Assessing the Land Command and Control Information Exchange Data Model using Naval Tactical Contact Data

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ABSTRACT

The Land Command and Control Information Exchange Data Model (LC2IEDM) is investigated from the perspective of naval tactical sonar data. The data content of a sonar contact is described. The contact data is then placed in the LC2IEDM database structure, illustrating both the order and location of data placement. Two data units, related to sensor and contact specific information, could not be placed in the LC2IEDM. General comments regarding the use of codes when linking systems are presented.

1.0 INTRODUCTION

The evolution of military systems has reached the stage where developers are constructing systems that are built from other component systems - commonly termed a system-of-systems. In such developments, the successful communication of data between the systems is crucial to the implementation. The importance of the communication has resulted in considerable resources being dedicated to data exchange solutions.

Traditional solutions to data communications between systems have involved individual translations between the systems. In an interoperable environment consisting of n components, the full communication between all components requires the development n(n-1) data translations. Such a solution has obvious scalability problems as the number of components becomes large.

As a result, data structures that are common to all components are now being considered to provide a level of interoperability among the component systems. These data structures may take the form of exchanged data files or a common database (*i.e.*, the LC2IEDM situation). By creating a central or common language, the developed system requires 2n translations. In this situation, each component is required to translate into and out of the common language [1].

In the international community, developments are underway to construct such common language structures. For example, the Land Command and Control Information Exchange Data Model (LC2IEDM) is a NATO development intended to store all information pertaining to an operation. The system, which has been in the development cycle for about two decades, provides a high-level object and resource view of the battle space.

LC2IEDM is now being used as the focal point for numerous software developments aimed at a fully interoperable coalition. LC2IEDM is also being investigated within virtual environments, under the auspices

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of The Technical Cooperation Program (TTCP) [2]. The interest in LC2IEDM is widespread and as a result, LC2IEDM is being promoted as a possible structure for joint operations. However, the LC2IEDM provenance is army operations, and its applicability to the navy environment needs to be assessed.

To investigate the LC2IEDM system from a naval perspective, we consider tactical contact information that originates from sonar data. This report first outlines the content of the contact data and supporting metadata. In some cases, the metadata are not strictly from a sonar contact source, but are included in the data to illustrate the data characteristics of the LC2IEDM.

2.0 CONTACT DATA

In a naval setting, a sonar contact may be considered a real-world object that has been identified using features of the acoustic signal. Sonar contact data typically consists of spatial-temporal information related to the real-world object. However, in this investigation we assume supplementary information on object properties is also available. For example, the contact's country of origin would be supplementary information resulting from intelligence rather than sonar contact data.

Repeated observation of the contact provides a series of contact positions, which collectively form a track for the real-world object. Such tracks are assigned unique identifiers, or track numbers. The track number, with the course and speed of the real-world object, form some of the reported properties of the contact (see Table 1). Note that the data includes both kinematic and attribute information on the target and sensor used in the detection. For the platform containing the sensor, the data includes the data owner, type of sensor being used and the position of the reporting platform. As well, multiple track numbers are used to represent a fusion of many tracks to produce the reported track.

The data being placed in the LC2IEDM consists of 25 data units as described in Table 2. The data describes a fictitious surface ship named HMCS Grove, located at 45°N, 50°W, operating a 300 Hz sonar. The sonar has detected a submerged submarine on a bearing 270 ± 6.75° T, range of 12 ± 0.5 km, at a depth of 100 ± 10 m. The submarine is model 1234 from country Orange. These data are placed in the LC2IEDM system in an attempt to reveal the strengths and weaknesses of the data model [3].

Table 1: Defining the data characteristics of the contact and supplementary information.

CHARACTERISTIC	DEFINITION
Owner	Owner of the data. Note that the owner is considered to be the platform where the sensor is based that took the measurements that identified the contact.
Sensor Type and Frequency	Type of sonar sensor including the frequency of operation.
Reporting Platform Position	Specific point in x,y,z space where the reporting platform is located.
Time	Time the contact position was determined.
Position Error	A measure of error associated with the position of the contact.
Contact Course	The course of the contact.
Contact Speed	The speed of the contact.
Track Number	Track number of the contact.
Components	Component tracks that have been fused to create the track.
Country of Origin	The contact's country of origin.
Domain of Operation	The spatial domain in which the contact is capable of operations.
Type of Platform	The type of vessel the contact is thought to be.
Identifiers	Any unique identifiers for the contact.
Threat Level	The threat level posed by the contact to the Owner.

Table 2: Data used to fill the LC2IEDM. The important point is determining whether or not the database can store the described data. The number in brackets following each data content description represents the note number in the following figures. An asterisk (e.g., *) indicates the content could not be stored in the LC2IEDM version 5.3.

CHARACTERISTIC	DATA CONTENT
Owner	HMCS Grove (2)
Sensor Type and Frequency	Sonar sensor (8) Operating frequency 300 Hz (*)
Reporting Platform position	45 N, 50 W (14)
Time	June 24, 2003 at 11:10:00 UTC (10)
Contact Course	Due east (20)
Contact Speed	5 m/s (20)
Other contact information	Contact is at a bearing of 270 degrees from the reporting platform, with an uncertainty of ± 6.75 degrees. (17) Range is 12 km, with uncertainty of ± 0.5 km. (17) The depth of the contact is 100 m below the water surface, with an uncertainty of ± 10 m. (15)
Track Number	BAD001 (2)
Components	This track is a fusion of tracks 1 and 4. (25,26,27)
Country of Origin	Thought to be a unit from country Orange. (5)
Domain of Operation	Underwater (22)
Type of Platform	Submarine (5)
Identifiers	Known to be a Model 1234 submarine. (3) Orange in colour with a large yellow dot. (3,* - the dot property could not be stored)
Threat Level	This is a hostile submarine. (11)

3.0 DATA PLACEMENT

The LC2IEDM is a highly normalized data model. This results in considerable dispersion of data over many tables within the LC2IEDM database. In turn, this makes it difficult to represent and document the data distribution. This report only briefly presents this dispersion. A more complete description can be found in [3].

The data placement into the database utilizes eXtensible Markup Language (XML) structures and the Operational Context Exchange Service (OCXS) [4], a Java software suite developed by the Naval Undersea Warfare Center in the US. The suite provides a consistent interface to LC2IEDM and removes the details of the data placement. The data are described in an XML structure consistent with the physical naming convention of the LC2IEDM. This allows one to focus on the content and structure of the data rather than the software details of interfacing with the LC2IEDM.

The placement of the contact information into the LC2IEDM database is presented in Figure 1, Figure 2 and Figure 3. Each figure consists of LC2IEDM tables and fields as based on the LC2IEDM documentation [5]. A rectangular box indicates a table. Column names and data types are indicated within the table. Primary keys are indicated as named columns above the horizontal separator line for the table and also by the key symbol. Below the separator line are non-key column names. Some of the column names are designated as foreign keys, and are indicated by FK following the column name.

Relationships are illustrated using the Integration Definition for Information Modelling (IDEF1X) notation [6]. This notation illustrates a relationship between tables as either a solid or dashed line. The solid line represents a relationship where the foreign key is part of the primary key in the child table (an identifying relationship). A dashed line represents a relationship where the foreign key is not part of the primary key in the child table (a non-identifying relationship). A solid black circle on the end of a line indicates zero, one or more records. A diamond symbol on the end of a line indicates zero or one records. No symbol on the end of a line indicates one record. Finally, a red dot indicates a specialization. A specialization is a relationship that requires a record entry in a particular child table based on the content in the parent table.

Each figure also contains a numbered series of shaded boxes. Each numbered box refers to a note in the figure caption. The numbering represents the order of data placement within the LC2IEDM. The order requirement is a result of the relationship specifications within the LC2IEDM.

Within each note is a description of content for the particular table. Notes will reference table names first by using the physical table name in the figure (denoted by uppercase characters above the rectangular box). Following the first use of the physical table name will be the logical table name (in parentheses). The logical names will be used from that point onward.

Figure 1 shows the initial load of database tables. The data inserted into these tables identifies the ownship object and an object associated with the contact. Properties of the contact real-world object are also included to exercise LC2IEDM capabilities.

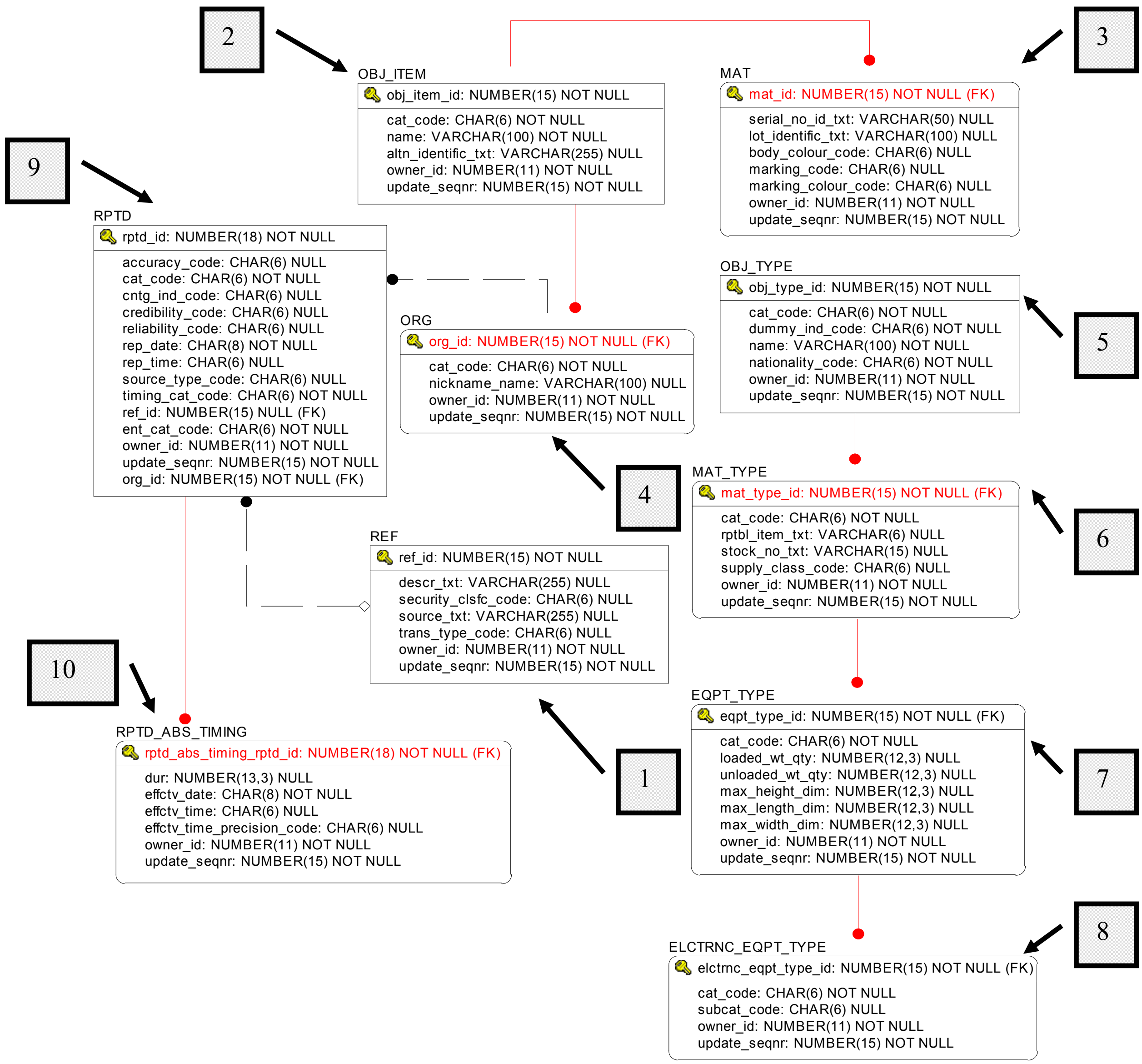

Figure 1: Shown here are 10 tables used in the initial filling of the LC2IEDM database with the contact data from Table 2. IDEF1X notation [6] is used to illustrate the entity-relationship diagram. The following notes apply to the numeric identifiers in the figure.

1: The REF (reference) table is used to identify the information source. Any reporting must have an identified information source.

2: The OBJ_ITEM (object-item) table is used to define the relevant objects. In this example, one object represents a materiel unit named "Red Force 1" with alternate identification being the track number. A second object item is a materiel unit described as "HMCS Grove". The second object represents ownship. The MAT (materiel) and the ORG (organisation) tables will reference these objects.

3: The MAT (materiel) table is used to describe the markings on the contact object. The markings are linked to the object item described by Note 2.

4: The ORG (organisation) table describes the organisations to which the objects belong. The organisations are also referenced in reporting-data, as any generated reports must originate from a defined organisation.

5: The OBJ_TYPE (object type) table defines the name, nationality and types of objects. For this example, two types need to be defined, one for the contact and one for the ownship. Note that type is different from the actual object. In a military context, the type can be thought of as similar to the class of ship. In the ownship case, the object type is defined by the name "Frigate". For the contact, the data in this table accounts for the contact nationality and the class of vessel.
6: The MAT_TYPE (materiel-type) table is used to specify equipment specific to a particular object.
7: The EQPT_TYPE (equipment-type) table is used to indicate that for this example the material-type indicated in Note 6 is actually electronic equipment.
8: The ELCTRNC_EQPT_TYPE (electronic-equipment-type) table is used to define the specifications of the electronic equipment. In this example the electronic equipment is described as a sonar sensor.
9: The record in RPTD (reporting-data) table manages the actual contact report. The timing information in this table refers to the database insertion time.
10: The RPTD_ABS_TIMING (reporting-data-absolute-timing) table contains the contact time.

Figure 2 illustrates those tables related to locating objects in space. The ownship is first located, followed by the range and bearing information used to locate the contact. The contact's position is described using a fan-area, or range and bearing values with associated errors.

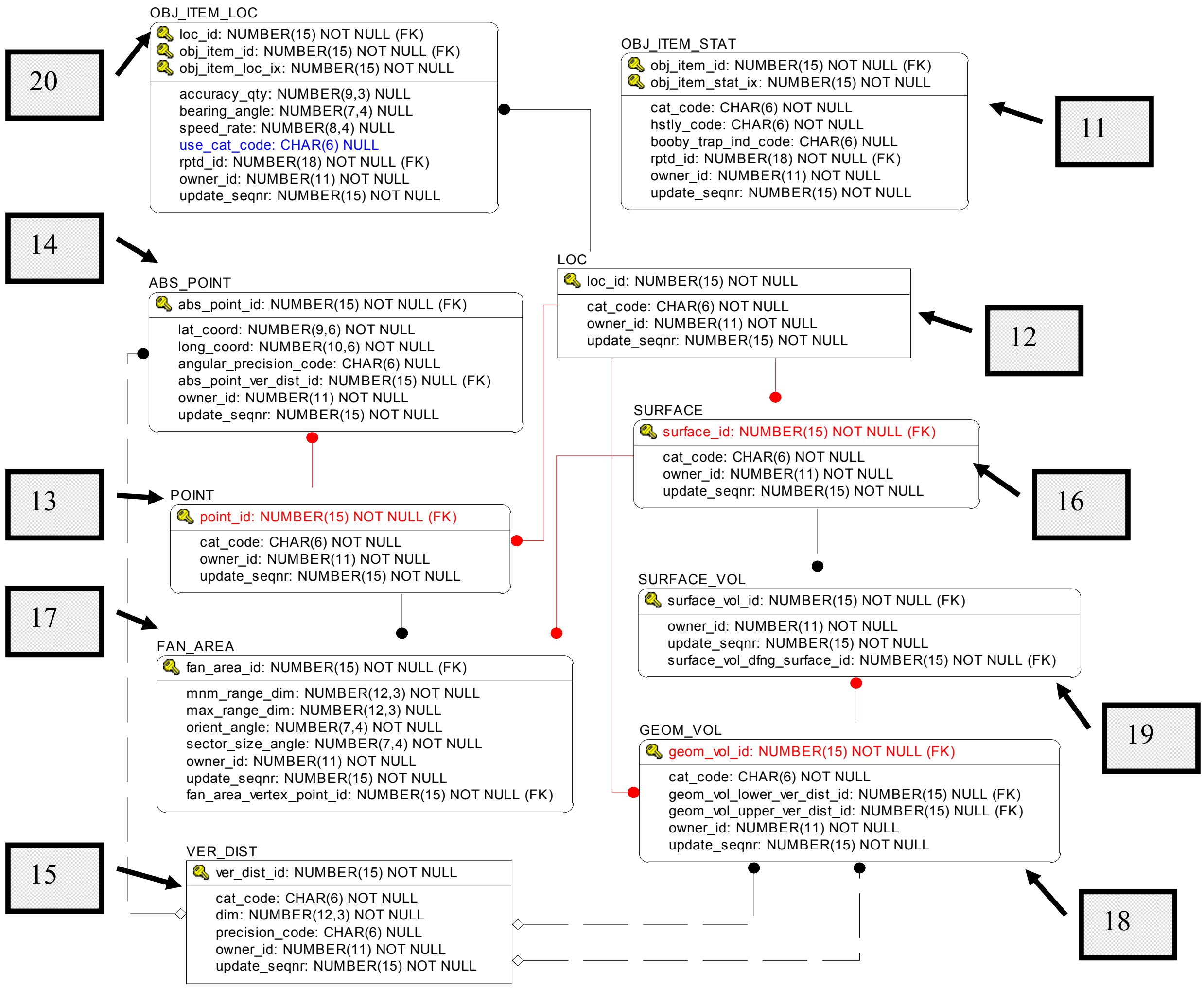

Figure 2. Shown here are 10 tables that continue the placement of the contact data into the LC2IEDM. These tables are predominantly related to positioning information.

- **11: The OBJ_ITEM_STAT (object-item-status) table is used to describe the status of a particular object. In this example the contact is described as "hostile".**
- **12: The LOC (location) table is used to categorize the types of locations. In this case, we categorize three locations: a point, a surface and a volume. Note that the location table does not spatially define a location, but rather assigns an identifier to the location.**
- **13: The POINT (point) table is used to categorize the point. In this example we describe absolute points.**
- **14: Having defined an absolute point, the ABS_POINT (absolute-point) table is used to store the coordinates of the ownship.**
- **15: The VER_DIST (vertical-distance) table is used to store the vertical extent of the volume for the contact. Note that LC2IEDM Version 5.3 does not allow negative values (the next iteration of the model, called the Command and Control Information Exchange Data Model Version 6.1 does allow negative depths). Storing the vertical extent of the contact area of uncertainty means the C2IEDM can represent the ± 10m indicated as the depth uncertainty in Table 2.**
- **16: The SURFACE (surface) table is used to categorize the surface. In this example we describe the surface as a fan area.**

17: The FAN_AREA (fan-area) table is used to describe the minimum and maximum range, and the orientation and sector size of the fan.
18: The GEOM_VOL (geometric-volume) table is used to define a geometric volume. In this case, the volume is described by a surface with a vertical extent.
19: The SURFACE_VOL (surface-volume) table defines a surface volume as based on a particular surface. In this case, the surface is a fan area.
20: The OBJ_ITEM_LOC (object-item-location) table assigns an object item to a particular location. This table is used to link the ownship with the specific location that was categorized as a point, and the contact that was categorized as a volume. The contact's course and speed are also stored in object-item-location.

Figure 3 shows those tables related to the mobility of the contact and the track fusion specification. Track fusion in LC2IEDM is represented as a context record that identifies the two initial records (*i.e.*, initial tracks) that have been combined to form the fused track.

4.0 DISCUSSION

Two obvious problems were encountered in the data load into the LC2IEDM. The first problem is related to the frequency of the sonar (Table 2). This level of equipment specific information is not present in the LC2IEDM. If users required this level of information, extensions to the table structure would be required (and are possible in the larger LC2IEDM system). The second point is that the 'dot' property of the colour identifier (Table 2) was not loaded into LC2IEDM. This property is described in LC2IEDM using a list of allowed codes, the most applicable code being 'symbol'.

As a more general comment, LC2IEDM is rich with many codes. Codes, which are simply abbreviated or hieroglyphic representations of larger definitions, are used throughout many of the tables within LC2IEDM. The general problem of code mapping will be encountered when attempting to link systems to the LC2IEDM. When systems are joined in an interoperable way, an important and implicit requirement is that the central set of codes accommodates the requirements of every component system. Code mappings are relationships between code sets from two or more systems. Such mappings are complex and tedious, requiring subject expertise in both domains [7].

The combination of codes within the LC2IEDM presents other difficulties. In defining the content of the data structure, codes are often used to provide discrete information units for an object. When these data units are combined, they can often lead to impossible combinations of attributes associated with the object. Possible solutions to such problems include database intersection tables or business rules [2].

The code combinations present in the reporting-data table illustrate this problem. Table 3 shows four fields and field descriptions present in the table [2]. The attribute codes indicate that the reported data is based on fact, from a completely reliable source that does not produce erroneous information. Yet, the accuracy code indicates that the reported data is probably erroneous.

A final LC2IEDM observation is related to the sensor information and data. The present investigation assumed the contact data was supplied from some other tactical system. We noted that the detailed sensor information was not stored in LC2IEDM because the model does not include data close to the sensor. However, in some cases it may be useful to share the data feeding the tactical system. Such data, when shared with other data feeds from remote platforms, may serve to discover contacts not obvious in either individual system.

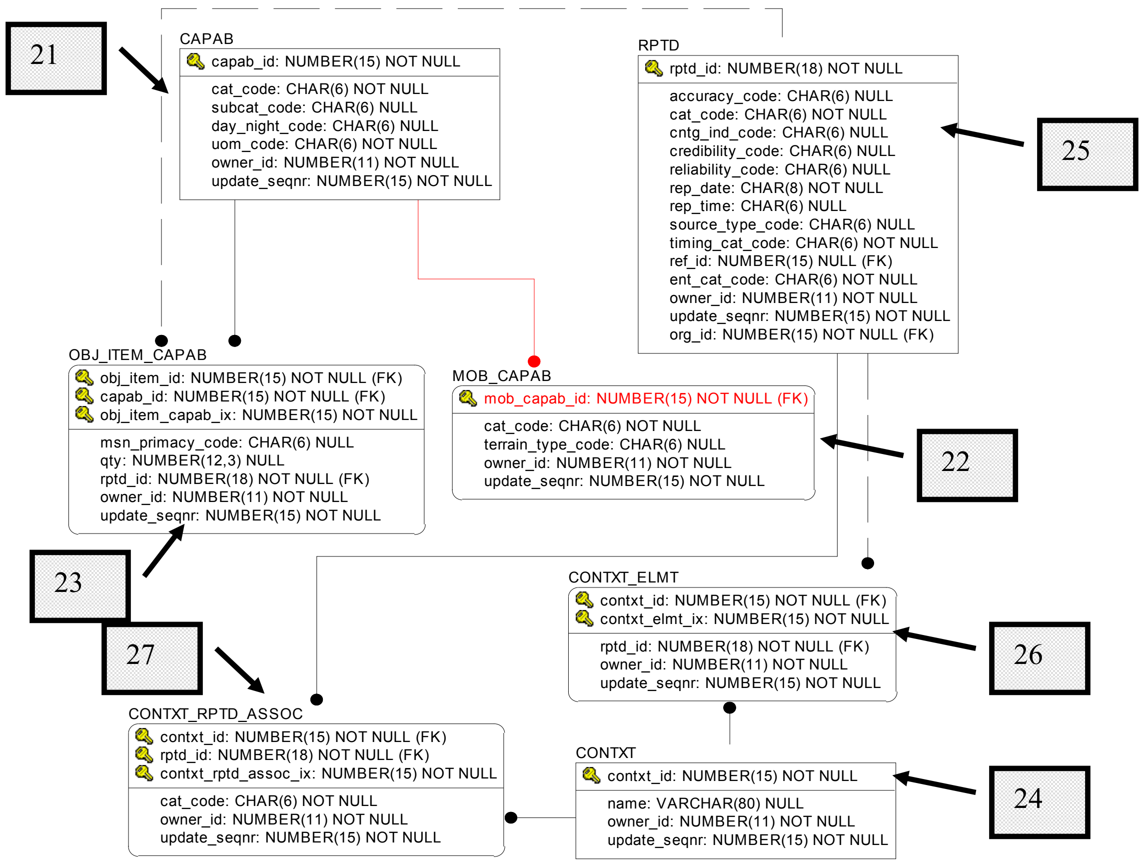

Figure 3. The final illustration shows six new tables (RPTD is repeated from Figure 1). These tables describe the capability of the contact and identify that the contact is based on fused information.

21: The capabilities of the contact are described. The CAPAB (capability) table categorizes functions that may be performed. In this example we use the table to categorize the mobility of the contact.

22: The MOB_CAPAB (mobility-capability) table identifies the mobility of the contact. In this example we describe the contact as subsea.

23: The OBJ_ITEM_CAPAB (object-item-capability) table provides links between the object item (e.g., the submarine), the capability of the object (e.g., its mobility is subsea), and the report pertaining to the object.

24: To represent a fusion of contact information, the CONTXT (context) table must first define a context. The context is given a description and a unique identifier.

25: The context will be linked to reports in the reporting-data table. For this example, the table must be filled with reports with IDs 1 and 4.

26: The CONTXT_ELMT (context-element) table then describes the context in terms of the elements that make up the context. In this case, reports corresponding to IDs 1 and 4 are linked to individual elements in the context.

27: The CONTXT_RPTD_ASSOC (context-reporting-data-association) table then links the report to the context. This then describes one report as a fusion of two other reports.

Table 3: Codes are used extensively within the reporting-data table. Some code values contradict other code values that can be used in the same record. For example, the codes shown below are valid in a single reporting-data record, but are contradictory. Reproduced from [2].

ATTRIBUTE	CODE	CODE DESCRIPTION
accuracy-code	5	Reported data shall be considered as probably erroneous.
category-code	REP	A REPORTING-DATA that points to data based on fact or observation.
credibility-code	RPTFCT	Data is reported by different sources whose integrity is not in question.
reliability-code	A	The source of the reported data can be considered as completely reliable (i.e., erroneous information cannot be produced).

5.0 CONCLUSIONS

The practical experimentation of placing naval sonar contact data into the LC2IEDM structure helps demonstrate more generally applicable issues related to coalition information interoperability. The normalized structure of the LC2IEDM results in considerable dispersion of information throughout the database. Such dispersion may have implications for the subsequent retrieval and reconstruction along with issues of responsiveness. The issue of dispersion is illustrated by the placement of the contact information into 33 records in 26 tables within the LC2IEDM. However, the dispersion is a result of the normalization process. Normalization with constraints provides the data integrity for the system.

Investigations into near-sensor data sharing are ongoing at DRDC Atlantic in the Networked Underwater Warfare Technology Demonstration Project [8]. This Project will define the data sharing requirements and implement a sharing solution for a multi-static sonar operation.

The practical experience of placing naval contact data into the LC2IEDM provides an opportunity to assess the LC2IEDM from a naval perspective. More generally, the experience provides a valuable critique of the data model and identifies potential integration issues with other systems.

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