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A Knowledge-Based Natural Language Database Interface

by
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This report describes the development of a user interface to the Construction Appropriations Control and Execution System (CAPCES) using artificial intelligence techniques. CAPCES is a database used by the U.S. Army Corps of Engineers to store data generated during the Military Construction, Army (MCA) program development process. The goal of this research was to produce an interface to simplify access to CAPCES data, increasing the data's usefulness throughout the construction programming process.

This research developed Expert-MCA, a prototype system that allows users to query CAPCES using ordinary English. Expert-MCA combines knowledge of the MCA Cycle and the CAPCES database to translate English queries into FOCUS database commands that are executed in the CAPCES database.

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13. ABSTRACT (Maximum 200 words)

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FOREWORD

This work was conducted for the Directorate of Military Programs, Programming and Execution Support Office, Headquarters, U.S. Army Corps of Engineers (HQUSACE), under Project 4A162734AT41, "Military Facilities Engineering Technology"; Work Unit SA-AB9, "Expert System for MCA Cycle Analysis." The HQUSACE technical monitor was Mr. John Sheehey, CEMP-P.

The research was performed by the Facility Systems Division (FS) of the U.S. Army Construction Engineering Research Laboratory (USACERL). Dr. Michael J. O'Connor is Chief, USACERL-FS. The USACERL principal investigator was Ms. Sandra Kappes. Dr. Arthur Baskin is an associate professor and Mr. Robert Reinke and Mr. Larry Holder are research assistants in the Department of Computer Science at the University of Illinois, Urbana, IL. The USACERL technical editor was Mr. William J. Wolfe, Information Management Office.

COL Everett R. Thomas is Commander and Director of USACERL, and Dr. L.R. Shaffer is Technical Director.

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A KNOWLEDGE-BASED NATURAL LANGUAGE DATABASE INTERFACE

1 INTRODUCTION

Background

Military Construction, Army (MCA) projects must follow steps defined by Army regulations, policies, and procedures before being accepted into the MCA Program. This program includes projects that meet the requirements of 10 major defense programs:

1. Strategic Forces
2. General Purpose Forces
3. Intelligence and Communications
4. Airlift and Sealift
5. Guard and Reserve Forces
6. Research and Development
7. Central Supply and Maintenance
8. Training, Medical, and Other General Personnel Activities
9. Administration and Associated Activities
10. Support of Other Nations.

Before construction can begin, each project must meet the requirements defined by the Military Construction, Army (MCA) Program Development Process (Figure 1). As a project steps through the MCA development cycle, it must be justified, reviewed, revised, programmed, and budgeted. Before construction can begin, it must be approved at the Congressional level. This process ensures that every project follow the guidelines established by the Department of Defense (DOD) to meet combat capability through the balanced allocation of resources.

The program development process generates a considerable amount of data that is stored in the Construction Appropriations, Control and Execution System (CAPCES). At any given time, the CAPCES database contains information on more than 15,000 active projects with approximately 500 data elements per project, tracking each project from inception to disposal.

To access the data in CAPCES, a user must have considerable knowledge of the structure and content of the database, the MCA cycle, and the FOCUS database command language. This complex retrieval process can inhibit the efficient use of CAPCES. To improve access to CAPCES data, USACERL developed a prototype knowledge-based natural language interface (Expert-MCA) to the CAPCES database. Expert-MCA enables users to pose questions to CAPCES in ordinary English and provides assistance in formulating and evaluating queries. This prototype demonstrates how the addition of a knowledge-based interface to a database can allow even casual users to quickly and easily generate accurate and meaningful reports.

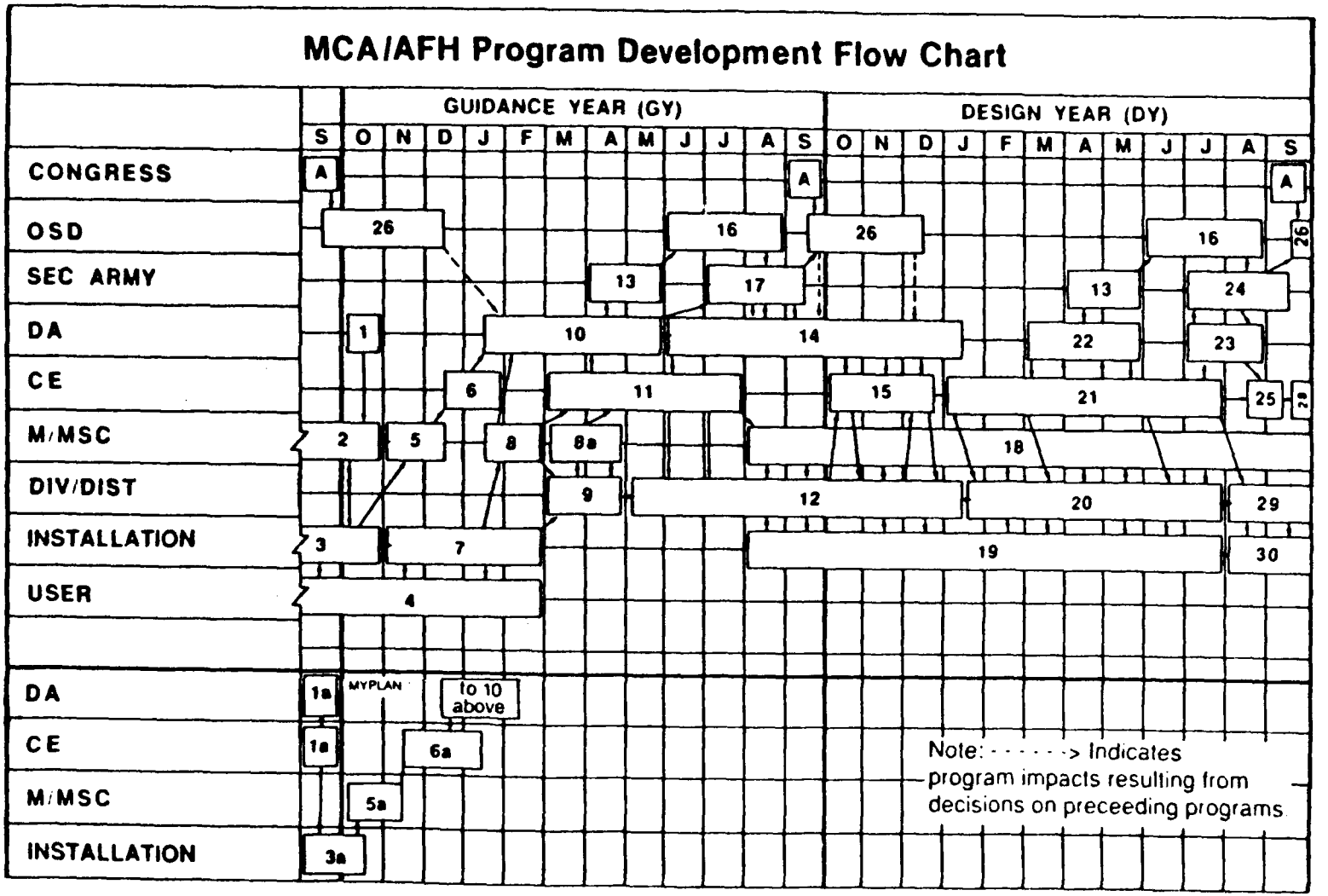


Figure 1. MCA program development flow chart.

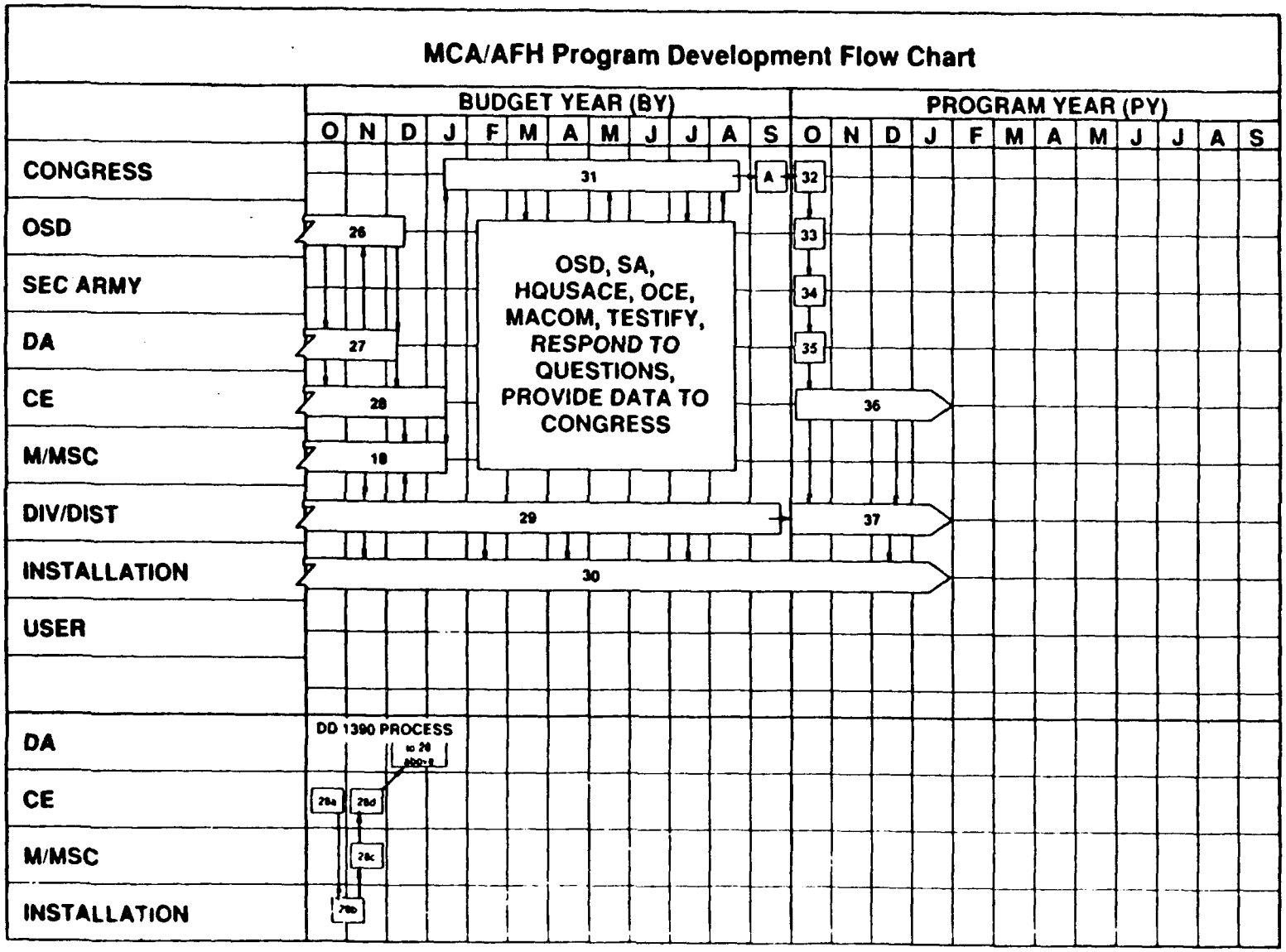


Figure 1. (Cont'd).

MCA/AFH Program Flow Chart Activities

A Authorization and Appropriation, PY Program
1. Army Guidance (Vol 2) and/or Engineer MILCON Program guidance to MACOMs.
1a. MYPLAN released
2. MACOM guidance to Installations
3. Installations prepare prioritized construction lists (in MYPLAN) and submit to MACOM. (See 3a.)
3a. Installations develop prioritized programs in MYPLAN and submit to MACOM.
4. Using agencies provide general functional requirements to Installations for projects in the program
5. MACOMs submit prioritized construction lists concurrent with PARR to HQDA. (See 5a.)
5a. MACOMs develop prioritized construction lists for submission concurrent with PARR, using MYPLAN. Submit MYPLAN to HQUSACE.
6. HQUSACE transfers MACOM programs from MYPLAN to DA CAPCES database.
6a. HQUSACE reviews MACOM MYPLAN submission and revises DA CAPCES database.
7. Installations submit full DD Forms 1391 to MACOM and detailed functional requirements (PDB) to designing agency (Note. PDBs not required for AFH.)
8. MACOMs submit full DD Forms 1391 to HQUSACE
8a. MACOMs review Division comments.
9. Divisions review DD Forms 1391, PDBs, and provide comment to MACOMs and HQUSACE
10. CRRC formulates initial Army program, releases projects for Code 1 (10% design) to HQUSACE, and provides guidance to MACOMs. 10 USC 2807 notification prepared and submitted to Congress not later than 15 April
11. HQUSACE reviews projects and directs Code 1 design of projects.
12. Districts initiate Code 1 activity, begin design. Review programs, progress, schedules of Districts. Districts submit 10% design ENG Forms 3086 to HQUSACE
13. Annual POM lock and submit
14. CRRC reviews/adjusts DA program, releases projects Code 2 Includes PBC, CSA, budget decisions. OCE releases revised DA program to installations, MACOMs, Districts, and Divisions
15. HQUSACE directs Code 2 design to FOAs
16. Issue papers. Defense Resources Board (DRB) adjusts and approves Army resources. Program Decision Memorandum (PDM) issued
17. Army Secretariat program review and approval (PDM)
18. MACOMs participate in Code 1/Code 2 design reviews
19. Installations participate in Code 1/Code 2 reviews
20. Code 2 design. District offices Submit concept level ENG Form 3086 cost data to HQUSACE not later than 1 August, DY
21. Adjust project costs (including concept level costs), notify CRRC, direct Code 6 final design, prepare program
22. CRRC reviews program, releases Code 6 final design. Annual POM submission to SA.
23. Final CRRC review and adjustment, submit to SA
24. Secretary of the Army review/approve budget submission
25. Prepare budget and submit to OSD. Provide MACOMs, Districts, Divisions with the revised program (OSD submit)
26. OSD/OMB review, adjust, approve BY program
27. DA responds to OSD issues, provides HQUSACE decisions
28. Prepare Military Construction budget justification data and submit to Congress. Provide installations, MACOMs, Districts, Divisions with the revised program. (Congressional Submit.)
28a. DD 1390, Implement 1390 process
28b. DD 1390, Process DD Forms 1390
28c. DD 1390, MACOMs review, modify, submit DD Forms 1390
28d. DD 1390, Review and incorporate DD Form 1390 in congressional budget submission
29. Districts accomplish final design (Code 6) of BY Program
30. Monitor project progress
31. Congress reviews Budget submission. Hearings conducted, projects challenged, questions issued
32. Authorization and Appropriation Bills produced, effective 1 October
33. Apportionment by OMB on or after 1 October.
34. Release program
35. USAFAC allocated funds
36. Allotments, construction directives to Districts by HQUSACE
37. Districts/Divisions complete design and begin construction

Figure 1. (Cont'd).

Objective

The objective of this research was to investigate the feasibility of developing a knowledge-based natural language interface to the CAPCES database (Expert-MCA), and to simplify data access so that users with little programming experience can generate FOCUS queries for data retrieval from CAPCES.

Approach

The CAPCES database was analyzed to determine the data content and its functional usage as it related to the MCA Cycle. Based on this analysis, a structure was generated to represent the knowledge in an object-oriented format. Using this format, a parsing algorithm was developed to translate the English queries into FOCUS code.

Mode of Technology Transfer

No USACE or Army guidance documents will be impacted by the results of this study. Technology transfer will be through field demonstrations and reports. It is anticipated that the final version of Expert-MCA will be made available by download from the Programming, Administration, and Execution System (PAX), in St. Louis, MO, and that software maintenance and support will be provided by the PAX administration.

2 ANALYSIS OF THE CONSTRUCTION APPROPRIATIONS CONTROL AND EXECUTION SYSTEM (CAPCES)

Overview

The CAPCES database resides on an Amdahl mainframe computer in St. Louis, MO. It is a major component of the Programming, Administration, and Execution System (PAX), which provides worldwide access to several applications and utilities that support the management of Military Construction programs. CAPCES is used to support funds management and program formulation for the Army's construction program. Its users include the facilities engineer/master planner at the installation level, Divisions and Districts, Major Subordinate Commands (MSCs), Major Army Commands (MACOMs), Office of the Chief of Engineers (OCE), Headquarters, U.S. Army Corps of Engineers (HQUSACE), and Headquarters, Department of the Army (HQDA).

Database Structure

CAPCES was developed using the FOCUS Data Base Management System (DBMS). FOCUS files represent data in a hierarchical structure that relates different segments of data in a parent-to-child relationship. The Project Monitoring Master File (PMMFILE) is the main FOCUS database file for CAPCES. (Appendix A to this report contains a listing of the PMMFILE.) This file contains a collection of segments that organizes the data by functional area within the MCA programming process. Each segment contains a set of data fields that are described by a field name, its alias (another name for referencing the field), and the type of data values (i.e., alphanumeric or integer) stored in it.

Database Content

CAPCES data fields include costs, activity start and completion dates, approval/review status, and certain descriptive items for project identification. Textual descriptions of the CAPCES data fields are contained in the Computer Applications Data Element Tracking Subsystem (CADETS). CADETS lists the field name, alias, data length, and type information found in the PMMFILE master description, along with the name of the PMMFILE segment location, the agency responsible for the data, an English name for the field, and a definition of the data field. Figure 2 shows an entry for the data field "CWE_AMT".

Reading the definitions in CADETS is the only way CAPCES users have for identifying the data fields that meet their reporting requirements. To assist users in accessing this information, it was necessary to analyze the data definitions to develop a logical structure for identifying data fields. This analysis determined several approaches for developing this structure.

```
CAPCES NAME = CWE_AMT     CAPCES ALIAS = CWE     ENGLISH NAME = CURRENT WORKING ESTIMATE     LENGTH = 008
SEGMENT NAME = AMPERS1                                                                       TYPE = N
AGENCY RESPONSIBLE - DAEN-ZCP-MB
                                THE ESTIMATE OF FUNDS IN THOUSANDS REQUIRED AT ANY
                                PARTICULAR POINT IN TIME TO COMPLETE THE EXPECTED
                                CONSTRUCTION PROJECT.
```

Figure 2. Sample CADETS data field entry.

The first structure generated organized fields into functional categories relating to the MCA process, assuming that most CAPCES users work in a particular area of the process, e.g., design. Therefore, they would most likely generate reports in data fields pertaining to that area. Using that concept as a foundation, the data fields were organized into primary categories based on five major functional areas within the MCA process and a sixth, independent category for project identification (i.e., project number and location):

1. Planning
2. Design
3. Programming
4. Budgeting
5. Construction
6. Descriptive information.

Each of these categories was broken down further into subcategories, the final subcategory being the name of the related data field. For instance, the Planning category contains subcategories for data relating to the DD Form 1391 and the Project Development Brochure (PDB). Each subcategory is broken down further to describe the type of information contained in CAPCES relating to these documents. This breakdown is continued until a subcategory describes an individual data field. A mapping from the primary functional category "Planning" to its final subcategories is shown in Figure 3.

By following the map in Figure 3, it is possible to determine which data field contains the information required for reporting requirements. A complete listing of this functional breakdown can be found in Appendix B.

The second method of organization was based on the concept that some users might want to view specific types of information regardless of its relationship to a particular area within the MCA process. For instance, a user who wanted information on the funding history of a project would want to choose between fields containing dollar amounts. To do that using functional category maps would require following all the primary categories to select just the fields containing funding information. To simplify this process, a structure was developed to organize data fields by information type. Four information types were used to categorize the data fields:

1. Dates
2. Dollar amounts
3. Status indicators
4. Descriptive.

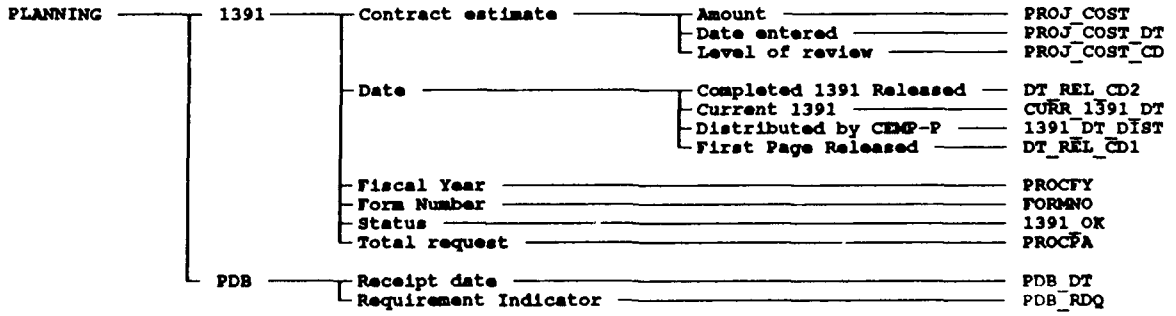


Figure 3. Map of functional category "Planning".

These four categories were also subcategorized as in the functional category grouping. Figure 4 shows mapping from the primary functional category "Dates" to its final subcategories describing the individual data fields.

A complete listing of the information type breakdown can be found in Appendix C.

The third method of organization was based on the need to see information relating to a specific event in the MCA Program Development Process (Figure 1). Each event was evaluated to determine if a CAPCES data field was either input or impacted during an event, and what other events might also be affected. For instance, Event 7, 1391 Submission, affects fields 1391_OK and CURR_1391_DT. A nonblank value in 1391_OK indicates that the form has been submitted, whereas CURR_1391_DT changes every time a new or revised form is submitted. Figure 1 shows event 7 to be preceded by events 3 and 4 and followed by 8 and 9. This structure of linear precedence was organized in a format to provide a listing, of events that can be associated with particular CAPCES fields, of fields that are affected, and of field values that indicate the occurrence of the event and the related events. The entry for DD Form 1391 Submission is shown in Figure 5.

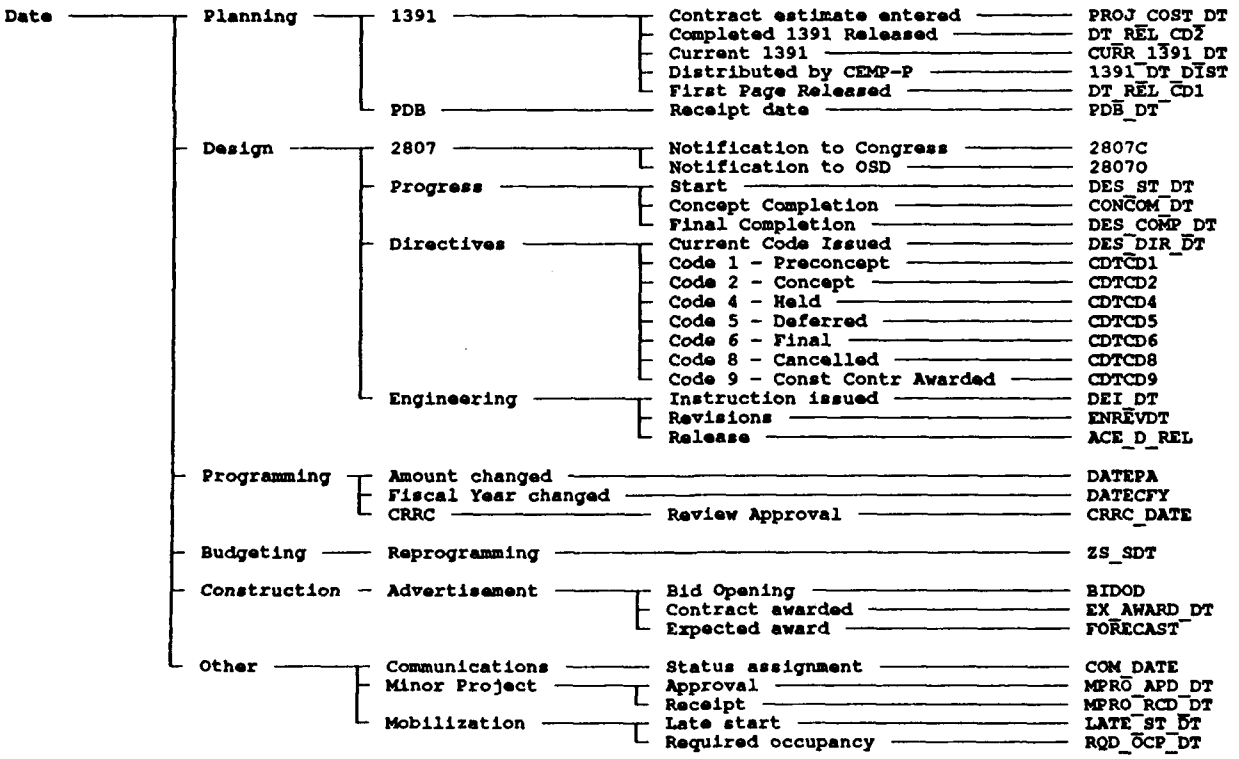


Figure 4. Map of information-type categories.

Event: 1391 Submission
Event Date: 1 Feb (GY)
Activity #: 7
Associated fields: CURR_1391_DT
1391_OK
Preceded by: 3,4
Followed by: 8,9
Note: 1391 should be submitted by 1 Feb, but will still be allowed until 1 Mar but are considered late submissions.
Significant values: A nonblank value in 1391_OK indicates that the form has been submitted. CURR_1391_DT changes every time a revised form is submitted so it will not reflect the original submission date.

Figure 5. DD Form 1391 submission entry.

A complete listing of the MCA Event/CAPCES relationship can be found in the Appendix D.

These organizational structures provide a simpler mechanism to help the user identify the data fields needed for reporting requirements. The next chapter describes how Expert-MCA incorporates these structures into knowledge bases used to help users formulate these information requests.

3 EXPERT-MCA

Overview

Expert-MCA is a knowledge-based natural language interface to the CAPCES database. Its purpose is to simplify access to CAPCES data by allowing users to access the database through English queries. By incorporating knowledge of the MCA Cycle, the CAPCES database, and the FOCUS command language, the system accepts natural language queries and translates them into FOCUS programming code that accesses the database.

Natural language processing is a research area within Artificial Intelligence (AI). For a computer to understand human language, the language must be converted into representations the computer can process. A commonly used representation in language understanding is the "parse tree," generated by a "parsing" analysis technique that uses syntactic constraints imposed by the English language to decompose the sentence into its components. A parsing algorithm is a computer program that implements a parsing technique for translating language input into a computer language representation.

Since the database domain is much smaller than that of the English language, parsing a database query involves developing a representation for the entered text that can be transformed into database commands. This requires a semantic understanding of the query in relation to the contents of the database. This is done by developing a dictionary of terms pertaining to the database that the parser uses to map phrases in the query into words and phrases stored in the dictionary. By decomposing database queries, the parser interprets natural language into the required representations for generating reports.

Some parsing algorithms for translating database queries use a simple pattern-matching approach to decompose queries into a database structure. This method is adequate for simple data retrieval, but does not help the user whose query is not understood. Users with partial understanding of the database domain get "stuck" and cannot retrieve the needed information.

Expert-MCA was designed to develop a new parsing technique that uses knowledge of both the CAPCES data and the MCA Cycle to analyze the user's query to determine what to include in the FOCUS report. Such a parsing technique would not only generate reports, but also assist the user in constructing and analyzing queries.

The following sections describe the design and implementation of the Expert-MCA system.

User Interface and Functional Capabilities

The Expert-MCA interface is a window- and menu-based environment for formulating and executing queries against the CAPCES database. The interface allows both keyboard and mouse-driven access to Expert-MCA functions, and provides multiple overlapping windows that can be moved and resized. This chapter describes the interface and the functions it provides.

The Expert-MCA screen (Figure 6) consists of four sections: (1) a pull-down menu bar, (2) an English-query input window, (3) an output window area, and (4) a help bar. The pull-down menu bar provides access to all the Expert-MCA functions. The English-query window is used for entering English queries against the CAPCES database. The output window area is used for communicating with

the user by displaying activity results (i.e., reports, FOCUS code) and system messages. The output window area may contain several active, overlapping windows that the user can choose by using either the mouse or keyboard. The help bar presents a context-sensitive list of currently available help functions, with the associated key used to activate them.

Pull-down Menu Bar

The remainder of this section describes the functions accessible from the pull-down menu bar. Some of the listed functions are new system capabilities not available in the initial release of Expert-MCA. These new features are marked by an asterisk (*) preceding the function name.

English-Query Input Window

The major function of the Expert-MCA system is the translation of English-language queries into FOCUS code, transmission of the code to CAPCES, and retrieval of the resulting report. Because of this, when Expert-MCA is invoked, the English-query input window is activated, awaiting input. The user may type in an English-language query immediately, using the arrow keys to edit the query if necessary. The query window also keeps a record of previous queries, which the user can retrieve and modify. Once the user is satisfied with the English version of the query, a single keystroke (Ctrl-T) will cause the query to be translated, and the resulting FOCUS code is displayed in the output window area. On the user's confirmation, the FOCUS code will be transmitted to CAPCES, and the resulting report stored in a local file named by the user. Once stored, the report may be viewed or printed from the **Tools** menu selection.

Query Menu. The **Query** menu provides facilities for creating, modifying, analyzing, sending, and saving queries. The commands in the menu include:

1. **New** clears and activates the query window so the user may begin a new query.

2. **Edit** returns the user to the query window with the currently active query displayed. If no queries have been entered, **Edit** has the same effect as the **New**.

3. **Edit FOCUS** opens an edit window in the output window area containing the currently active FOCUS code. This allows the user to modify the FOCUS code generated by the system. When the user completes the edit, the system asks whether the FOCUS code should be executed against the CAPCES database. (Notes: Expert-MCA does not have the capability to check the validity of user-modified FOCUS code, so such code may generate FOCUS errors when executed against CAPCES.)

4. **Construct** invokes a menu-based *Query Constructor* that assists the user in constructing FOCUS code directly without using English-query input. The *Query Constructor* uses Expert-MCA's knowledge bases to assist the user in choosing CAPCES fields to include in a report and to construct FOCUS code.

a. *Query Constructor* presents the user with a menu of FOCUS components used to generate reports based on the FOCUS command language. The user chooses the CAPCES fields to use each component. When a component is selected, the user is presented with a menu of methods to select CAPCES field names. These methods include selecting fields by their functional category, by the type

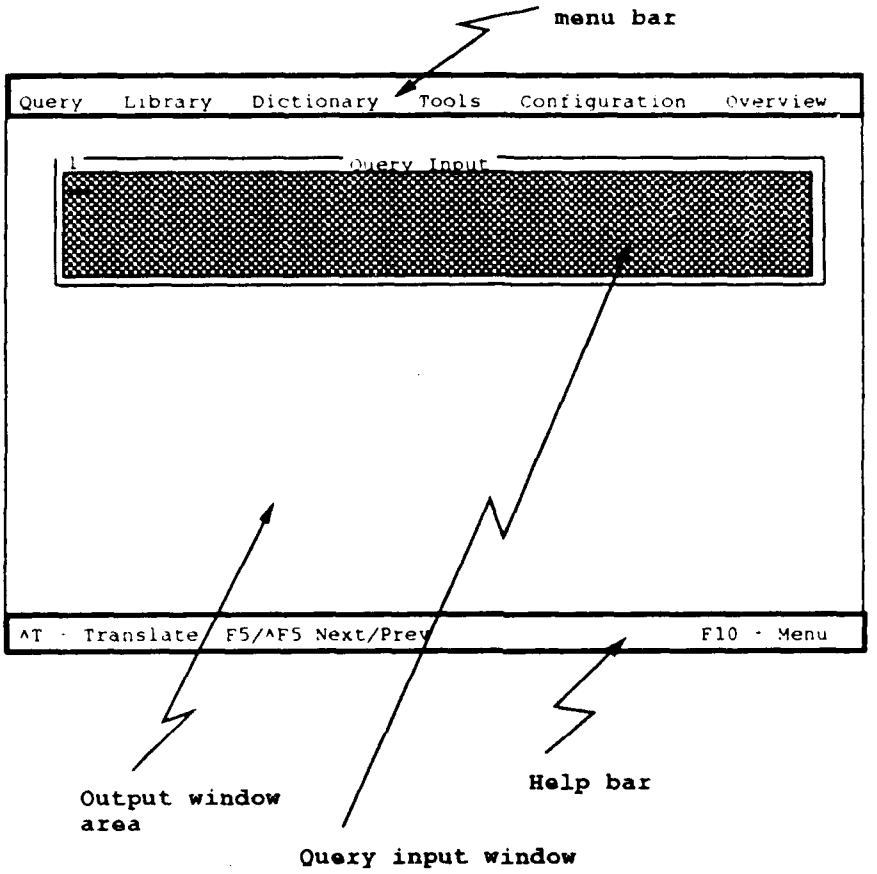


Figure 6. The Expert-MCA interface.

of information they contain, by where they are used in the MCA process, or by logical association with this query component. The query components used by the *Query Constructor* are:

(1) **Print** specifies which fields are to be printed in the columns of the generated report. At least one field must be selected for printing.

(2) **Select** specifies which records in the database will be included in the report. For each field chosen under Select, the user is prompted for a field value and a relation (e.g., greater than 1000) that must be satisfied for the record to be selected.

(3) **Sort** specifies the order for displaying records in the resulting report. If several sort fields are chosen, the report will be sorted by the fields in the order chosen.

(4) **Operate Over** specifies a FOCUS supplied operation (SUM, MINIMUM, MAXIMUM, or AVERAGE) to be performed on a selected field. For this feature, the user must choose

two CAPCES fields: one for *collecting* and one for *computing*, and the FOCUS operation to be performed. The resulting code will apply the operation on the compute field over each individual value of the collect field. For instance, if the collect field is STATE, the compute field is PROJ_COST, and the operation is SUM; the report will show the sum total of PROJ_COST for each STATE.

(5) **Generated Field** specifies a new field to be created for the purposes of the report, and how that field is to be computed. The generated field then becomes a valid field for printing, selecting, sorting, or operating. New fields may be generated using arithmetic operations over existing fields. For instance, the user may choose to generate a field named COST-OVERRUN, defined as "PROJ_COST - APPROP_AMT". COST-OVERRUN may then be used for printing, selecting, sorting, or operating on projects in the report.

(6) **Analyze** invokes a knowledge-based query analyzer that can analyze the currently active query. This function can do three types of analysis:

(a) **Syntactic Analysis** checks whether the values for fields specified in the query are reasonable, and whether only valid field names are included.

(b) **Report Analysis** estimates the size of the report that will result from the query, and tells the user if the query is likely to produce a report that is extremely long (many records) or extremely wide (many fields).

(c) **MCA Analysis** tries to determine whether the query is meaningful in relation to the MCA process. This component uses knowledge about data flow within the MCA process and the meaning of fields to determine if irrelevant fields are present or if fields that should be included are missing from the report. For instance, if the user were to ask for a report showing the date that design directives were released (DES_DIR_DT), the analyzer might suggest adding the field DIRCD, which specifies the current design directive issued because the two fields are closely related.

(d) **All** provides the ability to perform all three of the above analyses on the query.

5. **Send Batch** sends FOCUS commands accumulated in a batch file (see **Store**) to CAPCES for execution in sequence, and collects the resulting reports.

6. **Store** saves the currently active FOCUS code in a batch file for later transmission.

Library Menu

The **Library** menu invokes the Expert-MCA "librarian," which provides facilities for accessing, modifying, and saving libraries of queries. Expert-MCA maintains multiple libraries of existing queries and FOCEXECs, indexed by the MCA concepts in its knowledge bases (discussed in more detail in Chapter 3). The commands in the **Library** menu include:

1. **Browse** allows the user to look through the system's libraries of stored queries. The user may browse through stored queries by descending through a hierarchy of MCA concepts; at any point in the hierarchy, the user may ask to see all queries stored under that concept. Queries and FOCEXECs are stored by keywords and titles.

2. **Look Up Query** tries to find stored queries that match a specification given by the user. The user may specify a look up in one of three ways:

a. *By Keyword* - The user is prompted for keywords, and the librarian searches for stored queries that contain all or some of the given keywords.

b. *By Title* - The user may specify a title pattern (using "wild-card" characters), and the librarian returns the queries or FOCEXECs whose titles match the pattern.

c. **By Sample Query* - The librarian tries to find queries in the library that are like the last query translated by the parser. Similarity between queries is based on which CAPCES fields are used in the last query and how they are used.

3. **New** creates a new library for storing queries.

4. **Load** retrieves a library from disk.

5. **Store** saves a library file to disk.

6. **Delete** removes a currently loaded library and all of its queries from the system.

Dictionary Menu

The **Dictionary** menu provides facilities that allow the user to view and modify the dictionary of terms used by the Expert-MCA query parser. The commands in the **Dictionary** menu include:

1. **Browse** allows the user to look through the phrases stored in the currently loaded dictionaries.

2. **Look Up Phrase** allows the user to enter a phrase pattern (using wild cards) and returns a list of the phrases that match that pattern.

3. **Add Phrase** allows the user to define a new phrase. This process invokes the *Query Constructor*, which prompts the user to construct a whole or partial query that will be associated with the phrase in the dictionary.

4. **Edit Phrase** allows the user to change a phrase's definition.

5. **Delete Phrase** removes a phrase from the dictionary.

Tools Menu

The **Tools** menu provides facilities for accessing a variety of CAPCES and MCA tools that are not part of Expert-MCA but are valuable to users working in the MCA/CAPCES environment:

1. ***Expert-CADETS** invokes a hypertext system for knowledge-based guidance for identification of CAPCES fields.

2. ***MCA HyperText** invokes a hypertext version of Army Regulation 415-15, "Military Construction Program Development and Execution."

3. **Terminal Emulator** opens a terminal emulation window that connects to the PAX system. The terminal emulation window allows input-line editing and recovery locally before commands are sent to the PAX mainframe.

4. ***Download CAPCES** will enable users to download a portion of the CAPCES database to their personal computers (PCs).

Configuration Menu

The **Configuration** menu provides facilities for tailoring the appearance and performance of Expert-MCA. The options provided include:

1. **User Options** invokes a menu of control parameters and allows the user to change parameter values. The current set of parameters is:

a. **AutoSend** specifies whether Expert-MCA automatically sends a query to CAPCES once it has been translated. If AutoSend is On (the default), Expert-MCA will ask the user if a query should be sent once it has been translated. If AutoSend is Off, Expert-MCA will send a query only when commanded by the user.

b. **Ask for Definitions** controls whether Expert-MCA automatically invokes the Dictionary/Add Phrase option when an *undefined phrase* is found in a query. The default value is Off.

c. **AutoAnalyze** controls whether Expert-MCA automatically analyzes queries after translation. The default value is Off. The AutoAnalyze parameter can be set to Syntactic, Report, MCA, or All, corresponding to the values of the Analyze option in the Query menu.

2. **User Information** allows the user to provide information specific to his/her role in the MCA process. This information is used by Expert-MCA to modify how queries are translated and analyzed. Expert-MCA currently allows the user to specify three kinds of information: (1) CAPCES fields that should be included in every report, (2) selected restrictions on projects that should be included in every query, and (3) parts of the MCA process that are relevant to the user's job.

3. **Comm Parameters** allows the user to specify the COM port and baud rate of their modem, and the number to dial for connecting to the PAX system.

4. **Directories** allows the user to specify defaults for the Expert-MCA home and data directories.

5. **Save Config** stores the current configuration in a file in the Expert-MCA home directory.

6. **Load Config** allows the user to retrieve a previously stored configuration file.

7. **Colors** allows the user to change the Expert-MCA screen colors.

Overview Menu

The **Overview** menu provides a brief introduction to the Expert-MCA system.

Knowledge-Base Structure

This section describes the knowledge bases used by Expert-MCA in translating, analyzing, constructing, and storing queries. Expert-MCA contains several interrelated knowledge bases on the MCA process and the CAPCES database. These knowledge bases are implemented using a virtual-memory frame system. After description of the overall layout of the MCA knowledge bases, a section is devoted to a description of the capabilities and implementation of this frame system. The final five sections describe the individual knowledge bases in the context of the frame system.

For Expert-MCA to be useful to both novice and experienced users of CAPCES, it must provide both direct logical access to MCA and CAPCES information (for experts) and a user-friendly interface (for novices). MCA and CAPCES information was organized into Expert-MCA as a graph of interconnected pieces of information or concepts, represented by vertices, and the relationships between them, represented by lines. A knowledge base in Expert-MCA consists of a set of concepts and their associated relationships. There are four primary knowledge bases in Expert-MCA:

1. The *MCA Process* knowledge base contains concepts corresponding to events within the MCA process. It is organized to represent the relationship between the events and the order in which they occur as a project progresses from the planning phase to construction execution. This knowledge base is organized graphically with events represented by vertices, lines showing the relationships between events, and the relative position of the vertices indicating the order in which events occur.

2. The *Functional Category* knowledge base contains concepts corresponding to functional areas within the MCA process. For instance, "Design" is a meaningful functional area in the MCA process, and so is represented by a vertex in the graph. Functional information is organized in terms of category and subcategory, so the functional category graph is actually a tree (hierarchy) of concepts. Appendix B illustrates the graphical structure for this knowledge base, with the root indicating the main functional category, branches showing subcategories, and the leaves indicating the associated CAPCES data field.

3. The *Information Type* knowledge base contains concepts corresponding to the type of information stored in CAPCES fields. For instance, many CAPCES fields contain dollar amounts, so "Amounts" is a vertex in the Information Type knowledge base. As in the Functional Category knowledge base, the concepts are organized in a hierarchical tree structure (Appendix C).

4. The *Database* knowledge base contains concepts relevant to FOCUS database[1] queries and reports. For instance, "Printing a field as a report column" is a concept relevant to queries and reports, and is a vertex in its graphical representation. Expert-MCA does not capture the full range of possible actions on a relational database, so the Database knowledge base is a simple, single-level hierarchy of disjointed concepts relating to the different function components of database reporting languages.

[1] To ensure portability to other database environments, this perspective contains concepts relevant to relational databases in general.

The organization of these knowledge bases and their interrelationships are summarized in Figure 7. In the figure, concepts (graph vertices) are represented as circles or boxes, and relationship between concepts as lines. Also shown is a representation of the CAPCES data dictionary. Expert-MCA contains a list of the CAPCES fields relevant to the concepts in each of the other four knowledge bases. These knowledge bases contain pointers to fields related to those concepts. It is this organization that allows Expert-MCA to get from MCA concepts to relevant fields.

Figure 7 also shows the Expert-MCA phrase dictionary. The phrase dictionary is a mapping from English-language phrases to MCA concepts and to CAPCES fields. The dictionary is used by the query parser (next section) to convert English-language queries into relational query components. The phrase dictionary is also used by the other knowledge-based agents in Expert-MCA to get from English phrases to relevant concepts. For instance, the query librarian uses the dictionary to get from phrases to nodes under which queries may be stored. The query analyzer and the menu-based query constructor use the dictionary indirectly, as a tool to assist users in finding relevant fields.

For reasons of clarity, two important relationships are not shown in Figure 7. First, almost all concepts in the four knowledge bases have pointers to fields in the CAPCES data dictionary relevant to those concepts. Second, concepts may have pointers to queries that use those concepts. Queries in the library are in fact stored as part of the phrase dictionary (since they take the same form as phrase definitions); concepts in the knowledge bases will point to queries that are relevant to those concepts. For instance, a query that prints design costs for a set of projects is related to the "design" concept in the MCA Process and Functional Category knowledge bases, to the "Money" concept in the Information Type knowledge base, and to any associated fields that are printed under the Print concept in the Database knowledge base.

Virtual-Memory Frame System

The current Expert-MCA knowledge base contains information about 258 CAPCES fields, and over 120 concepts relevant to MCA and CAPCES queries. The phrase dictionary contains over 1000 English phrases with corresponding definitions. (There are fewer definitions than phrases since phrases may be synonymous.) Several types of pointers (lines) are stored with each concept, as well as textual information (names, descriptions, etc.). All of this makes for a sizeable knowledge base, too large to fit in the normal (640K) memory of a microcomputer. The next subsection describes the virtual-memory frame system that resolves this problem and provides an efficient implementation of the knowledge bases.

Implementation of the Expert-MCA knowledge bases required a system capable of representing the rich graph structure of knowledge, and capable of handling a large amount of data using a small amount of memory. The query parser required a system that could maintain a large number of record-like items (phrase definitions) that could be modified (during query translation) and then restored to their original state. The obvious choice for a general representation was a frame system. Frame-like systems are common in AI research and development; they typically provide a dynamic version of data records (i.e., data structures with named, typed components called slots) and a mechanism of inheritance (through which slots have dynamically modifiable default values).

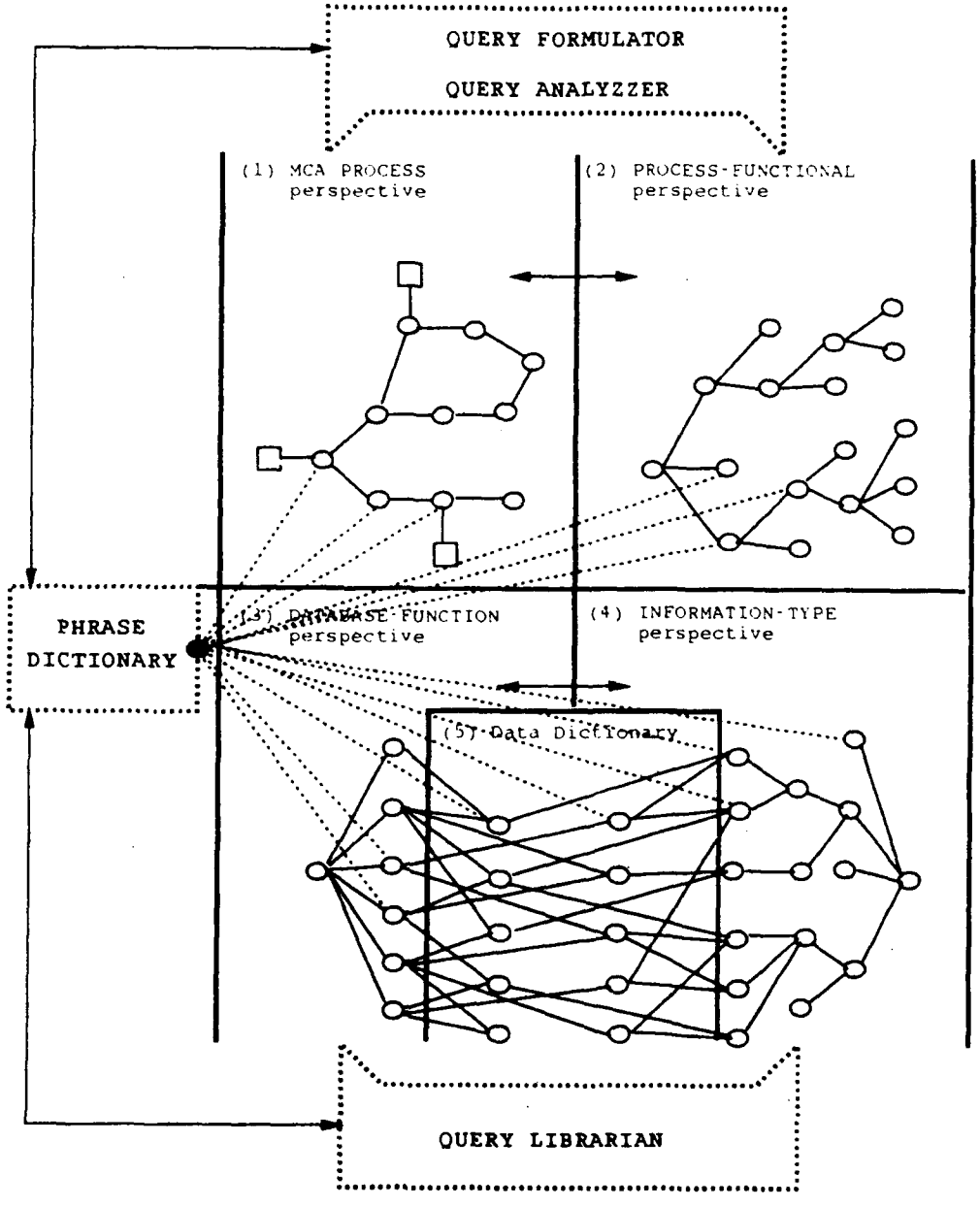


Figure 7. The organization of Expert-MCA knowledge.

Expert-MCA is implemented in object-oriented Turbo Pascal 5.5.[2] Pascal is not normally used for AI work because it is based on static structures (AI systems typically need to dynamically modify their data structures). There are no existing implementations of frame systems in Pascal for personal computers, and frame systems typically provide no memory management. Expert-MCA is therefore based on a new implementation of frames that provides most of the standard frame system functions, and automatically handles swapping of frames to and from disk when they are needed.

The Expert-MCA frame system is an object-oriented implementation of frames based on the VirtualArray object in the Object Professional software library from TurboPower Software.[3] The VirtualArray object implements large arrays (greater than 64K) that automatically swap array elements to and from disk as they are accessed and changed. The frame system uses a single large array of 16 Megabytes (4194304 indices with 4 bytes per index) as an address space.

The frame system is implemented as a single object class, called an environment. An environment object contains a virtual array used to store the frames. The frames are themselves addressed through *perspective* objects associated with the environment. The environment may have up to 32 perspectives, and each perspective may contain up to 8,192 frames. Each perspective defines a set of slots, possessed by all the frames in that perspective; each slot has a type and a default value. Up to 120 slots may be defined for a perspective.

Perspectives, slots, and frames may be created, deleted, and modified dynamically (i.e., without need for compilation). The frame system therefore provides the flexibility needed to implement Expert-MCA knowledge bases. Since all of the data regarding frames and perspectives are stored in the environment's virtual array, the data is automatically paged in and out of memory when it is accessed. The virtual array is set up so that its pages contain only complete frames, so that paging performance is directly related to frame use. The frame system environment allows eight types of slots in frames:

1. **Integer**: a four-byte signed integer value
2. **List of Integer**: a list of **Integers**
3. **Float**: a four-byte floating-point number
4. **List of Float**: a list of **Floats**
5. **String**: a Pascal string, up to 255 characters
6. **List of String**: a list of **Strings**
7. **Address**: a pointer to another frame[4]
8. **List Of Address**: a list of **Addresses**.

The major advantage of using this frame system for Expert-MCA is that it can read knowledge bases from text files and save them (in nontext form) on disk. Because knowledge bases can be read from text, they may be developed or modified on a second microcomputer, or modified directly in text form. Because the frame data is stored and swapped to and from disk on demand, it is easy to dump the entire system onto disk in binary form to save it. The knowledge bases can then be loaded by

[2] Turbo Pascal is a trademark of Borland International, Inc., Scotts Valley, CA.

[3] Turbo Power Software, PO Box 66747, Scotts Valley, CA.

[4] Note that the Address slot-value type contains indices into the virtual array rather than actual machine addresses. This is a significant advantage for reducing the load time of knowledge bases.

simply opening the paging file for the virtual array. Expert-MCA employs this technique on startup; it has resulted in a decrease in knowledge base load time (from the prototype version of the system, developed in LISP) from minutes to less than 10 seconds.

All of the Expert-MCA knowledge bases discussed below are implemented as individual perspectives in the virtual-memory frame system. The phrase dictionary (next section) is also implemented as frames stored in several different perspectives.

The MCA Process Knowledge Base

The MCA Process knowledge base contains frames representing states and significant actions in the life of a construction project in the MCA process. The following slots are defined for frames in the MCA Process knowledge base (where slots are given as slot name and slot type, separated by a colon, and a slot description follows a double semi-colon):

1. **Concept-Name**: String ;;A string briefly describing the concept.
2. **Followed-By**: ListOfAddress ;;Actions or states in the MCA process that follow immediately after this one.
3. **Preceded-By**: ListOfAddress ;;Actions or states in the MCA process that immediately precede this one.
4. **SubProcess**: ListOfAddress ;;A set of actions or states that are a part of this action or state.
5. **SuperProcess**: Address ;;An action or state of which this one is a part.
6. **Fields**: ListOfAddress ;;CAPCES fields that this state relates to.

There are currently about 50 frames in this knowledge base. A small example will suffice to illustrate the organization of this part of Expert-MCA's knowledge. One component of project development is review and modification of the DD Form 1391 after a project has been approved for 35 percent design by the Construction Requirements Review Committee. This process is represented in Expert-MCA by a single frame:

Concept-Name = "DD Form 1391 Review Process"
Followed-By = (ACE-PREP-CRRC-II MACOM-PREP-CRRC-II)
Preceded-By = (DEH-FINALIZE-1391)
SubProcess = (MACOM-REVIEW-1391 MACOM-SUBMIT-1391-TO-ACE
ACE-REVIEW-1391 ACE-SUBMIT-1391-TO-DISTRICT
DISTRICT-REVIEW-1391)
Fields = (CWE_AMT CURR_1391_DT)

In this description, phrases in capital letters represent pointers to other frames. This particular frame represents a relatively high-level description of part of the MCA cycle, so it has several pointers to lower level frames and only a few pointers to actual CAPCES fields. Pointers to fields will be stored at the higher level only if they are subject to change or modification at all of the lower level actions. In this case, at any point in the 1391 review process, the project's current working estimate (CWE_AMT) and current date on the 1391 form (CURR_1391_DT) may change, so these fields are associated with the entire process.

The Functional Category Knowledge Base

The Functional Category knowledge base contains frames representing concepts that group CAPCES fields by their functional use in the MCA process. These concepts are organized in a simple hierarchy, so frames in the process-functional knowledge base have only a few slots:

Concept-Name:String ;;A string briefly describing the concept
Functional-SubTypes:ListOfAddress ;;Concepts that are subordinate to this one
Functional-SuperTypes:ListOfAddress ;;Concepts that are superordinate to this one
Fields:ListOfAddress ;;CAPCES fields associated with this concept

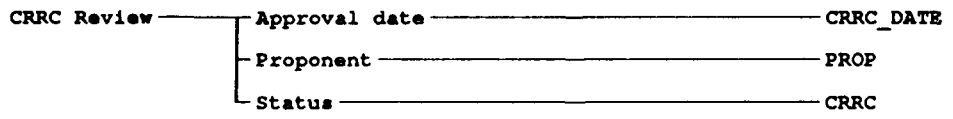
The Functional Category knowledge base is a tree whose leaves are CAPCES fields. Vertices in the tree represent commonalities between fields; as the tree is ascended, the commonalities become more abstract. The Functional-SubTypes slot points downwards in the tree, the Functional-SuperType slot points upwards. Figure 8 shows a subsection of the graphical structure for the knowledge base along with a sample of the frame representation for "Approval Date" concept.

The Functional Category knowledge base is used for browsing the dictionary and the library, and by the Analyzer. The browsers allow the user to traverse the Process-Functional tree when searching for queries, phrases or CAPCES fields. The Analyzer uses the knowledge base to seek commonalities between fields in a report; if a proposed query does not contain fields that belong together under some node in the Functional Category knowledge base, the user may have chosen the wrong field.

The Information-Type Knowledge base

The Information-Type knowledge base is much like the Functional Category knowledge base: frames in the knowledge base represent concepts that group CAPCES fields. In this case, however, fields are grouped by the type of information contained in them (rather than how they are used in the MCA Cycle). The slots in this knowledge base are exactly analogous to the slots in the Functional Category knowledge base:

Concept-Name: String ;;A string briefly describing the concept
Information-SubTypes: ListOfAddress ;;Concepts that are subordinate to this one
Information-SuperTypes: ListOfAddress ;;Concepts that are superordinate to this one
Fields: ListOfAddress ;;CAPCES fields associated with this concept




```
Concept-Name: "Approval Date"
Functional-SubTypes: ()
Functional-SuperTypes: (CRRC-Review)
Fields: (CRRC_DATE)
```

Figure 8. Graphical structure of Approval Date.

The Information-Type knowledge base is a tree whose leaves are CAPCES fields. The Information-SubTypes slot points downwards in the tree, the Information-SuperTypes slot points upwards. Some of the concepts in the Information-Type knowledge base are the same as concepts in the Functional Category knowledge base; this is not surprising, as field use in MCA is related to the type of information in the field. Figure 9 shows a subsection of the graphical structure for the knowledge base along with a sample of the frame representation for the "Advertisement" concept.

The Information-Type knowledge base is used by the dictionary and library browsers, and the menu-based query constructor, to help the user find queries, phrases, or CAPCES fields. The query analyzer uses this knowledge base to ensure that fields are being used in the correct role (e.g., that there are no computations used on descriptive fields).

The Database Knowledge Base

The Database Knowledge base is the simplest of the four major Expert-MCA knowledge bases. Like the previous two knowledge bases, frames in the Database-Function represent concepts that group CAPCES fields. In this case, fields are grouped by how they might be used in queries. The slots in this knowledge base are exactly analogous to the slots in the previous two knowledge bases:

Concept-Name: String ;;A string briefly describing the concept
DBFunction-SubTypes: ListOfAddress ;;Concepts that are subordinate to this one
DBFunction-SuperTypes: ListOfAddress ;;Concepts that are superordinate to this one
Fields: *ListOfAddress* ;;CAPCES fields associated with this concept

The Database-Function knowledge base is also a tree whose leaves are CAPCES fields, but in this case, the tree is only one layer deep. The DBFunction-SubTypes and DBFunction-SuperTypes fields are currently unused, but are present if more detailed FOCUS knowledge should be added to the system later. The Database-Function knowledge base currently groups all the CAPCES fields into one of the following five categories (fields may, of course, appear in more than one category):

1. Printed
2. Selected By
3. Collected By
4. Sorted By
5. Computed On.


```
Concept-Name: "Advertisement"
Information-SubTypes: (Bid-Opening Contract-awarded Expected-award)
Information-SuperTypes: (Construction)
Fields: ( )
```

Figure 9. Graphical structure of Advertisement.

Fields under the Printed frame are those that may be printed in a report. Fields under the Selected By frame are those that may be used to select projects included in the report (for instance, MACOM is under Selected By because CAPCES users in Major Commands typically want to see only projects under them). Fields under the Collected By frame are those that may be used to summarize projects with a single value for that field (for instance, STATE is under Collected By because it is reasonable to ask summary questions about all the projects in each state).

Fields under the Sorted By frame are those that may be used to sort reports (e.g., DD_SORT_CD). Fields under the Computed On frame are those that may be meaningfully used in an arithmetic formula (e.g., PROJ_COST).

The Database Function knowledge base is used primarily by the menu-based query constructor and the dictionary. Users see the five Database Function categories when constructing a query or adding a new phrase to the dictionary. The analyzer also uses this knowledge base to ensure that fields in a query are being used in their proper roles.

The Query Parser

The query parser translates English queries into an internal representation and then converts this internal form into a FOCUS query. The process consists of four phases. First, the English query is preprocessed to remove simple elements such as contractions and end punctuation. Second, phrases in the English query are replaced by structural equivalents following a dictionary lookup. Third, parse rules are applied to transform the structured query list into a parse tree, where each node in the tree represents a function to be performed on the data retrieved from the CAPCES database. The product of the third phase is the internal representation that Expert-MCA uses to store a query for later reuse. The fourth phase translates the internal representation (parse tree) into a FOCUS query that can be executed against the data in CAPCES.

The next section describes the dictionary used by the parser to look up phrases. The following four sections describe the four phases of the parsing process. The last section discusses future enhancements to the parser.

The Phrase Dictionary

One of the main functions of the parser is to look up meanings for the phrases in the English query. Phrase meanings are stored in the dictionary perspective indexed by the phrase string. Each entry in the dictionary perspective points to one or more entries in other subperspectives. Entries in the subperspectives can point to other entries within the subperspectives.

1. The **Garbage** perspective defines those phrases to be ignored during the parsing of the query.

2. The **Plural** perspective is used to define the plural version of phrases already in the dictionary.

3. The **CAPCES-Field** perspective is used to define fields in the CAPCES database.

4. The **Add-Field** perspective is used to define new fields that are formulas involving other fields. For example, Cost Overrun is defined as the difference between Project Cost and Appropriated Amount.

5. The **Format** perspective is used to specify which fields are to be printed and whether or not they should be sorted.

6. The **Select** perspective defines constraints on the values of CAPCES-Fields and Add-Fields.

7. The **Special-Def** perspective is used to define a variety of special phrases (e.g., relations, arithmetic operators, ranges) and values of all types (e.g., integer and real numbers).

For example, consider the query "PLEASE SHOW COST OVERRUNS FOR FY 90". The actual meanings retrieved from the Expert-MCA dictionary are shown in Figure 10. The entry for "90" does not actually exist in the dictionary, but is constructed during the parse of the query.

The next four sections describe the phases that retrieve meanings from the dictionary, fill in empty slots, and link the meanings together to form a query parse tree that can be converted to FOCUS code.

```
    "PLEASE"
[ Garbage
  Name = PLEASE ]

    "SHOW"
[ Format
  SortFields = ( )
  Verb = PRINT
  SortOrder = ]

    "COST OVERRUNS"
[ Plural
  Reference =
    [ Select
      Relation =
        [ Special-Def
          Type = RELATION
          StringVal = GT ]
      Field =
        [ Add-Field
          Formula = PROJ_COST - APPROP_AMT
          Result = COST-OVERRUN ]
      ValueList = (
        [ Special-Def
          IntVal = 0
          Type = INTEGER ] ) ] ]

    "FOR"
[ Select
  Relation = NULL
  Field = NULL
  ValueList = ( ) ]

    "FY"
[ CAPCES-Field
  Dbase-Name = FY
  Type = A
  Owner = DAEN-ZCP-MA
  Length = 2 ]

    "90"
[ Special-Def
  IntVal = 90
  Type = Integer ]
```

Figure 10. Dictionary meanings for sample query.

Preprocessing

The preprocessing phase removes unnecessary punctuation from the English query. There are three types of unnecessary punctuation: extra spaces, apostrophes, and end punctuation. First, the preprocessing phase removes all leading and trailing spaces from the query and ensures that there is only one space between words. Second, end marks (periods, question marks, and exclamation marks) are removed from the end of the query. Finally, internal punctuation (apostrophes) is removed. Contractions are expanded by matching them against a table of contraction/expansion pairs. Possessives and all remaining apostrophes are removed.

Parsing

After preprocessing, the English query is parsed into a list of perspective entries representing the meanings of the phrases within the query. The English query parser breaks the query into successively smaller phrases until the phrase is found in the dictionary, i.e., the phrase is a number or a phrase that can no longer be broken up. Figure 11 shows the sample query presented in the previous section is broken up during the identification of the dictionary phrase "PLEASE".

Next, the meaning for "PLEASE" returned from the dictionary is added to the list of meanings, and the process is repeated for the rest of the query. If a phrase is not found in the dictionary, is not a number, and cannot be broken up further, then the phrase is added to the list of unknown phrases and parsing continues with the rest of the query.

In the above example, meanings will also be found for "SHOW", "COST OVERRUNS", "FOR", and "FY". After the phrase "90" cannot be found in the dictionary, the parser recognizes it as a number. Numbers are converted to Special-Def perspective entries and added to the list of meanings. Thus, the completed English query parse for the sample query is the list of meanings shown in Figure 10.

Parse Rules

Parse rules modify the list of meanings to construct the final query parse tree. The Expert-MCA parse rules are defined in a separate file and are read in during the initialization of the Expert-MCA program. A parse rule consists of three parts: the name of the rule, the condition in which the rule is fired, and the action to be taken if the condition is met. Thus, the syntax of a parse rule is:

(Rule (rule-name) (condition) (action)).

Instead of describing the entire syntax of the rule components, several actual parse rules used in Expert-MCA that are applicable to the sample query are presented. Symbols beginning with "?" are variables that can match a single element in the list of meanings. English descriptions accompany each rule.

The RemoveGarbage rule removes any entries from the Garbage perspective. In the sample query, this rule would remove the entry for "PLEASE":

```
(Rule RemoveGarbage
    (Equal (Perspective ?x) Garbage)
        (Remove ?x))
```

Phrase to be Looked Up	Rest of Query to be Parsed
"PLEASE SHOW COST OVERRUNS FOR FY 90"	""
"PLEASE SHOW COST OVERRUNS FOR FY"	"90"
"PLEASE SHOW COST OVERRUNS FOR"	"FY 90"
"PLEASE SHOW COST OVERRUNS"	"FOR FY 90"
"PLEASE SHOW COST"	"OVERRUNS FOR FY 90"
"PLEASE SHOW"	"COST OVERRUNS FOR FY 90"
"PLEASE"	"SHOW COST OVERRUNS FOR FY 90"

Figure 11. Sample query parse.

The LookUpPlural rule replaces entries from the Plural perspective with the nonplural meaning. In the sample query, this rule replaces the entry for "COST OVERRUNS" with the singular Select meaning for "COST OVERRUN":

```
(Rule LookUpPlural
    (Equal (Perspective ?x) Plural)
    (Set ?x (SlotValue ?x Reference)))
```

The FillSelectFieldWithField rule fills in the Field slot of a Select perspective entry with a CAPCES-Field perspective entry if the slot is empty and if the CAPCES-Field perspective entry is right next to the Select perspective entry. Because the CAPCES-Field perspective entry now resides in the Field slot of the Select perspective entry, the CAPCES-Field entry can be removed from the query list. In the sample query, the CAPCES-Field perspective entry for "FY" is removed from the query list and stored in the Field slot of the Select perspective entry for "FOR".

```
(Rule FillSelectFieldWithField
    (And
        (Equal (Perspective ?s) Select)
        (Equal (SlotValue ?s Field) Nil)
        (Equal (Perspective ?f) CAPCES-Field)
        (Equal (Position ?f) (Plus (Position ?s) 1)))
    (And
        (Set (SlotValue ?s Field) ?f)
        (Remove ?f)))
```

The FillSelectRelationWithDefault rule fills in the Relation slot of a Select perspective entry with the default EQ relation when a relation does not occur in the query. The (LookUp EQ) expression in the rule retrieves the meaning of EQ from the dictionary, which in this case is a Special-Def of type RELATION. Because our sample query does not contain an explicit relation, this rule fills in the Relation slot with the EQ Special-Def. If the query had been "...FOR FY < 90", then this rule would not execute, and another rule would fill the Relation slot appropriately:

```
(Rule FillSelectRelationWithDefault
    (And
        (Equal (Perspective ?s) Select)
        (Equal (SlotValue ?s Relation) Nil)
        (Not (Equal (SlotValue ?s Field) Nil)))
        (Set (SlotValue ?s Relation) (LookUp EQ)))
```

The FillSelectValueListWithValue rule adds a value to the ValueList slot of a Select perspective entry if the ValueList slot is empty and a Special-Def perspective entry is right next to the Select perspective entry. The Special-Def entry is removed from the query list. In our sample query, the Special-Def perspective entry for "90" is removed from the query list and stored in the ValueList slot of the Select perspective entry for "FOR":

```
(Rule FillSelectValueListWithValue
    (And
        (Equal (Perspective ?s) Select)
        (Equal (SlotValue ?s ValueList) Nil)
        (Not (Equal (SlotValue ?s Field) Nil))
        (Equal (Perspective ?v) Special-Def)
        (Equal (Position ?v) (Plus (Position ?s) 1)))
(And
        (Set (SlotValue ?s ValueList) ?v)
        (Remove ?v)))
```

Two other rules execute for our sample query. One rule puts the "COST OVERRUN" Add-Field into the SortFields slot of the "SHOW" Format perspective entry. Another rule links the "SHOW" Format perspective entry to the "FOR" Select perspective entry.

The list of Expert-MCA parse rules are repeatedly applied in order until no rule executes. The result of parsing is an ordering of the operations on CAPCES that are specified by the phrase meanings. This ordering is expressed as a tree; operations higher in the tree are applied to the results of operations lower in the tree. Figure 12 shows the resulting tree for the sample query.

This parse tree is Expert-MCA's internal form for the query. If the user would like to store the query for future use or analyze the query for inconsistencies, Expert-MCA uses this internal form. The FOCUS code generator also uses this internal form to construct a FOCUS query.

FOCUS Code Generation

Currently, the FOCUS code generation phase resides in Pascal procedures, because the parse tree representation affords simple translation into FOCUS code. The procedures first define all Add-Field perspective entries in FOCUS DEFINE statements. Next, the SortFields of each Format perspective are converted to FOCUS verb and sort statements. Then, Select perspective entries are converted to FOCUS IF statements. Figure 13 shows the FOCUS code generated for our sample query.

Once the FOCUS code is generated, the major components of the parser are in place. Several queries in addition to the above sample query have been parsed successfully. More parse rules are needed to increase the scope of English queries understood by the parser. As more complex FOCUS code is needed to translate queries, the Pascal procedures will be replaced by a rule-based translation. Because the rule-processing procedures are already in place for the parse rules, this change requires only that more rules be written. Third, a mechanism for including default fields in the FOCUS code is needed. Such a mechanism would allow the Project Description field to be printed as well as COST-OVERRUN in our sample query.

```
"SHOW"
[ Format
  SortFields = (
    [ Add-Field
      Formula = PROJ_COST - APPROP_AMT
      Result = COST-OVERRUN ] )
  Verb = PRINT
  SortOrder = ]


"COST OVERRUN"
[ Select
  Relation =
    [ Special-Def
      Type = RELATION
      StringVal = GT ]
  Field =
    [ Add-Field
      Formula = PROJ_COST - APPROP_AMT
      Result = COST-OVERRUN ] ]


[ Add-Field
  Formula = PROJ_COST - APPROP_AMT
  Result = COST-OVERRUN ] ]


"FOR FY 90"
[ Select
  Relation =
    [ Special-Def
      Type = RELATION
      StringVal = EQ ]
  Field =
    [ CAPCES-Field
      Dbase-Name = FY
      Type = A
      Owner = DAEN-ZCP-MA
      Length = 2 ]
  ValueList = (
    [ Special-Def
      IntVal = 90
      Type = Integer ] ) ]


CAPCES Database
```

Figure 12. Complete parse for sample query.

```
DEFINE FILE PMMFILE
COST-OVERRUN = PROJ_COST - APPROP_AMT;
END

TABLE FILE PMMFILE
PRINT COST-OVERRUN
IF COST-OVERRUN GT 0
IF FY EQ 90
ON TABLE HOLD FORMAT WP
END
```

Figure 13. Generated FOCUS code for sample query.

4 CONCLUSION

The prototype Expert-MCA system demonstrates the feasibility of developing a knowledge-based natural language interface to the CAPCES database. Expert-MCA simplifies user's access to, and data retrieval from the CAPCES database by interpreting natural language requests into FOCUS command language queries. This interface may allow users with little programming experience to generate accurate and meaningful database reports.

APPENDIX A: Project Monitoring Master File (PMMFILE)

```
FILENAME=PMMFILE, SUFFIX=FOC,$
,$ ********************************************************************************
,$  FILE NAME - PROJECT MONITORING MASTER FILE
,$  FILE IDENTIFIER - PMMFILE
,$  REVISION DATE:  25 SEPTEMBER 1984
,$ ********************************************************************************
     SEGNAME=MAIN, SEGTYPE=S,$
          FIELD=KEYNR,          ALIAS=KN,            USAGE=A13,   FIELDTYPE=I,$
          FIELD=KN_UPD,         ALIAS=KNU,           USAGE=A1,$
          FIELD=KN_SDT,         ALIAS=,              USAGE=A12,$
          FIELD=INST,           ALIAS=STA_CD,        USAGE=A5,    FIELDTYPE=I,$
          FIELD=PFT,            ALIAS=PM_FILETYPE,   USAGE=A1,    FIELDTYPE=I,$
          FIELD=FY,             ALIAS=CFY,           USAGE=A2,    FIELDTYPE=I,$
          FIELD=DATECFY,        ALIAS=DT_CFY_CHG,    USAGE=I6YMDT,$
          FIELD=PCFY,           ALIAS=PREVIOUS_CFY,  USAGE=A2,$
          FIELD=OFY,            ALIAS=,              USAGE=A2,$
          FIELD=CMDC,           ALIAS=CMD_CD,        USAGE=A2,    FIELDTYPE=I,$
          FIELD=PRCD,           ALIAS=PROG_CD,       USAGE=A2,    FIELDTYPE=I,$
          FIELD=ORIG_USVC,      ALIAS=ORUSVC,        USAGE=A2,    FIELDTYPE=I,$
          FIELD=SITE_CODE,      ALIAS=INCODE,        USAGE=A5,$
          FIELD=CATCD5,         ALIAS=CAT5,          USAGE=A5,$
          FIELD=CMD_PRI,        ALIAS=CMDP,          USAGE=A5,$
          FIELD=DD_SORT_CD,     ALIAS=DDSC,          USAGE=A2,    FIELDTYPE=I,$
          FIELD=PROG_ELE,       ALIAS=PE,            USAGE=A6,$
          FIELD=PROJECT_DESC,   ALIAS=PDES,          USAGE=A26,$
          FIELD=CURR_SCOPE,     ALIAS=SCOPE_C,       USAGE=I9C,$
          FIELD=ORI_SCOPE,      ALIAS=SCOPE_O,       USAGE=I9C,$
          FIELD=TYPE_FUNDS,     ALIAS=TF,            USAGE=A1,$
          FIELD=MISSION,        ALIAS=,              USAGE=A1,$
          FIELD=TEMP_PN,        ALIAS=TPN,           USAGE=A7,$
          FIELD=PERM_PN,        ALIAS=PPN,           USAGE=A7,$
2         FIELD=MAIN_FILLER,    ALIAS=FILL1,         USAGE=A3,$
          FIELD=RKEY,           ALIAS=,              USAGE=A8,$
          FIELD=MOB_GROUP,      ALIAS=MOB_GP,        USAGE=A1,$
,$   ********************************************************************************
     SEGNAME=ZCPPFILE, PARENT=MAIN, SEGTYPE=U,$
          FIELD=PROGRAM_YEAR,   ALIAS=APYR,          USAGE=A2,$
          FIELD=AUTH_YR,        ALIAS=AUYR,          USAGE=A2,$
          FIELD=AUS,            ALIAS=AUTH_SUP,      USAGE=A2,$
          FIELD=CAPY,           ALIAS=CONG_APRV_YR,  USAGE=A2,$
          FIELD=APS,            ALIAS=APPROP_SUP,    USAGE=A2,$
          FIELD=PEYR,           ALIAS=PROG_EXEC_YR,  USAGE=A2,$
          FIELD=BUDGET_ACT,     ALIAS=BA,            USAGE=A13,$
          FIELD=MPRO_RCD_DT,    ALIAS=MPRO_DT,       USAGE=I6YMTD,$
          FIELD=MPRO_APD_BY,    ALIAS=MPRO_AB,       USAGE=A1,$
          FIELD=MPRO_APD_DT,    ALIAS=,              USAGE=I6YMTD,$
          FIELD=SUB,            ALIAS=,              USAGE=A1,$
          FIELD=UM,             ALIAS=UNIT_OF_MEA,   USAGE=A2,$
          FIELD=REMARK_2,       ALIAS=ZCPP_REM2,     USAGE=A60,$
          FIELD=REMARK_4,       ALIAS=ZCPP_REM4,     USAGE=A30,$
          FIELD=PROG_AMT,       ALIAS=PA,            USAGE=I8C,$
          FIELD=DATEPA,         ALIAS=DT_PA_CHG,     USAGE=I6YMDT,$
          FIELD=AUTH_AMT,       ALIAS=AA,            USAGE=I8C,$
          FIELD=APPROP_AMT,     ALIAS=APPA,          USAGE=I8C,$
          FIELD=PA_DES_COST,    ALIAS=,              USAGE=I8C,$
          FIELD=PUB_LAW_CD,     ALIAS=PLCD,          USAGE=A4,$
          FIELD=CON_DIR_AMT,    ALIAS=CON_AMT,       USAGE=D13.2,$
          FIELD=CON_STD,        ALIAS=,              USAGE=A1,$
          FIELD=REPLACE_CODE,   ALIAS=RC,            USAGE=A1,$
          FIELD=2807C,          ALIAS=2807_CONG_DT,  USAGE=I6YMTD,$
          FIELD=2807O,          ALIAS=2807_OSD_DT,   USAGE=I6YMTD,$
          FIELD=2807RQ,         ALIAS=2807_RQ,       USAGE=A1,$
          FIELD=DES_DIR_AMT,    ALIAS=DES_AMT,       USAGE=D13.2,$
          FIELD=DES_DISTR_CD,   ALIAS=,              USAGE=A2,$
          FIELD=EXEC_STATUS,    ALIAS=EXSTS,         USAGE=A1,$
          FIELD=CMD_PN,         ALIAS=CPN,           USAGE=A15,$
```

```
        FIELD=AR525_CODE,    ALIAS=CMTY_CD,       USAGE=A5,$
        FIELD=SORT1,         ALIAS=S1,            USAGE=A3,$
        FIELD=SORT2,         ALIAS=S2,            USAGE=A3,$
        FIELD=ZCP_X1,        ALIAS=ZX1,           USAGE=A1,$
        FIELD=ZCP_X2,        ALIAS=ZX2,           USAGE=A1,$
        FIELD=ZCP_X3,        ALIAS=ZX3,           USAGE=A2,$
        FIELD=ZCP_X4,        ALIAS=ZX4,           USAGE=A3,$
        FIELD=FN1,           ALIAS=FOOTNOTE1,     USAGE=A1,$
        FIELD=FN2,           ALIAS=EA,            USAGE=A1,$
        FIELD=FN3,           ALIAS=FOOTNOTE3,     USAGE=A1,$
        FIELD=SPN,           ALIAS=SHORTPN,       USAGE=A8,$
        FIELD=PAGE1391,      ALIAS=GRBK_1391PG,   USAGE=A4,$
        FIELD=INDXPAGE,      ALIAS=,              USAGE=A4,$
        FIELD=SFT,           ALIAS=SUBFUNDTYPE,   USAGE=A2,$
        FIELD=REMARKA,       ALIAS=RMKA,          USAGE=A10,$
        FIELD=REMARKB,       ALIAS=RMKB,          USAGE=A10,$
        FIELD=REMARKC,       ALIAS=RMKC,          USAGE=A10,$
        FIELD=PCA,           ALIAS=PREVCONGAUTH,  USAGE=A2,$
        FIELD=CACTION,       ALIAS=CONGACTION,    USAGE=A60,$
        FIELD=DRCN,          ALIAS=DES_CN_NO1,    USAGE=A3,$
        FIELD=DRCN2,         ALIAS=DES_CN_NO2,    USAGE=A3,$
        FIELD=CHGSW,         ALIAS=CHANGE_SW,     USAGE=A6,    FIELDTYPE=I,$
        FIELD=ZCPP_FILLER,   ALIAS=FILL2,         USAGE=A1,$
,$  ************************************************************************
    SEGNAME=ZCP2FILE,  PARENT=MAIN,  SEGTYPE=U,$
        FIELD=ZRD,           ALIAS=ZCP2_REF_DT,   USAGE=I6YMTD,$
        FIELD=CURR_1391_DT,  ALIAS=1391_DT,       USAGE=I6YMTD,$
        FIELD=1391_DT_DIST,  ALIAS=1391_DIST,     USAGE=I6YMTD,$
        FIELD=1391_OK,       ALIAS=,              USAGE=A1,$
        FIELD=FORMNO,        ALIAS=FNO,           USAGE=A7,    FIELDTYPE=I,$
        FIELD=PROCPA,        ALIAS=PROCESS_COST,  USAGE=I8C,$
        FIELD=CONTROL_CODE,  ALIAS=CNTRC,         USAGE=A1,$
        FIELD=PROCFY,        ALIAS=,              USAGE=A4,$
        FIELD=COMPONENT,     ALIAS=COMPT,         USAGE=A4,$
        FIELD=ZCP2_FILLER,   ALIAS=FILL3,         USAGE=A3,$
        FIELD=MOBPRI,        ALIAS=DA_PRI,        USAGE=A5,$
        FIELD=MOB_DIST,      ALIAS=,              USAGE=A2,$
        FIELD=LSD,           ALIAS=LATE_ST_DT,    USAGE=A5,$
        FIELD=ROD,           ALIAS=ROD_OCP_DT,    USAGE=A5,$
        FIELD=FILL11,        ALIAS=MOB_FILLER,    USAGE=A2,$
,$  ************************************************************************
    SEGNAME=ZCP3FILE,  PARENT=MAIN,  SEGTYPE=U,$
        FIELD=LONG_DESC,     ALIAS=LDESC,         USAGE=A42,$
        FIELD=AUTH_REQ,      ALIAS=REQAUTH,       USAGE=I8C,$
        FIELD=APPR_REQ,      ALIAS=REQAPPR,       USAGE=I8C,$
        FIELD=AUTH_CODE,     ALIAS=AUTHCD,        USAGE=A1,$
        FIELD=APPR_CODE,     ALIAS=APPRCD,        USAGE=A1,$
        FIELD=OSD_NOTE,      ALIAS=OSDN,          USAGE=A25,$
        FIELD=ARMY_REQ,      ALIAS=ARMQ,          USAGE=I8C,$
        FIELD=SASCAUTH,      ALIAS=SAUTH,         USAGE=I8C,$
        FIELD=HASCAUTH,      ALIAS=HAUTH,         USAGE=I8C,$
        FIELD=SAC_APPR,      ALIAS=SAPPR,         USAGE=I8C,$
        FIELD=HAC_APPR,      ALIAS=HAPPR,         USAGE=I8C,$
        FIELD=CONFAUTH,      ALIAS=CAUTH,         USAGE=I8C,$
        FIELD=CONFAPPR,      ALIAS=CAPPR,         USAGE=I8C,$
        FIELD=AMT1,          ALIAS=,              USAGE=I8C,$
        FIELD=AMT2,          ALIAS=,              USAGE=I8C,$
        FIELD=AMT3,          ALIAS=,              USAGE=I8C,$
        FIELD=AMT4,          ALIAS=,              USAGE=I8C,$
        FIELD=ZCP3_FILLER,   ALIAS=FILL4,         USAGE=A3,$
,$  ************************************************************************
    SEGNAME=AMPERS1, PARENT=MAIN, SEGTYPE=U,$
        FIELD=DES_PERCENT,   ALIAS=DES_%,         USAGE=A3,$
        FIELD=CWE_AMT,       ALIAS=CWE,           USAGE=I8C,$
        FIELD=CONCOM_DT,     ALIAS=CONCEPT,       USAGE=I6YMTD,$
        FIELD=DES_COMP_DT,   ALIAS=,              USAGE=I6YMTD,$
        FIELD=DES_ST_DT,     ALIAS=DES_SD,        USAGE=I6YMTD,$
        FIELD=AMPER_FILLER,  ALIAS=FILL6,         USAGE=A1,$

,$  ************************************************************************
```

```
SEGNAME=ACEFILE, PARENT=MAIN, SEGTYPE=U,$
    FIELD=CRRC,          ALIAS=,              USAGE=A1,$
    FIELD=LEVEL,         ALIAS=,              USAGE=A1,$
    FIELD=ACE_PA,        ALIAS=APROJA,        USAGE=I8C,$
    FIELD=PA_DATE,       ALIAS=DATE_PA_CHG,   USAGE=I6YMTD,$
    FIELD=PROP,          ALIAS=PROPONENT,     USAGE=A3,$
    FIELD=ACEWORK1,      ALIAS=AWK1,          USAGE=A4,$
    FIELD=ACEWORK2,      ALIAS=AWK2,          USAGE=A6,$
    FIELD=ACEWORK3,      ALIAS=AWK3,          USAGE=A3,$
    FIELD=ACEPRB_PRI,    ALIAS=,              USAGE=A4,$
    FIELD=REMARK_1,      ALIAS=ACE_REM,       USAGE=A60,$
    FIELD=ZB,            ALIAS=ZERO_BUDG,     USAGE=A2,    FIELDTYPE=I,$
    FIELD=CRRC_DATE,     ALIAS=CRD,           USAGE=I6YMTD,$
    FIELD=ACE_PY,        ALIAS=,              USAGE=A2,    FIELDTYPE=I,$
    FIELD=PY_DATE,       ALIAS=DATE_PY_CHG,   USAGE=I6YMTD,$
    FIELD=ACE_CMD_PRI,   ALIAS=ACMDP,         USAGE=A5,$
    FIELD=ACE_D_REL,     ALIAS=ACEDR,         USAGE=I6YMTD,$
    FIELD=ACE_DCD,       ALIAS=,              USAGE=A1,$
    FIELD=ZDTCD1,        ALIAS=ZCD1,          USAGE=I6YMDT,$
    FIELD=ZDTCD2,        ALIAS=ZCD2,          USAGE=I6YMDT,$
    FIELD=ZDTCD4,        ALIAS=ZCD4,          USAGE=I6YMDT,$
    FIELD=ZDTCD5,        ALIAS=ZCD5,          USAGE=I6YMDT,$
    FIELD=ZDTCD6,        ALIAS=ZCD6,          USAGE=I6YMDT,$
    FIELD=ZDTCD8,        ALIAS=ZCD8,          USAGE=I6YMDT,$
    FIELD=ZDTCD9,        ALIAS=ZCD9,          USAGE=I6YMDT,$
    FIELD=PROP_PRIOR,    ALIAS=P_PRI,         USAGE=A4,$
    FIELD=CRRC_PRIOR,    ALIAS=CRRC_PRI,      USAGE=A4,$
,$  ********************************************************************************
    SEGNAME=MPCAFILE, PARENT=MAIN, SEGTYPE=U,$
    FIELD=EX_AWARD_DT,   ALIAS=CONST_AW_DT,   USAGE=I6YMTD,$
    FIELD=EXEC_CODE,     ALIAS=,              USAGE=A1,$
    FIELD=MPCA_REM,      ALIAS=REMARK_5,      USAGE=A30,$
    FIELD=REMARK_5A,     ALIAS=RMK5,          USAGE=A30,$
    FIELD=REMARK_6,      ALIAS=RMK6,          USAGE=A60,$
    FIELD=CDTCD1,        ALIAS=CD1,           USAGE=I6YMDT,$
    FIELD=CDTCD2,        ALIAS=CD2,           USAGE=I6YMDT,$
    FIELD=CDTCD4,        ALIAS=CD4,           USAGE=I6YMDT,$
    FIELD=CDTCD5,        ALIAS=CD5,           USAGE=I6YMDT,$
    FIELD=CDTCD6,        ALIAS=CD6,           USAGE=I6YMDT,$
    FIELD=CDTCD8,        ALIAS=CD8,           USAGE=I6YMDT,$
    FIELD=CDTCD9,        ALIAS=CD9,           USAGE=I6YMDT,$
    FIELD=BIDOD,         ALIAS=BID_OPEN_DT,   USAGE=I6YMDT,$
    FIELD=NOBID,         ALIAS=NO_BIDDERS,    USAGE=I4,$
    FIELD=GOVT_EST,      ALIAS=GEST,          USAGE=I8C,$
    FIELD=LBID,          ALIAS=LOW_BID,       USAGE=I8C,$
    FIELD=HBID,          ALIAS=HIGH_BID,      USAGE=I8C,$
    FIELD=DIRCD,         ALIAS=ZCPP_DCD,      USAGE=A1,$
    FIELD=HL_DES,        ALIAS=IH_DES,        USAGE=A1,$
    FIELD=MPC_DCD,       ALIAS=,              USAGE=A1,$
    FIELD=CONS_COMP_DT,  ALIAS=CNCND,         USAGE=I6YMDT,$
    FIELD=BOD,           ALIAS=BEN_OCC_DT,    USAGE=I6YMDT,$
    FIELD=DES_DIR_DT,    ALIAS=DES_DR,        USAGE=I6YMTD,$
    FIELD=FORECAST,      ALIAS=FCST_AWD_DT,   USAGE=I6YMTD,$
    FIELD=AWD_CWE,       ALIAS=AWD_CWE_AMT,   USAGE=I8C,$
,$  ********************************************************************************
    SEGNAME=MPESFILE, PARENT=MAIN, SEGTYPE=U,$
    FIELD=EST_COST,      ALIAS=,              USAGE=I8C,$
    FIELD=SUPER_ADMIN,   ALIAS=SA,            USAGE=I8C,$
    FIELD=EST_DT,        ALIAS=,              USAGE=I6YMDT,$
    FIELD=PER_SA,        ALIAS=,              USAGE=F3.1,$
    FIELD=PROJ_COST_DT,  ALIAS=PCDT,          USAGE=I6YMTD,$
    FIELD=PROJ_COST,     ALIAS=PC,            USAGE=I8C,$
    FIELD=PROJ_COST_CD,  ALIAS=PCCD,          USAGE=A1,$
    FIELD=SOLAR,         ALIAS=,              USAGE=I8C,$
    FIELD=PDB_DT,        ALIAS=,              USAGE=I6YMTD,$
    FIELD=PDB_RDQ,       ALIAS=,              USAGE=A1,$
    FIELD=CAT_E_EQ,      ALIAS=CAT_E,         USAGE=I8C,$
    FIELD=PER_CONT,      ALIAS=PCONT,         USAGE=F4.1,$
    FIELD=CONT,          ALIAS=,              USAGE=I8C,$
    FIELD=PER_DSGN,      ALIAS=PDSN,          USAGE=F5.1,$
    FIELD=MPES_COMMENT,  ALIAS=MCOM,          USAGE=A20,$
```

```
     FIELD=MPES_FILLER,  ALIAS=FILL7,         USAGE=A2,$
,$   ********************************************************************************
     SEGNAME=MPENFILE, PARENT=MAIN, SEGTYPE=U,$
     FIELD=REMARK_3,     ALIAS=MPEN_REM,      USAGE=A60,$
     FIELD=DT_REL_CD1,   ALIAS=,              USAGE=I6YMTD,$
     FIELD=DT_REL_CD2,   ALIAS=,              USAGE=I6YMTD,$
     FIELD=DEI_DT,       ALIAS=,              USAGE=I6YMTD,$
     FIELD=MPEN_IND,     ALIAS=,              USAGE=A1,$
     FIELD=DEI_RQ,       ALIAS=,              USAGE=A1,$
     FIELD=MPEN_DCD,     ALIAS=MPED,          USAGE=A1,$
     FIELD=ENREVDT,      ALIAS=DT_REL_REV,    USAGE=I6YMDT,$
     FIELD=ENRN,         ALIAS=ENG_REV_NUM,   USAGE=A2,$
     FIELD=MPEN_FILLER,  ALIAS=FILL8,         USAGE=A3,$
,$   ********************************************************************************
     SEGNAME=SIGFILE, PARENT=MAIN, SEGTYPE=U,$
     FIELD=COM_COST,     ALIAS=,              USAGE=I9,$
     FIELD=COM_STAT,     ALIAS=,              USAGE=A3,$
     FIELD=COM_DATE,     ALIAS=,              USAGE=I6YMDT,$
     FIELD=TELER_NO,     ALIAS=TNO,           USAGE=A16,$
     FIELD=SIG_FILLER,   ALIAS=FILL9,         USAGE=A1,$
,$   ********************************************************************************
     SEGNAME=REPRFILE, PARENT=MAIN, SEGTYPE=S1,$
     FIELD=ZCP_PA_SPN,   ALIAS=ZSPN,          USAGE=A3,$
     FIELD=ZS_SDT,       ALIAS=,              USAGE=A12,$
     FIELD=ZS_REM,       ALIAS=,              USAGE=A26,$
     FIELD=ZS_PROG_AMT,  ALIAS=ZSPA,          USAGE=I8C,$
     FIELD=ZS_AUTH_AMT,  ALIAS=ZSAUA,         USAGE=I8C,$
     FIELD=ZS_APPR_AMT,  ALIAS=ZSAPA,         USAGE=I8C,$
     FIELD=REPR_FILLER,  ALIAS=FILL10,        USAGE=A3,$
,$   ********************************************************************************
     SEGNAME=SUBPFILE, PARENT=MAIN, SEGTYPE=S1,$
     FIELD=AMPRS_SPN,    ALIAS=,              USAGE=A3,$
     FIELD=SUBAMT,       ALIAS=,              USAGE=I8C,$
     FIELD=SUBEXYR,      ALIAS=,              USAGE=A4,$
     FIELD=SUB_UNIT_MEA, ALIAS=SUB_UM,        USAGE=A2,$
     FIELD=SUBSCOPE,     ALIAS=,              USAGE=I7C,$
     FIELD=SUBITEM_DESC, ALIAS=SDESC,         USAGE=A26,$
     FIELD=SUB_CONTR,    ALIAS=,              USAGE=A1,$
     FIELD=SUB_REM,      ALIAS=,              USAGE=A20,$
     FIELD=SCH_AWARD_DT, ALIAS=SUBAWD_DTSCH,  USAGE=I6YMTD,$
     FIELD=SUB_AWARD_DT, ALIAS=SUBAWD_DTACT,  USAGE=I6YMTD,$
     FIELD=SUBCAD,       ALIAS=SCON_AW_DT,    USAGE=I6YMTD,$
     FIELD=SUBBOD,       ALIAS=SBEN_OCC_DT,   USAGE=I6YMTD,$
     FIELD=SUBBIDOD,     ALIAS=SBID_OP_DT,    USAGE=I6YMTD,$
     FIELD=SUBNOBID,     ALIAS=SNO_BIDDERS,   USAGE=I4,$
     FIELD=SUBGEST,      ALIAS=SGOVT_EST,     USAGE=I8C,$
     FIELD=SUBLBID,      ALIAS=SLOW_BID,      USAGE=I8C,$
     FIELD=SUBHBID,      ALIAS=SUB_HIGH_BID,  USAGE=I8C,$
     FIELD=SAWD_CWE,     ALIAS=SUBAWD_CWE,    USAGE=I8C,$
     ********************************************************************************
     SEGNAME=MACOMSEG, PARENT=MAIN, SEGTYPE=U,$
     FIELD=MTPN,         ALIAS=M_TEMP_PN,     USAGE=A7,$
     FIELD=MPDES,        ALIAS=M_PROJ_DESC,   USAGE=A26,$
     FIELD=MFY,          ALIAS=M_FISCAL_YEAR, USAGE=A2,$
     FIELD=MOUS,         ALIAS=M_ORIG_US_SV,  USAGE=A2,$
     FIELD=MCATCD5,      ALIAS=M_CATCODE,     USAGE=A5,$
     FIELD=MPRI,         ALIAS=,              USAGE=A5,$
     FIELD=MDDSORT,      ALIAS=M_SORT_CODE,   USAGE=A2,$
     FIELD=MPE,          ALIAS=M_PROG_ELE,    USAGE=A6,$
     FIELD=MSCOPE,       ALIAS=M_SCOPE,       USAGE=I9C,$
     FIELD=MTF,          ALIAS=M_TYPE_FUNDS,  USAGE=A1,$
     FIELD=MMISSION,     ALIAS=M_MISSION,     USAGE=A1,$
     FIELD=MPA,          ALIAS=M_PROG_AMT,    USAGE=I8C,$
     FIELD=MCONS,        ALIAS=M_CONS_TYPE,   USAGE=A1,$
     FIELD=MRC,          ALIAS=M_REPLACE_CD,  USAGE=A1,$
     FIELD=MINCODE,      ALIAS=M_INCODE,      USAGE=A5,$
     FIELD=MPDIP,        ALIAS=M_PDIP,        USAGE=A4,$
     FIELD=MPDIPNAME,    ALIAS=MNAME,         USAGE=A6,$
     FIELD=MPRCD,        ALIAS=M_PR_CODE,     USAGE=A2,$
     FIELD=MRMKI,        ALIAS=M_REMARK,      USAGE=A120,$
     FIELD=MSDTC,        ALIAS=MSYS_DT_TIME,  USAGE=A12,$
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        FIELD=MPRISDTG,      ALIAS=MPRISYSDT,     USAGE=A12,$
        FIELD=MPASDTG,       ALIAS=MPASYSDT,      USAGE=A12,$
        FIELD=MFNO,          ALIAS=MFORMNO,       USAGE=A7,$
        FIELD=MMOBGP,        ALIAS=MMOB_GROUP,    USAGE=A1,$
        FIELD=MMPRI,         ALIAS=MMOBPRI,       USAGE=A5,$
        FIELD=MOBPRISDTG,    ALIAS=MOBSDT,        USAGE=A12,$
        FIELD=MLSD,          ALIAS=MLATE_ST_DT,   USAGE=A5,$
        FIELD=MROD,          ALIAS=MRQD_OCP_DT,   USAGE=A5,$
        FIELD=MTIER,         ALIAS=MACOMTIER,     USAGE=A1,$
        FIELD=OMPRI,         ALIAS=OTHERMPRI,     USAGE=A5,$
,$ ********************************************************************************
     SEGNAME=HISTZCP1, PARENT=MAIN,      SEGTYPE=SH1,$
        FIELD=HIS_ZCP1_DT,   ALIAS=,              USAGE=I6YMTD,$
        FIELD=HIS_PROG_AMT,  ALIAS=,              USAGE=I8C,$
,$ ********************************************************************************
     SEGNAME=HISTZCP2, PARENT=MAIN,      SEGTYPE=SH1,$
        FIELD=HIS_ZCP2_DT,   ALIAS=,              USAGE=I6YMTD, $
        FIELD=HIS_ZCP_DR,    ALIAS=,              USAGE=I6YMTD, $
        FIELD=HIS_ZCP_DCD,   ALIAS=,              USAGE=A1,     $
        FIELD=HZP2_FILLER,   ALIAS=FILL12,        USAGE=A3,$
,$ ********************************************************************************
     SEGNAME=HISTZCP3, PARENT=MAIN,      SEGTYPE=SH1,$
        FIELD=HIS_ZCP3_DT,   ALIAS=,              USAGE=I6YMTD, $
        FIELD=HIS_2807_CNG,ALIAS=,               USAGE=I6YMTD, $
        FIELD=HIS_2807_OSD,  ALIAS=,              USAGE=I6YMTD, $
        FIELD=HIS_2807_RQ,   ALIAS=,              USAGE=A1,     $
        FIELD=HZP3_FILLER,   ALIAS=FILL13,        USAGE=A3,$
,$ ********************************************************************************
     SEGNAME=HISTZCP4,    PARENT=MAIN,      SEGTYPE=SH1,$
        FIELD=HIS_ZCP4_DT,   ALIAS=,              USAGE=I6YMTD, $
        FIELD=HIS_1391_REC,  ALIAS=,              USAGE=I6YMTD, $
        FIELD=HIS_1391_DIS,  ALIAS=,              USAGE=I6YMTD, $
        FIELD=HIS_1391_OK,   ALIAS=,              USAGE=A1,     $
        FIELD=HZP4_FILLER,   ALIAS=FILL14,        USAGE=A3,$
,$ ********************************************************************************
     SEGNAME=HISTZCP5, PARENT=MAIN,      SEGTYPE=SH1,$
        FIELD=HIS_ZCP5_DT,   ALIAS=,              USAGE=I6YMTD, $
        FIELD=HIS_DSE_SD,    ALIAS=,              USAGE=I6YMTD, $
,$ ********************************************************************************
     SEGNAME=HISTACE1, SEGTYPE=SH1, PARENT=MAIN,  $
        FIELD=HATRANS,       ALIAS=ACE1TRANS,     USAGE=I6YMTD, $
        FIELD=HKN,           ALIAS=HISKEYNR,      USAGE=A13,$
        FIELD=HACTDR,        ALIAS=ACTDR,         USAGE=I6YMDT,$
        FIELD=HACEDR,        ALIAS=HISACEDR,      USAGE=I6YMTD, $
        FIELD=HACEDCD,       ALIAS=HISACEDCD,     USAGE=A1,     $
        FIELD=HPA,           ALIAS=HISPADES,      USAGE=I8C,$
        FIELD=HFY,           ALIAS=HISFYDES,      USAGE=A2,$
        FIELD=HSCP,          ALIAS=HISSCOPEDES,   USAGE=I9C,$
        FIELD=HPFY,          ALIAS=HISPCFY,       USAGE=A2,$
        FIELD=HDTFY,         ALIAS=HISDATEFY,     USAGE=I6YMDT,$
        FIELD=HDTPA,         ALIAS=HISDATEPA,     USAGE=I6YMDT,$
        FIELD=HODRCN,        ALIAS=HISOLDDRCN,    USAGE=A3,$
        FIELD=HNDRCN,        ALIAS=HISNEWDRCN,    USAGE=A3,$
        FIELD=HPDRCN,        ALIAS=HISPREDRCN,    USAGE=A3,$
        FIELD=HACEFILLER,    ALIAS=FILL15,        USAGE=A1,$
,$ ********************************************************************************
     SEGNAME=HISTMPES, SEGTYPE=SH1, PARENT=MAIN, $
        FIELD=HIS_MPES_DT,   ALIAS=,              USAGE=I6YMTD, $
        FIELD=HIS_CST_DT,    ALIAS=,              USAGE=I6YMTD, $
        FIELD=HIS_PRJ_CST,   ALIAS=,              USAGE=I8C,    $
        FIELD=HIS_CST_CD,    ALIAS=,              USAGE=A1,     $
        FIELD=HIS_SOLAR,     ALIAS=,              USAGE=I8C,    $
        FIELD=HMPS_FILLER,   ALIAS=FILL16,        USAGE=A3,$
,$ ********************************************************************************
     SEGNAME=HISTMPE1, SEGTYPE=SH1, PARENT=MAIN,  $
        FIELD=HIS_MPE1_DT,   ALIAS=,              USAGE=I6YMTD, $
        FIELD=HIS_MPE_DR,    ALIAS=,              USAGE=I6YMTD, $
        FIELD=HIS_DEI_DT,    ALIAS=,              USAGE=I6YMTD, $
        FIELD=HIS_DEI_RQ,    ALIAS=,              USAGE=A1,     $
        FIELD=HIS_MPE_DCD,   ALIAS=,              USAGE=A1,     $
        FIELD=HISENREVDT,    ALIAS=,              USAGE=I6YMDT,$
```
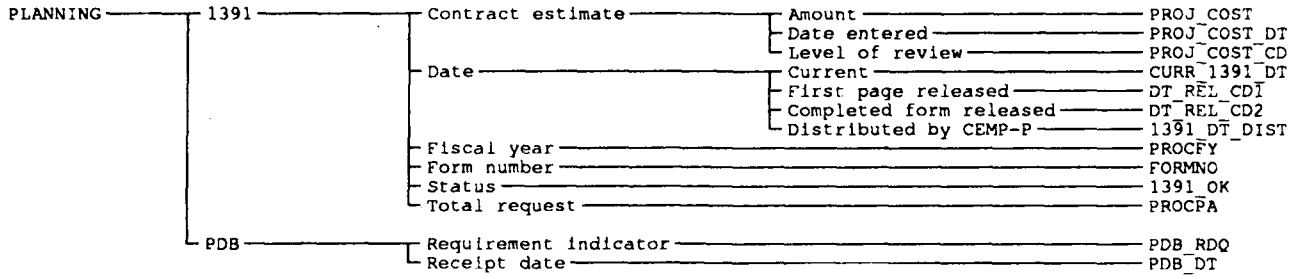
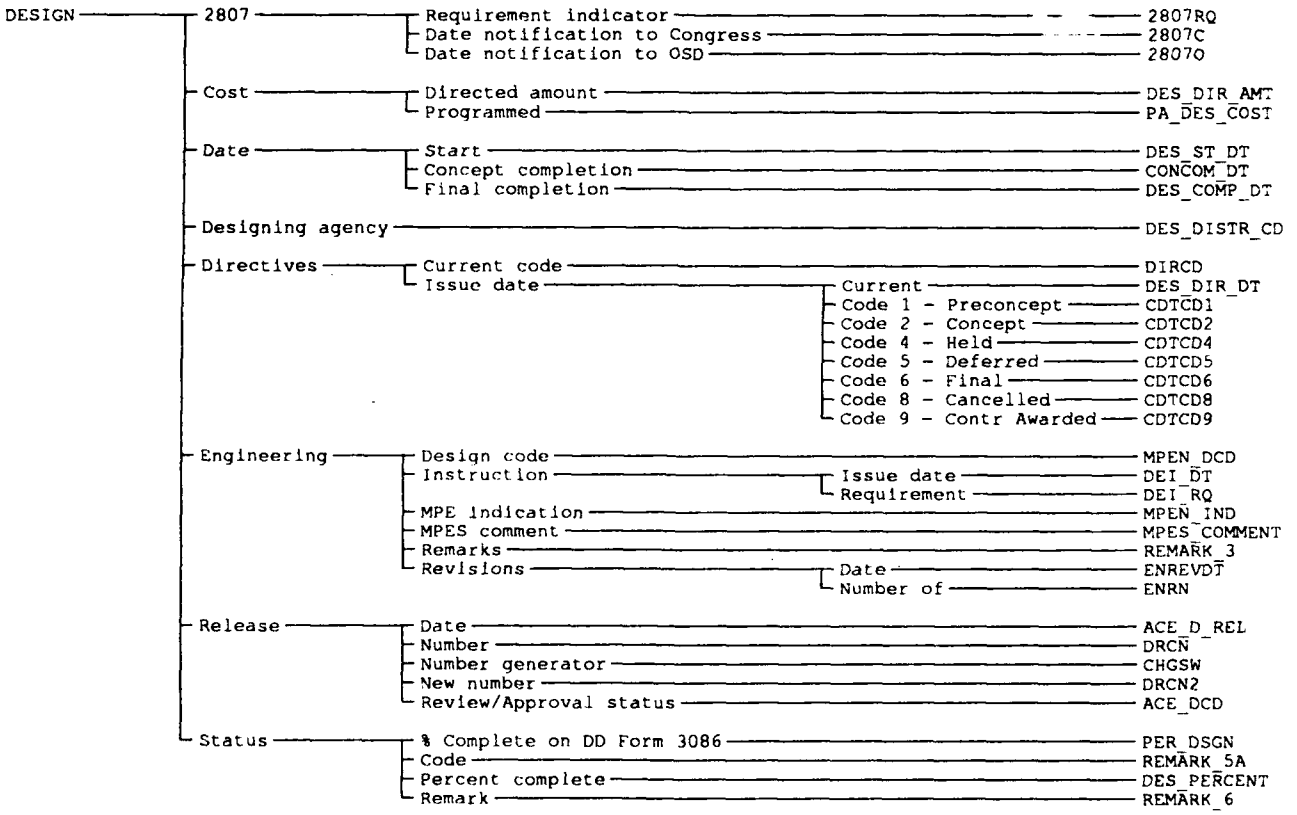
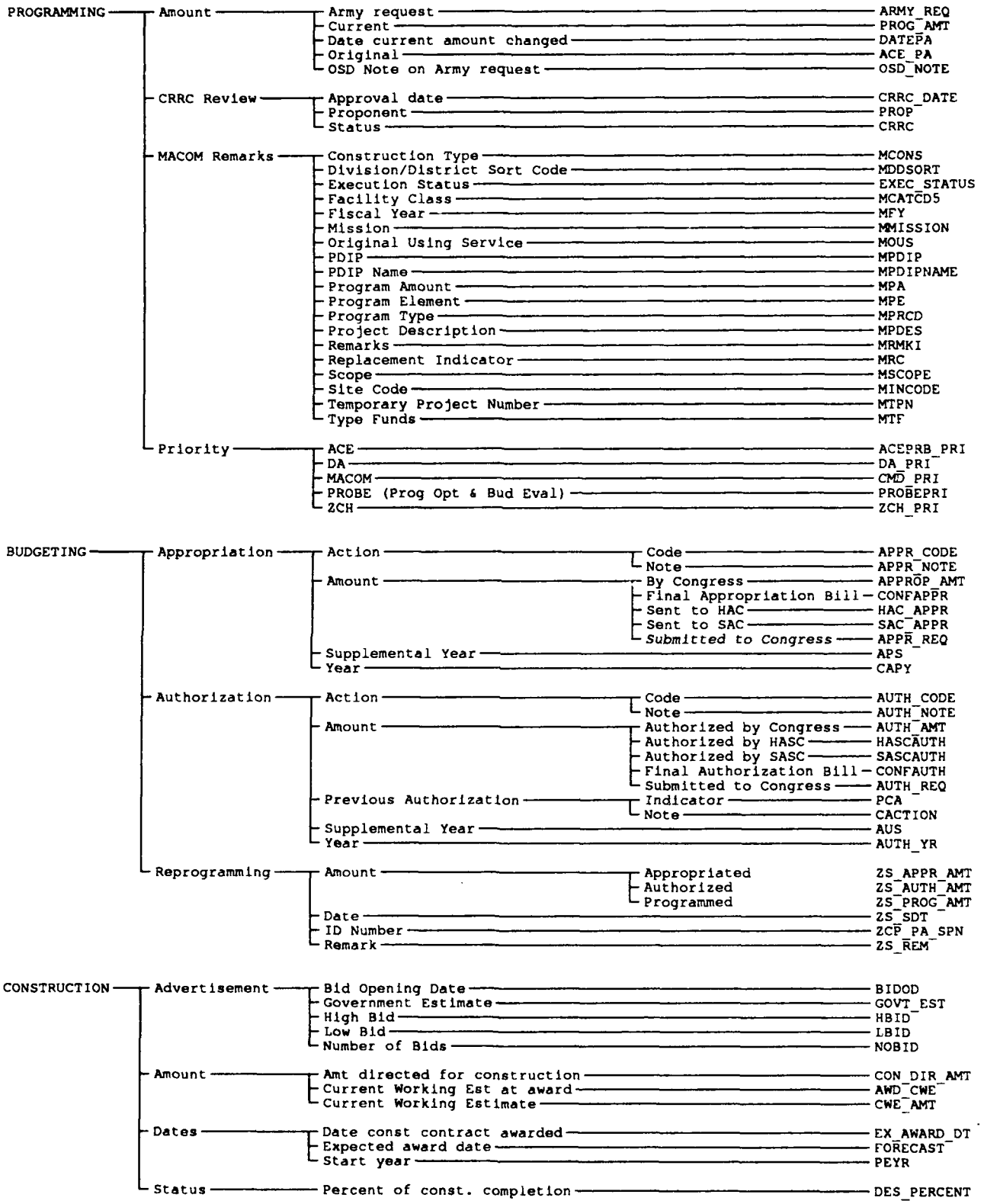
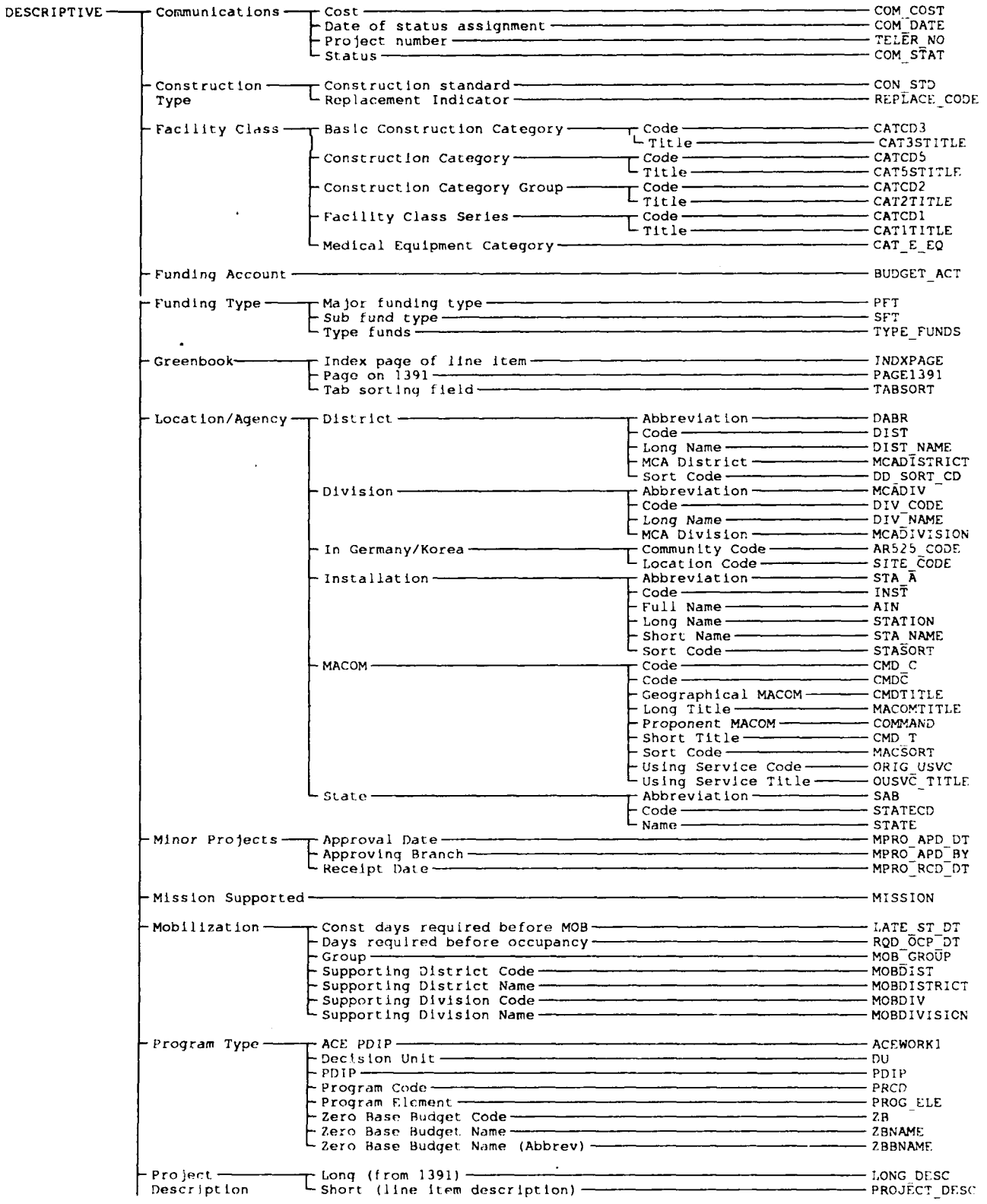

```
        FIELD=HISENRN,      ALIAS=,             USAGE=A2,$
,$  ********************************************************************************
     SEGNAME=HISTMPC1, SEGTYPE=SH1, PARENT=MAIN,  $
        FIELD=HIS_MPC1_DT,  ALIAS=,             USAGE=I6YMTD, $
        FIELD=HIS_DES_DD,   ALIAS=,             USAGE=I6YMTD, $
        FIELD=HIS_MPC_DCD,  ALIAS=,             USAGE=A1,     $
        FIELD=HMPC_FILLER,  ALIAS=FILL18,       USAGE=A3,$
,$  ********************************************************************************
     SEGNAME=HISTMPC2, SEGTYPE=SH1, PARENT=MAIN,  $
        FIELD=HIS_MPC2_DT,  ALIAS=,             USAGE=I6YMTD, $
        FIELD=HIS_CONCOM,   ALIAS=,             USAGE=I6YMTD, $
        FIELD=HIS_DES_AMT,  ALIAS=,             USAGE=I6C,     $
,$  ********************************************************************************
     SEGNAME=HISTLVL, PARENT=MAIN, SEGTYPE=SH1,$
        FIELD=HIS_DT_LVL,   ALIAS=,             USAGE=I6YMTD,$
        FIELD=HIS_LVL,      ALIAS=,             USAGE=A1,$
        FIELD=HLVL_FILLER,  ALIAS=FILL19,       USAGE=A3,$
,$  ********************************************************************************
     SEGNAME=HISTCFY, PARENT=MAIN, SEGTYPE=SH1,$
        FIELD=HIS_DT_CFY,   ALIAS=,             USAGE=I6YMTD,$
        FIELD=HIS_CFY,      ALIAS=,             USAGE=A4,$

,$   ********************************************************************************
,$   *****************          THE FOLLOWING ARE TABLES
,$   ********************************************************************************
  SEGNAME=COM2SEG, PARENT=MAIN, SEGTYPE=KU, CRFILE=COM2TBL, CRKEY=ORIG_USVC,$
  SEGNAME=SITESEG, PARENT=MAIN, SEGTYPE=KU, CRFILE=AR405TBL, CRKEY=SITE_CODE,$
  SEGNAME=CATSEG, PARENT=MAIN, SEGTYPE=KU, CRFILE=CATTBL, CRKEY=CATCD5,$
  SEGNAME=CAT3DESC, PARENT=CATSEG, SEGTYPE=KM, CRFILE=CATDETBL,$
  SEGNAME=DESCRSEG, PARENT=CAT3DESC, SEGTYPE=KL, CRFILE=CATDETBL,$
  SEGNAME=DIVSEG, PARENT=MAIN, SEGTYPE=KU, CRFILE=DIVTBL, CRKEY=DD_SORT_CD,$
  SEGNAME=INSTSEG, PARENT=MAIN, SEGTYPE=KU, CRFILE=INSTTBL, CRKEY=INST,$
  SEGNAME=MACMSEG, PARENT=MAIN, SEGTYPE=KU, CRFILE=MACMTBL, CRKEY=CMDC,$
  SEGNAME=ZBDICSEG, PARENT=MAIN, SEGTYPE=KU, CRFILE=ZBDICTBL, CRKEY=ZB,$
  SEGNAME=AUTHSEG, PARENT=MAIN, SEGTYPE=KM, CRFILE=AUTHTBL, CRKEY=AUTH_CODE,$
  SEGNAME=NOTEAUTH, PARENT=AUTHSEG, SEGTYPE=KL, CRFILE=AUTHTBL,$
  SEGNAME=APPRSEG, PARENT=MAIN, SEGTYPE=KM, CRFILE=APPROTBL, CRKEY=APPR_CODE,$
  SEGNAME=NOTESEG, PARENT=APPRSEG, SEGTYPE=KL, CRFILE=APPROTBL,$
END
```

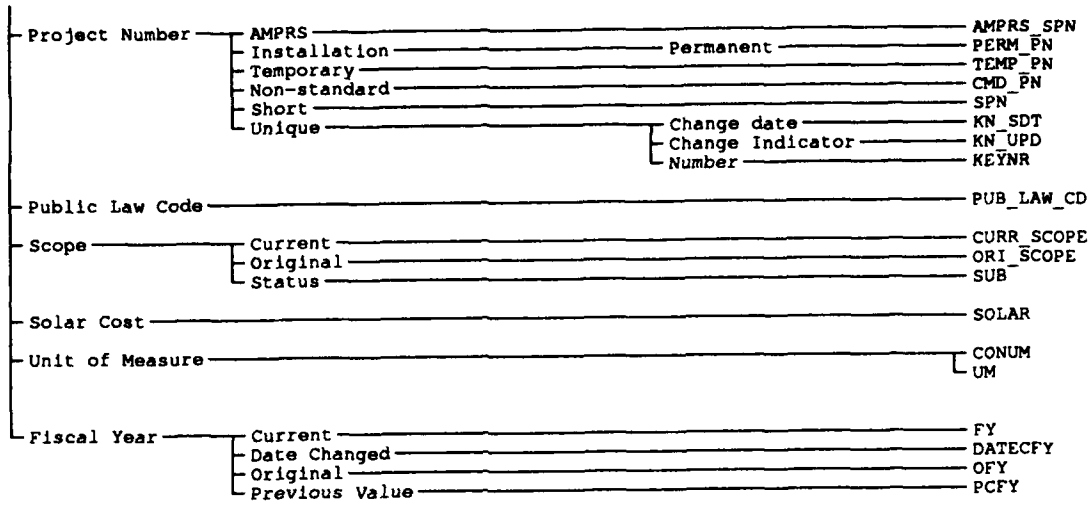
APPENDIX B: Map of CAPCES Data Elements by Functional Categories



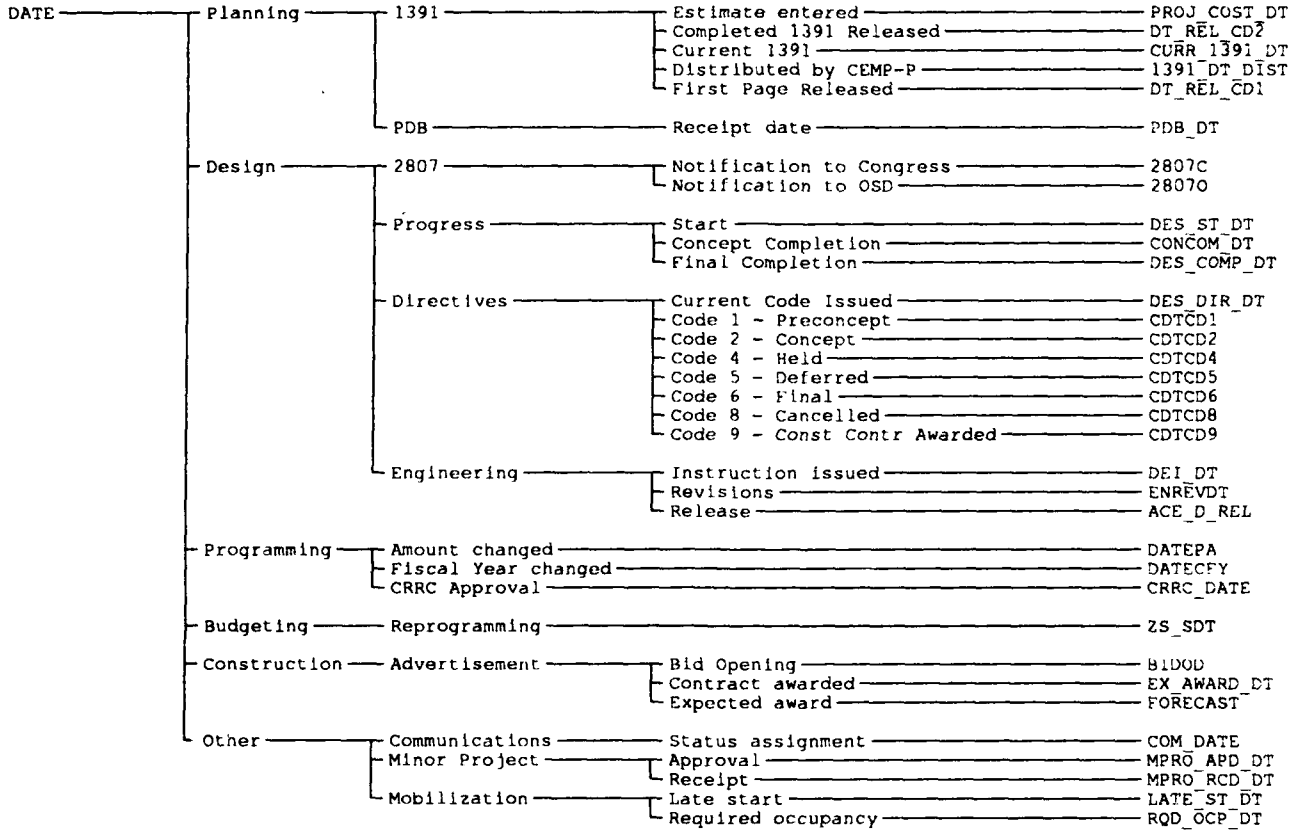


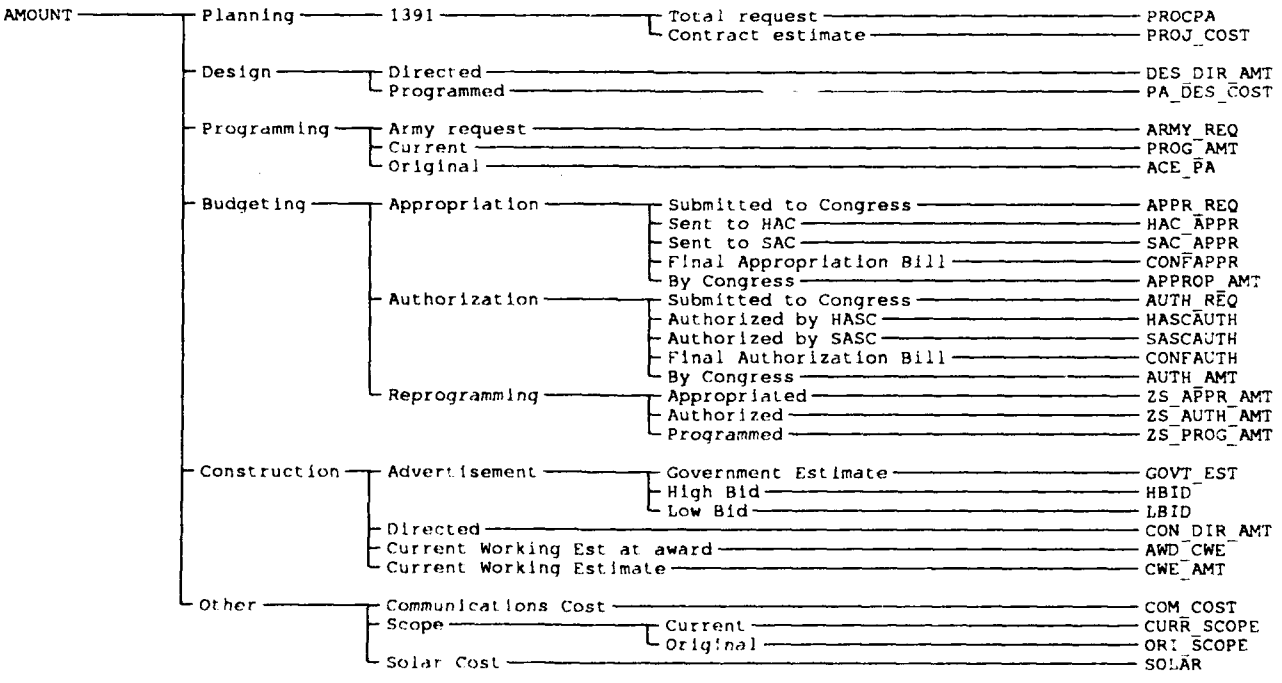

PROGRAMMING
Amount
Army request — ARMY_REQ
Current — PROG_AMT
Date current amount changed — DATEPA
Original — ACE_PA
OSD Note on Army request — OSD_NOTE
CRRC Review
Approval date — CRRC_DATE
Proponent — PROP
Status — CRRC
MACOM Remarks
Construction Type — MCONS
Division/District Sort Code — MDDSORT
Execution Status — EXEC_STATUS
Facility Class — MCATCD5
Fiscal Year — MFY
Mission — MMISSION
Original Using Service — MOUS
PDIP — MPDIP
PDIP Name — MPDIPNAME
Program Amount — MPA
Program Element — MPE
Program Type — MPRCD
Project Description — MPDES
Remarks — MRMKI
Replacement Indicator — MRC
Scope — MSCOPE
Site Code — MINCODE
Temporary Project Number — MTPN
Type Funds — MTF
Priority
ACE — ACEPRB_PRI
DA — DA_PRI
MACOM — CMD_PRI
PROBE (Prog Opt & Bud Eval) — PROBEPRI
ZCH — ZCH_PRI
BUDGETING
Appropriation
Action
Code — APPR_CODE
Note — APPR_NOTE
Amount
By Congress — APPROP_AMT
Final Appropriation Bill — CONFAPPR
Sent to HAC — HAC_APPR
Sent to SAC — SAC_APPR
Submitted to Congress — APPR_REQ
Supplemental Year — APS
Year — CAPY
Authorization
Action
Code — AUTH_CODE
Note — AUTH_NOTE
Amount
Authorized by Congress — AUTH_AMT
Authorized by HASC — HASCAUTH
Authorized by SASC — SASCAUTH
Final Authorization Bill — CONFAUTH
Submitted to Congress — AUTH_REQ
Previous Authorization
Indicator — PCA
Note — CACTION
Supplemental Year — AUS
Year — AUTH_YR
Reprogramming
Amount
Appropriated — ZS_APPR_AMT
Authorized — ZS_AUTH_AMT
Programmed — ZS_PROG_AMT
Date — ZS_SDT
ID Number — ZCP_PA_SPN
Remark — ZS_REM
CONSTRUCTION
Advertisement
Bid Opening Date — BIDOD
Government Estimate — GOVT_EST
High Bid — HBID
Low Bid — LBID
Number of Bids — NOBID
Amount
Amt directed for construction — CON_DIR_AMT
Current Working Est at award — AWD_CWE
Current Working Estimate — CWE_AMT
Dates
Date const contract awarded — EX_AWARD_DT
Expected award date — FORECAST
Start year — PEYR
Status
Percent of const. completion — DES_PERCENT

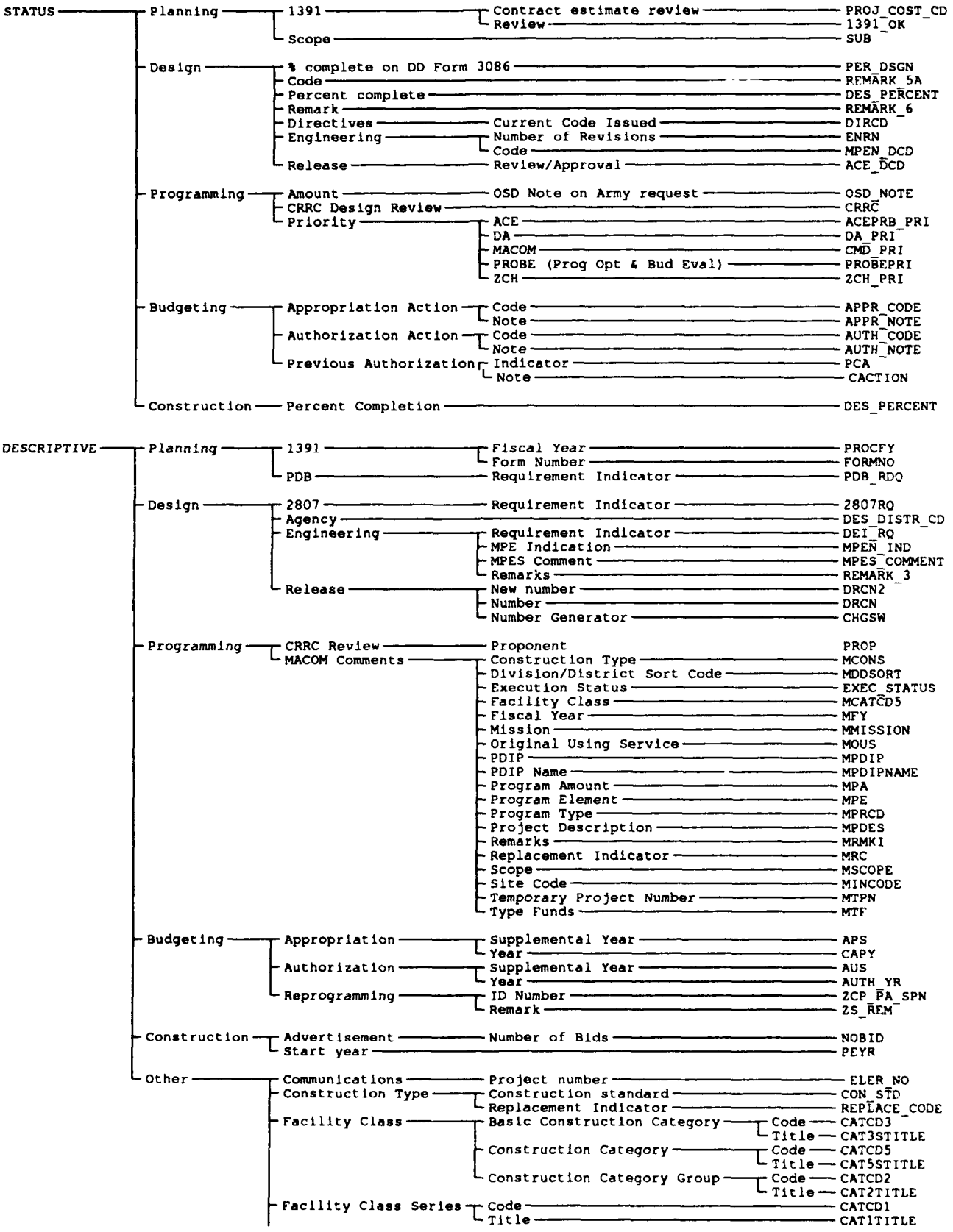

DESCRIPTIVE
Communications
Cost — COM_COST
Date of status assignment — COM_DATE
Project number — TELER_NO
Status — COM_STAT
Construction Type
Construction standard — CON_STD
Replacement Indicator — REPLACE_CODE
Facility Class
Basic Construction Category
Code — CATCD3
Title — CAT3STITLE
Construction Category
Code — CATCD5
Title — CAT5STITLE
Construction Category Group
Code — CATCD2
Title — CAT2TITLE
Facility Class Series
Code — CATCD1
Title — CAT1TITLE
Medical Equipment Category — CAT_E_EQ
Funding Account — BUDGET_ACT
Funding Type
Major funding type — PFT
Sub fund type — SFT
Type funds — TYPE_FUNDS
Greenbook
Index page of line item — INDXPAGE
Page on 1391 — PAGE1391
Tab sorting field — TABSORT
Location/Agency
District
Abbreviation — DABR
Code — DIST
Long Name — DIST_NAME
MCA District — MCADISTRICT
Sort Code — DD_SORT_CD
Division
Abbreviation — MCADIV
Code — DIV_CODE
Long Name — DIV_NAME
MCA Division — MCADIVISION
In Germany/Korea
Community Code — AR525_CODE
Location Code — SITE_CODE
Installation
Abbreviation — STA_A
Code — INST
Full Name — AIN
Long Name — STATION
Short Name — STA_NAME
Sort Code — STASORT
MACOM
Code — CMD_C
Code — CMDC
Geographical MACOM — CMDTITLE
Long Title — MACOMTITLE
Proponent MACOM — COMMAND
Short Title — CMD_T
Sort Code — MACSORT
Using Service Code — ORIG_USVC
Using Service Title — OUSVC_TITLE
State
Abbreviation — SAB
Code — STATECD
Name — STATE
Minor Projects
Approval Date — MPRO_APD_DT
Approving Branch — MPRO_APD_BY
Receipt Date — MPRO_RCD_DT
Mission Supported — MISSION
Mobilization
Const days required before MOB — LATE_ST_DT
Days required before occupancy — RQD_OCP_DT
Group — MOB_GROUP
Supporting District Code — MOBDIST
Supporting District Name — MOBDISTRICT
Supporting Division Code — MOBDIV
Supporting Division Name — MOBDIVISION
Program Type
ACE PDIP — ACEWORK1
Decision Unit — DU
PDIP — PDIP
Program Code — PRCD
Program Element — PROG_ELE
Zero Base Budget Code — ZB
Zero Base Budget Name — ZBNAME
Zero Base Budget Name (Abbrev) — ZBBNAME
Project Description
Long (from 1391) — LONG_DESC
Short (line item description) — PROJECT_DESC

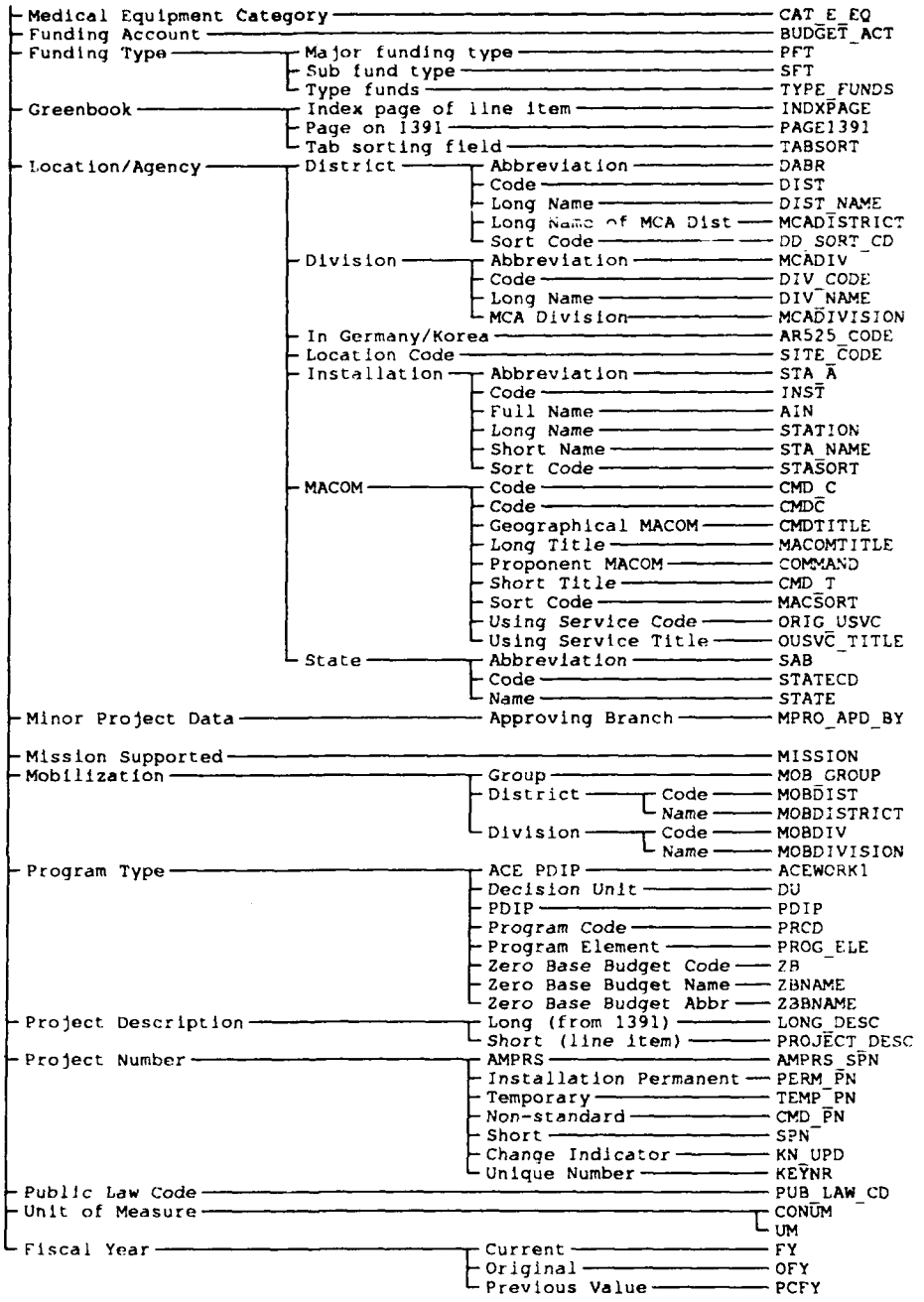

Project Number
AMPRS
Installation
Permanent
Temporary
Non-standard
Short
Unique
Change date
Change Indicator
Number
AMPRS_SPN
PERM_PN
TEMP_PN
CMD_PN
SPN
KN_SDT
KN_UPD
KEYNR
Public Law Code
PUB_LAW_CD
Scope
Current
Original
Status
CURR_SCOPE
ORI_SCOPE
SUB
Solar Cost
SOLAR
Unit of Measure
CONUM
UM
Fiscal Year
Current
Date Changed
Original
Previous Value
FY
DATECFY
OFY
PCFY

APPENDIX C: Map of CAPCES Data Elements by Information Type






STATUS
Planning
1391
Contract estimate review
PROJ_COST_CD
Review
1391_OK
Scope
SUB
Design
% complete on DD Form 3086
PER_DSGN
Code
REMARK_5A
Percent complete
DES_PERCENT
Remark
REMARK_6
Directives
Current Code Issued
DIRCD
Engineering
Number of Revisions
ENRN
Code
MPEN_DCD
Release
Review/Approval
ACE_DCD
Programming
Amount
OSD Note on Army request
OSD_NOTE
CRRC Design Review
CRRC
Priority
ACE
ACEPRB_PRI
DA
DA_PRI
MACOM
CMD_PRI
PROBE (Prog Opt & Bud Eval)
PROBEPRI
ZCH
ZCH_PRI
Budgeting
Appropriation Action
Code
APPR_CODE
Note
APPR_NOTE
Authorization Action
Code
AUTH_CODE
Note
AUTH_NOTE
Previous Authorization
Indicator
PCA
Note
CACTION
Construction
Percent Completion
DES_PERCENT
DESCRIPTIVE
Planning
1391
Fiscal Year
PROCFY
Form Number
FORMNO
PDB
Requirement Indicator
PDB_RDQ
Design
2807
Requirement Indicator
2807RQ
Agency
DES_DISTR_CD
Engineering
Requirement Indicator
DEI_RQ
MPE Indication
MPEN_IND
MPES Comment
MPES_COMMENT
Remarks
REMARK_3
Release
New number
DRCN2
Number
DRCN
Number Generator
CHGSW
Programming
CRRC Review
Proponent
PROP
MACOM Comments
Construction Type
MCONS
Division/District Sort Code
MDDSORT
Execution Status
EXEC_STATUS
Facility Class
MCATCD5
Fiscal Year
MFY
Mission
MMISSION
Original Using Service
MOUS
PDIP
MPDIP
PDIP Name
MPDIPNAME
Program Amount
MPA
Program Element
MPE
Program Type
MPRCD
Project Description
MPDES
Remarks
MRMKI
Replacement Indicator
MRC
Scope
MSCOPE
Site Code
MINCODE
Temporary Project Number
MTPN
Type Funds
MTF
Budgeting
Appropriation
Supplemental Year
APS
Year
CAPY
Authorization
Supplemental Year
AUS
Year
AUTH_YR
Reprogramming
ID Number
ZCP_PA_SPN
Remark
ZS_REM
Construction
Advertisement
Number of Bids
NOBID
Start year
PEYR
Other
Communications
Project number
ELER_NO
Construction Type
Construction standard
CON_STD
Replacement Indicator
REPLACE_CODE
Facility Class
Basic Construction Category
Code
CATCD3
Title
CAT3STITLE
Construction Category
Code
CATCD5
Title
CAT5STITLE
Construction Category Group
Code
CATCD2
Title
CAT2TITLE
Facility Class Series
Code
CATCD1
Title
CAT1TITLE


Medical Equipment Category — CAT_E_EQ
Funding Account — BUDGET_ACT
Funding Type
Major funding type — PFT
Sub fund type — SFT
Type funds — TYPE_FUNDS
Greenbook
Index page of line item — INDXPAGE
Page on 1391 — PAGE1391
Tab sorting field — TABSORT
Location/Agency
District
Abbreviation — DABR
Code — DIST
Long Name — DIST_NAME
Long Name of MCA Dist — MCADISTRICT
Sort Code — DD_SORT_CD
Division
Abbreviation — MCADIV
Code — DIV_CODE
Long Name — DIV_NAME
MCA Division — MCADIVISION
In Germany/Korea — AR525_CODE
Location Code — SITE_CODE
Installation
Abbreviation — STA_A
Code — INST
Full Name — AIN
Long Name — STATION
Short Name — STA_NAME
Sort Code — STASORT
MACOM
Code — CMD_C
Code — CMDC
Geographical MACOM — CMDTITLE
Long Title — MACOMTITLE
Proponent MACOM — COMMAND
Short Title — CMD_T
Sort Code — MACSORT
Using Service Code — ORIG_USVC
Using Service Title — OUSVC_TITLE
State
Abbreviation — SAB
Code — STATECD
Name — STATE
Minor Project Data
Approving Branch — MPRO_APD_BY
Mission Supported — MISSION
Mobilization
Group — MOB_GROUP
District
Code — MOBDIST
Name — MOBDISTRICT
Division
Code — MOBDIV
Name — MOBDIVISION
Program Type
ACE PDIP — ACEWORK1
Decision Unit — DU
PDIP — PDIP
Program Code — PRCD
Program Element — PROG_ELE
Zero Base Budget Code — ZB
Zero Base Budget Name — ZBNAME
Zero Base Budget Abbr — ZBBNAME
Project Description
Long (from 1391) — LONG_DESC
Short (line item) — PROJECT_DESC
Project Number
AMPRS — AMPRS_SPN
Installation Permanent — PERM_PN
Temporary — TEMP_PN
Non-standard — CMD_PN
Short — SPN
Change Indicator — KN_UPD
Unique Number — KEYNR
Public Law Code — PUB_LAW_CD
Unit of Measure
CONUM
UM
Fiscal Year
Current — FY
Original — OFY
Previous Value — PCFY

APPENDIX D: MCA Events and CAPCES Data Relationships

Event:	**MYPLAN Submission**
Event Date:	15 Dec (GY)
Activity #:	5,5a
Preceded by:	2,3,3a
Followed by:	6,6a
Associated fields:	CATCD5, CMD_PRI, CMDC, CON_STD, CURR_SCOPE, CWE_AMT, FORMNO, FY, INST, LSD, MISSION, MOB_GROUP, ORIG_USVC, PDIP, PERM_PN, PRCD, PROJECT_DESC, REPLACE_CODE, ROD, SITE_CODE, UB, TEMP_PN, TYPE_FUNDS, UM
Significant Values:	A nonblank value in the fields listed.
Note:	These are the fields that are submitted to CAPCES through the MYPLAN system. There is not a field that indicates the date this is done. The existence of a project in CAPCES indicates that it has occurred.

Event:	**1391 Submission**
Event Date:	1 Feb (GY)
Activity #:	7
Preceded by:	3,4
Followed by:	8,9
Associated fields:	CURR_1391_DT 1391_OK
Significant values:	A nonblank value in 1391_OK indicates that the form has been submitted. CURR_1391_DT changes everytime a revised form is submitted so it will not reflect the original submission date.

Event:	**PDB Submission**
Event Date:	1 Nov (GY) - 1 Feb (GY)
Activity #:	7
Preceded by:	4
Followed by:	8,9
Associated fields:	PDB_RDQ, PDB_DT
Significant values:	When PDB_RDQ is Y then a nonblank value in PDB_DT indicates the occurrance of this event.

Event:	**1391 Review**
Event Date:	1 Mar (GY) - 30 Apr (GY)
Activity #:	8,8a,9
Preceded by:	7
Followed by:	11,12
Associated fields:	1391_OK, DT_REL_CD1, DT_REL_CD2, CRRC
Significant values:	1391_OK indicates the status of the 1391. DT_REL_CD1 is the date that the first page is released by ECE-A for review by CRRC. DT_REL_CD2

is the date the the entire form is released for review. CRRC indicates the status of approval by CRRC.

Event: **CRRC formulates initial Army program, releases Code 1**
Event Date: 15 Jan (GY) - 30 May (GY)
Activity #: 10
Preceded by: 8,11
Followed by: 13,14,17
Associated fields: CRRC, ACE_DCD, CRRC_DATE, PROP
Significant values: The value in CRRC indicates the status of this review. A project is under review by CRRC if CRRC = J,K,L,M,N. CRRC_DATE indicates the date that the CRRC sends the 1391 to ASA for review. ACE_DCD eq B indicates it is being held for further review. ACE_DCD eq C indicates that it has been released to ASA for review. ACE_DCD eq X indicates that the project has been disapproved.

Event: **ACE Directs Code 1**
Event Date: May (GY)
Activity #: 11
Preceded by: 10
Followed by: 12,18
Associated fields: ACE_DCD, DIRCD, CDTCD1
Significant values: ACE_DCD eq 1 indicates Code 1 design release by ACE. DIRCD eq 1 indicates the occurrence of the Code 1 directive to the district. CDTCD1 is the date that the directive occurs.

Event: **Code 1 Design**
Event date: May (GY) - Dec (DY)
Activity #: 12
Preceded by: 11
Followed by: 20
Associated fields: CDTCD1, CONCOM_DT, DES_PERCENT
Significant values: CDTCD1 is the date that Code 1 design begins. CDTCD2 is the date used to indicate Code 1 design ending. Thus, Code 1 design time is CDTCD2 - CDTCD1. DES_PERCENT indicates the percentage of design completed (Code 1 design is 10% completion).

Event: **CRRC reviews Army program for Code 2.**
Event Date: 1 Jun (GY) - 15 Jan (DY)
Activity #: 14
Preceded by: 10
Followed by: 17,15

Associated fields:	CRRC, CRRC_DATE, PROP
Significant values:	The value in CRRC indicates the status of this review. CRRC_DATE indicates the date that the CRRC sends the 1391 to ASA for review. CRRC eq J or L indicates Code 2 review. ACE_DCD eq B indicates it is being held for further review. ACE_DCD eq C indicates that it has been released to ASA for review. ACE_DCD eq X indicates that the project has been disapproved.

Event:	**ASA reviews Army program**
Event Date:	July (GY) - 15 Sep (GY)
Activity #:	17
Preceded by:	10,13,14
Followed by:	26
Associated fields:	CRRC, CRRC_DATE, ACE_DCD
Significant values:	A project is under ASA Review if CRRC = 1 or 2 or H and ACE_DCD NE 2 OR 6 or ACE_DCD IS D,E,F,Y. The CRRC_DATE indicates the date the project was sent "TO ASA" for review.

Event:	**CRRC reviews program, releases projects for Code 2**
Event Date:	1 Jun (GY) - 15 Jan (DY)
Activity #:	14
Preceded by:	10
Followed by:	15
Associated fields:	CRRC, ACE_DCD
Significant values:	A project is under code 2 review by CRRC if CRRC = J OR L. If ACE_DCD = 2 then a project has been released for Code 2 design. There is no specific indicator that CRRC has done this. It is assumed that if ACE_DCD EQ 2 (ACE directs Code 2) then it had to have been done since it requires CRRC approval.

Event:	**ACE directs Code 2**
Event date:	Jan (DY)
Activity #:	15
Preceded by:	14
Followed by:	20
Associated fields:	ACE_DCD, DIRCD, CDTCD2
Significant values:	ACE_DCD eq 2 indicates Code 2 design release by ACE. DIRCD eq 2 indicates the occurrence of the Code 2 directive to the district. CDTCD2 is the date that the directive occurs.

Event:	**Code 2 Design**
Event date:	Jan (DY) - Jul (DY)

Activity #:	20
Preceded by:	15
Followed by:	29
Associated fields:	CDTCD2, CONCOM_DT, DES_PERCENT
Significant values:	CDTCD2 is the date that Code 2 design begins. CONCOM_DT is the date that concept design (35%) or code 2 design is completed. This should occur on or before 1 Sep. Thus Code 2 design time is CONCOM_DT - CDTCD2. DES_PERCENT indicates the percentage of design completed.

Event:	**CRRC reviews program, releases Code 6**
Event date:	Mar (DY) - May (DY)
Activity #:	22
Preceded by:	15, 21
Followed by:	21
Associated fields:	ACE_DCD
Significant values:	None of the CRRC values indicate the status of CRRC review for Code 6 design. The only indicator of this is that final design was directed by ACE (ACE_DCD eq 6) since CRRC release of Code 6 design precedes ACE release.

Event:	**ACE directs Code 6**
Event date:	Aug (DY)
Activity #:	21
Preceded by:	22
Followed by:	23, 29
Associated fields:	ACE_DCD
Significant values:	ACE_DCD eq 6 indicates that Code 6 has been directed.

Event:	**Final CRRC Review**
Event date:	Jul (DY) - Aug (DY)
Activity #:	23
Preceded by:	21
Followed by:	25
Associated fields:	ACE_DCD
Significant values:	No values indicate that this has been done. However, if ACE_DCD = 6 and CRRC = X then a project has been disapproved while in Code 6 design.

Event:	**Final design**
Event date:	Aug (DY) - Sep (BY)
Activity #:	29
Preceded by:	20
Followed by:	37
Associated fields:	CDTCD6, DES_COMP_DT, DES_PERCENT
Note:	CDTCD6 is the date that Code 6 (final) design

begins. DES_COMP_DT is the date that design is completed. However the value may be either an actual or projected date. Code 6 design time = DES_COMP_DT - CDTCD6. DES_PERCENT indicates the percentage of design completed.

Event:	**Prepare Annual Budget Submission (GREENBOOK)**
Event date:	Sep (DY) - Jan 15 (BY)
Activity #:	28
Preceded by:	25
Followed by:	31
Associated fields:	TABSORT
Significant values:	There are no values that indicate this has occurred, its occurance is based on a calendar date since it must be done by Jan 15 (DY). The existence of a value in TABSORT indicates that this is in progress or has been done.

Event:	**Congress reviews budget submission**
Event date:	Jan 15 (BY) - Aug 15 (BY)
Activity #:	31
Preceded by:	25
Followed by:	32
Associated fields:	*AUTH_CODE, AUTH_NOTE, APPR_CODE,* APPR_NOTE, AUTH_AMT, APPR_AMT
Significant values:	The values in the associated fields indicate the action taken by Congress. The existance of a value indicates that an action has occurred but non-existance does not indicate that an action has not occurred. The occurance of this is based on a calendar date, but a value in AUTH_AMT or APPR_AMT indicates that it has occurred since these values are the result of Congressional review.

Event:	**Authorization, Appropriation Bills produced**
Event date:	Oct 1 (PY)
Activity #:	32
Preceded by:	31
Followed by:	33
Associated fields:	AUTH_AMT, APPR_AMT
Significant values:	There is no value that indicates the date this occurred. The existance of values in AUTH_AMT and APPR_AMT indicates it has occurred.

Event:	**Construction directives to Districts by ACE**
Event date:	Oct (PY) -
Activity #:	36

Preceded by:	32,33,34,35
Followed by:	37
Associated fields:	DIRCD
Significant values:	There are no values that indicate the occurrance of this event. DIRCD = 9 (Construction contract awarded) indicates that it must have occurred at some time since contracts cannot be awarded without this directive.

Event:	**Construction contract awarded**
Event date:	Oct (PY) -
Activity #:	37
Preceded by:	36
Followed by:	none
Associated fields:	DIRCD
Significant values:	DIRCD = 9 indicates that this has occurred.

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