Future Combat Systems Training Integrated Product Team Environmental Representation Requirements and Mappings to Various Environmental Concepts Dictionaries

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ABSTRACT: *Many systems today have environmental representation requirements and those systems represent such requirements using a dictionary of terms or concepts. For the representation of environmental concepts there are several dictionaries that contain environmental terms and concepts. Each of these dictionaries usually provides a definition for the concepts it lists.*

The Future Combat Systems (FCS) Training Integrated Product Team (IPT) has established its requirements for environmental representation. Those requirements encompass multiple environmental domains to include terrain, atmosphere, ocean, space, urban, etc. In order to clearly capture these requirements in the FCS embedded training system, each requirement must have an unambiguous definition. The Training IPT used the Environmental Data Coding Specification (EDCS) as the Dictionary of Concepts to define its environmental representation requirements.

The Training IPT used the EDCS for three reasons. First, EDCS contains concepts in all the environmental domains required by FCS and the Training IPT. Second, for the concepts required by the Training IPT, EDCS provides fully referenced comprehensive definitions. Third, the DoD IT Management Plan dated 20 February 2004 provides a recommended hierarchy for standards used in DoD systems with International Standards heading the list. As a result, EDCS as an approved ISO/IEC International Standard ISO/IEC 18025 met this requirement.

Since FCS embedded training system will interoperate with other DoD systems that use other dictionaries to represent their environmental concepts, the Training IPT has developed mappings between its requirements and other dictionaries. The dictionaries considered were the Topographic Engineering Center's (TEC) new Army Battlespace Environment Feature Data Dictionary (ABE FDD), the DGIWG Feature Data Dictionary (DFDD), the NGA Feature Data Dictionary (NFDD), and the Feature and Attribute Coding Catalog (FACC) version 2.1. This paper describes the Training IPT requirements and the efforts to map those requirements to the dictionaries listed above. A brief description of each dictionary will be given and then the key aspects in mapping the relevant entries from each of the dictionaries to the Training IPT requirements will be presented.

1. Introduction

For this effort, a dictionary of concepts will be defined as an organized listing of all the data elements that are pertinent to the system (http://www.yourdon.com/books/msa2e/CH10/CH10.html), with precise, rigorous definitions so that both user and systems analyst will have a common understanding of all inputs, outputs, components of stores, and intermediate calculations. The dictionary defines the data elements by doing the following:

- Describing the *meaning* of the flows and stores shown in the dataflow diagrams.
- Describing the *composition* of aggregate packets of data moving along the flows, that is, complex packets (such as a customer address) that can be

broken into more elementary items (such as city, state, and postal code).

- Describing the *composition* of packets of data in stores.
- Specifying the relevant *values* and *units* of elementary chunks of in formation in the dataflows and data stores.
- Describing the details of *relationships* between stores that are highlighted in an entity-relationship diagram.

Also, each concept specified by an entry within the dictionary includes a label for the concept and a concept definition, and may contain other concept-dependent information (as defined above). The set of concept definitions within a Dictionary of Concepts must be unique (no two concepts within a dictionary have the same definition) and each label within a dictionary of concepts is also a unique identifier within that dictionary.

In this effort, we further refine the notion of a Dictionary of Concepts by considering that every dictionary entry within such a dictionary also specifies a code unique within that dictionary, and optionally specifies bibliographic reference information indicating lineage of the concept. For example, consider a hypothetical Dictionary of Concepts in which every entry consists of a label, a code, a concept definition, and an optional bibliographic reference for the definition. An entry in such a dictionary might have code 5, label ENGINE, definition "A machine that converts energy into mechanical force or motion", with reference given as The American Heritage Dictionary.

Note that a Dictionary of Concepts merely requires that the label be unique within the dictionary, not that it have any particular correspondence to other Dictionaries of Concepts elsewhere. The key to creating mappings between different Dictionaries of Concepts A and B is to determine which concept definition in A corresponds to a concept definition in B.

Further note that within a Dictionary of Concepts it is only necessary that definitions be unique and unambiguous, not that they be "normalized" such that no two concepts overlap within a Dictionary. It may be useful in a given domain of concepts, for example, not only to define the specific concept of an engine, as in the previous example, but the more general concept of a machine.

This paper deals with specific FCS Training IPT environmental representation requirements and how they map to different Dictionaries of Concepts used for environmental representation. The FCS Training IPT environmental representation requirements are presented at this conference in an associated paper titled "Future Combat Systems (FCS) Training IPT Environmental Representation Requirements and their Relationship to Military Functions and FCS Program Requirements". There were five (5) Dictionaries of Concepts evaluated for their suitability in supporting the FCS Training IPT Requirements: Army Battlespace Environment (ABE), DGIWG Feature Data Dictionary (DFDD), Environmental Data Coding Specification (EDCS), Feature and Attribute Coding Catalogue (FACC), and the NGA Feature Data Dictionary (NFDD). A brief review of each dictionary will be given and then a discussion of how each dictionary supported the FCS Training IPT environmental requirements will be presented.

2. Background

Before a review of the mappings of each dictionary can be presented, it is imperative that a brief description of each dictionary be made. It is not the intent here to provide an exhaustive discussion of each dictionary, but only a review. The reader will be referred to the web site for each dictionary for a complete discussion of that dictionary.

2.1. Background: ABE

The Army Battlespace Environment (ABE) dictionary of concepts is a relatively new technology being developed by the U.S. Army Topographic Engineering Center (TEC). Its development began about January 2004 and at the time was called the Joint Battlespace Environment Feature Data Dictionary (JBE FDD). The JBE FDD was briefed to the FCS Geospatial Battlespace Environment Working Group (GBE WG) in February 2004 and defined on slide #26 as "Across all domains…set of independent specifications of the feature types, feature attributes…that may be used to describe geographic data". Since that time, the JBE FDD was renamed and presented to the FCS GBE WG as the Army Battlespace Environment Profile of FACC with its objective to "Establish and maintain the Army geospatial data dictionary for the current and future force".

For this mapping effort, the FCS Training IPT requested a current copy of the ABE in February 2005 from TEC. The cover sheet of that delivery describes ABE as:

"The Army Battlespace Environment (ABE) Profile exists as an online information resource maintained by the Army Corps of Engineers Engineer Research and Development Center (ERDC) Topographic Engineering Center (TEC). The ABE Profile is realized within the ABE Registry. As a profile it includes items from multiple dictionaries. These dictionaries are established as separate registers in the ABE Registry. The ABE Registry is located at **https://www.XXXXXX/xxx/** . This workbook includes three sheets that specify a subset of information from valid items in the ABE Profile as of the date it was created; for complete information regarding a given item a hyperlink is provided to the complete specification of that specific item in the online resource. Additional information available online that is not included in this workbook includes an item source, zero or more item lineages, and zero or more alternative expressions in languages other than that of the ABE Registry (which uses English in accordance with the Oxford English Dictionary). Other information available online includes items that are not currently valid but may have historically been related to a valid item. The structure and content of the ABE Registry conform to ISO 19110, ISO 19135, and ISO 19126. Additional information regarding these standards and the structure/operation of the ABE Registry are available at the resource site." [1]

An alternative web site was also supplied for ABE, namely https://geo.aitcnet.org/ABE/.

A couple of interesting points were found. First, the name had changed to just be ABE Profile. Second, the objective of ABE had also changed from being a data dictionary to a registry of multiple dictionaries in accordance with the ISO standard 19110, 19126, and 19135. These standards are being developed under the ISO Technical Committee (TC) 211. In review of ISO 19126 at the TC 211 web site (www.iso**tc211**.org), it was found that the ISO 19126 project has been stopped. The note at the site says, "Note: Project has been deleted by ISO due to lack of progress, will be reballoted as a NWI."

For this effort, ABE Spiral 1 was used. Spiral 2 was to be delivered by May 2005, but as of the writing of this paper it had not been released. It is also expected that ISO 19126 will be revived. When these two events happen, the mappings between the FCS Training IPT environmental requirements and ABE will be updated.

2.2. Background: DFDD

The following information on the DFDD was provided in the spreadsheet "cover tab" of DFDD features and attributes provided to the Training IPT by the National Geospatial Intelligence Agency (NGA).

"The DGIWG Feature Data Dictionary (DFDD) exists as an online information resource maintained by the DGIWG Feature and Attribute Data (FAD) Project Team. The DFDD is realized as one of a set of registers within the DGIWG FAD Registry. The DGIWG FAD Registry is located at **https://www.dgiwg.org/FAD/**. This workbook includes three sheets that specify a subset of information from valid items in the DFDD register as of the date it was created; for complete information regarding a given item a hyperlink is provided to the complete specification of that specific item in the online resource. Additional information available online that is not included in this workbook includes an item source, zero or more item lineages, and zero or more alternative expressions in languages other than that of the DGIWG FAD Registry (which uses English in accordance with the Oxford English Dictionary). Other information available online includes items that are not currently valid but may have historically been related to a valid item. The structure and content of the FAD Registry conform to ISO 19110, ISO 19135, and ISO 19126. Additional information regarding these standards and the structure/operation of the DGIWG FAD Registry are available at the resource site." [2]

Based on the information provided above, the reader should note that DFDD is being developed by DGIWG as a replacement for its FACC. Also, DGWIG is active in the ISO TC 211 and as such it follows the standards produced by TC 211 to include ISO 19110, 19126, and 19135. Of course, DFDD will need to adopt its development as TC 211 redevelops 19126.

2.3. Background: EDCS

The Environmental Data Coding Specification (EDCS), as detailed in ISO/IEC 18025, is a collection of nine (9) dictionaries of environmental concepts. The dictionaries include [3]:

a. *classifications*: specify the type of environmental objects,
b. *attributes*: specify the state of environmental objects,
c. *attribute value characteristics*: specify information concerning the values of attributes,
d. *attribute enumerants*: specify the allowable values for the state of an enumerated attribute,
e. *units*: specify quantitative measures of the state of some environmental objects,
f. *unit scales*: allow a wide range of numerical values to be stated,
g. *unit equivalence classes*: specify sets of units that are mutually comparable,
h. *organizational schemas*: useful for locating classifications and attributes sharing a common context, and
i. *groups*: into which concepts sharing a common context are collected.

The EDCS provides mechanisms to unambiguously specify objects used to model environmental concepts. EDCS is not limited in regard to what categories of environmental phenomena may be described by its concepts. Specific environmental phenomena include, but are not limited to, the following [3]:

a. abstract concepts (for example: absolute latitude accuracy, geodetic azimuth),
b. airborne particulates and aerosols (for example: cloud, dust, fog, snow),
c. animals (for example: civilian, fish, human, whale pod),
d. atmosphere and atmospheric conditions (for example: air temperature, humidity, rain rate, sensible and latent heat, wind speed and direction),
e. bathymetric physiography (for example: bar, channel, continental shelf, guyot, reef, seamount, waterbody floor region),
f. electromagnetic and acoustic phenomena (for example: acoustic noise, frequency, polarization, sound speed profile, surface reflectivity),
g. equipment (for example: aircraft, spacecraft, tent, train, vessel),
h. extraterrestrial phenomena (for example: asteroid, comet, planet),
i. hydrology (for example: lake, rapids, river, swamp),
j. ice (for example: iceberg, ice field, ice peak, ice shelf, glacier),
k. man-made structures and their interiors (for example: bridge, building, hallway, road, room, tower),
l. ocean and littoral surface phenomena (for example: beach profile, current, surf, tide, wave),
m. ocean floor (for example: coral, rock, sand),
n. oceanographic conditions (for example: luminescence, salinity, specific gravity, turbidity, water current speed),
o. physiography (for example: cliff, gorge, island, mountain, reef, strait, valley region),
p. space (for example: charged particle species, ionospheric scintillation, magnetic field, particle density, solar flares),
q. surface materials (for example: concrete, metal, paint, soil), and
r. vegetation (for example: crop land, forest, grass land, kelp bed, tree).

Also, a registry is maintained for EDCS so that each dictionary may be expanded to include additional concepts. A copy of the EDCS standard is available at the ISO/IEC JTC 1 SC 24 web site (http://www.iso.org/iso/en/stdsdevelopment/tc/tclist/TechnicalCommitteeDetailPage.TechnicalCommitteeDetail?COMMID=117&scopelist=). For other information the reader can go to www.sedris.org.

2.4. Background: FACC

As stated earlier, the Feature Attribute Coding Catalogue (FACC) 2.1 is hosted by DGIWG (https://www.dgiwg.org/dgiwg/index.htm). It is defined as "a means for encoding real world entities or objects for the purpose of an orderly exchange of digital geospatial information between organizations. FACC describes the world in terms of features and attributes. Attributes are the properties, or characteristics associated with features. Standards for DGI exchange require a standard method for documenting features and attributes necessary to distinguish those features commonly found in Mapping, Charting, and Geodesy (MC&G), and GIS, and for the orderly exchange of such data between MC&G organizations. (http://www.digest.org/html/gp45.htm") It further states, "FACC has not been developed to the requirements of any single application, or level of resolution, and in itself cannot support a digital product. For a product, the menus of features and attributes must be employed in concert with a product specification. Users of FACC are advised that, as with any dictionary, there may be more than one way to encode geographic entities, either by offering a choice of features or a combination of features and attributes. For example, a heliport is listed as feature GA035 (Heliport), but could also be encoded as feature code GB006 (Airfield) with attribute APT (Airfield type) with a coded value of 009 (Heliport). Another example would be AK090 (Fairgrounds) and AK091 (Exhibition Grounds) which could be interchanged, depending on the user's own interpretation. A table of options for encoding geographic entities has been compiled and is available as an informative annex to FACC." [4]

2.5. Background: NFDD

The following information on the NFDD was provided in the spreadsheet "cover tab" of DFDD features and attributes provided to the Training IPT by the National Geospatial Intelligence Agency (NGA).

"The NSG Feature Data Dictionary (DFDD) exists as an online information resource maintained by the National Center for Geospatial-Intelligence Standards (NCGIS). The NFDD is realized as a profile within the NSG FAD Registry. As a profile it includes items from the DGIWG FDD (DFDD) and the NSG National Extensions FDD (NEFDD). The NSG FAD Registry is located at **https://www.XXXXXX/XXX/** . This workbook includes three sheets that specify a subset of information from valid items in the NFDD profile as of the date it was created; for complete information regarding a given item a hyperlink is provided to the complete specification of that specific item in the online resource. Additional information available online that is not included in this workbook includes an item source, zero or more item lineages, and zero or more alternative expressions in languages other than that of the NSG FAD Registry (which uses English in accordance with the Oxford English Dictionary). Other information available online includes items that are not currently valid but may have historically been related to a valid item. The structure and content of the FAD Registry conform to ISO 19110, ISO 19135, and ISO 19126. Additional information regarding these standards and the structure/operation of the NSG FAD Registry are available at the resource site." [5]

An alternative web site was also supplied for NFDD, namely https://geo.aitcnet.org/NGA/.

Based on the information provided above, the reader should note that NFDD is a registry similar to that of ABE. It contains the complete DFDD and some other extensions based on its requirements. Also, NFDD is part of the ISO TC 211 activities and as such it follows the standards produced by TC 211 to include ISO 19110, 19126, and 19135. Of course, NFDD will need to adopt its development as TC 211 redevelops 19126.

3. FCS Training IPT requirements

The FCS Training IPT has determined its environmental representation requirements. The derivation of the requirements is fully described in an accompanying paper in this conference – Future Combat Systems (FCS) Training IPT Environmental Requirements and their Relationship to Military Functions and FCS Program Requirements. The following is a brief description of how the Training IPT environmental representation requirements were established.

The FCS Training IPT has a program level requirement to support all facets of embedded training across the entire FCS. This requirement is levied through a Key Performance Parameter (KPP) called Embedded Training. To help satisfy this requirement, the Training Common

Component (TCC) program was established with Environmental Representation (ER) a key TCC. The objective of the ER TCC is to provide a consistent and authoritative representation of operationally relevant environmental features and attributes for the complete TCC.

The initial ER TCC requirements were derived from previous Army training and simulation. The Common Data Modeling Framework (CDMF) Environmental Data Models (EDMs) were used to derive operationally relevant features and attributes that were of interest to the FCS embedded training TCC. The requirements were then relate to the overall FCS requirements as found in program documents such as the FCS Operational Requirements Document (ORD), System of System (SoS) Specification, and the Operational and Organizational (O&O) Plan. Also, the ER were mapped to Military Functions (MF) that have operational relevance. These MFs were derived from the OOS Environment Runtime Component (ERC) Military Functional Uses (MFU) developed originally to assist the software engineers in implementing OOS ER. After the extended MFUs were derived, they were mapped into the FCS O&O Unit of Action missions. This mapping ensured that all TCC environmental features and attributes were operationally relevant. Parallel to this effort, the FCS ORD was reviewed for environmental representation requirements. These requirements were mapped into four basic domains that align with those defined by the FCS GBE WG, land, air, sea, and space. All numbered ORD requirements were then mapped into the corresponding SoS Specification, which is tied to the FCS O&O. This series of mappings between the features and attributes and relating them to the MF and FCS program documents provide a pedigree for Training IPT features and attributes. This pedigree also ensures that the requirements are operationally relevant and that the Training IPT trains based on the missions of FCS.

4. Mapping

The lineage of the various dictionaries of concepts in this analysis was extremely helpful in determining which concepts in one dictionary of concepts should be considered as possible mapping targets by concepts from a separate dictionary of concepts. For ABE, DFDD, and NFDD, each dictionary of concepts was developed directly or indirectly as a derivation/refinement of FACC 2.1, so mapping analyses performed for FACC 2.1 are of use in determining candidate mappings for ABE, DFDD, and NFDD.

4.1. Mapping: ABE

As a registry of dictionaries, ABE has several Dictionaries of Concepts listed in it. The Spiral 1 delivery of ABE was based on DFDD and the concepts therein. With DFDD being derived from FACC, the mapping was simplified because the mappings now are just a subset of the FACC mappings. However, ABE development is not complete and thus several concepts that are in the Training IPT requirements are missing.

Initially, we will show the dependency of Spiral 1 of ABE on DFDD (Table 1). Of the 312 Feature Types in ABE, 281 (90.06%) map to Feature Types in DFDD, 281 (90.06%) map to Feature Types in NFDD, while 287 (91.99%) map to Feature Types in FACC 2.1.

Table 1: Content of ABE in DFDD.

	Count	Percentage
Total Features in ABE	312	
In DFDD	281	90.06%
In NFDD	281	90.06%
In FACC 2.1	287	91.99%

Unlike DFDD and NFDD, ABE contains some support for the atmosphere environmental domain. However, the concepts of ABE have very sparse definitions, and in constructing mappings for Training IPT requirements to ABE a great deal of latitude in interpretation had to be permitted to allow mapping to occur at all. For example, "absolute humidity" in ABE is defined simply as "Absolute humidity". If this is treated as equivalent to "The ratio of the mass of water vapour to the volume occupied by the mixture of water vapour and dry air; the absolute humidity", a mapping can take place; otherwise no mapping can occur.

If such leeway is permitted in the interpretation of ABE's definitions of its concepts, 51.86% of the Training IPT environmental representation 592 Feature Requirements map to ABE and 37.20% of the Training IPT environmental representation Attribute Requirements map to the ABE.

4.2. Mapping: DFDD

DFDD is one of several Dictionaries of Concepts derived from FACC 2.1. There are a total of 548 feature types in DFDD. The ABE maps 281 of its features (51.28%) map to Feature Types in DFDD, whereas 491 (89.60%) FACC 2.1 features map to Feature Types in DFDD. There is a 100% mapping of the DFDD features to NFDD. The summary is found in Table 2.

Table 2: DFDD Mapping statistics.

	Count	Percentage
Total DFDD features	548	
In FACC 2.1	491	89.60%
In NFDD	548	100.00%
In ABE	281	51.28%

DFDD appears to support a significant percentage of the concepts previously supported by FACC 2.1, but there are some subtle changes. For example, the concept of an aerodrome, designated GB005 by both DFDD and FACC 2.1, is defined somewhat similarly in DFDD as in FACC 2.1, but the DFDD definition of GB005 eliminated all references to water. In the case of aerodromes such as aircraft carriers, this means that concepts previously designated by GB005 in FACC 2.1 could not be supported by GB005 in DFDD.

Of the 592 Training IPT environmental representation feature requirements, 79.73% map to DFDD. The Training IPT environmental representation requirements specify 742 Attribute Requirements, of which 57.01% map to DFDD (only 57% of the Training IPT requirements can be found in DFDD).

4.3. Mapping: EDCS

All Training IPT environmental representation requirements map to the EDCS for a 100% coverage.

4.4. Mapping: FACC 2.1

As discussed above, the FACC 2.1 was developed primarily for the support of terrain requirements and thus contains no support for the atmosphere environmental domain. Doing a mapping from EDCS to FACC 2.1 has been maintained for several years by the SEDRIS Organization and is well developed. In fact, many of the concepts in the EDCS ISO standard have direct reference to the FACC as the source. Therefore, one would expect that FACC would show a comprehensive mapping, with the exception of the non-terrain requirements. Of the 592 Training IPT feature requirements, 84.12% can be found in FACC 2.1 and 57.28% of the attribute requirements can be found in FACC 2.1.

4.5. Mapping: NFDD

NFDD contains DFDD as a proper subset, so NFDD has all the same mapping issues previously discussed in the Mapping: DFDD section.

NFDD contains 278 attributes in addition to those corresponding to DFDD's attributes. Of these 278 there are some issues for mapping that will be discussed here. First, three have "TBD" as their definition, while 31 have uniqueness issues. Five different attributes have "Alternate frequency for communicating with the facility." as their concept definition, three are defined as "Appropriate date value or space character filled if null", and two are defined as "Associated with Bottom Characteristics (BF010)." The five attributes for categories of aircraft approach have identical definitions, as do the five attributes for categories of descent height on such approaches, the five attributes for weather minimums on such approaches, and the six attributes for categories of runway visibility.

There are 592 Training IPT environmental representation feature requirements. Of the 592 requirements, 473 (79.90%) requirements map to NFDD, one more than for DFDD. For the 742 Training IPT Attribute Requirements, 57.01% map to NFDD.

5. Summary

For the 592 Training IPT environmental representation feature requirements, Table 3 shows the percentage of support by the various Dictionaries of Concepts.

Table 3: Summary of Training IPT feature requirements supported by each dictionary of concepts.

	Count	Percentage
Total Training IPT features	592	
ABE	307	51.86%
DFDD	472	79.73%
EDCS	592	100.00%
FACC 2.1	498	84.12%
NFDD	473	79.80%

For the 742 Training IPT environmental representation attribute requirements, Table 4 shows the percentage of support by the various Dictionaries of Concepts.

Table 4: Summary of Training IPT attribute requirements supported by each dictionary of concepts.

	Count	Percentage
Total Training IPT attributes	742	
ABE	276	37.20%
DFDD	423	57.01%
EDCS	742	100.00%
FACC 2.1	425	57.28%
NFDD	423	57.01%

6. Bibliography

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[3] ISO/IEC 18025, *Information technology – Computer graphics and image processing – Environmental data coding specification (EDCS)*, available at the ISO/IEC JTC 1 SC 24 web site.

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[5] NSG Feature Data Dictionary (DFDD), February 2005, provided by the U. S. National Geospatial Intelligence Agency.

7. Author Biographies

Ms. MICHELE L. WORLEY has been a member of the SEDRIS core team at Science Applications International Corporation for the past 7 years. She is an editor of the Environmental Data Coding Specification and coordinates work on the Data Representation Model. Ms. Worley has a Bachelor of Science degree in Computer Science from the University of Central Florida.

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Mr. JESSE J CAMPOS is at Science Applications International Corporation where he works on projects involving environmental data representation. He is a member of the SEDRIS core team and has worked with the SEDRIS technologies for the past 7 years. He received B.S. degree in Electrical Engineering, a B.A degree in Political Science, and a Master's in Business Administration. from the University of Central Florida.