%. The class org.land.equip_group has an attribute number_of_platforms that stores the number of platforms in the equipment group. In LC2IEDM, an OBJECT-ITEM may have an associated HOLDING; the HOLDING-OPERATIONAL-QUANTITY attribute records the number of items held. The type of number_of_platforms is long. The domain of HOLDING-OPERATIONAL-QUANTITY is NUMBER(9). LC2IEDM therefore can't model any JSIMS simulation where an equipment group has over a billion platforms. But when will such a simulation occur? In practice, then, the degree of Value-level alignment is 100%. The assessors are expected to use common sense to determine what range is realistic. And they should be sure to record their rationale in their Value-level assessment!

As with Boolean-typed attributes, there are situations where alignment of an integer value is possible even though the LC2IEDM doesn't have a matching attribute, because the integer is represented by the existence of entities and relationships. The previous paragraph (which contains a little white lie) is an example. The way to obtain the number of platforms would be to model an equipment group as an ORGANISATION, to model platforms as MATERIEL, and to count the number of ORGANISATION-MATERIEL-ASSOCIATION entities (where the value of ORGANISATION-MATERIEL-ASSOCIATION-CATEGORY-CODE is CTRL) where the ORGANISATION-MATERIEL-ORGANISATION-SUBJECT-ORGANISATION-ID attribute is that of the equipment group in question.

E.4.4 Rules for String Domains

A JSIMS string is encoded as a 4-byte integer n giving the length of the string, followed by n bytes containing the string (padded to 4-byte chunks). The maximum length of a string in JSIMS is therefore $2^{31} - 1$.

LC2IEDM uses `VARCHAR( $n$ )` to represent strings. There are at least two cases for calculating Value-level degree of alignment. Both depend upon knowledge of the string-typed JSIMS attribute j_a whose alignment is being assessed.

1. If j_a is constrained to have a predefined length l , then it aligns 100% if the corresponding LC2IEDM attribute's domain is `VARCHAR( $n$ )`, $n \geq l$. Otherwise, its Value-level degree of alignment is 0%.

As an example, JSIMS associates a name with each organization in the `org_name` attribute of the `org` class. The corresponding LC2IEDM attribute is `UNIT-FORMAL-NAME`, the representation of which is `VARCHAR(25)`. Now suppose (this is purely hypothetical) that a particular simulation adopts the convention that all unit names are to be exactly 30 characters long. There is no way to model even one JSIMS unit name in the LC2IEDM, so the Value-level degree of alignment is 0%.

2. If j_a is not constrained to have a predefined length, then it is necessary to know if the length of j_a will ever exceed n . If not, then the Value-level degree of alignment is 100%.

If it is possible that $\text{length}(j_a) > n$, then there are at least two ways to assess the degree of alignment:

- a) If probability p that $\text{length}(j_a) > n$ is known (by frequency analysis, say), then the Value-level degree of alignment is then $1 - p$.
- b) Otherwise, we assume that all lengths are equally likely. The assessor should identify a probable maximum length m (i.e., j_a will not be longer than m in practice). The Value-level degree of alignment is n/m .

Note that assuming that all lengths are equally likely is not the same as assuming that all values are equally likely. The latter would yield a much lower degree of alignment: 256^{m-n} (assuming 256 possible characters). If the assessor has reason to believe that all values are equally likely, he should assess alignment based on that assumption.

There are some other cases worth mentioning.

3. Strings don't always map to strings. JSIMS models object identifiers as strings. The LC2IEDM models identifiers using one of three domains: `NUMBER(12)`, `NUMBER(15)`, and `NUMBER(18)`. Since a simulation is unlikely to have 10^{12} distinct objects, to say nothing of 10^{18} , the degree of Value-level alignment for identifiers is 100%. To implement alignment would require defining a function that transforms identifiers between the two models.

4. JSIMS contains a few “description” attributes (e.g., in `natsim.missions`) whose purpose is to provide for free text description. LC2IEDM has a few such attributes; their domain is either `VARCHAR(255)` or `VARCHAR(2000)`. 255 characters isn’t long enough for much free text, and even 2000 characters is stingy. But using the formulas above will result in unreasonably small degrees of alignment. If the assessor assumes a description might have at most 100,000 characters, its degree of alignment would be $1 - (100000 - 2000)/100000 = 2\%$, which seems low. It is probably best to use an arbitrary value such as 75% for the degree of alignment.

E.4.5 Rules for Double Domains

If the type of JSIMS attribute j_a is double, then the general approach to alignment involves determining whether the corresponding LC2IEDM attribute(s) can model both the range and precision of a real number represented as a 64-bit floating-point quantity. The assessor should constrain this approach based on the actual values that might be used in JSIMS, rather than the complete range of floating-point numbers that can be represented in 64 bits.

In both JSIMS and the LC2IEDM, real numbers are used to model physical characteristics: coordinates, speed, capacity, etc. The purpose of an attribute constrains its range. Latitude will always be in the range ± 90 . Longitude will always be in the range ± 180 . Speeds will never exceed 10^4 (or possibly 10^5 for a satellite). Dimensions of cargo containers can be measured in tens (possibly hundreds) of meters.

Unfortunately, JSIMS does not state the required number of significant digits. It does state units, and perhaps the assumption is that numbers are expected to be resolved to those units.

The LC2IEDM uses fixed-point domains. These domains specify both precision (number of significant digits) and scale (number of digits after the decimal point).

The following rules apply. Suppose the State-level assessment of j_a aligns it to exactly one LC2IEDM attribute whose representation is `NUMBER(m,n)`. Derive, based on the purpose of j_a , its minimum and maximum possible values, and the number of significant digits it must contain such that j_a can represent a value to within ± 1 unit of measure.² Then:

1. The Value-level degree of alignment is 100% if `NUMBER(m,n)` can represent the complete range with the necessary precision.
2. If `NUMBER(m,n)` can represent the complete range but not the necessary precision, then the Value-level degree of alignment is $1 - s/m$, where s is the number of significant digits that `NUMBER(m,n)` can’t represent.³

² Sometimes this doesn’t work. For instance, JSIMS measures latitude in degrees. Sixty nautical miles isn’t sufficiently precise resolution. In cases like this, the assessor has to get the required precision from JSIMS.

³ LC2IEDM uses base 10 whereas JSIMS uses base 2; this makes calculating s tricky, because m significant digits in base 10 doesn’t usually equate to an integral number of significant digits in base 2. This may result in small rounding errors, but we deemed them insignificant.

3. If $\text{NUMBER}(m,n)$ can represent the necessary precision but not the complete range, then the Value-level degree of alignment is the percentage of the range that is covered.
4. If $\text{NUMBER}(m,n)$ can represent neither the necessary precision nor the complete range, then the Value-level degree of alignment is the product of items 2 and 3.

Appendix F. WARSIM–JCDB ALIGNMENT ASSESSMENT⁴

Table of Contents

F.1	INTRODUCTION	F-7
F.1.1	Problem Statement	F-7
F.1.2	Overview of the Joint Common Database	F-8
F.1.3	Overview of Appendix.....	F-9
F.2	ANALYSIS APPROACH	F-9
F.2.1	Analysis Process	F-9
F.2.2	Scoring.....	F-11
F.2.3	Non-Issues	F-11
F.3	SUMMARY OF ALIGNMENT ANALYSIS RESULTS.....	F-13
F.3.1	Mapping WARSIM into the JCDB.....	F-13
F.3.2	Mapping JCDB into WARSIM.....	F-15
F.4	CONCLUSIONS	F-17
F.4.1	Concepts modeled in WARSIM missing from the JCDB.....	F-17
F.4.2	Concepts modeled in the JCDB missing from WARSIM.....	F-18
F.4.3	Differences in the ways details are modeled.....	F-18
F.5	RECOMMENDATIONS	F-19
F.6	ALIGNMENT DETAIL TABLES	F-20

⁴ An earlier version of this appendix was published separately as [MHLW 2002].

List of Figures

Figure F-1. High-level depiction of battlefield objects in the JDM	F-8
Figure F-2. Example Unit area alignment mapping and assessments	F-10
Figure F-3. Unit area alignment assessment results	F-15
Figure F-4. Equipment area alignment assessment results.....	F-15
Figure F-5. Organization area alignment assessment results	F-17

List of Tables

Table F-1. Summary of Assessment Results for Mapping WARSIM Object Classes into JCDB Entities	F-13
Table F-2. Summary of TCDM Assessment	F-14
Table F-3. JCDB Primary Entities mapped to the WARSIM Object Model.....	F-16
Table F-4. Mapping WARSIM unit area to JCDB	F-23
Table F-5. Mapping TCDM Features into the JCDB	F-32
Table F-6. Mapping org.land.equip_group to JCDB.....	F-40
Table F-7. Mapping org.land.supply_cache to JCDB	F-47
Table F-8. Mapping platform.shelter.equipment to JCDB	F-52
Table F-9. Mapping minefield.land to JCDB	F-56
Table F-10. Mapping abstract.land.equip_type to JCDB	F-57
Table F-11. Mapping abstract.land.personnel_type to JCDB.....	F-59
Table F-12. Mapping abstract.land.rotary_wing_type to JCDB.....	F-60
Table F-13. Mapping ORG to WARSIM	F-62
Table F-14. Mapping MAT to WARSIM.....	F-65
Table F-15. Mapping ENEMY_MAT to WARSIM	F-68
Table F-16. Mapping MAT_ITEM to WARSIM.....	F-76
Table F-17. Mapping CONSUMABLES to WARSIM.....	F-80
Table F-18. Mapping EQUIP_TYPE to WARSIM.....	F-83
Table F-19. Mapping SENSOR_TYPE to WARSIM	F-85

F.1 Introduction

In the main body of this report, the degree of alignment between NATO's Land C2 Information Exchange Data Model (LC2IEDM) [NATO 2000] and the Warfighter's Simulation (WARSIM) "object model" is described, along with a methodology for doing the analysis. This appendix extends that analysis to present assessment results of an analysis of alignment between the WARSIM object model and the Joint Common Database (JCDB) Data Model (JDM).

While the LC2IEDM is a well-tested specification for data exchange within coalition operations, for historical reasons the US Army has not adopted it for use in its national C2 systems. That role corresponds to the JCDB, a physical database developed with considerable effort, that is currently used in every major Army Tactical Command and Control System in its Army Battle Command System (ABCS). In addition, the WARSIM program, the largest training simulation in the Army, has a requirement to interface to the JCDB of the ABCS. This requirement has not yet been met, and the alignment analysis described here is considered an important step in achieving the necessary interoperability.

Thus, while we judged the LC2IEDM to be the best reference model for Army C4I data, we realized that WARSIM's alignment with the JCDB is also an important issue. The JCDB alignment results are an important part of the overall study and show a more short-term alignment picture. The alignment results cited here show the actual alignment between the WARSIM models and a C4I data model and physical database.⁵

F.1.1 Problem Statement

The U.S. Army has several reasons for wanting to connect models and simulations to operational command and control (C2) systems, including:

- Training soldiers in using the C2 systems without needing to have all other elements of a force present.
- Testing C2 equipment without needing to have all other systems present.
- Simulating alternative proposed courses of action.
- Rehearsing planned missions.

In spite of these and other requirements to make modeling and simulation (M&S) systems and C2 systems interoperate, making them do so is still a very difficult task. One of the main sources of this difficulty is the lack of alignment among the object/data models used by these two communities.

There is a trend in the Army, however, that will, in the not-to-distant future make it much easier to make these data models align: The Army is standardizing its data models in each of these communities for future systems. Already, the Army C4I community has adopted the JCDB as a common database for all Army tactical C4I systems, and the SIMCI OIPT is developing a C4I-M&S Reference Object Model (C-ROM) for M&S development that incorporates all the JCDB data requirements. Hence, an assessment of the current JCDB

⁵ Based on Version 5.0 of the JCDB and Version 6.0 of the JSIMS FOM.

data alignment with WARSIM provides one indication of how much needs to be done to create a common reference model that supports both M&S and C4I system data requirements. The immediate objective of the analysis reported in this appendix is to show the degree to which the specific JCDB data model aligns with a current Army Simulation, and where they do not align, to provide some of the details on what needs to change. In the short term, this should assist WARSIM in developing their interface to the JCDB. The longer term objective is to provide input to developing a common C4I-M&S reference model, whose use could ensure data interoperability and promote effective and efficient integration of Army C4I and M&S systems.

F.1.2 Overview of the Joint Common Database⁶

The version of the JCDB used in this assessment corresponds to the release of October 2001 by PEO-C3S at Ft. Monmouth. It contains 572 entities, 379 of which are independent. Out of the 379 independent entities 329 represent externalized codes which permit reuse within the model, and facilitate maintenance and update. The JCDB has the 5 battlefield instance entities FACILITY, FEATURE, MATERIEL, ORGANIZATION and PERSON, as well as its own version for their respective type entities, namely, FACILITY-TYPE-SYMBOL, FEATURE-TYPE-SYMBOL, MATERIEL-ITEM, ORGANIZATION-TYPE and PERSON-TYPE, as shown in Figure F-1. Information about enemy objects is separately maintained in ENEMY-ORGANIZATION, ENEMY-PERSON, and ENEMY_MATERIAL. It also contains a rich superstructure to handle data related to PLANS, ACTION, TASK, MISSION, and DOCUMENT entities among others.

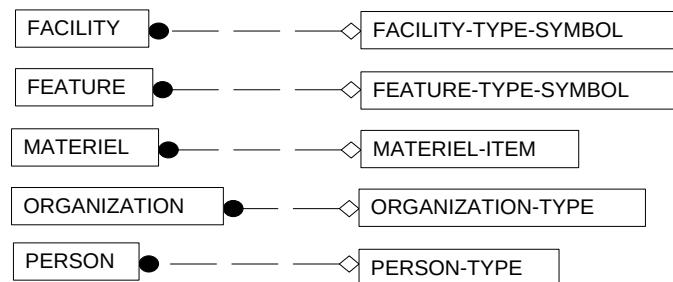


Figure F-1. High-level depiction of battlefield objects in the JDM

The model and physical schema for the JCDB were developed by the Army's PEO-C3S (now the PEO-C3T) at Ft. Monmouth to support the C2 requirements of the Army Battle Command System (ABCS). It is an operational implementation of the C2CDM and has interfaces to the major Army C4ISR information systems. As with the model developed by the International Army Tactical Command and Control Information System (ATCCIS) [Tolk 1999] for coalition operations, the JCDB is meant to serve as the common specification for information exchange among all the components of the ABCS. Substantial portions of the JCDB have undergone standardization under the DoD 8320 process, and data segments have been created by the Common Operating Environment (COE) ShaDE to provide interoperability with other information systems. The model is maintained under strict configuration control by PEO-C3T.

⁶ An overview of the WARSIM object model can be found in Section 2 of the main body of this report. [HHHLMMPW 2002].

The current release of the JCDB is version 5.0. The major changes with respect to the previous deployed version are in the area of valid domain codes needed to support newly identified ABCS information requirements. A more complete description of the JCDB can be found in [HB 1999, THGS 1998].⁷

F.1.3 Overview of Appendix

Section F-2 describes the analysis approach taken to arrive at the results summarized in Section F-3. Section F-4 then provides our conclusions about those results, and Section F-5 provides our recommendations on the way forward. This is followed by two sets of tables that provide the details on the assessments of alignment. Tables F-4 to F-12 provide details on mapping WARSIM to JCDB, and Tables F-13 to F-19 provide details on mapping JCDB to WARSIM.

F.2 Analysis Approach

F.2.1 Analysis Process

The basic approach to the analysis is described fully in the main body of this report, as well as in [HLMP 2002a, WHLH 2002, WHLH 2001a, WHLH 2001b]. Some shortcuts in that methodology were made in this work due to time and resource constraints, and are described in this section. The analysis of the degree of alignment between WARSIM and the JCDB was conducted in two phases. In phase 1, the ability to move WARSIM data into the JCDB was analyzed. The focus in this phase was on instance data. That is, given an instance of a class in WARSIM, is it possible to represent that instance faithfully in the JCDB. In phase 2, the opposite direction was analyzed.

The first step phase 1 is to identify the classes in WARSIM that can represent instances. The second step is to identify all the attributes of such instances. Such attributes may come from the classes that have instances, superclasses, classes that are related through relationships, or classes that represent complex data types of these attributes.

Once all the attributes of possible instances are known, the task is to identify entities in JCDB that represent the same kind of instances, and determine if the attributes of WARSIM can be represented in the corresponding JCDB entities. It is not expected that a single WARSIM class will map into a single JCDB entity, because, just as all the attributes of a WARSIM-modeled instance are not found in a single class, instance data for a JCDB-modeled instance are not found in a single JCDB entity, as illustrated in Figure F-2. This figure shows how the WARSIM attribute `org.land.unit.task` maps into the JCDB attribute `ORGANIZATION-OPERATIONAL-STATUS-current-activity-code` and required associated attributes in the `ORGANIZATION` and `PERCEPTION` entities. Also shown is the WARSIM attribute `org.land.unit.frequency`, with its mapping into the JCDB attribute `NETWORK-LINK operating frequency rate` and required associated attributes in the `NETWORK`, `ORGANIZATION-NETWORK`, and `ORGANIZATION` entities.

⁷ Additional information regarding the JCDB can be found on the JCDB website:
<https://peoc3s.monmouth.army.mil/peoc3sjcdb.nsf/>
This requires registration, which is possible at:
<http://www.monmouth.army.mil/newpages/vCpeoc3s.html>

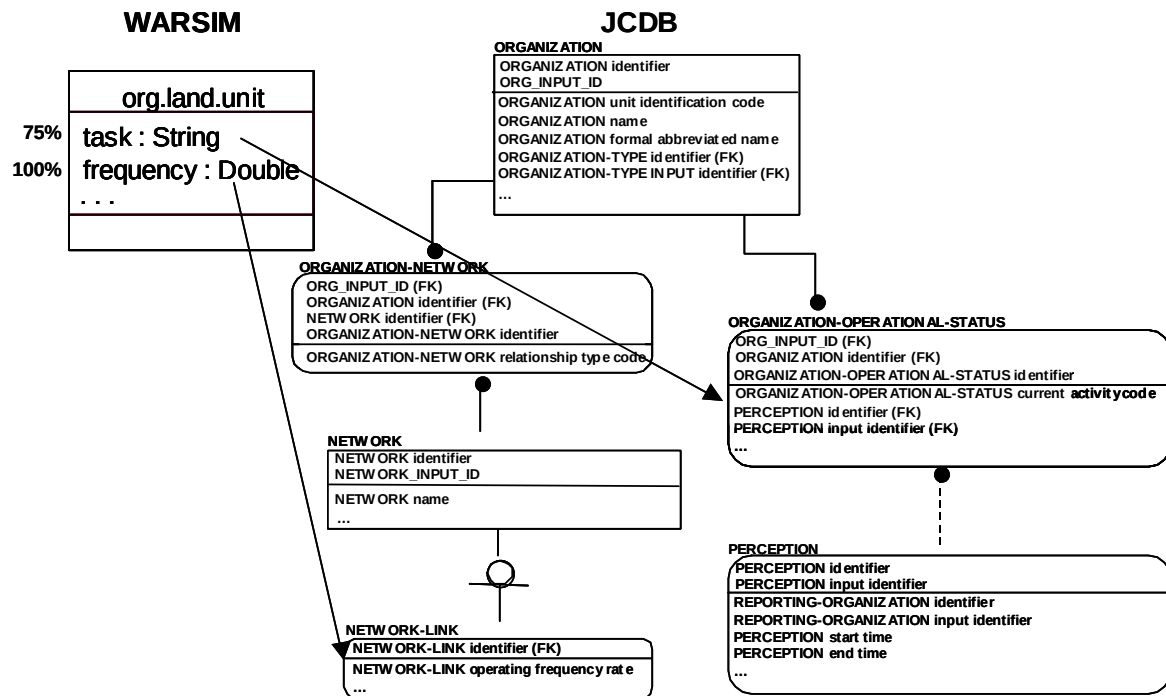


Figure F-2. Example Unit area alignment mapping and assessments

Compare this diagram to Figure 21 in Section 6.1.2 in the body of the report. The mappings to the JCDB are quite different from those to the LC2IEDM. The JCDB models frequency perfectly, but it models task imperfectly. In the LC2IEDM, the current task of an organization is identified by an association between the Organization and an Action-Task. In the JCDB, this identification is made in an attribute of ORGANIZATION.

For phase 2, analogous considerations apply to assessing the possibility of moving elements from the JCDB to WARSIM. The relevant attributes of instances of JCDB entities include attributes of subtypes, associations, and entities related by a parent-child relationship. For example, the attributes of an ENEMY ORGANIZATION come from the following entities:

- ENEMY-ORGANIZATION
- ENEMY-ORGANIZATION-OPERATIONAL-STATUS
- ENEMY-ORGANIZATION-POINT
- ENEMY-TRACK-HISTORY
- CANDIDATE-TARGET
- MATERIEL-ITEM-ENEMY-ORGANIZATION-HOLDING
- PERSON-TYPE-ENEMY-ORGANIZATION-HOLDING
- ORGANIZATION-TYPE

Such a collection of classes with a focal class (e.g., ENEMY-ORGANIZATION) corresponds to a concept at the conceptual level of analysis defined in the companion paper [HLMP 2002b] and elsewhere [HLMP 2002a, WHLH 2002, WHLH 2001a].

F.2.2 Scoring

The assessment is aimed at producing a numeric value that represents the degree of alignment at each of several levels in the data model. At the lowest level, some of the numbers are assigned on a subjective basis but with the intent to reflect the assessor's opinion of how well the JCDB data elements can capture the semantics of the WARSIM data elements, or vice versa. Due to resource constraints, it was not possible to calculate exhaustively the degree of alignment for all cases. The values assigned at the lower level are then averaged to arrive at an assessment of each of the succeeding higher levels of the assessment.

One group of WARSIM attributes which were not included in these assessments are those related specifically to the management of models and simulations. These attributes clearly have no counterparts in the JCDB, but they are published by WARSIM for the purpose of coordination among models and simulations that may need to be working in the same federation, or even in a different federation.

In some cases, attributes have been assessed to align at 100% even though there is no counterpart attribute. This is usually in the case where a foreign key in one model is represented by an aspect of the structure of the other model that allows a representation of the same linkage through some other means. For example, to indicate how many people of each occupational specialty are authorized for any unit, the WARSIM object model provides a complex attribute `AUTHORIZED_PERSONNEL_LEVELS` of the class `ORGLAND.UNIT` that contains two sub-attributes, `AUTHORIZED_AMOUNT` and `MOS` (Military Occupational Specialty). In the JCDB, however, `PERSONNEL-TYPE` is a separate entity, and there is an association between it and `ORGANIZATION` called `PERSON-TYPE-ORGANIZATION-HOLDING` that has an attribute `AUTHORIZED-QUANTITY`. This JCDB entity has as foreign keys, the key attributes of `ORGANIZATION` and `PERSONNEL-TYPE`, as well as an additional key to permit multiple instances of such holdings.

This example highlights the fact that whereas the WARSIM object model uses structure to represent relationships, the JCDB uses foreign keys. The attribute `AUTHORIZED_PERSONNEL_LEVELS` is a list of values, one for each equipment group in a unit. The association with a specific unit is established by position on the list. That is, there is also a list of equipment groups, and the *i*-th equipment group has the *i*-th authorized personnel level. This way of representing such a relationship is just as explicit and unambiguous as the way the JCDB uses foreign keys, but in moving data from the JCDB to the WARSIM object model, the use of foreign keys in the JCDB to link entities is replaced by the structure of the WARSIM complex attributes.

F.2.3 Non-Issues

Before describing problems with the alignment of the two subject data models, it may be useful to the reader to point out some areas of superficial misalignment that are not real problems given the focus here on model support for exchange of instance data. They fall

into three categories, mapping high-level classes/entities, and mapping low-level classes, and category code entities.

High-level classes or entities provide a structuring mechanism that permits instance classes to inherit attributes. The structuring mechanisms used by JCDB do not match those of WARSIM virtually anywhere, but instances take on most of the same set of attributes in many cases. Since the main concern is moving instance data, the inability to map between the higher-levels of WARSIM classes and JDM entities may be of no concern in such cases.

High-level classes generally, serve organizing purposes that go beyond the exchange of instance data. But, some high-level entities (i.e., an IDEF1X incomplete categorization) can provide a flexibility to models by supporting an open-ended set of instance subtypes through an attribute such as a type name (as expressed in IDEF1X incomplete subtype relations – see Appendix A). This can enable such models to distinguish more subtypes of instances than would be possible without those entities, even though they both equally support all the other attributes of such instances. However, such entities don't seem involved in the WARSIM-JCDB alignment assessment. High level entities also support the normalization of data models in ER modeling and efficient structuring of inheritance for object models. But, these were not concerns in this alignment assessment with its focus on instance data.

WARSIM makes use of “low-level” elements as complex data types for attributes. For example, the data type of many location attributes is `COORDINATE_3D_C`, a complex data type with three attributes, elevation, latitude, and longitude. Due to their structure, such elements are treated as distinct for alignment assessment purposes. The JCDB does not have such an abstract entity, but every entity that needs a 3-dimensional location has those same attributes. Hence, although the `COORDINATE_3D_C` class has no direct counterpart in the JCDB, at the instance level it makes no difference. This is one of the reasons the context of an instance is important in mapping WARSIM data into the JCDB. For example, in WARSIM, movement data is maintained in the complex data type `MOVE_SEGMENT_C` for all things that move. Several of the attributes of this type are themselves modeled as complex data types, and several of these store positions in the three coordinate structure described above.

However, when it comes to mapping these WARSIM complex data types into the JCDB, the context determines how the mapping should be done. For example, in the JCDB the position of a unit needs to be mapped into `FRIENDLY-ORGANIZATION-POINT` or `ENEMY-ORGANIZATION-POINT` depending on whose unit it is, but the position of a platform needs to be mapped into `MATERIAL-POINT` or `ENEMY-MATERIEL-POINT`.

Category code entities are used in the JCDB to “externalize” the metadata about the acceptable values for category code attributes, which are the discriminators used to distinguish subclasses in the JDM. Another model may be well aligned with the JCDB without having separate classes or entities for these codes, provided it has attributes or subclasses that support all the values in those codes.

F.3 Summary of Alignment Analysis Results

This section presents a summary of the some of the key results of the analysis. The detailed results are presented in Tables F-4 to F-19 at the end of this appendix. Tables F-4 to F-12 provide details on mapping WARSIM to JCDB, and Tables F-13 to F-19 provide details on mapping JCDB to WARSIM.

F.3.1 Mapping WARSIM into the JCDB

F.3.1.1 Entity Level Assessments

Table F-1 shows the results of the assessment of the primary WARSIM managed classes from the JSIMS FOM [JSIMS 2001] for which assessment results are available for this paper. The numbers in the table should be viewed primarily as relative to each other. For example, the JCDB represents units (as organizations) better than it does equipment groups, and supply caches are represented only poorly by comparison.

Table F-1. Summary of Assessment Results for Mapping WARSIM Object Classes into JCDB Entities

WARSIM Class	Assessment
ORG	61
ORG.LAND	56
ORG.LAND.UNIT	56
ORG.LAND.EQUIP_GROUP	43
ORG.LAND.SUPPLY_CACHE	23
ABSTRACT	18
ABSTRACT.LAND	63
ABSTRACT.LAND.EQUIPMENT_TYPE	48
ABSTRACT.LAND.PERSONNEL_TYPE	58
ABSTRACT.LAND.ROTARY_WING_TYPE	48
PLATFORM	41
PLATFORM.SHELTER	41
PLATFORM.SHELTER.EQUIPMENT	42
MINEFIELD	42
MINEFIELD.LAND	32

In all, a total of 26 WARSIM object model classes were assessed. In addition to the 15 classes listed above, an additional 11 complex data types were assessed. This does not include those complex data types for which there is only one attribute, such as ID_C or MOVE_DATA_C. Of these 26 classes, only four are assessed at zero percent alignment, and all four of them are not actually used by WARSIM (being used by other federates in JSIMS). These are the movement types GREAT_CIRCLE_C, KEPLERIAN_C, LOITER_C, and RHUMB_LINE_C.

Assessment results at the “entity” level are also available for the TCDM [JSIMS 1999]. The “features” which are organized into the environmental “coverage” areas cited above in Section F.2.3, correspond to entities in a relational model. This study examined TCDM features only at the entity level to determine if the JCDB has explicit representations for these features. More detail on the TCDM alignment can be found in Table F-5.

The features of the TCDM map primarily into the FEATURE and FACILITY entities in the JDM. This study examined all 167 TCDM features that have attributes. About half of these map into standard representations in the JCDB. The details of the TCDM alignment assessment are summarized in Table F-2 by feature coverage area. The last column of this table, shows the percentage of TCDM classes in a given coverage area that have a standard representation in the JCDB.

The JCDB provides facility-specific attributes for only three types of facilities, airport, seaport, and bridge. There are many other types of facilities identified by enumerated codes, but the attributes of these are just the generic attributes of the entity FACILITY. The JCDB FEATURE hierarchy has a similar structure with about 10 explicit types with further subtypes distinguished by codes. An assessment of alignment of individual attributes of TCDM “features” was not performed, however, due to resource constraints.

Table F-2. Summary of TCDM Assessment

TCDM Coverage		Number of TCDM Classes	Percent TCDM Classes Mapped
	Subcoverage		
Surface Areal			
	Physiography	7	29
	Vegetation	12	58
	Urban	27	48
	Water	9	78
Point Culture		35	66
Linear and Point Hydro- graphy		15	47
Linear and Areal Terrain Obstacles		17	37
Maritime Trafficability		18	28
Linear and Point Trans- portation		21	48
Administrative Bounda- ries		10	0
Battlefield Elements		12	8
Linear Connectivity		3	0
Geotile reference		1	0

F.3.1.2 Attribute Level Assessments

Table F-4 (in Section F.6 below) shows the detailed assessments for the attributes that contributed the entity level scores for the Unit area shown above in Table F-1. These at-

tribute assessment results in the Unit area are summarized below in the chart of Figure F-3. This chart shows, for example, that 18 attributes, of the total 63, assessed at the 100% level. Figure F-4 shows the summary of results for the equipment area.

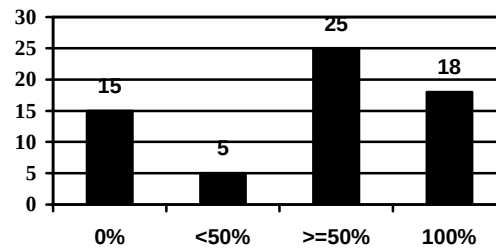


Figure F-3. Unit area alignment assessment results

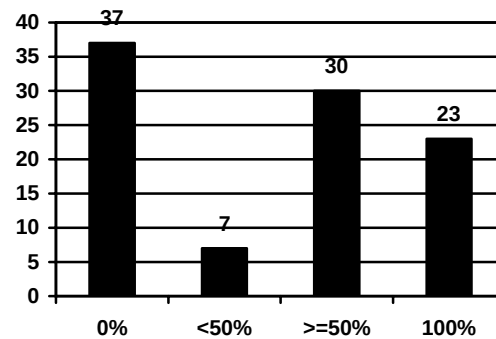


Figure F-4. Equipment area alignment assessment results

F.3.2 Mapping JCDB into WARSIM

F.3.2.1 General

The assessment of the mapping of JCDB into WARSIM was carried out at the conceptual, entity, and state levels, with acknowledgement of certain kinds of similarities and differences at the value level in carrying out the state level assessments. That is, the main focus was on assessing the alignment of attributes. Part of this assessment included noting if the values were generally compatible. The attribute assessments were then rolled up to the entity level, and the entity levels were rolled up to the conceptual level.

F.3.2.2 Entity Level Assessments

Of the 242 entities in the JCDB that are not enumeration lists, 158 seem to have no useful counterpart in the WARSIM object model. The JCDB has 19 entities that can be considered to represent major concepts in that they are independent, i.e., not tied in any subordinate way to any other entities. Of these, only eleven have any WARSIM equivalent (see Table F-3), and even these generally have very poor attribute alignments. For example, for the most part the WARSIM object model does not support the concept of an individual person, but an EQUIPMENT_GROUP can contain a person or group of persons rep-

resented as a platform. The PLATFORM_TYPE of such an equipment group is used to distinguish a platform as a person or group of persons. The attributes such a person would have would be mostly those that any platform would have (ID, KILL_TYPE, MOVE_DATA, NAME, SYMBOL_CODE, and TYPE) except that PERSON_TYPE contributes one attribute, VOLUME. Several specific attributes for persons that form the crew of a platform can also be identified via crew attributes for CMF, MOS, health, and grade. The JCDB, in contrast, does not model the volume of a person, but it does have approximately 175 other attributes of a person that are distinctly related to personhood.

Table F-3. JCDB Primary Entities mapped to the WARSIM Object Model

Primary Entities	Mapped to WARSIM
Action	
Address	X
Candidate Target	
Document	
Enemy Materiel	X
Enemy Organization	X
Event	
Facility	X
Feature	X
Filter Definition	
Materiel	X
Matériel Item	X
Organization	X
Organization Type	X
Person	X
Person Type	X
Plans	
Supported Target	
Target Engagement	

F.3.2.3 Attribute Level Assessments

Figure F-5 shows the distribution of attribute alignment assessments for the Organization area of the JCDB, which comprises ORGANIZATION, ENEMY-ORGANIZATION and their related entities. The results for MATERIEL and ENEMY-MATERIEL, while not specifically tabulated, appear to be comparably skewed toward the low end of the scale (see Tables F-14 through F-19).

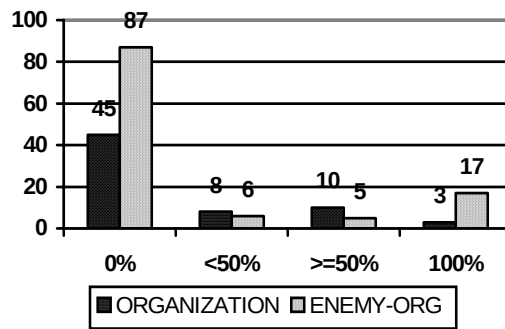


Figure F-5. Organization area alignment assessment results

F.4 Conclusions

If the C4I and M&S communities want their systems to interoperate effectively, the data models they use need to be better aligned than they are today as represented by the JCDB and the WARSIM models. This analysis demonstrates the incompleteness of the mapping of WARSIM data into JCDB data, and vice versa. Numerous concepts that are modeled in one of the models have no counterpart in the other, and many others are represented very incompletely. Of the 103 attributes that contribute to the alignment of ORG.LAND.EQUIP_GROUP, 30 received scores of zero, and another 11 received scores below 50, but only 24 received scores of 100. Similarly, the low alignment level of ORGANIZATION is because WARSIM has a very incomplete representation of command and control data.

As noted above, the FEATURE and FACILITY aspects did not fare better. In spite of the existence of an Army standard terrain model, it is largely unknown outside the modeling and simulation communities.

More telling than these specific cases, however, is the order of magnitude difference in the number of attributes represented in the two models (see Section F.4.2 below). This is clearly not a case where a quick fix can patch things together. From the perspective of the JCDB, the WARSIM object model is missing 90% of what is needed.

F.4.1 Concepts modeled in WARSIM missing from the JCDB

The most obvious concept modeled in WARSIM that is not modeled in JCDB is simulation. Many classes have attributes that are only present to support the simulations that use the WARSIM object model. For example, there is a Boolean attribute of a unit that indicates whether the unit is real or simulated.

The JCDB has no concept of a security classification for organizations or materiel. Security classification is an attribute only of PLAN in the JCDB. WARSIM recognizes the possibility of security markings on just about anything.

F.4.2 Concepts modeled in the JCDB missing from WARSIM

To appreciate the magnitude of the problem of mapping the JCDB into WARSIM Object Model classes, one need only look at the size of the two models that were examined in this study. There were a total of 26 WARSIM classes (in the JSIMS FOM) with a total of 248 attributes. The JCDB data model, however, has 242 entities that are not enumeration lists with a total of 2963 attributes. Some of those entities and attributes are modeled in WARSIM in structural ways, but an order of magnitude difference is very hard to overcome.

One of the main concepts in the JCDB is that of a plan, but that concept does not appear in WARSIM. There are several other concepts in the JCDB that are related to plans that are also missing from WARSIM, such as OVERLAY and DOCUMENT.

While WARSIM does model a very limited set of attributes about individual people that are members of a crew and items of materiel that belong to organization, it does not model individual people or things in the fundamental way the JCDB does. Similarly, while WARSIM identifies the networks to which an organization belongs, it does not model networks themselves.

Another concept that is recorded in the JCDB but not modeled in WARSIM is the state of JCDB updates. That is, as some of the JCDB records are updated, their changes are scheduled for transmission to other instances of the JCDB, and the status of these transmissions is also recorded in the JCDB. Thus, if a model is supposed to simulate the operation of a system that contains the JCDB, it should model the state of these transmissions and reflect the fact that different instances of the JCDB may be in different states.

F.4.3 Differences in the ways details are modeled

There are numerous cases where individual attributes are modeled differently between WARSIM and JCDB. A large block of such differences can be found in the way features and facilities are modeled. WARSIM utilizes the Terrain Common Data Model (TCDM), which models a long list of features and facilities, each with attributes appropriate to that specific feature or facility. The JCDB, however, has type-specific attributes for very few features or facilities, and provides a few generic attributes for the rest. It has enumerated lists of features and facilities that aligns reasonably well with the list of classes modeled in the TCDM, so one can assert that most of the features and facilities in the TCDM are modeled in the JCDB, but not at the same level of detail.

As an example of the many ways in which a specific concept can be modeled, consider direction. Both models have representations for direction, but WARSIM models it in 3-space with a starting point and ending point, while the JCDB models it in 2-space, in some cases as 16 compass points and in other cases as a bearing angle.

WARSIM keeps counts of a number of things, such as the number of platforms belonging to a unit. In the JCDB, these quantities have to be computed by counting the number of appropriate entries in the appropriate table. WARSIM also uses Boolean variables to indicate the presence or absence of various capabilities of platforms (e.g., does it have a ra-

dio). In the JCDB that question can only be answered by examining all the pieces of equipment associated with the platform to see if any of them are radios and checking the association type to see if the radio is on the platform.

More importantly, for both counts and Booleans, moving data from WARSIM to the JCDB is likely to require creating instance data, not just storing a value somewhere. For example, if the JCDB data for a unit does not already indicate that it has the required number of a particular platform, those platforms will need to be created of the right type, and suitable associations created linking them to the correct unit. This is an example of the general problem of “disaggregation” wherein something represented only at an aggregate level (e.g., counts of types of things) in one context needs to be disaggregated in another. The problem is that important data (e.g., location) on the instances will be missing when they are disaggregated.

F.5 Recommendations

The main result to come out of the analysis presented in this appendix is the recognition of significant differences in the data modeled by the WARSIM portion of the JSIMS object model and the JCDB. The degree to which this will affect interoperability depends on specific data interchange needs. If much of the data in either model needs to be exchanged, then at least one model and system may require major rework because so many of the data elements and codes in one model are not in the other. If systems only need to exchange a small subset of each other's data, and if it turns out to be the right subset, they might get by with minor adjustments.

However, since our assessments were limited to the WARSIM managed object classes and attributes of the JSIMS FOM (and the TCDM), we have undoubtedly missed some data modeling capabilities internal to WARSIM that are not reflected in these parts of the JSIMS FOM. Thus, WARSIM itself should provide somewhat better coverage of JCDB data elements than our assessments indicate. Unfortunately, the internal software development models for WARSIM were not up to date when we started this study, so the JSIMS FOM was our best source for identifying WARSIM modeling capabilities.

Reaching a better alignment of these two models will require a concerted effort on the part of both communities working together. The study acknowledges that this is already occurring to some degree via the Simulation to C4I Interoperability (SIMCI) OIPT [Army 2002]. In recent informal discussions at the Simulation Interoperability Workshop, representatives from the M&S community agreed that most of the onus for change was on them to meet the standards being set within the C2 community. We agree, but caution that the C2 community also needs to be more aware of the requirements for M&S with respect to the need to incorporate models and simulations into C2 decision making, as well as the need to incorporate C2 systems into testing and training activities.

It should not be expected that a single data model could serve both M&S and C2 requirements completely since the performance objectives are frequently very different. The real world abstractions that are incorporated into M&S frequently ignore details of interest to the operational user. This, coupled with the need to sometimes execute in faster

than real time, requires optimizations in the use of data by M&S that do not readily map into the operational data. As a consequence, it is expected that some translation between operational representation and simulated representation will always be necessary. Nevertheless, significant advancement in the alignment of their respective models is necessary if improvement in the state of interoperability between these two communities is to be achieved. Every effort should be made to reach agreement on the use of data standards wherever they make sense.

An essential step in this process is to reach an agreement on how data standards are to be decided. There are two aspects to this recommendation. Most obviously there is a need to agree on a process for meeting existing requirements. However, it should be recognized that standards are primarily intended to facilitate meeting future, unknown interoperability requirements. Hence, the process needs to consider standards that go beyond known existing requirements to address areas where standards are possible, even if not yet required. Moreover, the process of agreeing to data model standards should be expected to be an on-going one that addresses an ever-changing need.

One way to begin the data model alignment process is to examine the concepts modeled by both existing models. There are many concepts that are common to both communities, and there are many that are not. The zeros in Table F-4 are generally good leads for finding concepts modeled in WARSIM that are not modeled in the JCDB. They may not need to be, but at least that need should be questioned. Similarly, this study also identifies a large number of concepts and attributes modeled in the JCDB that are missing from WARSIM.

Once the concepts to be modeled in a common way have been agreed upon, the next step is to decide how each concept is to be modeled. The current disparities between the two models are frequently extreme. For example, WARSIM has only a few attributes unique to persons or crew members. And a person's VOLUME is singled out as the only distinctive attribute of the PERSON_TYPE entity. While the JCDB does not have that attribute, it does have approximately 175 other attributes of a person. This example underscores the differences in current requirements of the two communities, but it is also an example of why those models need to be rethought.

It should also be noted that we originally interpreted Environmental Data Coding System (EDCS) Classification Codes as being part of the TCDM. In fact this is not always the case. During the review of this report, we learned that some of our Value-level TCDM assessments use non-TCDM codes. Unfortunately we did not have the resources to revise the assessments. Some assessments may therefore have a higher degree of alignment than indicated. However, we do not expect that the results in Table F-5 would change significantly if we were to re-conduct these assessments.

F.6 Alignment detail tables

The tables which follow provide the details of the alignment assessment. Tables F-4 to F-12 relate to aligning the WARSIM object models to the JCDB. In all of these tables except F-5, the column headings have the following meanings:

- Attribute Name – Name of the attribute from the WARSIM object class
- Data Type – Data type of the attribute in the WARSIM object class
- Field Name – If the Data Type is complex, and hence, a class, then the field name is the name of an attribute of that complex data type
- Data Type – The second Data Type field is the type of the Field of the complex data type
- Entity Name – The name of a JCDB entity
- Attribute Name – The second Attribute Name is an attribute of that JCDB entity
- Data Type – The third Data Type field is the data type of the attribute of the JCDB entity
- Assessment – The assessment column contains the assessment of the mapping of the specific WARSIM attribute or field or the overall assessment of the WARSIM object class (in shaded rows). The assessment of the WARSIM object class is determined by averaging the assessments of its attributes, included inherited attributes.

Table F-5 maps the TCDM features into the corresponding code table in the JCDB. Its column headings have the following meanings.

- TCDM Coverage – The name of a high-level “coverage” area in the TCDM which groups features of a similar type
- Subcoverage – The name of a more specific subcoverage area in the TCDM which provides subgroupings of features in a coverage
- Feature Code – The code used to represent a specific feature in the TCDM which fits into the Coverage and Subcoverage (if any) groupings of the prior columns
- Feature Name – The name used to represent a specific feature in the TCDM specified by the Feature Code of the prior column
- JCDB File Name – The name of the code table in the JCDB which contains an enumeration value which corresponds to the feature identified in the TCDM columns.

Note that the JCDB File Name column may contain multiple entries when a single TCDM feature maps into multiple codes in the JCDB. And, this column contains the text “N/M” when no mapping exists for the TCDM code. Question mark entries are used to indicate an inability to determine whether or not a suitable mapping exists.

Tables F-13 to F-19 relate to aligning the JCDB with the WARSIM object model. In these tables, the column headings have the following meanings:

- Attribute/ Association Name – The name of an attribute or an association of that JCDB entity
- Key Association Attribute – Where the second column identifies an association, this column names the attribute of that association used for the assessment
- Data Type – The data type of the JCDB attribute identified in the second or third column
- Class – The name of a WARSIM object class
- Attribute – The attribute of the WARSIM class that most closely aligns with the identified JCDB attribute

- Data Type – The data type of the WARSIM attribute
- Assessment – The first assessment column is the assessment of the mapping of the specific JCDB attribute to the WARSIM object model or the overall assessment of the JCDB entity, determined by averaging the assessments of the attributes.

Certain rows are shaded in some of these tables to identify the row as containing the evaluation for the whole entity/class whose attributes follow.

Table F-4. Mapping WARSIM unit area to JCDB

WARSIM					JCDB		Assess- ment
Attribute Name	Data Type	Field Name	Data Type	Entity Name	Attribute Name	Data Type	
Object Class: org							
faction_id	id_c			org	country	enumerated	61
					affiliation_cd	enumerated	75
host_id_o	id_c			org			NA
id_u	id_c				org_id	number	90
					org_input_id	number	
location_type	location_type_e						0
move_data	move_data_c						
mtp_network_id_o	string		move_segment_o		[see move_segment_c below]		24
				org_ntwrk	orgnet_relat_typ	index to enumerated	100
				network	ntwrk_name	string	
					ntwrk_purpose_cd	index to enumerated	
org_name	string			org	org_name	string	100
perfect_ids_o	id_c				WARSIM perfect_ids_o is used for simulation purposes; JCDB perception information is used for operational purposes; only enemy orgs have perceptions		NA
role_id_o	string				WARSIM role_id_o is used for simulation purposes		NA
security_mark_o	security_mark_c		base_classification				0
			security_caveats_o				
		security_try_codes_o	count-string				
subscribed_mtp_network_ids_o	id_c			org_ntwrk	orgnet_relat_typ	index to enumerated	93
					ntwrk_name	string	
					ntwrk_purpose_cd	index to enumerated	
symbol_code_o	string			org_type_symbol	symbol_code	enumerated	90
uic	string			org	name_uic	string	100

WARSIM				JCDB			Assessment
Attribute Name	Data Type	Field Name	Data Type	Entity Name	Attribute Name	Data Type	
zone_o	string						0
Object Class: org.land							56
command_org	string			org	org_parent_name	string	100
comms_status	long			mat_opl_stat	mat_primary_use	number	50
					oper_stat	enumerated	
log_item_amounts	double			matitem_holdings	matihldng_qty	number	100
type	string			org_type_symbol	symbol_code	enumerated	75
terminal_status	long			mat_opl_stat	mat_primary_use	number	50
					oper_stat	enumerated	
spacing	double						0
log_item_ncis	string						0
firepower_status	long			mat_opl_stat	mat_primary_use	number	50
					oper_stat	enumerated	
health_status	long			per_opl_stat	duty_stat_code	index to 50	
						enumerated	
echelon	string			org_type	echelon_cd	index to 90	
						enumerated	
log_item_midbs	string						0
log_item_dodacs	string			mat_item	matim_tech_id	string	100
log_item_lins	string			mat_item	matim_tech_id	string	100
restart	boolean						NA
crew_status	long			per_opl_stat	duty_stat_code	index to 50	
						enumerated	
radio_status	long			mat_opl_stat	mat_primary_use	number	50
					oper_stat	enumerated	
parent_org	string			org	org_parent_name	string	100
mobility_status	long						0
log_item_nsns	string			mat_item	matim_tech_id	string	100
sensor_status	long			mat_opl_stat	mat_primary_use	number	50
					oper_stat	enumerated	
formation	string						0

WARSIM				JCDB			Assess- ment
Attribute Name	Data Type	Field Name	Data Type	Entity Name	Attribute Name	Data Type	
Object Class: org.land.unit							
authorized_equipment_levels	author- ized_equipment_levels_c	authorized_eg_ equip- ment_levels	authorized_equipment_c. authorized_amount (long) authorized_equipment_ c.mldb (string)	matitem_holdings	matitm_auth_qty	number	56
subordinate_orgs	id_c	eg identifier	id_c string	org org	org_name org_name org_parent_name	string string string	66
air_rules_of_engagement_o	air_roe_c	land_roe_parent target_priority_list	land_roe_c air_target_type_e	[see land_roe_c below] cnidt_trgt	priority_cd	index to enumerated	5
authorized_personnel_levels	author- ized_personnel_levels_c	authorized_eg_ personnel_levels	authorized_personnel_c. authorized_amount (long) authorized_personnel_c. mos (string)	pertyp_holdings per_type	pertyp_auth_qty occ-spec-cd	number index to enumerated	90
capturing_unit	id_c	eg identifier	id_c string	org org	org_name org_id or org_name	string number or string	90
distribution_lists	distribution_list_c	frequencies name terminal_addresses	double string string	ntwrk_link network wrkststation	netlink_opng_freq_rt ntwrk_name ws_name	string string string string	90
distribution_table	distribution_table_row_c	direct_event forward forward_distribution_set message_type periodic_times primary_distribution_set queryable subscription_set	long long distribution_set_c string double distribution_set_c long distribution set c	[see distribution_set_c below] message [see distribution_set_c below] [see distribution_set_c below]	msg_format_typ_cd	index to enumerated	37.5

WARSIM				JCDB			Assess- ment
Attribute Name	Data Type	Field Name	Data Type	Entity Name	Attribute Name	Data Type	
extended_perceived_truth_list	ex- tended_perceived_unit_c	object_id	id_c	enemy_org	unit_master_key or unit_id or unit_name or unit_normal_name or unit_number	string	75
		platforms	platform_info_c. health_status (long)	mat_opl_stat	oper_stat	enumerated	
			platform_info_c.midb (string)	supported_target	midb_be_number and midb_o_suffix and midb_cat_number and midb_enemy_unit_id and midb_fac_name	string, string, number, string, string	
ground_rules_of_engagement_o	ground_roe_c	land_roe_parent	land_roe_c	[see land_roe_c below]			5
		target_priority_list	string	cnedt_trgt	priority_cd	index to enumerated	
initialization_fo_id	id_c	identifier	string				NA
perceived_features	perceived_feature_c	detection_method	string				75
		feature_kind	string	feat	feat_cat_cd	index to enumerated	
		identifier	string	feat	feat_name	string	
		level_of_knowledge	level_of_knowledge_e	perception_ref	percep_eval	index to enumerated	
		location	coordinate_3d_c	feat_loc_pt_ref	featpt_lat, featpt_lon, elevation_m	number	
		time_known	sim_time_c (double)	perception_ref	percep_reprt_dttm	date	

WARSIM			JCDB			Assess- ment
Attribute Name	Data Type	Field Name	Data Type	Entity Name	Attribute Name	Data Type
perceived_units	org_perceived_unit_c	acquisition_level	acquisition_level_e			0
		acquisition_source	string	perception_ref	rprrptng_org_id	number
		detection_method	string			50
		direction	double	en_org_pt	course	0
		echelon	string	org_type	echelon_cd	number
relationship_list	relationships_c	identifier	string	enemy_org	index to 90	enumerated
					unit_master_key or unit_id or unit_name or unit_normal_name or unit_number	string
		location	coordinate_3d_c			100
		relationship	string	enemy_org	current_latitude, current_longitude, elevation_m	number
		speed	double	en_org_pt		100
		time_known	sim_time_c (double)	perception_ref		100
		unit_type	string	org_type	percep_reprrt_dttm	date
		frequency	double	ntwrk_link	msn_cd	enumerated 90
		name	string	network	netlntk_opng_frq_rt	string
		terminal_id	string	wrkstation	ntwrk_name	string
subordinate_orgs	id_c	unit_id	id_c	org	ws_name	string
		identifier	string	org	org_name	string
		identifier	string	org	org_name	string
		identifier	string	org	org_name	string
		unit_kind_e			org_name	string
mission_effectiveness	long			org_opl_stat	org_combat_eff_cd	index to 75
agg_org_name	string					enumerated
bed count_o	long					0
						0

WARSIM			JCDB				Assess- ment
Attribute Name	Data Type	Field Name	Data Type	Entity Name	Attribute Name	Data Type	
behaviors_o	string			action	act_vrb_cd	index to 90 enumerated	
frequency	double			ntwrk_link	netlnk_opng_frq_rt	string	100
mission	string			mission_area	msn_area_descr_txt	string	100
posture	string			action	act_vrb_cd	index to 33 enumerated	
mission_id	string			mission_area	msn_area_name	string	100
mopp_level	string			org_opl_stat	mopp_lvl_cd	index to 90 enumerated	
morale	long						0
pdp_level	long			org_opl_stat	org_exposure_lvl	index to 50 enumerated	
platform_counts	long						0
platform_midbs_o	string						0
readiness	long			org_opl_stat	org_redines_cndtn	index to 50 enumerated	
terminal_address_o	string			ip-add	ip_add_no	string	100
intent	string						0
task	string			task	task_amplify_text	string	100
Object Class: move_segment_c							24
constant_position	constant_position_c	position	double	frnd_org_pt en_org_pt	or [lat, lon, elev from each]	number	100
coordinate_system	coordinate_system_e						0
end_time	sim_time_c (double)						NA
great_circle	great_circle_c	delta_altitude	double				0
		initial_altitude	double				
		theta	double				
		u0	double				
		u1	double				
		velocity_parallel	double				
		velocity_perpendicular	double				

WARSIM			JCDB				Assess- ment
Attribute Name	Data Type	Field Name	Data Type	Entity Name	Attribute Name	Data Type	
ground_linear	ground_linear_c	altitude	double	frnd_org_pt en_org_pt	or [elevation each]	from	number
		base_location	double	frnd_org_pt en_org_pt	or [lat, lon, elev each]	from	number
		move_medium	move_medium_e				
		speed	double	frnd_org_pt en_org_pt	or [speed from each]		number
		direction	direction_c [see below]	frnd_org_pt en_org_pt	or [bearing from each]		number
keplerian	keplerian_c	a	double				0
		a_init	double				
		a1_impact	double				
		av	double				
		e	double				
		g_mass	double				
		l	double				
		move_medium	double				
		o	double				
		radius_earth	double				
		time_impact	double				
		v_init	double				
		v1_impact	double				
		w	double				
		x_init	double				
		x1_impact	double				
loiter	loiter_c	altitude	double				0
		radius	double				
		speed	double				
		ux	double				
		uy	double				
		uz	double				

WARSIM				JCDB			Assess- ment
Attribute Name	Data Type	Field Name	Data Type	Entity Name	Attribute Name	Data Type	
rhumb_line	rhumb_line_c	bearing	double				0
		delta_altitude	double				
		kappa1	double				
		kappa2	double				
		phi	double				
		rho	double				
		theta	double				
		velocity_parallel	double				
	velocity_perpendicular	double					
start time		sim_time_c (double)					NA
Object Class: land_roe_c							10
engagement_area	ser_coordinate_c	elevation	double	rule_of_engagement	rule_of_engagement	text	
		latitude	double				
		longitude	double				
fire_restricted_areas	spatial_area_c	coordinates	ser_coordinate_c				
fire_threshold	double						
weapon_control	weapon_control_status_e						
Object Class: distribution_set_c							75
distribution_lists	string			network	ntwrk_name	string	
frequencies	double			ntwrk_link	netlink_opng_frq_rt	string	
relationships	string			org_assoc	org_assoc_typ_cd	index to enumerated	
					org_assoc2_typ_cd	index to enumerated	
terminal_addresses	string			wrkstation	ws_name	string	

WARSIM				JCDB			Assessment
Attribute Name	Data Type	Field Name	Data Type	Entity Name	Attribute Name	Data Type	
Object Class: direction_c							
head	coordinate_3d_c	elevation	double	frmd_org_pt en_org_pt	or or course	number	
		latitude	double				
		longitude	double				
tail	coordinate_3d_c	[see head]	[see head]				
							50

Table F-5. Mapping TCDM Features into the JCDB

TCDM Coverage	Subcoverage	Feature Code	TCDM Feature Name	JCDB File Name
Surface Areal				
	Physiography	SA030	exposed bedrock	Indfeat_surface_cd
		DA010	ground surface element	??
		DB160	volcanic dike	N/M
		BH150	salt pan	N/M
		DB170	sand dune	Indfeat_roughness
		BH160	sebkha	N/M
		BJ100	snow field	N/M
	Vegetation	EC010	Bamboo/Cane	N/M
		EC040	Clear way/Cutline/firebreak	N/M
		EA010	Cropland	N/M
		EB010	Grassland	Indfeat_vegchar_cd
		EA055	Hops	fac_type_symbol or matitem_sup_class
		BH095	Marsh/Swamp	Swamp - Indfeat_shorIn_cat. Marsh - Indfeat_shorIn_cat
		EA040	Orchard/Plantation	N/M
		BH135	Ricefield	N/M
		EB020	Scrub/Brush/Bush	Brush - Indfeat_vegchar_cd
		EC030	Trees	Indfeat_vegchar_cd
		BJ110	Tundra	N/M
		EA050	Vineyards	N/M
	Urban	GB005	Airport/Airfield	Airport – airport, fac_cat_cd, fac_subcat_cd. Airfield - fac_subcat_cd, fac_typ_symbol, feat_symbol_cd.
		AK030	Amusement Park	N/M
		GB015	Apron/Hardstand	Apron - feat_symbol_cd
		AE010	Assembly Plant	N/M
		AL015	Building	fac_typ_symbol

TCDM Coverage	Subcoverage	Feature Code	TCDM Feature Name	JCDB File Name
		AL020	Built-up Area	N/M
		AT050	Communication Building	N/M
		AM101	Depot (Storage)	fac_typ_symbol
		AA010	Extraction Mine	N/M
		BH040	Filtration Bed/Aereation Bed	N/M
		AK110	Grandstand	N/M
		GB035	Heliport	fac_typ_symbol
		AL135	Native Settlement	N/M
		AC040	Oil/Gas facilities	Depot - POL or ?
		AA052	Oil/Gas field	N/M
		AD010	Power Plant	fac_typ_symbol
		AC000	Processing Plant/Treatment Plant	fac_typ_symbol
		AA012	Quarry	Indfeat_roughness
		AK130	Race Track	N/M
		AN060	Railroad Yard/Marshalling Yard	Railroad Yard - fac_typ_symbol
		AL200	Ruins	N/M
		BH155	Salt evaporator	N/M
		AL105	Settlement	N/M
		AC030	Setteling Basin/Sludge Pond	N/M
		AK160	Stadium/Ampatheatre	N/M
		AD030	Substation/Transformer Yard	Substation - fac_typ_symbol
		GB075	Taxiway	N/M
	Water	BH010	Aqueduct	fac_typ_symbol
		BH020	Canal	fac_typ_symbol
		BH050	Fish Hatchery/Fish farm/Marine farm	N/M
		BA020	Foreshore	N/M
		BH190	Lagoon/Reef/Pool	N/M

TCDM Coverage	Subcoverage	Feature Code	TCDM Feature Name	JCDB File Name
		BH080	Lake/Pond	Lake - fac_typ_symbol, wet_rte_typ_cd. Pond- Indfeat_roughness
		BH130	Reservoir	N/M
		BH140	River/Stream	River - fac_typ_symbol, wet_rte_typ_cd. Stream - feat_symbol_cd, wet_rte_typ_cd
		BA040	Water (except Inland)	???
Point Culture		AK030	Amusement Park	N/M
		AE010	Assembly plant	N/M
		AC010	Blast Furnace	N/M
		AL015	Building	fac_typ_symbol
		AL020	Built-up Area	N/M
		AC020	Catalytic Cracker	N/M
		AF010	Chimney/Smokestack	N/M
		AT050	Communications Building	Radio/Wireless Station
		AT080	Communications Tower	N/M
		AF030	Cooling Tower	N/M
		AF040	Crane	fac_typ_symbol
		AM010	Depot (Storage)	Depot - General
		AT010	Disk/Dish Antenna	Antenna - ntdev_cat_cd
		BB090	Drydock	ship_typ_cd
		AF070	Flare Pipe	Pipeline
		AM020	Grain Bin/Silo	Silo - fac_typ_symbol
		AK110	Grandstand	N/M
		BC050	Lighthouse	N/M
		AL135	Native Settlement	N/M
		AD040	Nuclear Reactor	Nuclear Feature. fac_typ_symbol
		BB170	Offshore Loading Facility	N/M
		AD010	Power Plant	fac_typ_symbol

TCDM Coverage	Subcoverage	Feature Code	TCDM Feature Name	JCDB File Name
		AC000	Processing Plant/Treatment Plant	fac_typ_symbol
		AQ116	Pumping Station	fac_typ_symbol
		AK130	Racetrack	N/M
		AA040	Rig/Superstructure	Rig - ???
		AL200	Ruins	N/M
		AL105	Settlement	N/M
		AK160	Stadium/Amphitheatre	N/M
		AM060	Storage Bunker/Storage Mound	N/M
		AM070	Storage Tank	fac_typ_symbol
		AD030	Substation / Transformer Yard	Substation - fac_typ_symbol
		AL240	Tower (Non-communication)	Tower - fac_typ_symbol, msn_cd
		AM080	Water Tower	N/M
		AJ050	Windmill	N/M
Linear and Point Hydrography		BH010	Aqueduct	fac_typ_symbol
		BZ010	Aqueduct Centerline / Nexus	N/M
		BH020	Canal	fac_typ_symbol, wet_rte_typ_cd
		BZ020	Canal Centerline / Nexus	N/M
		BI010	Cistern	N/M
		BA010	Coastline / Shoreline	N/M
		BI020	Dam / Weir	Dam - fac_typ_symbol, Indfeat_surface_cd
		BI030	Hydrographic Lock	N/M
		BZ080	Lake / Pond Centerline / Nexus	N/M
		BH120	Rapids	N/M
		BZ130	Reservoir Centerline / Nexus	N/M

TCDM Coverage	Subcoverage	Feature Code	TCDM Feature Name	JCDB File Name
		BH140	River / Stream	River - fac_typ_symbol, wet_rte_typ_cd. Stream - fac_typ_symbol, wet_rte_typ_cd
		BZ140	River / Stream Centerline / Nexus	N/M
		BH170	Spring / Water Hole	Spring - fac_typ_symbol
		AA050	Well	fac_typ_symbol
Linear and Areal Terrain Obstacles		DB010	Bluff / Cliff / Escarpment	N/M
		DB090	Embankment / Fill	Fill - fac_typ_symbol
		DB110	Fault	N/M
		AM020	Grain Bin / Silo	Silo - fac_typ_symbol
		AM030	Grain Elevator	N/M
		DB200	Gully / Gorge	N/M
		EA020	Hedgerow	Indfeat_roughness
		BJ040	Ice Cliff	N/M
		BH030	Irrigation Ditch	N/M
		DB145	Miscellaneous Obstacle	fac_typ_symbol, feat_cat_cd, rte_access_cd
		AQ113	Pipeline / Pipe	Pipeline - fac_subcat_cd, fac_typ_symbol. Pipe - fac_subcat_cd, fac_typ_symbol
		AA012	Quarry	Indfeat_roughness
		DB160	Rock Strata / Rock Formation	N/M
		BB230	Seawall	N/M
		DB070	Terrain Cut	N/M
		DB080	Terrain Depression	N/M
		DB190	Volcanic Dike	N/M
		AL260	Wall	feat_symbol_cd, Indfeat_roughness, protct_leve_cd
Maritime Trafficability		BB010	Anchorage	fac_typ_symbol
		BF010	Bottom Characteristics	N/M

TCDM Coverage	Subcoverage	Feature Code	TCDM Feature Name	JCDB File Name
		BB040	Breakwater / Groin	N/M
		BB140	Jetty	N/M
		FC021	Maritime Limit Boundary	N/M
		BB042	Maritime Mole	N/M
		BD110	Maritime Platform	N/M
		BD180	Maritime Wreck	N/M
		AA052	Oil / Gas Field	N/M
		BJ070	Pack Ice	N/M
		BB190	Pier / Wharf / Quay	Pier - ??, Warf - fac_typ_symbol, feat_symbol_cd
		BD100	Pile / Piling / Post	Piling - fac_typ_symbol
		BJ080	Polar Ice	N/M
		BD120	Reef	??
		FC165	Route (Maritime)	??
		OZ165	Route (Maritime) Centerline	/N/M
		BD130	Nexus	
		BD000	Submerged Rock	N/M
			Underwater Danger / Hazard	N/M
Linear and Point Transportation				
		AQ010	Aerial Cableway Lines / Ski Lift Lines	N/M
		GB010	Airport Lighting	N/M
		AQ040	Bridge / Overpass / Viaduct	Bridge - bridge, equipt_cat_cd, fac_cat_cd, fac_design, fac_typ_symbol, feat_symbol_cd. Overpass - fac_typ_symbol. Viaduct - fac_typ_symbol.
		AQ045	Bridge Span	N/M
		AP010	Cart Track	N/M
		AQ064	Causeway	src_cd
		AQ060	Control Tower	N/M
		AQ070	Ferry Crossing	N/M

TCDM Coverage	Subcoverage	Feature Code	TCDM Feature Name	JCDB File Name
		BH070	Ford	fac_typ_symbol, feat_symb_cd
		GA035	Navigation Aids (Aeronautical)	N/M
		AN010	Railroad	equipt_cat_cd, fac_subcat_cd, fac_typ_symbol.
		AZ010	Railroad in Built-Up Area Centerline / Nexus	N/M
		AN050	Railroad Siding / Railroad Spur	Railroad Siding - fac_typ_symbol.
		AZ060	Railroad Yard / Marshalling Yard Centerline / Nexus	N/M
		AP030	Road	equipt_cat_cd, fac_subcat_cd, fac_typ_symbol, feat_symbol_cd, ntwrk_trnsprt_cd
		AZ030	Road in Built-Up Area Centerline / Nexus	N/M
		GB055	Runway	fac_typ_symbol.
		AL210	Snow Shed / Rock Shed	N/M
		AP050	Trail	fac_subcat_cd, fac_typ_symbol, feat_symbol_cd, lan-drte_descrtyp
		AQ130	Tunnel	fac_typ_symbol
Administrative Boundaries		FA000	Administrative Boundary	N/M
		FA020	Armistice Line	N/M
		FA030	Cease Fire Line	N/M
		FA040	Claim Line	N/M
		FA060	Defacto Boundary	N/M
		FA070	Demilitarized Zone	N/M
		FA110	International Date Line	N/M
		FA050	Mandate Line / Convention Line	N/M
		FA170	Zone of Occupation	N/M
Battlefield Elements		AH035	Infantry Trench	N/M
		AH021	Cross Country Barrier	N/M

TCDM Coverage	Subcoverage	Feature Code	TCDM Feature Name	JCDB File Name
		AH031	Defensive Position	N/M
		AQ041	Engineering Bridge	N/M
		AM061	Hardened Aircraft Shelter	N/M
		AH035	Infantry Trench	N/M
		AH080	Military Area	N/M
		AH025	Minefield	minefield, equipt_cat_cd, fac_typ_symbol, feat_cat_cd, feat_symbol_cd.
		AH030	Prepared Defensive Positions Area	N/M
		AH040	Prepared Defensive Region	N/M
		AM062	Tunnel Shelter	N/M
		AP041	Vehicle Barrier	N/M
Linear Connectivity		AT030	Power Transmission Line	N/M
		AT040	Power Transmission Pylon	N/M
		AT060	Telephone Line / Telegraph Line	N/M
Geotile reference		ZD050	Boundary Line	N/M
		ZD013	Geographic Information Area	N/M

Table F-6. Mapping org.land.equip_group to JCDB

WARSIM				JCDB		Assessment
Attribute Name	Data Type	Field Name	Data Type	Entity Name	Attribute Name	Data Type
Object Class : org						
faction_id	id_c			org	country	enumerated
						enumerated
host_id_o	id_c					
id_u	id_c			org	org_id	number
						org_input_id
location_type	location_type_e					
move_data	move_data_c	move_segment_o	move_segment_c	[see move_segment_c below]		
mtp_network_id_o	string			org_ntwrk	orgnet_relat_type	index to enumerated
				network	ntwrk_name	string
					ntwrk_purpose_cd	index to enumerated
org_name	string			org	org_name	string
perfect_ids_o	id_c			WARSIM perfect_ids_o is used for simulation purposes; JCDB perception information is used for operational purposes; only enemy orgs have perceptions		
role_id_o	string			WARSIM role_id_o is used for simulation purposes		
security_mark_o	security_mark_c	base_classification	base_classification_e			
		security_caveats_o	string			
		security_country_codes_o	string			
subscribed_mtp_network_ids_o	id_c			org_ntwrk	orgnet_relat_type	index to enumerated
				network	ntwrk_name	string
					ntwrk_purpose_cd	index to enumerated
symbol_code_o	string			org_type_symbol	symbol_code	enumerated
uic	string			org	name_uic	string
zone_o	string					

WARSIM				JCDB		Assess- ment
Attribute Name	Data Type	Field Name	Data Type	Entity Name	Attribute Name	Data Type
Object Class: org.land						
command_org	string			org	org_parent_name	string
comms_status	long			mat_opl_stat	mat_primary_use	number
					oper_stat	enumerated
log_item_amounts	double			matitem_holdings	matldng_qty	number
type	string			org_type_symbol	symbol_code	enumerated
terminal_status	long			mat_opl_stat	mat_primary_use	number
				oper_stat	enumerated	
spacing	double					
log_item_ncis	string					
firepower_status	long			mat_opl_stat	mat_primary_use	number
					oper_stat	enumerated
health_status	long			per_opl_stat	duty_stat_code	index to enumer- ated
echelon	string			org_type	echelon_cd	index to enumer- ated
log_item_midbs	string					
log_item_dodacs	string			mat_item	matitm_tech_id	string
log_item_lins	string			mat_item	matitm_tech_id	string
restart	boolean					
crew_status	long			per_opl_stat	duty_stat_code	index to enumer- ated
radio_status	long			mat_opl_stat	mat_primary_use	number
					oper_stat	enumerated
parent_org	string			org	org_parent_name	string
mobility_status	long					
log_item_nsns	string			mat_item	matitm_tech_id	string
sensor_status	long			mat_opl_stat	mat_primary_use	number
					oper_stat	enumerated
formation	string					

WARSIM				JCDB		Assessment	
Attribute Name	Data Type	Field Name	Data Type	Entity Name	Attribute Name	Data Type	Assessment
Object Class: org.land.equip_group							
abstract_id_o	id_c	identifier	string	[see abstract below]			43
initialization_fo_id	id_c	identifier	string				18
mount_object_id	id_c	identifier	string	mat_assoc	sbjct_mat_indx or object_mat_indx or sbjct_enat_indx or object_enat_indx	number	50
					sbjct_mat_input or object_mat_input or or sbjct_enat_input or object_enat_input	number	
platform_id_u	platform_id_c	identifier	string	mat or enemy_mat	mat_indx or enemy_mat_indx mat_input_id or emy_mat_input_id	number en-number	
platform_move_data	move_data_c	move_segment_o	move_segment_c	[see move_segment_c below]			24
mount_status	mount_status_e			mat_assoc or en-emy_mat_assoc	mat_assoc_type or emat_assoc_type	enumerated	50
platform_kill_type	kill_type_e						0
platform_type	platform_type_e						0
crewman_grade	string			per_type	rank_cd	enumerated	100
active_sensor_mode	boolean			mat_opl_stat	activity	text	100
cooperation_level	long						0
crewman_cmf	string						0
crewman_health	string			per_opl_stat	duty_stat_cd	index to enumerated	50
					perop_stat_cd	index to enumerated	
					occ_spec_cd	index to enumerated	
crewman_mos	string			per_type			100
exposure	long						0

WARSIM				JCDB			Assessment
Attribute Name	Data Type	Field Name	Data Type	Entity Name	Attribute Name	Data Type	
platform_symbol_code_o	string			sensor_type	sensor_type_cd	index to enumerated	50
				weapon_type	weapon_fire_type_cd	index to enumerated	
				vehicle_type	veh_cat_cd	index to enumerated	
				org_assoc	org_assoc_type_cd	index to enumerated	
follow_role	string						50
number_of_platforms	long			org_mat	[count the number of distinct associations to platforms]	number	50
platform_name_o	string			mat_item	matim_name	string	100
platform_midbs	string			[only supported targets have MIDBs]			10
associated_side	string			allegiance	affiliation_cd	index to enumerated	50
Object Class: move_segment_c							
constant_position	constant_position_c	position	double	frnd_org_pt en_org_pt	or [lat, lon, elev from each]	number	100
coordinate_system	coordinate_system_e						0
end_time	sim_time_c (double)						NA
great_circle	great_circle_c	delta_altitude	double				0
		initial_altitude	double				
		theta	double				
		u0	double				
		u1	double				
		velocity_parallel	double				
		velocity_perpendicular	double				

WARSIM				JCDB			Assessment
Attribute Name	Data Type	Field Name	Data Type	Entity Name	Attribute Name	Data Type	
ground_linear	ground_linear_c	altitude	double	frnd_org_pt en_org_pt	or [elevation from each]	number	65
		base_location	double	frnd_org_pt en_org_pt	or [lat, lon, elev from each]	number	
		move_medium	move_medium_e				
		speed	double	frnd_org_pt en_org_pt	or [speed from each]	number	
		direction	direction_c [see below]	frnd_org_pt en_org_pt	or [bearing from each]	number	
keplerian	keplerian_c	a	double				0
		a_init	double				
		a1_impact	double				
		av	double				
		e	double				
		g_mass	double				
		l	double				
		move_medium	double				
		o	double				
		radius_earth	double				
		time_impact	double				
		v_init	double				
		v1_impact	double				
		w	double				
		x_init	double				
		x1_impact	double				

WARSIM				JCDB		Assessment
Attribute Name	Data Type	Field Name	Data Type	Entity Name	Attribute Name	Data Type
loiter	loiter_c	altitude	double			0
		radius	double			
		speed	double			
		ux	double			
		uy	double			
		uz	double			
rhumb_line	rhumb_line_c	bearing	double			0
		delta_altitude	double			
		kappa1	double			
		kappa2	double			
		phi	double			
		rho	double			
		theta	double			
		velocity_parallel	double			
		velocity_perpendicular	double			
start_time	sim_time_c (double)					NA
Object Class: direction_c						50
head	coordinate_3d_c	elevation	double	fnd_org_pt en_org_pt	or fnd_pt_bearing,an or [en_org_pt] course	number
		latitude	double			
		longitude	double			
tail	coordinate_3d_c	[see head]	[see head]			
Object Class: land_roe_c						10
engagement_area	ser_coordinate_c	elevation	double	rule_of_engagement	rule_of_engagement	text
		latitude	double			
		longitude	double			
fire_restricted_areas	spatial_area_c	coordinates	ser_coordinate_c			
fire_threshold	double					
weapon_control	weapon_control_status_e					

WARSIM				JCDB		Assessment	
Attribute Name	Data Type	Field Name	Data Type	Entity Name	Attribute Name	Data Type	Assessment
Object Class: distribution_set_c							75
distribution_lists	string			network	ntwrk_name	string	
frequencies	double			ntwrk_link	netlink_opng_frq_rt	string	
relationships	string			org_assc	org_assc_typ_cd	index to enumerated	
					org_assc2_typ_cd	index to enumerated	
terminal_addresses	string			wrkststation	ws_name	string	
Object Class: abstract							18
equipment_designation	string			supported_target	midb_be_number and midb_o_suffix and midb_cat_number and midb_enemy_unit_id and midb_fac_name	string, string, number, string, and string	5
id_u	string			mat or enemy_mat	mat_idx or enemy_mat_idx	number	50
					mat_input_id or enemy_mat_input_id	en-number	
security_mark_o	security_mark_c	base_classification	base_classification_e				0
		security_caveats_o	string				
		security_country_codes_o	string				

Table F-7. Mapping org.land.supply_cache to JCDB

WARSIM				JCDB		Assess- ment
Attribute Name	Data Type	Field Name	Data Type	Entity Name	Attribute Name	Data Type
Object Class: org						
faction_id	id_c			org		
host_id_o	id_c				country	enumerated
id_u	id_c			org	affiliation_cd	enumerated
location_type	location_type_e				org_id	number
move_data	move_data_c				org_input_id	number
mtp_network_id_o	string	move_segment_o	move_segment_c	[see move_segment_c below]		
				org_ntwrk	orgnet_relat_type	index to enumerated
				network	ntwrk_name	string
					ntwrk_purpose_cd	index to enumerated
org_name	string			org	org_name	string
perfect_ids_o	id_c			WARSIM perfect_ids_o is used for simulation purposes; JCDB perception information is used for operational purposes; only enemy orgs have perceptions		
role_id_o	string			WARSIM role_id_o is used for simulation purposes		
security_mark_o	security_mark_c	base_classification	base_classification_e			
		security_caveats_o	string			
		security_country_codes_o	string			
subscribed_mtp_work_ids_o	net_id_c			org_ntwrk	orgnet_relat_type	index to enumerated
				network	ntwrk_name	string
					ntwrk_purpose_cd	index to enumerated
symbol_code_o	string			org_type_symbol	symbol_code	enumerated
uic	string			org	name_uic	string
zone_o	string					

WARSIM				JCDB			Assess- ment
Attribute Name	Data Type	Field Name	Data Type	Entity Name	Attribute Name	Data Type	
Object Class: org.land							
command_org	string			org	org_parent_name	string	56
comms_status	long			mat_opl_stat	mat_primary_use	number	100
					oper_stat	enumerated	50
log_item_amounts	double			matitem_holdings	matihldng_qty	number	100
type	string			org_type_symbol	symbol_code	enumerated	75
terminal_status	long			mat_opl_stat	mat_primary_use	number	50
					oper_stat	enumerated	
spacing	double						0
log_item_ncis	string						0
firepower_status	long			mat_opl_stat	mat_primary_use	number	50
					oper_stat	enumerated	
health_status	long			per_opl_stat	duty_stat_code	index to enumer- ated	50
echelon	string			org_type	echelon_cd	index to enumer- ated	90
log_item_midbs	string						0
log_item_dodacs	string			mat_item	matitm_tech_id	string	100
log_item_lins	string			mat_item	matitm_tech_id	string	100
restart	boolean						NA
crew_status	long			per_opl_stat	duty_stat_code	index to enumer- ated	50
radio_status	long			mat_opl_stat	mat_primary_use	number	50
					oper_stat	enumerated	
parent_org	string			org	org_parent_name	string	100
mobility_status	long						0
log_item_nsns	string			mat_item	matitm_tech_id	string	100
sensor_status	long			mat_opl_stat	mat_primary_use	number	50
					oper_stat	enumerated	
formation	string						0

WARSIM				JCDB			Assess- ment
Attribute Name	Data Type	Field Name	Data Type	Entity Name	Attribute Name	Data Type	
Object Class: org.land.supply_cache							
platform_id_u	platform_id_c	identifier	string	mat or enemy_mat	mat_idx or enemy_mat_idx mat_input_id or enemy_mat_input_id	number en-number	
platform_move_data	move_data_c	move_segment_o	move_segment_c	[see move_segment_c below]			
platform_kill_type	kill_type_e					0	
platform_type	platform_type_e					0	
number_of_platforms	long			org_mat	[count the number of distinct association to platforms]	number 50	
platform_midbs	string			[only supported targets have MIDBs]			
platform_name	string			mat_item	matitm_name	string 100	
rigged_supply_classes_o	supply_class_e					0	
rigged_percentage_o	double					0	
exposure	long					0	
Object Class: move_segment_c							
constant_position	constant_position_c	position (3X)	double	mat_pt	mat_pt_lat, mat_pt_lon, elevation_m	number 100	
coordinate_system	coordinate_system_e					0	
end_time	sim_time_c (double)					NA	
great_circle	great_circle_c	delta_altitude	double			0	
		initial_altitude	double				
		theta	double				
		u0	double				
		u1	double				
		velocity_parallel	double				
		velocity_perpendicular	double				

WARSIM			JCDB				Assess- ment
Attribute Name	Data Type	Field Name	Data Type	Entity Name	Attribute Name	Data Type	
ground_linear	ground_linear_c	altitude	double	mat_pt	elevation_m	number	65
		base_location	double	mat_pt	mat_pt_lat, mat_pt_lon, elevation_m	number	
		move_medium	move_medium_e				
		speed	double	mat_pt	speed_kmh	number	
		direction	direction_c [see bearing_low]	mat_pt	course	number	
keplerian	keplerian_c	a	double				0
		a_init	double				
		a1_impact	double				
		av	double				
		e	double				
		g_mass	double				
		l	double				
		move_medium	double				
		o	double				
		radius_earth	double				
		time_impact	double				
		v_init	double				
		v1_impact	double				
		w	double				
		x_init	double				
		x1_impact	double				
loiter	loiter_c	altitude	double				0
		radius	double				
		speed	double				
		ux	double				
		uy	double				
		uz	double				
rhumb_line	rhumb_line_c	bearing	double				0
		delta_altitude	double				
		kappa1	double				
		kappa2	double				

WARSIM				JCDB			Assess- ment
Attribute Name	Data Type	Field Name	Data Type	Entity Name	Attribute Name	Data Type	
		phi	double				
		rho	double				
		theta	double				
		velocity_parallel	double				
		velocity_perpendicular	double				
start_time	sim_time_c (double)						NA
Object Class: direction_c							25
head	coordinate_3d_c	elevation	double	mat_pt	course	number	50
		latitude	double				
		longitude	double				
tail	coordinate_3d_c	[see head]	[see head]				

WARSIM							JCDB			Assess- ment
Attribute Name	Data Type	Field Name	Data Type	Entity Name	Attribute Name	Data Type				
symbol_code_o	string			enemy_mat	equip_symbol_cd	string	50			
zone_o	string						0			
Object Class: platform.shelter								41		
associated_sne_feature_o	string								N/A	
org_id_o	id_c			org	org_id	number	90			
					org_input_id	number				
organization	string						0			
Object Class: platform.shelter.equipment								42		
mounted_equipment_o	id_c			mat_or_enemy_mat	mat_idx or enemy_mat_idx		50			
					mat_input_id or enemy_mat_input_id					
Object Class: move_segment_c									20	
constant_position	constant_position_c	position (3X)	double	mat_pt	mat_pt_lat, mat_pt_lon, elevation_m	number	100			
coordinate_system	coordinate_system_e						0			
end_time	sim_time_c (double)						NA			
great_circle	great_circle_c	delta_altitude	double				0			
		initial_altitude	double							
		theta	double							
		u0	double							
		u1	double							
		velocity_parallel	double							
		velocity_perpendicular	double							
ground_linear	ground_linear_c	altitude	double	mat_pt	elevation_m	number	65			
		base_location	double	mat_pt	mat_pt_lat, mat_pt_lon, elevation_m	number				
		move_medium	move_medium_e							
		speed	double	mat_pt	speed_kmh	number				
		direction	direction_c [see below]	mat_pt	course	number				

WARSIM			JCDB				Assessment
Attribute Name	Data Type	Field Name	Data Type	Entity Name	Attribute Name	Data Type	
loiter	loiter_c	altitude	double				0
		radius	double				
		speed	double				
		ux	double				
		uy	double				
		uz	double				
keplerian	keplerian_c	a	double				0
		a_init	double				
		a1_impact	double				
		av	double				
		e	double				
		g_mass	double				
		l	double				
		move_medium	double				
		o	double				
		radius_earth	double				
		time_impact	double				
		v_init	double				
		v1_impact	double				
		w	double				
		x_init	double				
rhumb_line	rhumb_line_c	x1_impact	double				0
		bearing	double				
		delta_altitude	double				
		kappa1	double				
		kappa2	double				
		phi	double				
		rho	double				
		theta	double				
		velocity_parallel	double				
		velocity_perpendicular	double				

WARSIM				JCDB			Assessment
Attribute Name	Data Type	Field Name	Data Type	Entity Name	Attribute Name	Data Type	
start_time	sim_time_c (double)						NA

Table F-9. Mapping minefield.land to JCDB

WARSIM				JCDB			Assessment
Attribute Name	Data Type	Field Name	Data Type	Entity Name	Attribute Name	Data Type	
Object Class: minefield							
faction_id	id_c			org	country	enumerated	42
					affiliation_cd	enumerated	75
id_u	id_c			minefield	feat_indx	number	50
					feat_input_id	number	
security_mark_o	security_mark_c	base_classification	base_classification_e				0
		security_caveats_o	string				
		security_country_codes_o	string				
symbol_code_o	string						N/A
Object Class: minefield.land							
creator	string			org	org_name	string	32
density	double			minefield	density_cd	enumerated	100
duration	double			minefield	duration_class_cd	enumerated	50
eq_restart	boolean						50
feature_handle	string						N/A
lane_ids	string						N/A
lane_markings	string						0
lane_point_pairs	coordinate_3d_c						0
lane_widths	double						0
mine_type	string			minefield	mine_type_cd	enumerated	50
minefield_marking	string						0
perimeter_points	coordinate_3d_c	elevation	double	feat_loc_pt_ref	elevation_m	number	100
		latitude	double		featpt_lat	number	
		longitude	double		featpt_lat	number	
type	minefield_type_e						0
visibility	boolean						0

Table F-10. Mapping abstract.land.equip_type to JCDB

WARSIM				JCDB			Assessment
Attribute Name	Data Type	Field Name	Data Type	Entity Name	Attribute Name	Data Type	
Object Class: abstract							
equipment_designation	string			supported_target	midb_be_number and midb_o_suffix and midb_cat_number and midb_enemy_unit_id and midb_fac_name	string, number, string, string	
id_u	id_c			equip_type	mat_itm_idx and mat_itm_input	number, number	
security_mark_o	security_mark_c	base_classification	base_classification_e				
		security_caveats_o	string				
		security_country_codes_o	string				
Object Class: abstract.land							
eq_restart	boolean						
radio_capability	boolean						
terminal_capability	boolean						
sensor_capability	boolean						
weapon_capability	boolean						
radar_capability	boolean						
ir_capability	boolean						
crew_size	long			vehicle_type	crew_qty_ea	number	
model	string						
Object Class: abstract.land.equipment_type							
passengers	long			vehicle_type	pasngr_qty_ea	number	
cargo_height	double						
wet_cargo	double						
width	double			equip_type	equipt_width_dim_m	number	
signature_type	string						
radar_cross_section	double						
height	double			equip_type	equipt_ht_dim_m	number	
dry_cargo	double						
cargo_width	double						
cargo_length	double						

WARSIM				JCDB			Assessment
Attribute Name	Data Type	Field Name	Data Type	Entity Name	Attribute Name	Data Type	
cargo_volume	double						0
length	double			equip_type	equipt_lngth_dim_m	number	100

Table F-11. Mapping abstract.land.personnel_type to JCDB

WARSIM				JCDB			Assess ment
Attribute Name	Data Type	Field Name	Data Type	Entity Name	Attribute Name	Data Type	
Object Class: abstract							
equip- ment_designation	string			sup- ported_target	midb_be_number midb_cat_number midb_fac_name	midb_o_suffix and midb_enemy_unit_id and string, string, num- ber, string, string	18 5
id_u	id_c			equip_type	mat_itm_idx and mat_itm_input	number, number	50
security_mark_o	secu- rity_mark_c	base_classification	base_classification_e				0
		security_caveats_o	string				
		secu- rity_country_codes_o	string				
Object Class: abstract.land							
eq_restart	boolean						80
radio_capability	boolean						N/A
terminal_capability	boolean						90
sensor_capability	boolean						90
weapon_capability	boolean						90
radar_capability	boolean						90
ir_capability	boolean						90
crew_size	long			vehicle_type	crew_qty_ea	number	100
model	string						0
Object Class: abstract.land.personnel_type							
volume	double						58
							0

Table F-12. Mapping abstract.land.rotary_wing_type to JCDB

WARSIM			JCDB			Assess- ment
Attribute Name	Data Type	Field Name	Data Type	Entity Name	Attribute Name	Data Type
Object Class: abstract						
equip- ment_designation	string			sup- ported_target	midb_be_number and midb_o_suffix and midb_cat_number and midb_enemy_unit_id and midb_fac_name	string, string, num- ber, string, string
id_u	id_c			equip_type	mat_itm_idx and mat_itm_input	number, number
security_mark_o mark_c	security_ mark_c	base_classification	base_classi- fication_e			0
		security_caveats_o	string			
		security_country_ codes_o	string			
Object Class: abstract.land						
Object Class: abstract.land						63
eq_restart	boolean					N/A
radio_capability	boolean					90
terminal_capability	boolean					90
sensor_capability	boolean					90
weapon_capability	boolean					90
radar_capability	boolean					90
ir_capability	boolean					90
crew_size	long			vehicle_type	crew_qty_ea	number
model	string					0
Object Class: abstract.rotary_wing_type						
Object Class: abstract.rotary_wing_type						48
cargo_volume	double					0
width	double			equip_type	equip_width_dim_m	number
wet_cargo	double					100
signature_type	string					0
radar_cross_section	double					0
passengers	long			vehicle_type	passngr_qty_ea	number
length	double			equip_type	equip_lngth_dim_m	number
height	double			equip_type	equip_ht_dim_m	number
cargo_width	double					0
cargo_length	double					0
cargo_height	double					0

WARSIM				JCDB			Assess- ment
Attribute Name	Data Type	Field Name	Data Type	Entity Name	Attribute Name	Data Type	
dry_cargo	double						0

Table F-13. Mapping ORG to WARSIM

JCDB				WARSIM		Assessment
Attribute/ Association Name	Key Association Attribute	Data Type	Class	Attribute	Data Type	
Entity Name: ORG						
AFFILIATION_CD		enumerated	org	faction_id	string	36
COUNTRY		enumerated				50
DISSEM_LEVEL_CD		number				0
NAME_UIC		string	org	uic	string	0
ORG_FORML_ABB_NM		string				100
ORG_ID		number	org	id_u	string	0
ORG_INPUT_ID		number				50
ORG_NAME		string	org	name	string	0
ORG_PARENT_NAME		string	org.land	parent_org	string	100
RECORD_STATUS		enumerated				100
RECORD_STATUS_DTTM		date				0
SRC_CD		string				0
URN		number				0
ACTOBJ_ORG		complex				0
ACTRES_ORG		complex				0
FRND_ORG_PT		complex	org	move_data	complex	0
ORG_ADD		complex	org.land.unit	terminal_address_o	string	42
			org	mtp_network_ids_o	id_c	33
ORG_ASSC	org_assc_typ_cd	enumerated	org.land.unit	subordinate_orgs	id_c	0
				supported_orgs_o	id_c	18
				supporting_orgs_o	id_c	0
ORG_CAPABILITY_EST		complex	[see ORG CAPABILITY_EST below]			0
ORG_DOC	orgdoc_relat_typ	enumerated				0
ORG_ENEMY_ASSC	org_enemy_assc_cd	enumerated	org.land.unit	capturing_unit	id_c	8
ORG_FAC	orgfac_assc_typ_cd	enumerated				0
ORG_FEAT	orgfeat_asstyp_cd	enumerated				0
ORG_MAT	orgmat_assc_typ_cd	enumerated				6
ORG_MISS_AREA	oma_typ_cd	enumerated				0
	oma_req_redines_cd	enumerated				
ORG_NTWRK	orgnet_relat_typ	enumerated	org.land.unit	distribution_lists, distribution_table, frequency, termi-	complex	30

JCDB				WARSIM			Assessment
Attribute/ Association Name	Key Association Attribute	Data Type	Class	Attribute	Data Type		
ORG_OPL_STAT		complex	[see ORG_OPL_STAT below]	na_id_o			
ORG_PER	orgper_ assc_typ	enumerated					0
ORG_PERTYP_TRKNG	ctil_ind_cd	enumerated					0
ORG_TASK		complex	[see ORG_TASK below]				
ORG_TYPE	funct_role_cd	enumerated					0
	echelon_cd	enumerated	org_land	echelon	enumerated		25
	msn_specialty	enumerated					0
	msn_cd	enumerated	org_land	type	enumerated		50
	mobility_cd	enumerated					0
	ob_type	enumerated					0
	orgt_rmk_txt	string					0
PLAN_ORG	plan_org_role_cd	enumerated					0
POST	rank_cd	enumerated					0
	post_typ_cd	enumerated					
TRGT_ENG_ORG_ASSC	trgt_org_ assc_cd	enumerated	org.land.unit	air_rules_of_engagement_o ground_rules_of_engagement_o	or target_priority_list (string)		50
Entity Name: ORG_CAPABILITY_EST							5
CAPA_CAT_CD		enumerated	org.land.unit	behaviors_o	string		5
CAPA_UM_RATE_CD		enumerated					
CAPA_QUAL_CD		enumerated					
CAPA_UM_CD		enumerated					
CAPA_QTY		number					
PERCEP_REF_INDX		number					
PERCEP_INPUT_ID		number					
Entity Name: ORG_OPL_STAT							18
CRNT_ACTIVITY_CD		enumerated	org.land.unit	task	string		50
PRJCTD_ACTIVITY_CD		enumerated	org.land.unit	intent	string		50
ORG_CBAT_REDINESS		enumerated	org.land.unit	readiness	long		50
ORG_COMBAT_INT_CD		enumerated					0
WEAPONS_CTRL_CD		enumerated					0
OPL_ENVIRO_CD		enumerated					0

JCDB				WARSIM				Assessment
Attribute/ Association Name	Key Association Attribute	Data Type	Class	Attribute	Data Type			
ORG_EXPOSURE_LVL		enumerated	org.land.unit	pdp_level	long			50
ORGOP_RENFRC_CD		enumerated						0
ORG_REDINES_CNDTN		enumerated						0
ORG_RADS_QTY_CD		enumerated						0
ORG_COMBAT_EFF_CD		enumerated	org.land.unit	mission_effectiveness	long			50
ORG_AD_WARNG_CD		enumerated						0
OPSTAT_AMP_TXT		text						0
MOPP_LVL_CD		enumerated	org.land.unit	mopp_level	string			90
PERCEP_REF_INDX		number						0
PERCEP_INPUT_ID		number						0
RECORD_STATUS								0
RECORD_STATUS_DTTM								0
DISSEM_LEVEL_CD								0
Entity Name: ORG_TASK								0
ORGTSK_TYP_CD		enumerated						0
CANTPRO_CD		enumerated						0
ORGTSK_ENEMY_ACT		enumerated						0
ORGTSK_ASSC_CAT		enumerated						0
ORGTSK_STRT_DTTM		date						0
ORGTSK_END_DTTM		date						0
ORGTSK_PHASE_NO		number						0
ORGTSK_PHASE_DUR		number						0
ORGTSK_REQ_CAT_CD		enumerated						0
ORGTSK_REQ_SUBCAT		enumerated						0
ORGTSK_SUPREQ_TXT		string						0

Table F-14. Mapping MAT to WARSIM

JCDB			WARSIM			Assessment
Attribute/ Association Name	Key Association Attribute	Data Type	Class	Attribute	Data Type	
Entity Name: MAT						
MAT_INDXX		number	platform	id_u	string	19
MAT_INPUT_ID		number	platform	id_u	string	50
MAT_ITM_INDX		number	platform	abstract_id	string	50
MAT_ITM_INPUT		number	platform	abstract_id	string	50
ALLEGIANCE		enumerated				0
MAT_CAT_CD		enumerated				0
SERIAL_NUMBER		string				0
MAT_ALT_ID		string	platform	platform_name	string	100
MAT_LOT_TXT		string				0
RECORD_STATUS		enumerated				0
DISSEM_LEVEL_CD		enumerated				0
RECORD_STATUS_DTTM		date-time				0
MAT_ASSC	MAT_ASSC_TYP	enumerated				0
MAT_FEAT	MATFEAT_ASSC_TYP	enumerated				0
MAT_NTWK	MATNET_RELAT_TYP	enumerated				0
MAT_PER	MATPER_ASSC_TYP_CD	enumerated				0
Entity Name: MAT_ITEM						
MAT_ITM_INPUT		number	platform	abstract_id	string	17
MAT_ITM_INDX		number	platform	abstract_id	string	50
MATITM_CAT_CD		enumerated				0
MATITEM_SUP_CLASS						0
BRIL_TRACK_IND_CD						0
MATITM_NAME						0
MATITM_TECH_ID						0
MATITM_DESCR_TXT						0
MATITEM_SYMBOL_CD		enumerated	platform	symbol_code_o	string	100
RECORD_STATUS						0
RECORD_STATUS_DTTM						0
DISSEM_LEVEL_CD						0

JCDB			WARSIM			Assessment
Attribute/ Association Name	Key Association Attribute	Data Type	Class	Attribute	Data Type	
Entity Name: MAT_OPL_STAT						
MAT_OPL_STAT_INDX		number				9
MAT_INDX		number	platform	id_u	string	0
MAT_INPUT_ID		number	platform	id_u	string	50
AVAILABILITY_CD		enumerated				0
MAINTAINABILITY_CD		enumerated				0
MAINT_RT_DTTM		date-time				0
CONDITION		enumerated				0
ACTIVITY		enumerated				0
OPER_STATUS		enumerated	platform	health_status	number	50
MAT_RADS_QTY		number				0
MAT_PRIMARY_USE		enumerated				0
PERCEP_REF_INDX		number				0
PERCEP_INPUT_ID		number				0
RECORD_STATUS		number				0
RECORD_STATUS_DTTM		date-time				0
DISSEM_LEVEL_CD		enumerated				0

JCDB				WARSIM			Assessment
Attribute/ Association Name	Key Association Attribute	Data Type	Class	Attribute	Data Type		
Entity Name: MAT_PT							42
MAT_PT_INDX			platform	move_data_c			0
MAT_INDX							100
MAT_INPUT_ID							100
LOC_ASSC_CD							0
ACCURACY_QTY							0
COURSE					ground_linear_c		100
SPEED_KMH					ground_linear_c		100
COORD_ROA							0
EQUIP_QTY							0
MAT_PT_LAT					constant_position_c		100
MAT_PT_LON					constant_position_c		100
ALTITUDE_FT					ground_linear_c		100
ELEVATION_M					constant_position_c		100
PERCEP_REF_INDX							0
PERCEP_INPUT_ID							0
RECORD_STATUS							0
RECORD_STATUS_DTTM							0
DISSEM_LEVEL_CD							0
MAT_PT_OLAY	MATOLAY_APPL_DTTM						0

Table F-15. Mapping ENEMY_MAT to WARSIM

JCDB			WARSIM		Assessment	Comment
Attribute/Association Name	Key Association Attribute	Data Type	Class	Attribute	Data Type	
Entity Name: ENEMY_MAT						
ENEMY_MAT_INDEX		number	platform	id_u	string	22
ENEMY_MAT_INPUT		number	platform	id_u	string	50
ALLEGIANCE						50
EQUIP_MASTER_KEY						0
NOMEN						0
SHORT_NOMEN						0
EQP_CODE						0
EQP_SK						0
MOBILITY_STATUS		varchar(2)	platform	mobility_status	long	50
EQUIP_SYMBOL_CD		enumerated	platform	symbol_code_o	string	100
MLS_CLASSIFICATION		string	platform	security_mark_c	string	100
RECORD_STATUS						0
RECORD_STATUS_DTTM						0
DISSEM_LEVEL_CD						0
PERCEP_REF_INDEX						0
PERCEP_INPUT_ID						0
Entity Name: ENEMY_MA_ASSCT						
EN_MAT_ASSC_INDEX						0
						There is only one such association in WARSIM, platform.shelter.equipment that relates radar equipment to the shelter it is in, compared to n factorial types of associations for large n in JCDB.
						org.land.equip-group identifies "mounted" equipment, but "mounted" is not not one of the JCDB association types.
SBJECT_EMAT_INDEX						
OBJECT_EMAT_INDEX						
OBJECT_EMAT_INPUT						

JCDB				WARSIM			Assessment	Comment
Attribute/ Association Name	Key Association Attribute	Data Type	Class	Attribute	Data Type			
SBJCT_EMAT_INPUT								
EMAT_ASSC_CD								
SBEQUIP_MASTER_KEY								
OBEQUIP_MASTER_KEY								
MLS_CLASSIFICATION								
RECORD_STATUS								
RECORD_STATUS_DTTM								
DISSEM_LEVEL_CD								
PERCEP_REF_INDX								
PERCEP_INPUT_ID								
Entity Name: ENEMY_MAT_HOLDING							0	
EORG_MAT_HLDN_INDX								The identification of platforms with organizations in WARSIM is only from the organization side. The only relationship supported is "owned" and none of the other attributes of holdings are supported.
ENEMY_MAT_INDX								
EORG_INDX								
EORG_INPUT_ID								
ENEMY_MAT_INPUT								
QTY_EQUIP								
MATHLDNG_OPL_QTY								
QTY_DESTROYED								
QTY_DAMAGED								
EORG_HLDNG_AMP_TXT								
MLS_CLASSIFICATION								
PERCEP_REF_INDX								
PERCEP_INPUT_ID								
RECORD_STATUS								
RECORD_STATUS_DTTM								
DISSEM_LEVEL_CD								

JCDB				WARSIM		Assessment	Comment
Attribute/Association Name	Key Association Attribute	Data Type	Class	Attribute	Data Type		
Entity Name: ENEMY_MAT_OPL_STAT						0	WARSIM does not support any of the attributes of enemy_mat_opl_stat
ENMAT_OPLSTAT_INDX							
ENEMY_MAT_INDX							
ENEMY_MAT_INPUT							
CONDITION							
AVAILABILITY_CD							
OPER STATUS							
ACTIVITY							
PERCEP_REF_INDX							
PERCEP_INPUT_ID							
RECORD_STATUS							
RECORD_STATUS_DTTM							
DISSEM_LEVEL_CD							
Entity Name: ENEMY_MAT_PT						49	
ENEMY_MAT_PT_INDX						100	WARSIM platform move data supports multiple move segments, each of which has a base point
ENEMY_MAT_INDX						100	These keys are supported structurally in WARSIM
ENEMY_MAT_INPUT						100	
LOC_ASSC_CD		enumerated				0	WARSIM only has a stored location for a specific time, with subsequent positions calculated based on movement type
ACCURACY_QTY						0	Calculated positions are assumed to be accurate
COURSE		number	platform.move_data.ground_linear	direction.head/tail	coordinate_3d_c	90	Course angle can be calculated from head and tail locations
SPEED_KMH		number	platform.move_data.ground_linear	speed	double	100	
COORD_ROA						0	Not modeled
EQUIP_QTY						0	

JCDB			WARSIM			Assessment	Comment
Attribute/Association Name	Key Association Attribute	Data Type	Class	Attribute	Data Type		
EN_MAT_PT_LAT		number	platform.move_data	constant_position	double (3)	100	
EN_MAT_PT_LON		number	platform.move_data	constant_position	double (3)	100	
ALTITUDE_M		number	platform.move_data_group_linear	altitude	double	100	
ELEVATION_M		number	platform.move_data	constant_position	double (3)	100	
PERCEP_REF_IDX						0	
PERCEP_INPUT_ID						0	
RECORD_STATUS_DTTM						0	
DISSEM_LEVEL_CD						0	
RECORD_STATUS						0	
Entity Name: ENEMY_MAT_PT_HIST							
ENMAT_PT_HIST_IDX						52	
ENEMY_MAT_PT_IDX						100	WARSIM platform move data supports multiple move segments, each of which has a base point
ENEMY_MAT_PT_IDX						100	WARSIM platform move data supports multiple move segments, each of which has a base point
ENEMY_MAT_IDX						100	These keys are supported structurally in WARSIM
ENEMY_MAT_INPUT						100	
LOC_ASSC_CD		enumerated				0	WARSIM only has a stored location for a specific time, with subsequent positions calculated based on movement type
ACCURACY_QTY						0	Calculated positions are assumed to be accurate
COURSE		number	platform.move_data_group_linear	direction.head/tail	coordinate_3d_c	90	Course angle can be calculated from head and tail locations

JCDB				WARSIM			Assessment	Comment
Attribute/ Association Name	Key Association Attribute	Data Type	Class	Attribute	Data Type			
SPEED_KMH		number	platform.move_data_group_linear	speed	double	100		
COORD_ROA						0	Not modeled	
EQUIP_QTY						0		
EN_MAT_PT_LAT		number	platform.move_data	constant_position	double (3)	100		
EN_MAT_PT_LON		number	platform.move_data	constant_position	double (3)	100		
ALTITUDE_M		number	platform.move_data_group_linear	altitude	double	100		
ELEVATION_M		number	platform.move_data	constant_position	double (3)	100		
PERCEP_REF_INDX						0		
PERCEP_INPUT_ID						0		
RECORD_STATUS_DTTM						0		
DISSEM_LEVEL_CD						0		
RECORD_STATUS						0		
Entity Name: EN_PER_EN_MAT						0		
E_PER_E_MAT_INDX							WARSIM does not model individual people	
ENEMY_MAT_INDX								
E_PERSON_INDX								
ENEMY_MAT_INPUT								
E_PERSON_INPUT								
EPER EMAT ASSC CD								

JCDB			WARSIM			Assessment	Comment
Attribute/Association Name	Key Association Attribute	Data Type	Class	Attribute	Data Type		
EQUIP_MASTER_KEY							
INDIVID_MASTER_KEY							
MLC_CLASSIFICATION							
RECORD_STATUS							
RECORD_STATUS_DTTM							
DISSEM_LEVEL_CD							
PERCEP_REF_INDX							
PERCEP_INPUT_ID							
Entity Name: FAC_EN_MAT							
FAC_INDX						0	
ENEMY_MAT_INDX							WARSIM does not model relationships between facilities and material
FAC_INPUT_ID							
ENEMY_MAT_INPUT							
FAC_EN_MAT_ASSC_CD							
FAC_MASTER_KEY							
EQUIP_MASTER_KEY							
MLS_CLASSIFICATION							
PERCEP_REF_INDX							
PERCEP_INPUT_ID							
RECORD_STATUS							
RECORD_STATUS_DTTM							
DISSEM_LEVEL_CD							
Entity Name: CNDT_TRGT							
CTRGT_INDX						0	
CTRGT_INPUT_ID							WARSIM has no concept of a candidate target
CTRGT_FOCUS_TYP_CD							
TRGT_SYMBOL_CD							
EORG_INDX							
EORG_INPUT_ID							
ENEMY_MAT_INDX							
ENEMY_MAT_INPUT							

JCDB				WARSIM			Assessment	Comment
Attribute/Association Name	Key Attribute	Association Attribute	Data Type	Class	Attribute	Data Type		
E_PERSON_INDX								
E_PERSON_INPUT								
FEAT_INDX								
FEAT_INPUT_ID								
FAC_INDX								
FAC_INPUT_ID								
PRIORITY_CD								
MSN_VALUE								
CTRGT_VCNTY_DUR								
CTRGT_LENGTH_DIM_M								
CTRGT_WIDTH_DIM_M								
CTRGT_RADIUS_DIM_M								
CTRGT_HEIGHT_DIM_M								
CTRGT_ATTITUD_MILS								
CTRGT_AMP_TXT								
COMMON_TRGT_NUM								
HULTEC_NUMBER								
ABCA_NO								
RECORD_STATUS_DTTM								
RECORD_STATUS								
DISSEM_LEVEL_CD								
Entity Name: EN_MAT_EVENT							0	
E_MAT_EVTN_INDX								WARSIM has no concept of an event
ENEMY_MAT_INDX								
EVENT_INDX								
ENEMY_MAT_INPUT								
EVENT_INPUT								
EMAT_EVENT_ASSC_CD								
EVENT_MASTER_KEY								
EQUIP_MASTER_KEY								
MLS_CLASSIFICATION								

JCDB		WARSIM			Assessment	Comment
Attribute/Association Name	Key Association Attribute	Data Type	Class	Attribute		
PERCEP_REF_INDX						
PERCEP_INPUT_ID						
RECORD_STATUS						
RECORD_STATUS_DTTM						
DISSEM_LEVEL_CD						

Table F-16. Mapping MAT_ITEM to WARSIM

JCDB		WARSIM		Assessment	Comment
Attribute Name	Data Type	Class	Attribute	Data Type	
Entity Name: MAT_ITEM					
MAT_ITM_INPUT	number	abstract	id_u	string	15 mat_item aligns with abstract.land.equipment_type
MAT_ITM_IDX	number	abstract	id_u	string	50
MATITM_CAT_CD					50
					0 The distinction between consumables and equipment is not modeled in WARSIM
MATITEM_SUP_CLASS					SIM
BRIL_TRACK_IND_CD					0 WARSIM does not model the supply class of materiel types
MATITM_NAME					0 Not modeled by Warsim
MATITM_TECH_ID	string	abstract.land	model	string	75 It is not clear that the intention of model is to serve as a name
MATITM_DESCR_TXT					0 WARSIM only offers MIDB as the description of a materiel type
MATITEM_SYMBOL_CD					0
RECORD_STATUS					0
RECORD_STATUS_DTTM					0
DISSEM_LEVEL_CD					0
Entity Name: MAT_ITEM_ASSC					
MAT_ITM_ASSC_IDX					0 The relationship between two materiel types is not modeled in WARSIM
SBJCT_MAT_ITM_IDX					
OBJCT_MAT_ITM_IDX					
OBJCT_MATITM_INPUT					
SBJCT_MATITM_INPUT					
MAT_ITEM_ASSC_TYP					
MATITEM_GRP_NOMEN					
MATITM_ASC_MAX_QTY					
MAT_ASSC_STRT_DTTM					
MAT_ASSC_END_DTTM					
RECORD_STATUS					
RECORD_STATUS_DTTM					
DISSEM_LEVEL_CD					

JCDB		WARSIM			Assessment	Comment	
Attribute Name	Data Type	Class	Attribute	Data Type			
Entity Name: MAT_ITEM_HOLDINGS							
MAT_ITM_INPUT	number	abstract	id_u	string	50	22 Materiel item holdings for an organization are aligned with org.land.unit. org.land.equip_group can be used when it is a subordinate org	
MAT_ITM_INDX	number	abstract	id_u	string	50		
ORG_ID	number	org	id_u	string	50		
ORG_INPUT_ID	number	org	id_u	string	50		
MATIHLDNG_QTY	number	org.land.equip_group	number_of_platforms	long	100		
MATIHLDNG_OPL_QTY	number	org.land.equip_group	platform_kill_type	[counted]	75		
MATITEM_SUP_CLASS	number				0		
MATITM_AUTH_QTY	number	org.land.unit	authorized equipment c	long	100		
QTY_DAMAGED	number	org.land.equip_group	platform_kill_type	[counted]	50		WARSIM does not have a generic "damaged" kill type
QTY_RECUP					0		
QTY_DESTROYED	number	org.land.equip_group	platform_kill_type	[counted]	75		
MATI_DAYS_QTY					0		
REPORT_ACTUAL_DTTM					0		
DUEIN_QTY_CURRENT					0		
DUEIN_QTY_D1					0		
DUEIN_QTY_D2					0		
DUEIN_QTY_D3					0		
DUEIN_QTY_D4					0		
DUEIN_QTY_D30					0		
DUEIN_QTY_D60					0		
DUEIN_QTY_D90					0		
HLDNGS_AMP_TXT					0		
PERCEP_INPUT_ID					0		
PERCEP_REF_INDX					0		
RECORD_STATUS					0		
RECORD_STATUS_DTTM					0		
DISSEM_LEVEL_CD					0		

JCDB		WARSIM		Assessment	Comment
Attribute Name	Data Type Class	Attribute	Data Type		
Entity Name: MAT_ITEM_CONSUMPTION				0	WARSIM does not model materiel item consumption
MAT_ITM_INPUT					
ORGT_INPUT_ID					
ORG_TYP_INDEX					
MAT_ITM_INDEX					
ORGT_CONSUMPT_INDEX					
OPL_THEATER_CD					
ENVIRO_REGION_CD					
OPL_ENVIRO_CD					
CONSUM_UM_CD					
ORGT_CONSUMPT_QTY					
OPL_SUST_DAYS_QTY					
Entity Name: MATITM_FEAT_HLDNGS				0	WARSIM does not model materiel held at a feature
MAT_ITM_INPUT					
MATI_FHLD_INDEX					
FEAT_INDEX					
MAT_ITM_INDEX					
FEAT_INPUT_ID					
MATIFEAT_HLDNG_QTY					
DUEIN_CURRENT_QTY					
DUEIN_D1_QTY					
DUEIN_D2_QTY					
DUEIN_D3_QTY					
DUEIN_D4_QTY					
RECORD_STATUS					
RECORD_STATUS_DTTM					
DISSEM_LEVEL_CD					
PERCEP_INPUT_ID					
PERCEP_REF_INDEX					

JCDB		WARSIM		Assessment	Comment	
Attribute Name	Data Type	Class	Attribute			Data Type
Entity Name: MATITM:TRKNG_HIST						0
MAT_ITM_INPUT						
ORG_MATI_TRK_INDX						
ORG_ID						
MAT_ITM_INDX						
ORG_INPUT_ID						
CTIL_IND_CD						
RECORD_STATUS						
RECORD_STATUS_DTTM						
DISSEM_LEVEL_CD						
PERCEP_REF_INDX						
PERCEP_INPUT_ID						

Table F-17. Mapping CONSUMABLES to WARSIM

JCDB			WARSIM			Assessment
Attribute/ Association Name	Key Association Attribute	Data Type	Class	Attribute	Data Type	
Entity Name: MAT						19
MAT_INDX		number	platform	id_u	string	50
MAT_INPUT_ID		number	platform	id_u	string	50
MAT_ITM_INDX		number	platform	abstract_id	string	50
MAT_ITM_INPUT		number	platform	abstract_id	string	50
ALLEGIANCE		enumerated				0
MAT_CAT_CD		enumerated				0
SERIAL_NUMBER		string				0
MAT_ALT_ID		string	platform	platform_name	string	100
MAT_LOT_TXT		string				0
RECORD STATUS		enumerated				0
DISSEM_LEVEL_CD		enumerated				0
RECORD STATUS_DTTM		date-time				0
MAT_ASSC	MAT_ASSC_TYP	enumerated				0
MAT_FEAT	MATFEAT_ASSC_TYP	enumerated				0
MAT_NTWK	MATNET_RELAT_TYP	enumerated				0
MAT_PER	MATPER_ASSC_TYP_CD	enumerated				0
Entity Name: MAT_ITEM						17
MAT_ITM_INPUT		number	platform	abstract_id	string	50
MAT_ITM_INDX		number	platform	abstract_id	string	50
MATITM_CAT_CD		enumerated				0
MATITEM_SUP_CLASS						0
BRIL_TRACK_IND_CD						0
MATITM_NAME						0
MATITM_TECH_ID						0
MATITM_DESCR_TXT						0
MATITEM_SYMBOL_CD		enumerated	platform	symbol_code_o	string	100
RECORD STATUS						0
RECORD STATUS_DTTM						0

JCDB			WARSIM			Assessment
Attribute/ Association Name	Key Association Attribute	Data Type	Class	Attribute	Data Type	
DISSEM_LEVEL_CD						0
Entity Name: MAT_OPL_STAT						
MAT_OPL_STAT_INDX		number				9
MAT_INDX		number	platform	id_u	string	0
MAT_INPUT_ID		number	platform	id_u	string	50
AVAILABILITY_CD		enumerated				0
MAINTAINABILITY_CD		enumerated				0
MAINT_RT_DTTM		date-time				0
CONDITION		enumerated				0
ACTIVITY		enumerated				0
OPER_STATUS		enumerated	platform	health_status	number	50
MAT_RADS_QTY		number				0
MAT_PRIMARY_USE		enumerated				0
PERCEP_REF_INDX		number				0
PERCEP_INPUT_ID		number				0
RECORD_STATUS		number				0
RECORD_STATUS_DTTM		date-time				0
DISSEM_LEVEL_CD		enumerated				0

JCDB				WARSIM			Assessment
Attribute/ Association Name	Key Association Attribute	Data Type	Class	Attribute	Data Type		
Entity Name: MAT_PT							
MAT_PT_INDX			platform	move_data_c		42	
MAT_INDX							
MAT_INPUT_ID							
LOC_ASSC_CD							
ACCURACY_QTY							
COURSE							
SPEED_KMH					ground_linear_c	100	
COORD_ROA					ground_linear_c	100	
EQUIP_QTY						0	
MAT_PT_LAT						0	
MAT_PT_LON					constant_position_c	100	
ALTITUDE_FT					constant_position_c	100	
ELEVATION_M					ground_linear_c	100	
PERCEP_REF_INDX					constant_position_c	100	
PERCEP_INPUT_ID						0	
RECORD_STATUS				0			
RECORD_STATUS_DTTM				0			
DISSEM_LEVEL_CD				0			
MAT_PT_OLAY	MATOLAY_APPL_DTTM			0			
Entity Name: CONSUMABLES							
MAT_ITM_INPUT						0	
MAT_ITM_INDX							
CONSUM_CAT_CD							
CONSUM_SUBCAT_CD							
CONSUM_UNIT_ISS_CD							
CONSUM_UNIT_ISS_QTY							
CONSUM_UM_CD							
CONSUM_UNIT_VOL							
CONSUM_UNIT_WT							

Table F-18. Mapping EQUIP_TYPE to WARSIM

JCDB			WARSIM			Assessment
Attribute/ Association Name	Data Type	Class	Attribute	Data Type		
Entity Name: MAT_ITEM						
MAT_ITM_INPUT	number	abstract	id_u	string	13	
MAT_ITM_INDX	number	abstract	id_u	string	50	
MATITM_CAT_CD	enumerated				50	
MATITEM_SUP_CLASS					0	
BRIL_TRACK_IND_CD					0	
MATITM_NAME					0	
MATITM_TECH_ID					0	
MATITM_DESCR_TXT					0	
MATITEM_SYMBOL_CD	enumerated	platform	symbol_code_o	string	50	
RECORD_STATUS					0	
RECORD_STATUS_DTTM					0	
DISSEM_LEVEL_CD					0	
Entity Name: EQUIP_TYPE						
MAT_ITM_INPUT	number	abstract	id_u	string	41	
MAT_ITM_INDX	number	abstract	id_u	string	50	
EQUIPT_LNGTH_DIM_M	number	abstract.land.equipment_type	length	double	50	
EQUIPT_WDTH_DIM_M	number	abstract.land.equipment_type	width	double	100	
EQUIPT_HT_DIM_M	number	abstract.land.equipment_type	height	double	100	
EQUIPT_WT_LBS	number				0	
EQUIPT_MOB_CD	enumerated				0	
EQUIPT_CAT_CD	enumerated				0	
EQUIPT_POP_NAME	string				0	
EQUIPT_NOMEN_ID	string				0	
EQUIP_TYP_RCP	enumerated	platform	symbol_code_o	string	50	
Entity Name: EQUIPT_CONSUMPTION						
EQUIPT_CONSMP_INDX					0	
CNSMR_MATITM_INPUT						
CNSMD_MATITM_INPUT						
CONSUMER_MATITM						
CONSUMED_MATITM						

JCDB		WARSIM			Assessment
Attribute/ Association Name	Data Type	Class	Attribute	Data Type	
OPL_ENVIRO_CD					
ENVIRO_REGION_CD					
EQUIP_RT_UM_CD					
EQUIPT_CNSUMPT_QTY					
SUSTAIN_TM_QTY					
PERCEP_REF_INDX					
PERCEP_INPUT_ID					
RECORD_STATUS					
RECORD_STATUS_DTTM					
DISSEM_LEVEL_CD					

Table F-19. Mapping SENSOR_TYPE to WARSIM

JCDB		WARSIM			Assessment
Attribute Name	Data Type	Class	Attribute	Data Type	
Entity Name: MAT_ITEM					13
MAT_ITM_INPUT	number	abstract	id_u	string	50
MAT_ITM_IND_X	number	abstract	id_u	string	50
MATITM_CAT_CD	enumerated				0
MATITEM_SUP_CLASS					0
BRIL_TRACK_IND_CD					0
MATITM_NAME					0
MATITM_TECH_ID					0
MATITM_DESCR_TXT					0
MATITEM_SYMBOL_CD	enumerated	platform	symbol_code_o	string	50
RECORD_STATUS					0
RECORD_STATUS_DTTM					0
DISSEM_LEVEL_CD					0
Entity Name: EQUIP_TYPE					41
MAT_ITM_INPUT	number	abstract	id_u	string	50
MAT_ITM_IND_X	number	abstract	id_u	string	50
EQUIPT_LENGTH_DIM_M	number	abstract.land.equipment_type	length	double	100
EQUIPT_WIDTH_DIM_M	number	abstract.land.equipment_type	width	double	100
EQUIPT_HT_DIM_M	number	abstract.land.equipment_type	height	double	100
EQUIPT_WT_LBS	number				0
EQUIPT_MOB_CD	enumerated				0
EQUIPT_CAT_CD	enumerated				0
EQUIPT_POP_NAME	string				0
EQUIPT_NOMEN_ID	string				0
EQUIP_TYP_RCP	enumerated	platform	symbol_code_o	string	50
Entity Name: SENSOR_TYPE					6
MAT_ITM_INPUT	number	abstract	id_u	string	50
MAT_ITM_IND_X	number	abstract	id_u	string	50
SENSOR_TYP_CD					
SENSOR_CLSS_CD					

JCDB		WARSIM			Assessment
Attribute Name	Data Type	Class	Attribute	Data Type	
SNSR_SCAN_CD					
ACCRCY_DIM_FT					
ELVAT_MAX_ANG					
ELVAT_MIN_ANG					
FQY_LOW_LIM_RT					
FQY_UPP_LIM_RT					
LIM_LFT_ANG					
LIM_RT_ANG					
RNG_MAX_DIM_M					
RNG_MIN_DIM_M					
RELIABTY_RT					
SCAN_RATE_HZ					

REPORT DOCUMENTATION PAGE				Form Approved OMB No. 0704-0188	
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.					
1. REPORT DATE (DD-MM-YY) December 2002		2. REPORT TYPE Study		3. DATES COVERED (From – To)	
4. TITLE AND SUBTITLE A Comparison of the WARSIM Object Model with Army Command and Control Data Models				5a. CONTRACT NUMBER DASW01-98-C-0067 DASW01-02-C-0012	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBERS	
6. AUTHOR(S) Brian A. Haugh, Task Leader, Francisco L. Loaiza, Reginald N. Meeson, Richard P. Morton, Steven P. Wartik, Deborah Heystek, Michael R. Hieb, Lesley J. Painchaud				5d. PROJECT NUMBER	
				5e. TASK NUMBER BC-5-1943	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESSES Institute for Defense Analyses 4850 Mark Center Drive Alexandria, VA 22311-1882				8. PERFORMING ORGANIZATION REPORT NUMBER IDA Paper P-3740	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) SAIS-IOE-I (ENT ARCH & ACQ) 2531 Jefferson Davis Hwy Arlington, VA 22202				10. SPONSOR'S / MONITOR'S ACRONYM	
				11. SPONSOR'S / MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; unlimited distribution: 3 June 2003.					
13. SUPPLEMENTARY NOTES This paper has an accompanying CD-ROM, which contains databases and spreadsheets of assessment findings.					
14. ABSTRACT This paper presents an assessment of data model/object model alignment between C4I and M&S models. In the C4I domain, two models are examined: NATO's Land Command and Control Information Exchange Data Model (LC2IEDM), and the Joint Common Database (JCDB) Data Model (JDM). In the M&S domain, the model is from WARSIM, the Land Component of the Joint Simulation System (JSIMS). The paper shows that, although there is substantial overlap in the data modeled by WARSIM and the C4I models, some data areas have significant problems in mutual coverage and compatibility. The LC2IEDM and JDM do not adequately capture some of the dynamic data that is necessary in simulation, and the WARSIM model cannot fully describe the real world as the LC2IEDM and JCDB expect. The paper addresses data alignment between WARSIM and the LC2IEDM, making specific recommendations for changes to them that would improve their interoperability.					
15. SUBJECT TERMS Army Battle Command System (ABCS), Army C4I-M&S Reference Object Model (C-ROM), Warfighter's Simulation (WARSIM), Joint Data Model (JDM), Joint Simulation System (JSIMS), Interoperability, Object Model.					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			MAJ Scott Tufts
Unclassified	Unclassified	Unclassified	Unlimited	250	19b. TELEPHONE NUMBER (Include Area Code) (703) 602-6401

