# Representing the Future Combat Systems Training Integrated Product Team Environmental Representation Requirements in a Logical Data Model


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**ABSTRACT**: *The Future Combat Systems (FCS) program is identifying promising systems and technologies for achieving the Army's vision of fielding a "Future Force". The Future Force is the Army's full spectrum force: organized, manned, equipped, and trained to be more strategically responsive, deployable, agile, versatile, lethal, survivable, and sustainable across the entire spectrum of military operations.*

*As stated, a key component of the FCS is training and the embedded training Key Performance Parameter (KPP). Critical to meeting the embedded training KPP is the ability to accurately represent the environment in training scenarios. The environment is defined by the FCS Geospatial Working Group as "Mission-relevant, earth-referenced data pertaining to air, land, sea, and space".*

*The FCS Training IPT has defined its environmental requirements and shown how they meet FCS requirements (an accompanying paper) and how those requirements are unambiguously defined by a dictionary of environmental concepts (an accompanying paper). Now attention is focused on taking the Training IPT requirements and representing them in a Logical Data Model (LDM).*

*The FCS Chief Data Architect (CDA) is using as its base or core LDM, the Command and Control Information Exchange Data Model (C2IEDM). The C2IEDM was developed for command and control applications. While there is some environmental representation in the C2IEDM, it is sparse. In order to ensure the FCS embedded training KPP is met, the C2IEDMmust be extended to capture the full range of FCS operationally relevant features and attributes that the Training IPT must have represented to accomplish its mission. This paper describes how the Training IPT, working with the FCS CDA team, took the training environmental representation requirements and provided a suggested representation of them in the FCS Data Model.*

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## 1. Introduction

The Future Combat Systems (FCS) program is identifying the promising systems and technologies for achieving the Army's vision of fielding a "Future Force.” The Future Force is the Army's full spectrum force; organized, manned, equipped and trained to be more strategically responsive, deployable, agile, versatile, lethal, survivable, and sustainable across the entire spectrum of military operations. FCS tactics will enable the Future Force to see first, understand first, act first and finish decisively as the means to tactical success. This program will be a multi-functional, multi-mission re-configurable system of systems to maximize joint inter-operability, strategic transportability and commonality of mission roles including direct and indirect fire, reconnaissance, troop transport, counter mobility, non-lethal and C2 on the move. The goal of this effort is to develop a network centric advanced force structure, quantify its benefits and identify materiel solutions and technologies within the context of that force. To achieve this goal of interoperability and commonality across the FCS, there is a requirement for a common environmental representation.

For many years, the U.S. Army has focused its environment efforts on the terrain. This common environment also means that the operators and trainers will be using the same environmental representation.

As mentioned above, the FCS identified the environment as an area that spans all domains and they must be defined. To that end the FCS Geospatial Battlespace Environment (GBE) Working Group (WG) has the charter to define the problem space and in concert with the FCS IPTs identify the requirements that must be met. The FCS GBE WG under the auspices of the FCS Functional Decomposition Functional Allocation (FD/FA) effort developed the definition of “geospatial” that would apply to the FCS and meet the FCS requirement of the total environment. That definition is:

“Mission-relevant, earth-referenced data pertaining to air, land, sea, and space.”

In order to help meet the requirements and the need for the total environment, the FCS Training IPT developed the Training Common Component (TCC) program. One of the seven (7) TCCs is called Environmental Representation (ER). The ER has the task to identify the environmental requirements needed to create an environmental representation of the complete environment, not just the terrain for the Training IPT.

## 2. Background

### 2.1. FCS Data Architecture Team

The FCS program has identified a team call the Data Architecture Team (DAT) that is responsible for developing the integrated FCS Data Model. That data model is called the Unit of Action (UA) Information Model (IM).

The UA IM will be developed and delivered to software development in both logical and physical forms. It is being developed using the Unified Modeling Language (UML) and supporting IBM Rational Rose tool. To get to a normalized common view of the data model, the DAT is taking a two (2) phased approach called a Core-View Development (CDV). CDV involves the identification and integration of “core” data definitions and relationships and development common data views needed by system applications. It provides a means for leveraging legacy and planned enterprise reference data models to support the development system unique data representations. It supports the three (3) tiered data management architecture necessary for information sharing in a network-centric environment: Data Store, Mediation, and Application layers.

The basis for the FCS UA IM is the C2IEDM. The Command and Control Information Exchange Data Models (C2IEDM) is the Army’s planned Command and Control (C2) data model for network centric warfare. From the core data definitions, entities, and relationships, the CVD approach provides for the development of common and system unique data “views”. These views can then be developed by FCS architecture and software development teams to define the data views needed by FCS applications. The result is a standards compliant data architecture.

The common and unique views form the data mediation layer of the 3-tiered data management model and are directly traceable to system specifications.

The Training IPT has taken the direction of the DAT per program requirements and delivered its feature and attribute requirements for the environment to the DAT team. That delivery happened in April 2005. With that delivery, the DAT team has not only the individual Training IPT feature and attribute requirements, but the unambiguous definition of each concept, and how the Training IPT suggests that concept should be represented in the UA IM, which is the subject of this paper. That representation is different from extensions to the C2IEDM. There is another paper in this conference titled, “Integration of Environmental Extensions into the C2IEDM (Methodology and Lessons Learned)”, that will discuss issues such as extending the C2IEDM, mediation layers and the lessons learned from that effort. While these two efforts were preformed in concert with one another, this paper takes the step into the FCS data model.

## 2.2. FCS TCC Environmental Requirements

The FCS Training IPT environmental representation requirements are key to the Training Common Component and are detailed in the accompanying paper cited earlier. The next several paragraphs are supplied as an overview of that effort.

A key step during the process of determining the FCS Training IPT environmental representation requirements was to ensure the requirements have a pedigree. This means that all FCS Training IPT environmental representation requirements must be traceable to current U.S. Army approved documents/doctrine. To do this, the FCS requirements were parsed to identify what requirements are needed for training. Once identified the requirements were identified as air, land, sea, or space per the definition of geospatial for FCS. Then the requirements were linked to the FCS System of System (SoS) Specification. This gave the Training IPT its top level requirements. Next individual features and attributes were determined. These were identified by reviewing the established features and attributes for the systems that were identified in FCS requirements documents that FCS must be able to interoperate with and are called complementary programs. These features and attributes were then classified as air, land, sea, space requirements and thus showing their pedigree to the FCS. Finally, the features and attributes were abstracted up one level. What this means is several categories called Military Functions (MFs) were defined and related to the FCS Unit of Action (UA) missions. All MFs were mapped to the missions and to the individual features and attributes. The product is a complete pedigree of the individual Training IPT ER features and attributes from MFs to the missions to the FCS requirements. As stated above, the complete description of this effort can be found in the paper titled, “Future Combat System (FCS) Training IPT Environmental Requirements and their Relationship to Military Functions and FCS Program Requirements”.

Before the requirements can be mapped to the FCS UA IM, the individual features and attributes have to be identified. This was done as discussed above. However, the UA IM requires an unambiguous definition of each concept that is to be represented in the UA IM. For the TCCs, we used the international standard ISO/IEC 18025 — Environmental Data Coding Specification (EDCS). In doing this, the DAT can be assured of the exact definition of each concept the Training IPT requires to be represented. The Training IPT also understands that the DAT may be required to represent environmental data required by other IPTs and the dictionary they use will be different than EDCS. To mitigate the mapping effort required by the DAT team, the Training IPT provided mappings of the TCC environmental representation requirements to five (5) different dictionaries. That effort is described in an accompanying paper in this conference titled, “Future Combat Systems Training Integrated Product Team Environmental Representation Requirements and Mappings to Various Environmental Concepts Dictionaries”.

## 2.3. Providing TCC environmental requirements for the UA IM

The effort to provide the TCC environmental requirements in a manner which was both acceptable and practical for the FCS DAT began in the summer of 2004 with work that was sponsored by the Defense Modeling and Simulation Office (DMSO). One of the specific outputs of that work was a mapping from EDCS to the C2IEDM with specific consideration to the FCS TCC requirements as captured with EDCS.

At that point in time the focus was to provide a mapping from EDCS into the C2IEDM realizing that this would be the bulk of the mapping from the TCC environmental requirements into the UA IM. This work was carried out in parallel with other work that the DAT was executing to bring in other requirements within FCS. Both teams realized that the TCC requirements would be the first large set of requirements and it was in everyone's best interest to share as much information as possible in order to expedite the introduction of the TCC requirements into the UA IM.

Technical exchanges occurred from the summer of 2004 until the requirements were delivered in April of 2005. Initial exchanges such as Nov 10, 2004 were preliminary presentation of results from the DMSO team. Other exchanges such as in February 17, 2005 involved more structured presentations by the DAT on the UA IM. These technical exchanges culminated in the delivery of the TCC requirements in April where the TCC provided the results in the form of ERWin files that represent the full scope of EDCS concepts that contain the TCC requirements. This delivery by the TCC also provided a walk through and description of the ERWin model that was provided and opportunity for questions from the DAT.

# 3. C2IEDM

## 3.1. C2IEDM background

This paper discusses the results of mapping the TCC requirements into the UA IM with specific emphasis on the problems and issues encountered. While this effort concentrated on the UA IM, the UA IM is built on the C2IEDM. As a result a cursory introduction to the C2IEDM's capabilities and underlying concepts is necessary. The following synopsis has been extracted from [1] and condensed for the relevant points in this analysis.

The C2IEDM is an entity-relationship (ER model) represented in IDEF1X format. The current version of the model is 6.0. Initially, the scope of the C2IEDM was limited to the "land" domain. It has been extended by the participants to include some concepts from maritime domain. However, coverage of non-land domains remains sparse. The purpose of C2IEDM remains C2 data interchange – enabling interoperability of command and control information systems across echelons to support multinational combined and joint operations.

## 3.2. C2IEDM Capabilities

In C2IEDM an *entity* is any distinguishable person, place, thing, event, or concept about which information is to be kept. Properties or characteristics of an entity are referred to as *attributes*. The C2IEDM contains 194 entities that are independent or not. An i*ndependent* entity is one in which its identification does not depend on any other entity. Independent entities are listed below with clarifying information when necessary:

- ***ACTION***
- ***ADDRESS***
- ***AFFILIATION***
- ***CANDIDATE TARGET-LIST***
- ***CAPABILITY***
- ***CONTEXT*** — A reference to one or more REPORTING-DATAs.
- ***COORDINATE***
- ***GROUP CHARACTERISTIC***
- ***LOCATION***.
- ***OBJECT-ITEM*** — An individually identified object that has military significance.
- ***OBJECT-TYPE*** — An individually identified class of objects that has military significance.
- ***REFERENCE***
- ***REPORTING-DATA*** — The specification of source, quality and timing that applies to reported data.
- ***RULE-OF-ENGAGEMENT***
- ***VERTICAL DISTANCE*** — altitude or height

## 3.3. Things in C2IEDM

One underlying principle of the C2IEDM is the criteria for "things" in the model. The criteria is military significance and a desire to interchange the data. This is applicable with the UA IM requiring to define entities that are both of interest to FCS and to be shared among FCS components. As a result, the effort to map TCC requirements into the C2IEDM and hence the UA IM, revolved around using the proper entities regarding environmental things in the models.

### 3.4. Object Type & Object Item

The C2IEDM encompasses two categories of objects: those that can be identified individually, Object Items, and those that represent grouped or class properties, Object Types. Data characteristics are entered either on the item side or the type side as appropriate and any characteristic described on the type side also applies to the item when the item is assigned a type classification. For example, if a characteristic is about a type (e.g., M1A1 Abrams Tank), it is an attribute of OBJECT-TYPE. Thus, calibre of main gun, track width, and load class are characteristics of OBJECT-TYPE. However, the call sign, actual fuel level, munitions holdings, and current operational status of a specific tank are characteristics of an OBJECT-ITEM.

### 3.5. Hieararchies of Objects

Item and type objects are subdivided into extensive hierarchies. The first level hierarchy is parallel and has five categories or *subtypes* to encompass any object within the scope of the model as follows:

- ***FACILITY*** An OBJECT-ITEM that is built, installed, or established to serve some particular purpose and is identified by the service it provides rather than by its content, for example a field hospital or a command post.
- ***FEATURE*** An OBJECT-ITEM that encompasses meteorological, geo-graphic, and control features of military significance, for example a forest.
- ***MATERIEL*** An OBJECT-ITEM that is equipment, apparatus or supplies without distinction as to its application for administrative or combat purposes for example a ships or tank.
- ***ORGANISATION*** An OBJECT-ITEM that is an administrative or functional structure.
- ***PERSON*** An OBJECT-ITEM that is a human being to whom military significance is attached.

Parallel to the object item hierarchy is an object type hierarchy that has parallel entities that are used to represent specific instances of an object item.

### 3.6. Bridge example

Consistent with the above design, the C2IEDM defines two entities for what is commonly know as a “bridge”. The entity BRIDGE is defined as:

“A FACILITY that is a structure(including overpass and viaduct), fixed or moveable, spanning and/or providing passage over an object.”

With the following attributes:

- bridge-longest-span-length-dimension,
- bridge-span-quantity,
- bridge-usage-code,
- facility-category-code,
- facility-height-dimension,
- facility-primary-construction-material-code,
- facility-width-dimension,
- object-item-alternate-identification-text,
- object-item-category-code,
- object-itemd-id, and
- object-item-name.

Furthermore a BRIDGE may be used as follows:

- as an objective or a resource in carrying out an ACTION,
- having a HOLDING,
- specified with a CAPABILITY,
- having a STATUS,
- classified with a TYPE,
- as the object of a CONTEXT,
- specified in a CANDIDTATE-TARGET-LIST,
- defined with a LOCATION,
- specified in an ACTION-EFFECT-ITEM,
- having and ADDRESS,
- is the subject of an OBJECT-ITEM-ASSOCIATION
- have an OBJECT-ITEM-GROUP-ACCOUNT,
- have an AFFILIATION, and
- may be assigned an ESTABLISHMENT.

## 4. Mapping from TCC to UA IM

### 4.1. Initial concerns

When mapping from the TCC requirement to the UA IM through the C2IEDM a set of initial issues surfaced. First was that the model was an entity-relationship data model and the concepts are described in terms of an IDEF1X representation. That is, each entity has an associated set of attributes which form the keys for that entity. The EDCS is not an entity-relationship model. The concepts representing entities have no permanently associated set of attributes describing them. Each implementation is free to associate any attribute(s) with any entity to form the necessary description of a concept. Thus, within the TCC requirements although there is a grouping of concepts between entities and attributes, these are flexible and could change. As a result there were many possible methods to provide the mappings and capabilities into the UA IM. What follows is the task performed and the guidelines followed when creating the mapping.

### 4.2. General steps

One of the first steps was to analyze the entire set of EDCS attributes and associated each attribute with a rational set of the EDCS entities. For example, an attribute of Water-Depth is not associated with and entity of Living Room, unless of course it was the summer of 2004 and the living room resided in Florida. Nonetheless, defining these non-sensical relationships was one of the initial steps in the mapping.

Given the attribute to entity pairings, a hierarchy for all the entities in the EDCS was begun in order to define where the TCC entities would reside along with their defined attributes. These entities were labeled FCS_*entity name* in the ERWin model that was provided to the DAT. This hierarchy defines an inheritance of attributes from parent to child where the children add additional attributes to, and specialize, the parent. In some cases, additional concepts were added as entities to facilitate the hierarchy construction. These concepts are labeled with XNEWLABEL_NOT_FCS_*entity name* if they are concepts not part of the FCS requirements, or FCS_XNEWLABEL_*entity name* if they are concepts that are part of the FCS requirements but not part of the EDCS.

Having completed a reasonable, albeit incomplete, hierarchy, the analysis was then performed to determine how to best accommodate the newly created EDCS hierarchy in the ERWin model. The final results were thus provided to the DAT team in April 2005 as mentioned previously.

### 4.3. Guiding principles

The following sections cover specific aspects that were encountered in performing the final step and how they were handled or the ramifications of the issue.

### 4.4. Deep Integration of EDCS into C2IEDM

The most effective way to incorporate or map the entities is using "Deep Integration". In this method, small, coherent segments of the hierarchy are spliced into the C2IEDM as specializations or subtypes of existing entities. This approach maintains the existing structure as opposed to including the entire hierarchy as a distinct extension. The latter alternative would have been a poor choice, because it would have meant the entire hierarchy would simply hang off the C2IEDM as a top-level branch. This approach would lead to confusion among users as to where concepts from their domain, and thus data, would be mapped and accommodated in the model.

### 4.5. Placement according to dominant characteristics

The added entities are located in C2IEDM according to their dominant, essential characteristic. EDCS concepts have rigorous definitions that typically relate them to several other concepts. For instance, a PARK entity is described in terms of a region, as well as in terms of it's function as a recreational facility. The definition states, a PARK is

"A REGION of a PLANETARY_SURFACE used for recreational or ornamental purposes; a park."

The function portion of the definition describes the essence of a park, whereas the region characteristics are simply the spatial area it occupies. The mapping of PARK to the C2IEDM creates an extension to the C2IEDM concept of a Facility-Type to include a PARK entity. The concept of REGION is added to the C2IEDM and an association between the PARK entity and the REGION entity is created. The REGION entity holds some additional attributes that are applied to the Facility-Type PARK. This design principle was applied to both the EDCS concept of REGION and the concept of BOUNDARY and to all the entities that are related to them.

### 4.6. Single inheritance

The C2IEDM convention is to employ single inheritance, i.e., no entity can have more than one parent supertype. However, relationships between entities allow additional attributes to be associated with an entity, such as the BRIDGEexample described in previous section. This convention is followed by adding an entity based on it's dominant characteristic and associating it with other entities as necessary to obtain additional attribution.

### 4.7. Preservation of the C2IEDM subtyping hierarchy

In some cases the most correct way to map entities would be to interject them into the middle of the C2IEDM hierarchy (e.g., the decomposition structure for vehicles). However, rather than "break" the existing C2IEDM structure, the entities were added in parallel and associating relationships used to clarify the way these entities should be correlated. In the vehicle example, the C2IEDM describes Vehicle-Type as a subtype of Equipment-Type, which is a subtype of Materiel-Type. For the mapping, the entity FCS_Physical_Object was added with a subtype FCS_Man_Made_Object which in turn has the subtype FCS_Equipment which in turn has subtype of FCS_Vehicle. In order to provide the proper attribution, FCS_Physical_Object has an association relationship with the C2IEDM entity Materiel-Type.

### 4.8. Preservation of entity definitions

In many cases there were differences between the definition of the C2IEDM and the TCC requirement definitions within EDCS. In such cases, the C2IEDM entity definitions were preserved for mapping purposes. For example, the Geographic-Feature-Type is defined as:

"a FEATURE-TYPE that describes terrain characteristics to which military significance is attached."

will contain concepts that are present in the C2IEDM's definition of terrain as opposed to EDCS's definition of terrain. Many of the EDCS water features are defined as water over a terrain surface, for example RAPID or WATERFALL while others describe the body of water itself such as OCEAN or SEA. In these cases there is a separate EDCS entity describing the terrain under the OCEAN, called the OCEAN_FLOOR. When mapping the TCC requirements the concepts like RAPID and WATERFALL, and the concepts like OCEAN and SEA were all placed under Geographic-Feature-Type since the definition of terrain in the C2IEDM is more consistent with the EDCS definition of LAND.

### 4.9. Addition of high-level entities when required

Additional concepts were added that did not have proper mappings withing the C2IEDM hierarcy Additional entities included FCS_Material and FCS_Living_Organism, These concepts, among others, were added at the top level under the Object-Type entity. FCS_Material includes concepts such as water, sand, rock, and dust and FCS_Living_Organism includes concepts such as Plant, Animal, Fungus, Lichen, Moneran, and Protist. Other concepts were introduced to capture entities such as electromagnetic pulses, aurora, magnetosphere plasma, magnetic disturbances, pods, fish schools, and personnel.

### 4.10. Addition of mid-level entities when required

Some intermediate subclasses were added to the EDCS hierarchy to partition the concepts. For example, the EDCS entities that had been classified as a type of Marker were subdivided into two subclasses based their definitions and attributes. Some Marker entities are defined primarily in terms of their function, and others are defined primarily in terms of their structure. This additional hierarchy structuring allowed a more precise allocation of attributes to entities. Addition of mid-level entities also allowed z relationships to be created from a concept to a group of entities.

## 5. Future work

Although the TCC has provided these results to the DAT, it is recognized that this is one of the initial steps in accomplishing the complete tasking of defining a mechanism to capture the full set of TCC requirements within the UA IM. As such there is further work in developing and working with TCC requirements into the UA IM. This work encompasses both work that needs to be accomplished to the mapping of the TCC requirements into the UA IM as well as work to perform the actual validation of the UA IM from the TCC perspective. The following is a discussion of both categories.

### 5.1. Extending Object-Type vs. Object-Item hierarchies

The ERWin model capturing the TCC requirements have all been captured in the Object-Type hierarchy. However, many of the concepts can and should be transitioned over to the hierarchy under the Object-Item entity. In this way specific instances of an entity will have the appropriate associations with other entities, such as LOCATION. When the extensions are made to the Object-Item hierarchy attributes will migrate to appropriate side of the Object-Type/Object-Item tree. That is, following the convention established in the C2IEDM, static attributes will be assigned to entities in the Object-Type hierarchy. Dynamic attributes will be assigned to the Object-Item hierarchy. No attribute will appear in both places.

### 5.2. Collapse of Leaf-Level Entities Without Attribution:

Further work needs to be accomplished in the collapsing leaf-level entities and representing them simply as enumerants of a category code in the parent entity. This design approach follows the convention established in the C2IEDM and it remains to be seen whether the UA IM will follow this convention. For lineage, the TCC requirements had not taken the step of collapsing the leaf entities in order to make integration easier and allowing this step to be considered at the UA IM level.

### 5.3. Addition of Key information

Every attribute associated with each entity will be analyzed and a determination made as to it's designation as a primary or secondary key. Attributes may also be designated as foreign keys where appropriate. This step is a transition from the mapping work into a validation and creation of a physical data model with actual data being passed from the TCC to other FCS components.

### 5.4. Data exchange

Work is planned on developing an actual data exchange of data encoded according to the TCC requirements and exporting it into the UA IM. For such work, the TCC data will be limited to a subset which will prove the mapping into the UA IM has in fact worked and is both possible and efficient. Such an exchange should provide the basis for changes to the TCC requirements as well as lessons for both the application and development of the UA IM. This work will take place when the UA IM and its physical model is mature enough to allow it.

## 6. Conclusion

In summary, work has steadily progressed in defining the FCS TCC environmental requirements and mapping these requirements to the FCS UA IM. This work has provided great lessons for both the TCC as well as other FCS components that will integrate and work with the FCS DAT in using and modifying the UA IM.

The work has continued in a collaborative effort to both expedite the UA IM and integration of data requirements into the UA IM. This paper has presented a small facet of the work along with other papers related to the work and the different facets. This work will continue with further results provided as the work continues to mature within the FCS community.

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