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**INFORMATION MANAGEMENT
FOR
NUCLEAR POWER STATIONS
SYSTEM DESIGN CONCEPT**

PROJECT DIRECTOR: DANIEL W. HALPIN, PHD.

**PREPARED FOR: THE UNITED STATES DEPARTMENT OF
ENERGY CONTRACT EY-76-S-05-5270
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MARCH 1978

VOLUME II

**GEORGIA INSTITUTE OF TECHNOLOGY
SCHOOL OF CIVIL ENGINEERING
ATLANTA GEORGIA 30332**

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INFORMATION MANAGEMENT FOR
NUCLEAR POWER STATIONS

SYSTEM DESIGN CONCEPT

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PROGRAM MANAGER: CHARLES A. THOMPSON

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FOREWORD

This report consists of five volumes numbered ORO-5270-1 through ORO-5270-5. Volume I (ORO-5270-1), the Project Description, briefly describes the purpose, approach, and results of the study. It contains no supporting material. An extensive description of the study is presented in this volume, System Design Concept (ORO-5270-2). Appendices A-F contain supporting material upon which the concepts and results of Volume II are based. The appendices are bound as three separate volumes with the following designations:

- (1) Appendices A-D   ORO-5270-3
- (2) Appendix E   ORO-5270-4
- (3) Appendix F   ORO-5270-5

Copies of all five volumes can be obtained from the National Technical Information Service (NTIS), Springfield, Virginia 22161, USA. Further details regarding the contents of the volumes appear as Exhibit I at the end of Volume I.

The information developed and the results realized during this study are the joint effort of a number of organizations and consultants. In directing this study, Georgia Institute of Technology was assisted by Construction Systems Associates, Inc. (Atlanta, Georgia) and Daniel International Corporation (Greenville, South Carolina). Both firms served as technical advisors to the project. Duke Power Company provided the utility viewpoint and played a major role in providing information and assisting personnel to the program. Other firms and utilities

providing personnel and information to the project on a consulting basis include:

- (1) Southern Company Services, Inc., Birmingham, Alabama
- (2) Ebasco Services, Inc., Atlanta, Georgia
- (3) Fluor-Pioneer, Inc., Chicago, Illinois
- (4) Gilbert Associates, Inc., Reading, Pennsylvania

In addition, numerous utilities and nuclear construction support groups were interviewed during the course of the study and provided valuable information and insights regarding existing methods of operation.

ACKNOWLEDGMENTS

The Systems Design Concept Volume was written as a cooperative effort with contributions from several principal members of the study team. Integration of all material into the final format was done at Georgia Institute of Technology by D. W. Halpin. Concepts presented in Chapter 3 are based on work and written material contributed by A. M. Burger. The system design material presented in Chapter 4 is the work of Dr. William Cotterman and Dr. R. A. Lewallen. The report was typed by Margaret Vogt. Mrs. Nancy Coplen did the drawings and figures.

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CHAPTER I

Project Development and Methodology

1.1 Background and Need

This study of the information management structure required to support nuclear power plant construction was performed by a joint university-industry group under the sponsorship of the Department of Energy (DOE), formerly the Energy Research and Development Administration (ERDA). The purpose of this study was (1) to study methods for the control of information during the construction and start-up of nuclear power plants, and (2) identify those data elements intrinsic to nuclear power plants which must be maintained in a structured format for quick access and retrieval.

The complexity inherent in nuclear power projects has placed extraordinary demands on traditional methods of information and project management. Methods which are quite adequate for \$10-\$20 million projects are not acceptable on \$100-\$200 million projects. Similarly, management information systems which have proved acceptable on \$100 million projects have been found to be inadequate on projects in the \$500 million to one billion plus range. These large projects are characterized by a highly sophisticated interaction between owner, governmental organizations, local regulatory agencies, constructors, financier, designer, and subcontractors. Control of such projects requires integrated decision making based on parallel actions occurring within the design, procurement, construction, start-up and plant operation phases.

An indication of the scope of some of this decision making is shown in Figure 1.1.

Typically, various phases overlap and generation of planning and design documents occurs simultaneously with actions regarding procurement and while field construction is taking place. This leads to a complex flow of information between a wide range of project oriented organizations. These organizations place demands on the information system and must be kept up to date on project control actions if the project is to develop smoothly. These organizations must access portions of a common pool of data. Failure of one organization to know of critical decisions affecting its area of responsibility can lead to "the left hand not knowing what the right hand is doing." The project organizations and their interface with and access to a common body of information are shown conceptually in Figure 1.2. The need for this diverse group of organizations to pass information back and forth motivates the need to find a common basis upon which these organizations can communicate.

This research has identified the physical components of the project and their configuration in an operational nuclear facility as the common denominator to which all organizations can relate. The concept of a Project Configuration Model is developed in detail in Chapter 3. The assumption used is that the nuclear plant consists of physical segments for which information related to individual users can be generated and organized. The segmentation of the project is done according to natural structural or system (e.g., mechanical, electrical) boundaries.

- SPECIFICATIONS, INQUIRIES, PURCHASE ORDERS ASSOCIATED WITH MODEL SEGMENTS, COMPONENTS
- LEAD DATES ESTABLISHED
- EXPEDITING ACCORDING TO SEQUENCE OF MODEL ERECTION

Procurement

Design

Suppliers Vendors

Warehousing Material, Eq. Control

Field Engineering

- SUPPLIERS IDENTIFICATION ESTABLISHED IN RELATION TO PCM
- DOCUMENTATION, DWGS. IDENTIFIED
- SUPPLIERS DATA ATTACHED TO MODEL
- MODEL IS MORE REFINED

- RECEIVING INFORMATION ENTER THE MODEL
- WAREHOUSE DOCUMENTATION
- ISSUING FOR CONSTRUCTION

Field Construction

- ERECTION STATUS
- SCHEDULING
- PRODUCTIVITY & COST CONTROL
- Q.C. DOCUMENTATION & STATUS
- TURNOVER TO START UP

Start Up

Operation

- STARTUP SCOPING
- TESTING INFORMATION
- DOCUMENTATION
- START UP PLANNING

- EQUIPMENT RELIABILITY DATA
- PLANT MASTER PARTS LIST
- PLANNING FOR SCHEDULED SHUTDOWNS
- INFORMATION DATA MODEL OF THE PLANT

- MODEL IS INITIATED
- NUMBERING SYSTEM ESTABLISHED
- MODEL SEGMENT ARE GRADUALLY SCOPED BOUNDARIES OF SYSTEMS AND STRUCTURES ESTABLISHED
- INDIVIDUAL COMPONENTS AND RELATIONSHIPS BEING IDENTIFIED
- ENGINEERING FACTS ENTERED INTO MODEL
- DESIGN DOCUMENTS IDENTIFIED WITH PCM

- MONITORING OF MATERIAL REQUIREMENTS & AVAILABILITY
- GENERATION OF FIELD DOCUMENTATION
- CONSTRUCTION SUPPORT

USAGE OF PROJECT CONFIGURATION MODEL (PCM)

Figure 1.1: Project Phases and Related Actions

Figure 1.2: Data Base Interfaces with Project Organizations

The model is established according to the need for data control intrinsic to individual project groups. In short, the physical plant itself is used as the model structuring individual project management functions to include cost control, engineering, procurement, material control, and labor management. This "model" based on the physical components of the end-product (i.e. the plant) provides a common view of the project to all groups and provides the basis for a better integrated structure to be used in project management.

The need for an improved project control system that expedites information exchange between the various organizations making up the modern nuclear plant construction team is best supported by a computerized data base management system which can be readily accessed and updated by appropriate members of the management team. What is needed is a PCS based on a well-defined and understood model which will be sufficiently large and detailed in scope so that user groups and organizations at all levels of management can use it as a means of communication. This should include groups from supporting areas such as engineering, personnel, records management, purchasing, expediting, quality control, accounting, warehousing and payroll. This study has been performed to investigate the requirements and develop the basic concepts of such a system.

1.2 Existing Project Control Systems

Overall project control has become an important and sophisticated function on large projects. The term PROJECT CONTROL as used here covers all systems activities related to the construction project.

The estimating, cost control, planning, scheduling, and resource control functions are the key sub-elements of a Project Control System (PCS). The integration of PCS sub-systems is becoming more and more critical for the analysis of project information and progress data. This has led to the development of a considerable number of project control systems within the past 5 years. Such systems utilize the concept of feedback and comparison of actual performance vs. expected performance targets to activate the decision process. This is shown conceptually in Figure 1.3 below.

FIGURE 1.3: PROJECT CONTROL CYCLE

As noted by David H. Smith of Project Management Corporation in describing the CRBRP project control concept:

"The most crucial aspect of this feedback process is the measurement step. Without proper visibility over key status variables, the loop is not able to function, no matter how well the other aspects work. The most capable management team is helpless without information."

This emphasizes the importance of timely data contained in a data pool which can be readily accessed and update by appropriate members of the

the management team. More information on existing project control systems is given in Exhibit I.

Data integration is required in order to service the measurement requirements of such systems. That is, large bodies of data must be maintained, organized, and accessed by all organizations within the project management group. Present integration efforts normally favor a lead function which is placed in a dominant position. This function might be Planning/Scheduling, Cost Control, or some similar function, depending upon which group is the driving force behind the data integration effort. Since integration is normally based upon the characteristics and viewpoints of one group, the models utilized are preferred by one of the management groups and are less satisfactory to others. Scheduling and project management tend, for instance, to emphasize activity oriented time control models while cost organizations are more comfortable with data organization based on cost codes and accounts. Engineers and quality control groups view the project in terms of systems to be designed and inspected.

In current control systems, the plant configuration tends to be masked and is not controlled and managed. The physical and functional composition of the plant deserves more attention than provided by present concepts. The physical components and systems of the plant, as explained in Chapter 3, provide a skeleton on which all project functional groups can attach their information.

1.3 Project Configuration Model Segmentation

The common data reference point within the Project Configuration Model (PCM) is the segment. The segment (a physical element within the plant) forms the basis for packaging data within the project data base. Consider, for example, a segment of the model which relates to the concrete in the turbine building (TB) at elevation 120. Scheduling might have one or several activities associated with this segment. Estimating would have quantities and unit prices. Cost control would report cost against this segment. Engineering monitors the material and documentation associated with this segment while quality control monitors the field documentation and quality of associated work. The model segments provide a common reference in terms of which all groups can view the project. This view of the plant in terms of physical segments has the advantage that it provides an ever increasingly precise model which over time becomes constant. That is, as various portions of the plant are completed, previously dynamic segments become constant and fixed.

1.4 Organization and Methodology

In order to establish the scope of the Project Configuration Model and the basis for project segmentation, the Project Team made a study of all categories of data associated with the construction of a nuclear power station. Areas requiring data were defined and subdivided into functions, processes, and data flows. During the first stage of the study, the research team concentrated on developing Application Area

Descriptions and documenting the present state of the art in each of the following application area groups:

- (1) Project Control
- (2) Material Control
- (3) Construction Control
- (4) Plant Performance Compliance

Information developed during this stage of the study provides the basis for Appendices A-D contained in a separate volume.

1.4.1 Application Area Reports

An Application Area, as referred to in this report, consists of a group of functions required to support the construction of a nuclear power station and demanding or generating data or both. An Application Area Report was prepared for each of the four groups noted above. These reports identified application area objectives, established descriptions, commented on existing and planned systems and problems, and suggested possible improvements. Information sources for these reports were varied and included the previous experience of project team members, site visits to nuclear power stations under construction, consultation with constructor and client personnel, previous studies, and documentation of existing systems. Table 1.1 shows those application areas which were studied during this period and their grouping within the application area groups.

TABLE 1.1: APPLICATION AREA GROUPINGS

APPLICATION AREA GROUPS	APPLICATION AREAS
I. Project Control	(1) Project Management (2) Planning and Scheduling (3) Estimating (4) Cost Control (5) Project Services
II. Material Control	(6) Design/Procurement (7) Engineering/Quantity Take-Off (8) Purchasing/Expediting (9) Warehousing
III. Construction Control	(10) Field Construction Control (11) Construction Equipment Control
IV. Plant Performance Compliance	(12) Quality Assurance/ Quality Control (13) Document Control (14) Plant Start-Up

1.4.2 Development of Application Area Definitions and Specifications

The Application Area Reports became the basis for the system design oriented efforts in the second stage of the project. The first step in this direction was the preparation of Application Area Definitions. The activity of developing Application Area Definitions consisted of two distinct components. First, specific information elements and processes were identified and distilled from the material gathered for the Application Area Reports. Secondly, an effort was made to establish the general structure of these processes so that they would reflect industry wide

practice rather than something unique to a single constructor, designer, or utility.

The Application Area Definition became the input to the second system design step of developing Application Area Specifications. The Application Area Specifications and their relationship to the original Application Area Groups are given in Table 1.2. Specifications were not developed for Project Management and Design Procurement due to limited resources. Engineering/Quantity Take-Off was expanded

TABLE 1.2: APPLICATION AREA SPECIFICATIONS

ORIGINAL APPLICATION AREA GROUP	APPLICATION AREA SPECIFICATIONS
I. Project Control	(1) Planning and Scheduling (2) Estimating (3) Cost Control (4) Project Services
II. Material Control/ Field Engineering	(5) Purchasing/Expediting (6) Warehousing (7) Field Engineering/Civil (8) Field Engineering/Mechanical (9) Field Engineering/Electrical
III. Construction Control	(10) Field Construction Control/Civil (11) Field Construction Control/Mechanical (12) Field Construction Control/Electrical (13) Construction Equipment Control
IV. Plant Performance Compliance	(14) Quality Control/Quality Assurance (15) Document Control (16) Plant Start-Up

into three sets of specifications (Civil, Mechanical, Electrical) and redesignated Field Engineering. Similarly, Field Construction Control was divided into Civil, Mechanical, and Electrical Field Construction Control. The idea at this step was to critically evaluate the information elements and processes in terms of what should be rather than what exists. In the development of each Application Area Specification, the study team member responsible attempted to determine what information outputs were essential to successfully meet the objectives for the area. After specifying the outputs, the necessary inputs and process steps were specified. The Application Area Specifications are contained in Appendix E.

1.4.3 Function-Process-Data Hierarchies

In order to develop the Application Area Specifications, each Application Area was decomposed into its fundamental functions. Each of the functions intrinsic to a given application area is further subdivided into data demanding or generating processes. Finally, individual steps, inputs, and outputs associated with the defined processes are established. This technique of breaking the Application Areas into Function-Process-Data hierarchies is described conceptually in Figure 1.4. This procedure is discussed in detail in Section 2.7.

As an additional aid in establishing the relationship between the Application Area Specifications and the overall System Design, a technique called Hierarchy plus Input, Process, Output (HIPO) was also used. This technique is a combination of graphics and text to give an

FIGURE 1.4: FUNCTION-PROCESS-DATA ELEMENT TECHNIQUE

overview of the functions contained in an application area or system. This technique is particularly helpful in communicating information regarding the application area functions or processes to the system analyst charged with design of the totally integrated system. Using the process descriptions discussed above, HIPO produces a set of diagrams which permit application functions to be more easily visualized. HIPO charting as used in this study is described in Section 4.3.

1.4.4 Data Element Dictionary

For each data element (individual item of data) contained in the inputs and outputs of the application area processes, a Data Element

Dictionary Form was developed, listing identifying characteristics. These data element description sheets were prepared based on the input and output elements defined within the Application Area Specifications. This allows a data base directory to be established containing information about each element and its location within the data pool. This directory plays somewhat the same role in organizing data and establishing access and retrieval routes which a card catalogue in a library of books plays. The aggregate of the individual Data Element Dictionary Forms provides a directory which itself can be placed on the computer to expedite location, access, and retrieval of information.

Several operations were performed on the Data Element Descriptions in preparing the first draft of the Data Element Dictionary. First duplicate data elements were eliminated and an attempt was made to identify synonyms for all data element names. Secondly, an effort was made to trace the process path taken by each data element. This step included location of initial sources for all required data elements. The Data Element Descriptions are contained in the Data Element Dictionary Volume (Appendix F).

1.4.5 Design in Principle

The Application Area Specifications, Data Element Descriptions, and the Project Configuration Model (See Sections 1.1, 1.3, and Chapter 3) are the major input to the actual system design processes. Based on this information, both conceptual and data base designs-in-principle were developed.

It is important to be aware of the limitations intended by the use of the term "design-in-principle." The philosophy underlying this entire project is that an effective design, which ultimately will be successfully implemented, can be achieved via a series of iterations, with each iteration producing a design in finer detail, yet consistent with the scope and contents of the preceding design. Thus, the intent is to produce a design which:

- (1) Encompasses the entire scope of the construction of a nuclear power station from design to operation.
- (2) Specifies the necessary systems components and their relationships at the general level.
- (3) Specifies system performance in user terms.

More specifically, a design-in-principle as defined in this report will:

- (1) Provide a design concept.
- (2) Define a system embodying that design concept in terms of system components and their relationships at a general level.
- (3) Define user performance characteristics in terms of input and output specifications. Hardware and software components of the system design will be specified in generic terms only.

The design-in-principle is intended to provide a logically sound and consistent conceptual base for subsequent increasingly detailed system design.

1.5 Report Organization

In order to aid the reader in using this volume, a brief discussion of its organization follows. First, the information characteristics of a nuclear power construction project are examined and described in Chapter II (Sections 2.1 and 2.2). The organization and communication flow at the project level must be understood in order to appreciate the systems integration concepts presented later. This discussion is designed to indicate the tremendous complexity of the information being processed.

After discussing some of the specific problems experienced with existing system approaches (Section 2.3), the design concepts of the system are reviewed. The key concept is that a set of application systems will all access a common data base. The use of a data base management system (DBMS) will allow each user to view the data base from his own perspective, using only that portion of the data base needed for its own processing (Sections 2.4 to 2.6). The techniques of establishing the application area specifications and data element descriptions which dictate the form and content of the data base are described in detail in Sections 2.7 to 2.9.

The final organization of the data base is based on the Project Configuration Model (PCM) described in Chapter 3. This chapter deals with the user's view of the recommended system and explains the concept of the PCM and its relationship to nuclear power plant construction. This chapter also discusses the computerization of the PCM and the role played by the PCM segment in its role as the basic organizational unit within the data base.

Based on these considerations, the recommended system design-in-principle is developed in Chapter IV. The overview systems chart presented in this chapter shows the use of the data base by each system. A set of data structure diagrams describes the overall data base and the logical view of the data base as seen by each of the application systems. This chapter also includes a short discussion of implementation considerations and future work.

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CHAPTER II

Information Management System Description

2.1 Basic Characteristics of the Information Management System

Nuclear power stations are typical of the large and complex projects which pose new logistical and management problems for project managers. Typical nuclear projects cost well in excess of one billion dollars, require from 8 to 10 years to construct, and during peak periods concentrate up to 4000 workers and 500-800 non-manual support personnel on a relatively compact construction site. The project organization must interface with a continually changing mix of external organizations and control a plethora of internal divisions and functions.

Some of the characteristics which set nuclear power construction systems apart from more conventional types of construction are:

- (1) Extensive government and industry regulation during construction
- (2) Complex Quality Control and Quality Assurance programs
- (3) Large number of design documents
- (4) Sophisticated technology and complicated design
- (5) Coordination of very large numbers of highly specialized subcontractors and vendors
- (6) Very concentrated work site
- (7) Extensive retained documentation of materials, components, and processes
- (8) Large number of components in plant

The number of drawings required for a single nuclear plant is in excess of 100,000 and accounting for these drawings is a major activity. Some drawings have as many as six or seven revisions which reach the field site and must be distributed and controlled. Over two million documents must be retained in the form of "as-built" documentation of the plant. A typical plant contains 20,000 valves, 45,000 welds, and 20,000 instruments, all of which require extensive "as-built" documentation. This level of information flow and accountability is unprecedented in "conventional" construction. Access to and retrieval of this information is critical to the proper control of nuclear power construction projects.

In order to design an information system which effectively supports such an object system, the systems analyst must thoroughly understand the object system itself. Such an understanding must be built on an accurate conceptual foundation. The conceptual base for this study of the Object System Model considered here is presented over the next few pages. The idea of the model is to present our conception of the physical processes of nuclear power station construction when viewed from a relatively high level (i.e., low level of detail). To this purpose, the construction of a nuclear power station is viewed as the application of various resources via a set of processes to produce the set of physical components which constitutes a nuclear power station.

First, a nuclear power station is clearly a set of structures and elevations as indicated by the simplified set of arrangement drawings shown in Figures 2.1 and 2.2. It can, however, also be seen as a set of systems which cuts across structures. This relationship is indicated

FIGURE 2.1: SIMPLIFIED GENERAL ARRANGEMENT DRAWING

ROOF
E1.-123.17

OPER.DEST
E1.-115.55

MEZ
E1.-107.62

GRADE
E1.-100.00

E1.- 94.21

E1.- 89.64

E1.- 82.85

ROOF

E1.-115.55

E1.-107.62

E1.-100.3

FIGURE 2.2: SIMPLIFIED PLANT ELEVATION

Figure 2.3: Pressurized Water Reactor System/Structure Interfaces

BOILING WATER REACTOR SYSTEM / STRUCTURE INTERFACES:

A Partial Example

of levels occurring

1 ■
2 ■
3 ■
4 ■
5 ■
all □

Structures

AUXILIARY BUILDING
CIRCUIT WATER PMPHSE
DRYWELL
GENERAL SERVICE PMPHS
REACTOR BUILDING
RHR BUILD NG
RADW BUILDING
SERVICE BUILDING
TURBINE BUILDING
YARD

Figure 2.4: Boiling Water Reactor System/Structure Interfaces

BOILING WATER REACTOR SYSTEM / STRUCTURE INTERFACES:

A Partial Example

of levels occurring

Structures

AUXILIARY BUILDING
CIRCUIT WATER PMPHSE
DRYWELL
GENERAL SERVICE PMPHS
REACTOR BUILDING
RHR BUILDING
RADW BUILDING
SERVICE BUILDING
TURBINE BUILDING
YARD

Systems con't

WASTE OIL SYS.
FIRE PROTECTION SYS
CHEMICAL SYSTEMS
DRIPS - DRAINS - VENTS
AUX SYSTEM
SYS SERVICE TRANSFORMER
SWITCHGEAR
GROUNDING
MTR. CTL. CNTR. DIST. CBNT
MOTORS
STNDBY EMER PWR SYS.
VITAL & POWER SYSTEMS
DC SYSTEMS
WIRE - CABLE
RACEWAYS - FITTINGS
LIGHTING - COMMUNICATION
GENERATOR TRANSFORMER
GENERATOR BUS
GEN. METERING SYNCHRONIZING
TELEMETRY MICH PWR PL
345 KV LN INSTRUMENTATN
345KV SWITCHYARD
CRANES - HOIST - ELEVATORS
GENERAL SERVICE WATER
HVAC HEATING - VENT - A/C
POTABLE WATER - PLUMBING
DW - RB EQPMT DRAIN SYS.
STNDBY GAS TREATMENT SYS.
CONT ATMOSP COOLING SYS
COMPRESSED AIR SYS.
PMV CONT ATMOSP MONTR
ELECTRICAL SYS
PIPING
INSTRUMENTATION
FIRE PROTECTION SYS
INSULATION
CHLORINATION SYSTEM
COOLING TOWERS
SCREENS - TRASH RACKS
HV - HEATING - VENTILATING

Figure 2.4: Boiling Water Reactor System/Structure Interfaces (Continued)

in the two matrices which follow the arrangement drawings (Fig. 2.3, 2.4). In the first matrix, a partial list of systems present in Pressurized Water Reactor (PWR) nuclear power stations is shown as column headings while the various major structures are shown as rows. The relationship of systems to structures is shown in the main body of the matrix. When a system is present in one or more elevations in a given structure, that fact is illustrated in the square at the intersection of the appropriate row and column. A similar matrix is included for Boiling Water Reactor (BWR) systems. In a more integrated view, components can be seen in their relationship to either the system or the structure of which they are a part.

2.2 The Management Control System

Central to the proper control of such massive projects is the concept of a single point of responsibility for project planning and control. This concept implies the need for a management control system that encompasses all phases of project development throughout the life of the project. This management control system must integrate the key elements of planning, estimating, cost control, and resource control, while supporting other project activities such as purchasing, quality control, accounting, warehousing, field engineering, document control, personnel, and payroll. Most management control systems currently in use focus attention on one or a small combination of these areas. A few systems consider most of these areas, but generally from a single viewpoint, such as that of the designer.

The management team is concerned with all of the project activities mentioned above. A typical nuclear power construction organization is shown in Figure 2.5. Developing the description of a system which can support the management organization requires the definition and integration of control, process, and status keeping systems currently being used by a number of functional organizations involved in developing nuclear power plants. These organizations use information to answer questions and prepare reports relative to the application areas described in Chapter I. This data needs to be available for query, update, and expansion from the project formulation phase (conceptual) through the design, procurement, construction, and start-up/testing phases. It should also be available to the client utility during actual operation of the power station as historical reference data for quick reconciliation of operational problems.

2.3 Problems with Existing Systems

Based on interviews with users at several projects representing several companies, the following items have been identified as the major problems encountered in implementing and using existing computerized systems:

Figure 2.5: Organization Structure (an example)

- (1) Training of personnel in the use of the system
- (2) User acceptance and support
- (3) Output usability
- (4) Numbering systems
- (5) Data acquisition
- (6) Integration between systems
- (7) Overdesign of system
- (8) Organizational problems

The first two items, training and user support, are required for the success of any computerized system. Without these critical elements, a system will probably fail, or at best limp along at far less than its designed capability. Proper training for users must be provided as part of the installation of the system. Sufficient resources and time for this activity should be factored into a system project's budget and schedule. User support can best be gained by involving the user in the system design activities. This makes him feel that it truly is his system and not only the property of the systems analyst.

The problem of output usability relates to both the timeliness and the form of the computer-produced reports. The information contained in the report may be out of date by the time the report is distributed, or the report may contain so much data that it is difficult for the user to extract the desired information. In either case, the system does not provide the kind of support the user wants. If the information produced is essential to the performance of the user's job, he will probably continue using the system. If the information can be obtained

some other way, he may cease using the system and obtain the desired information via the alternate method.

Problems with numbering systems are of two types. The first problem relates to the structure of the number itself. The second concerns the difficulty of maintaining the same number through all steps of the project life cycle. Selecting a numbering structure involves a choice between sequential assignment of numbers or building "intelligence" into the number. So-called "intelligent" numbers may also use information concerning the origin of the component as part of its identification (e.g., isometric drawing number, system number, etc. become part of the component number). Intelligent numbers have the inherent problem that when this information is revised, every identification number which uses it must also be revised. This revision process may become very time-consuming, since revision is an ongoing process during design and construction. A compromise may be the best approach, using intelligent numbers for certain items (e.g., the identification of the reactor and associated critical components), while sequential numbers can be used for all bulk items (e.g., purchase orders, field material requisitions, etc.).

The second difficulty with numbering systems (i.e., the maintenance of the same number throughout all steps in the project cycle) normally does not present a major problem within one organization. It is compounded, however, when several organizations, each with its own unique procedures, are involved in the project effort. Imposing a single numbering system requires that each firm adopt this system or maintain both numbers if the standard system differs from their own.

The data acquisition or input development problem relates to the timeliness and accuracy of the data which feeds a system. For some applications, batching of transactions for input on a periodic basis is acceptable. In other cases, input must occur on a real-time basis when the transaction occurs. The method used for input should meet the requirements of the application being supported. Real-time input of data is an unnecessary expense if the system does not require it. On the other hand, batch input may render an otherwise good system almost useless if the application demands up-to-the-minute timeliness of the data.

Regardless of whether batch or real-time input is used, methods need to be used to ensure the accuracy of the input data. For batch input, batch balancing, range checking, check digits, and table look-ups can be used. For the one-line or real-time input, all the above methods with the exception of batch balancing can be used to verify the accuracy of the data as it enters the system. Every attempt should be made to capture the data at the source origin and in the format most common to the user. The clerical modification of data should be kept to a minimum. The proper classification of physical components and typical activities at the project level is very helpful to this effort.

When information contained in one system is required by another system, the transfer can be done manually or by computer. If the data formats of the two systems are not compatible, considerable effort may be involved in accomplishing the data transfer. As a general rule, if inter-system data transfer is needed on a regular basis, the system designs should provide for this added function. Some systems now being

developed have total system integration as a fundamental part of the system requirements. Inter-system data transfer in these systems can be totally automated.

In some cases, systems have been implemented based on only a cursory understanding of the requirements of the system users. Many assumptions are made which represent the system analyst's impression of what the user needs. This often results in an over-designed system, which may perform the function desired by the user, but does it in such a complex fashion that it is extremely difficult to use. Systems designed in this manner may offer more capability than the user wants, needs, or is willing to maintain. The unneeded portions of the system soon fall into disuse.

The organizational environment in which a system is developed and used can have a significant impact on both the success of the system implementation and its use after implementation. A well-designed, efficient system may still perform poorly if organizational problems abound. An example of such a problem is the collection of similar information by several departments. This is clearly wasted effort, but may not be recognized as such by the department managers involved. Attempts at reorganization may be hindered by company politics. No amount of technical systems expertise can make a system perform well in a bad political situation.

2.4 The Data Base Approach

A data base management system is an advanced data processing technique which:

- (1) Provides the mechanism for organization of data in large logical structures.
- (2) Allows sharing of data by multiple applications.
- (3) Separates data definition from data application.

A data base file is a carefully planned structure containing the basic data elements and their organization. The data base file has several implications for management information systems. First, it assumes that the fundamental data elements have been rigorously identified. Secondly, the data files are so defined and structured to assure reliability and integration of all data elements. Thirdly, the accessibility of a variety of data elements permits increased flexibility and responsiveness of the system to unique as well as recurring information requirements.

The data base concept provides a suitable environment for a sophisticated user-oriented information management system. Data used and generated at the project level is stored and maintained in a highly integrated structure instead of in separate application files. This approach permits organization of data in a hierarchical or relational system. For example, given the scheduling network number of an activity of interest other information such as associated cost codes, required resources, equipment utilized, associated pour numbers, bills of materials, materials purchased, and material received can be retrieved.

The data is organized around strategically selected "keys" at several hierarchical levels. Typical keys are cost code numbers, activity numbers, Total Plant Numbering System (TPNS) numbers, start-up numbers, drawing numbers, purchase order numbers, concrete pour numbers, personnel badge numbers, equipment numbers, work locations, and vendor codes. This organization permits the retrievability of data which crosses several levels of data structure. Reports can be prepared using the information maintained by several departments. The structure also provides the means for a systematic approach to collection and utilization of information.

The system is capable of information retrieval in real time via display terminals. Report retrieval language is designed so that non-programming personnel can use the system. Exception and "ad hoc" reports can be processed within a few minutes or hours depending on the complexity of the report.

Each project has a separate and unique data base file for security and maintenance reasons. Such a file is used primarily by the project personnel, although provisions can be made for retrieval of vital information by corporate departments.

2.5 Basic Data Base Schema

Data base schema design has to reflect the operational characteristics of the project. The data structure and the physical location of components within the plant should be compatible. The relational

grouping of data is established according to reporting and update experience. A comprehensive data dictionary has to be developed to maintain the data in the schema. The data elements can be thought of as books in a library. The data dictionary acts as a "card catalogue" in defining the relationships between the data elements. Normally, the project control manager will have a data base administrator in his group who is fully responsible for maintenance and management of the data base and its usage. Every user receives a sub-schema of the data base containing the information he needs. The schema or sub-schema has mapping characteristics which structure the data and define their relationships. Figure 2.6 indicates the concept of relationships between data and applications through a schema. In Figures 2.7(a) and (b), a simple example of a detailed concrete pour sub-schema is shown. The information is directly related to every pour number as well as through cross referencing to a cost code or schedule activity number. The information can be retrieved in this format. If a report is required relating the information to facility components, this can also be summarized. One might be interested in a report parameter such as the unit manhours per cubic yard of concrete placed in the outside walls of an auxiliary building during January and February at elevation 100. This information can be retrieved since the data is there and presumably proper relationships have been established. The data base application is best employed when a large variety of exception reporting is required.

FIGURE 2.6: DATA BASE USER RELATIONSHIPS

FIGURE 2.7(a): CONCRETE POUR SUBSCHEMA

FIGURE 2.7(b): CONCRETE POUR SUBSCHEMA

2.6 Conventional versus Data Base Methods

To contrast existing methods with the integrated data base approach, consider one of the most common data processing applications used on construction projects - labor cost control. The foreman's timecard is the most common form used to collect labor cost and productivity information. Usually projects have a chart of accounts system developed by cost engineers which is used to collect cost information related to project activities. In the traditional approach, the foreman writes the description of every activity performed during the reporting period plus expended manhours and craft identification. The foreman's timecards are then processed by cost engineers to assign the proper cost code for every activity described. Sometimes the foremen are trained to enter cost codes directly in the field under close supervision by the cost engineers. This cost coding is later verified by cost engineers for accuracy. The traditional approach is shown in Figure 2.8.

In the data base approach, as illustrated in Figure 2.9, physical component numbers preassigned by the design engineer, vendor or construction engineer for cost control coding are used. Payroll and productivity data as well as erection status information are read directly to those portions of the data base to which they pertain. The preassigned component numbers are read by the computer. Using information from the cross reference index, the component codes are interpreted and information is then generated to the scheduling, estimating, and cost control systems. The outer line connecting the circles indicates the

FIGURE 2.8: TRADITIONAL COSTING APPROACH

FIGURE 2.9: DATA BASE COSTING APPROACH *

*The data base areas are indicated as circles.

connectivity between elements of the data base.

Typical physical component code categories which might be used are:

1. Civil: Concrete pour number; structural steel piece number; prefabricated concrete member number; and caisson number.
2. Mechanical/Instrumentation: Equipment number; spool number; line number; weld number; hanger number; valve number; duct number; and instrument number.
3. Electrical: Cable number; cable tray number; conduit number; and electrical equipment number.
4. Codes common to several disciplines: Building number; zone; elevation (floor); section; and system number.

These numbers are directly available to the foreman in the field in the form of drawings, field sketches, work orders, etc. These are documents to which he is accustomed; much more accurate reporting of work performed can be expected using this system.

Typical work activities for a physical component - a concrete pour - for every craft activity are as follows:

1. C - Concrete Placement: C1 - preparatory work; C2 - concrete placement; C3 - finishing; C4 - protection and cleanup; C5 - curing; and C6 - rework.
2. F - Formwork; F1 - prefabrication; F2 - erection and handling; F3 - scaffolding; F4 - shoring; F5 - metal deck; F6 - stripping and cleaning; F7 - cleanup; and F8 - rework.

3. R - Reinforcing Steel: R1 - unloading and warehousing; R2 - prefabrication; R3 - placement No. 04-No. 11 bar; R4 - placement No. 14-No. 18 bar; and R5 - rework.

4. E - Embedments; E1 - electrical; E2 - mechanical; E3 - civil; E4 - reinforcement supports; and E5 - rework.

5. W - Cadwelds; W1 - preparing; W2 - testing; and W3 - rework.

Each craft performs a fairly small number of work activities, so that very little training is required to report the activity properly. The foreman reports the following information for work performed on concrete pours:

1. Crew No. _____
2. Worker I.D. No. _____
3. Hours expended for every activity:
  - (a) Regular time
  - (b) Overtime.

The following information is reported for every activity:

CONCRETE POUR NUMBER - From concrete pour card posted in the field

WORK ACTIVITY NUMBER - From the list of activities applicable to the physical component.

Completed foreman's time cards are entered into the data base every day and this information updates several integrated sub-systems. In the data base, indexes cross referencing cost codes, schedule activity numbers, start-up numbers, and building numbers are maintained. This information is summarized and sorted according to user requirements.

For instance, the sort might be according to cost code for cost engineers and estimators and by schedule activity numbers for the planning and scheduling engineers. This brief example indicates that if the system is properly designed one data entry into the data base can support several individual users and applications.

2.7 Design Concepts and Procedures

The design procedures used during Phase I of the project have been briefly described in Chapter I. Figure 1.4 indicated the conceptual approach utilized to develop process and data element descriptions from the application areas. Based on the application areas defined during the "state-of-the-art" portion of Phase I (1 December 1976 - 30 May 1977), functions and processes inherent in these application areas were established.

The relationship is shown in somewhat greater detail in the Design Concept Chart of Figure 2.10. This figure indicates that processes accept data (DATA IN) and generate data (DATA OUT). This data is retrieved from data files (e.g., DATA FILE A) and following access returned to storage in the same or other data files. For example, Data Set I and Data Set II residing in DATA FILE A constitute input to the process indicated. This generates data back to DATA FILE A (as well as DATA FILE C and D) in the form of Data Set III.

This chart represents the germinal or first step in the evolution of the design concept. The first idea represented is simply that the appearance of the system to the user should be consistent with the way

in which the user currently operates. There are really two sub-ideas here; first, that the user interfaces of the system should be generally structured in terms of the processes and organization by which nuclear power stations are constructed today and second, that the system must adapt to the specific user rather than the user adapting his processes or organization to the system. The second major idea is that the system should utilize a data base approach. The system consists of a number of modules which support the user interface, interface with the data base, and perform specific functional tasks. Other modules might consist of existing software, such as CPM processors, or software to be designed and built as part of a specific implementation of the overall system.

APPLICATION AREAS - USER ORIENTATION

USER INTERFACE

DATABASE - SYSTEM ORIENTATION

Figure 2.10: System Design Chart

The analysis forms shown in Figures 2.11-2.14 were designed to standardize the application area process descriptions as much as possible. (Application areas were assigned to individuals on the project in accordance with familiarity with specific subject matter.) The analysis forms were used as work sheets. As exemplified by the analysis forms, each application area was divided into more detailed processes. In most cases, each process description consists of a narrative, discrete process steps, identification of data elements as input or output information, and the user's concept of source and destination processes for information flow. The analysis of processes resulted from the study of existing industry practices, the experiences of each participating organization, and the collective experiences of the individuals on the project.

Based on the application areas of Chapter I, approximately 300 process descriptions have been defined and constitute the system design specifications. A discussion of the forms given in Figures 2.11 to 2.14 will serve to illustrate the procedure used. Each application area was subdivided into its component functions. The Application Area Outline form (Figure 2.11), for example, breaks the Plant Start-Up and Operation application area into six functions as follows:

CODE FORMAT		RANKING	
PL-1-1	Process Function Appl. Area	1 = Primary 2 = Secondary	
APPLICATION AREA OUTLINE			
..... APPLICATION AREA ..... FUNCTION (S) ..... PROCESS (ES)		FUNCTION CODE RANK	
PLANT STARTUP/OPERATION		SU	
Prepare Test Procedures		SU-1	
Scope Test Procedures		SU-1-01	
Plan/Prepare for Writing		SU-1-02	
Write Test Procedures		SU-1-03	
Review Test Procedures		SU-1-04	
Approve Test Procedures		SU-1-05	
Conduct Construction Acceptance Test Program		SU-2	
Scope CAT Program		SU-2-01	
Plan/Prep. for CAT Program		SU-2-02	
Execute CAT Program		SU-2-03	
Report CAT Results		SU-2-04	
Conduct System Test Program		SU-3	
Scope System Test Program		SU-3-01	
Plan/Prepare System Test Program		SU-3-02	
Execute System Test Program		SU-3-03	
Evaluate/Report Results		SU-3-04	
Conduct Plant Test Program		SU-4	
Scope Plant Test Program		SU-4-01	
Plan/Prep Plant Test Program		SU-4-02	
Execute Plant Test Program		SU-4-03	
Evaluate/Report Results		SU-4-04	
Prepare Plant Procedures		SU-5	
Scope Plant Procedures		SU-5-01	
Plan/Prepare for Writing		SU-5-02	
Write Plant Procedures		SU-5-03	
Review Plant Procedures		SU-5-04	
Approve Plant Procedures		SU-5-05	
Coordinate Plant System Turnover		SU-6	
Scope Turnover Boundaries		SU-6-01	
Assign Startup Numbers		SU-6-02	

Figure 2.11: Application Area Outline

- (1) Prepare Test Procedures (SU-1)
- (2) Conduct Construction Acceptance Test Program (SU-2)
- (3) Conduct System Test Program (SU-3)
- (4) Conduct Plant Test Program (SU-4)
- (5) Prepare Plant Procedures (SU-5)
- (6) Coordinate Plant System Turnover (SU-6)

The system code of SU is assigned to all start-up and operational functions and processes. The first function within the Start-Up and Operation area (Prepare Test Procedures) is designated SU-1.

The functions themselves are divided into the next level of hierarchy, the process level. The SU-1 function consists of five processes as follows:

- (1) Scope Test Procedures (SU-1-01)
- (2) Plan/Prepare for Writing (SU-1-02)
- (3) Write Test Procedures (SU-1-03)
- (4) Review Test Procedures (SU-1-04)
- (5) Approve Test Procedures (SU-1-05)

Similarly the code designates the first process within the first function of the SU application area as SU-1-01. The legend for this code is given in the upper left hand corner of the Application Area Outline form. This code will be used later in hierarchy and interface diagrams to indicate the levels of information and information flow relationships. The Application Area codes are given above in parentheses following the application area's name.

A typical process description sheet utilized is shown in Figure 2.12. This sheet includes a statement of the process objective and a verbal description of the process. The summary verbal description is reduced to a detailed step-by-step description. The S designated steps indicate steps relying upon data generated within the process. The X designated steps indicate steps based on data generated outside of the process.

The process INPUT-OUTPUT sheet of Figure 2.13 shows the steps ordered based on their function in generating input or output data to the process. The input-output data relationship is shown graphically in Figure 2.14. This External Interface Diagram gives the processes providing FROM or input data and those receiving TO or output data. In this figure, for instance, it can be seen that test procedures schedule and detailed required information are required at S1 and S2 from processes outside of the Start-Up and Operation application area. Process SU-1-01 and SU-1-04 (other processes within the same function) provide input to S3 and X1. Outputs are generated to SU-1-04 and to outside application areas requiring STATUS CODE UPDATES. These individual process interface diagrams provide the building blocks for construction of the application area interface diagram presented later in discussing the data base design-in-principle (Chapter 4). These also motivate the definition of the data elements which must be contained in the data base. The data elements, as shown in Figure 1.4, are the flow units which are demanded and generated by the process steps. Once the category

PROCESS DESCRIPTION:1

function	page__of__	code
PREPARE TEST PROCEDURES		SU-1-03
source		
PROCESS		
<u>WRITE TEST PROCEDURES</u>		
Objective:		
To produce (write) each test procedure which has been determined to be needed for startup testing.		
Summary Description:		
From individual procedure scopes, and the wealth of information relating to design, specific components, government regulations, etc., a detailed (step-by-step) test procedure is written by a cognizant engineer. Sometime after preparation of a draft, the document is surrendered to the document control group for further handling and working copy control during review, approval execution, etc.		
Detailed Description		
S1) Receive schedule for test procedure writing from scheduling		
S2) Obtain from document control the detail information required for each procedure as previously determined.		
S3) Obtain test procedure number, title and scope.		
S4) Develop draft test procedure.		
S5) Surrender draft procedure to document control for control/handling.		
X1) Receive comments on draft procedure from document control.		
X2) Hold meeting to resolve comments on draft procedures.		
X3) Update draft to reflect comments as resolved.		
X4) Surrender final draft to document control for control/handling.		
INPUT		OUTPUT

Figure 2.12: Process Description I (1 of 2)

PROCESS DESCRIPTION:1

function		page_of_	code
PREPARE TEST PROCEDURES			SU-1-03
source			
Summary Description: a) Summary scope of procedures b) Detailed information -drawing -manuals -administrative procedures, -etc. c) Comments on draft test procedure d) Schedule Detailed Description - S1) Test Procedure Writing Schedule -Date to begin each procedure -Date to complete each procedure - S2) Detail Information Required -Flow diagrams -Elementaries -isometrics -set-point documents -vendor test specs -Etc. - S3) Test Procedure Number Test Procedure Title Test Procedure Summary Scope - X1) Draft Procedure Comments		Summary Description: a) Draft test procedure b) Finished test procedure c) Status code updates Detailed Description: - S2) Status Code Update - S3) Status Code Update - S5) Draft Test Procedure -Date transmitted -Written by, date -Typed by, date -Proofed by, date Status Code Update - X2) Status Code Update - X4) Final Draft Procedure -Date Transmitted -Updated by, date -Typed by, date -Proofed by, date Status Code Update	
INPUT		OUTPUT	

Figure 2.13: Process Description I (2 of 2)

PD-SHEET TWO

Figure 2.14: PD Sheet Two (External Interface Diagram)

of data required for each step can be established, the writing of data element descriptions can be undertaken.

This is the procedure which was, in fact, utilized. Using the individual process description steps as generation points, approximately 1300 data element descriptions have been defined. These data element descriptions are contained in Appendix F. These data element descriptions consist of the following items:

- (1) Data Element Name
- (2) Data Element Description
- (3) Synonyms
- (4) TO and FROM relationship

Since the same data element may be referred to by several different names depending upon the user's viewpoint or functional requirement, establishing synonym relationships is important. The worker's badge number, for instance, may be referred to as a MAN ID by payroll, a WORKER NO by cost accounting, and a BADGE NO by field construction control. Although three different names are used, one piece of data can service all three application areas. The FROM and TO relationship establishes the processes from which the data element is generated and to which it is routed. An activity number, for instance, can be generated in PL-2-03 (i.e., the third process, second function of planning) and routed to the CC-4-02 (the second process, fourth function of cost control). A typical data element description page from Appendix F is shown as Figure 2.15.

DATA ELEMENT DICTIONARY

BILL OF LADING NUMBER *****

*****

IDENTIFICATION NUMBER ASSIGNED TO EACH SHIPPING B.O.L.

FLOW	:	FROM	TO		FROM	TO
		CARRIER	WG-2-01	*	CARRIER	WG-2-01
		WG-2-01	WG-2-03	*	WG-2-01	WG-2-03
		WG-2-01	WG-2-03	*	WG-2-01	WG-2-03
		WG-2-03	DC-2-02	*	WG-2-03	EM-1-02
		WG-2-03	PS-1-01	*		

BILL OF MATERIAL NO. *****

*****

IDENTIFIER OF A LIST OF ITEMS AND QUANTITIES

SYNONYMS: EQUIPMENT LIST

MATERIAL LIST

BOM NUMBER

FLOW	:	FROM	TO		FROM	TO
		EE-5-01	WG-4-01	*	EM-3-05	EM-4-01
		EM-3-05	WG-4-01	*	EM-4-02	CC-8-06
		FE-4-02	WG-4-02	*	FM-3-01	WG-4-02
		WG-3-03	WG-4-02	*	WG-4-01	WG-3-03
		WG-4-01	WG-3-03	*	WG-4-02	WG-3-03

BLDG: ELEV *****

*****

DEFINES THE PHYSICAL LOCATION OF A COMPONENT WITHIN A
BUILDING AT A PARTICULAR FLOOR OR ELEVATION

SYNONYMS: ZONE

FIGURE 2.15: TYPICAL DATA ELEMENT DESCRIPTION PAGE
(APPENDIX F)

2.8 Hierarchy Charts

The identification of processes within the application areas provides a basis for defining a hierarchy of processes. Figure 2.16 shows a typical process hierarchy chart for the Mechanical Engineering (EM) application area. The major functions within the EM application as shown by the chart are:

- (1) MAINTAIN FILES OF INCOMING INFORMATION (EM-1)
- (2) MAINTAIN COMPONENT AND DOCUMENT NUMBERING REGISTERS (EM-2)
- (3) PRODUCE WORK ASSIGNMENT (EM-3)
- (4) PROCURE AND ALLOCATE MECHANICAL MATERIALS (EM-4)
- (5) LIAISON ENGINEERING (EM-5)

Twenty-nine processes are hierarchically defined within these EM functions. Similarly, Hierarchy Charts for all of the sixteen application areas have been developed and are given in Exhibit II. In addition to the code required by the Application Area Outline sheet, a numeric code (e.g., 2.4.3.1) is utilized to establish the process of function level within the four application area groupings. The meaning and significance of this code will be discussed later in the section on Hierarchical Input-Process-Output Charting (Chapter IV, Section 4.3). The Hierarchy Chart is a user-generated device which allows the systems analyst to develop HIPO diagrams. These diagrams aid in the establishment of information flow patterns.

Figure 2.16: Typical Hierarchy Chart

2.9 Intent of the Design Methodology

The intent of the design methodology adopted has been to work from the higher level application areas to the detail level of the data elements themselves. The first phase of this research is concerned mainly with defining the data elements and the processes which generate and demand them. Once this has been accomplished, the question of how these elements are best organized and retrieved can be tackled. Again, using the analogy of the data element as a library book, the first question addressed in detail in Appendices E and F is what books are to be included in the data library. This can be best established by determining which books (i.e., data elements) are required to accomplish the functions of the individual application areas. That is, what data elements are required by the processes of project management. Just as a library is a dynamic structure, adding books as demand arises, so the data element dictionary (i.e., card catalogue) expands as new data requirements derive from the process level. The 1300 data elements identified in this research are by no means exhaustive. They establish merely a point of departure for further development - a basic library of reference.

The next question of interest is, "How should the books (data elements) be stacked?" That is, how should the data elements be structured in storage to provide ease of access, retrieval, and update. Obviously, those books which are most often checked in and out should be most readily accessible. Similarly, those data elements which are demanded most often should be most readily retrieved. As the project progresses, the frequency of demand will vary. Engineering data which has a high demand

rate early in the design phase will experience a reduction in frequency of access as the project progresses. The organization of the data base must allow for this.

In addition, compatibility between categories must be established. The basis for storing certain types of data together must be addressed. Certain "data packages" occur again and again and therefore a retrieval sequence which is repetitive occurs. This must be considered in determining how data is to be organized. A new and logical rationale for organizing the data is presented in the next chapter. It is based on the integration of the management and control functions at the project level.

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CHAPTER III

Project Configuration Model

3.1 Project Configuration Model Description

The Project Configuration Model (PCM) is a hierarchical and relational description of the physical segments of the project. Every project segment* or "building block" should be well identified in terms of its boundaries. These "building blocks" are physically or functionally oriented. They represent a characteristic of the final product. The system governed or controlled by this model is a product driven system. The model has hierarchical dimensions such as location, system, and category of the structure. Model segments at the same hierarchical level for the same dimension cannot overlap their boundaries. Figure 3.1 is a chart describing major dimensions of the model. The combination of these dimensions (or parameters) identifies a model segment. For example, the following could be defined as segments at various hierarchical levels of the configuration model:

- (1) Turbine building
- (2) Concrete structures in auxiliary building at Elevation 100'00"
- (3) Turbine generator
- (4) Boron system
- (5) Boron system at Elevation 150 in auxiliary building
- (6) Spool HBD-100-10
- (7) Weld W-HBD-100-10
- (8) Cable

The turbine generator is hierarchically subordinate to the turbine building. The boron system is hierarchically subordinate to the

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*See Section 1.3.

PROJECT

FIGURE 3.1: POTENTIAL DIMENSIONS OF THE "PROJECT CONFIGURATION MODEL - PCM"

auxiliary building. The spool, weld, and cable could be subordinate to the boron system at their various levels. However, they are segments of the overall Project Configuration Model (PCM).

3.1.1 Model Segments and Structures

The model is developed in hierarchical fashion from top down according to the availability of detail information from design. Three phases (levels) of model development are described in the following paragraphs. These three phases are not mandatory, but serve to demonstrate the development of the model during major periods of the plant life cycle as determined by design effort. Certainly other phases might be identified to increase the efficiency of the modeling concept.

3.1.2 Concept Phase

The model composition during this phase reflects the needs associated with initial planning and estimating of the plant. The level of detail of information available at this period is relatively gross and the segmentation of the model must be developed accordingly. The model segments follow major structural, system, or material boundaries. The model during this phase might have in the range of 100-150 segments. The model segments are scoped according to the preliminary design concept, available historical information about similar plants, and expected usage of the model during this period. The requirements of modeling structure and composition are established by initial user-planners, estimators, project managers, and engineers. Every model segment has

associated additional information such as activities, events, work packages, quantities (material, labor), cost, and distribution curves.

The building of the Project Configuration Model (PCM) starts in the early planning and design period and ends in plant operation where it can be used as a complete master list of all components in the plant. Figure 3.2 indicates some of the cross referencing which develops immediately during the concept stage. Solid lines represent primary relationships and dotted lines represent secondary or auxiliary relationships. Four plant dimensions are shown at the highest level referencing (1) Structures, (2) Start-up System, (3) Component Categories, and (4) Engineering Systems. These dimensions provide a basis for developing segments. Within Structures, the auxiliary building is identified as a segment at the next level of hierarchy. Concrete is a major sub-segment within the auxiliary building segment. It has a child relationship to the parent (auxiliary building) segment. It also has a child relationship to the parent CONCRETE STRUCTURES which is a segment within the component category dimension. A similar multiple parent relationship exists for the piping sub-segment shown under primary systems. It has a child-parent relationship with both the piping segment within the Component Category dimension and Primary Systems within the Engineering Systems dimension.

3.1.3 Numbering System and Codes

The development and utilization of a model of this magnitude requires very systematic and consistent numbering of individual components and

FIGURE 3.2: PROJECT CONFIGURATION MODEL
CONCEPT PHASE

plant segments. The characteristic of the numbering system should reflect the utilization of the model for many users as well as the processing of the model by computer. The numbering should be simple to use. Short codes and unique numbers should serve primarily for identification purposes. Attempting to build too much intelligence into the unique component number should be avoided. From a practical point of view, the component number should not have more than 6-8 characters. The establishment of a uniform coding structure for the project is a key concept in the development of the PCM. The uniform coding structure should establish control for the appropriate items required by the application areas. Among these items are:

- (1) Buildings, zones, floors
- (2) Status codes
- (3) Codes for drawings
- (4) Craft codes
- (5) Document types
- (6) Dates
- (7) Systems, and
- (8) Components

This approach will simplify the communication among individual users of the model as well as allow more comprehensive integration of reporting.

3.1.4 Budget Phase

As engineering progresses, increased detail will support the creation of a more accurate model of the plant. The segments generated during the concept phase can be expanded into smaller segments. Also,

the structure of the model developed during the concept phase can be modified if necessary according to use of the model. The model should retain the values and estimates developed during the initial phase and, also, be able to summarize similar values from lower level segments for comparative purposes. In Figure 3.3, an example of model segments identified in this phase is presented. The segmentation is being done primarily from locational point of view or from system point of view. Every building can be sub-divided into prismatic three-dimensional segments such as:

- (1) Substructures, superstructures
- (2) Individual floor/zones
- (3) Component/structure categories

Similarly, systems/subsystems can be identified and subdivided into system components categories related to locations. In the example, valves are located in the Containment Building at Elevation 100 and belong to the Fuel Handling System. This system, in turn, is part of the Primary System having valves. Valves can also be considered part of the total piping system or category. The example contains another set of valves which belongs to the same system but is located at Elevation 120 of the Containment Building. Therefore, the valves from the engineer's viewpoint belong to the same system. From the installation viewpoint, however, they are in two different locations, and, therefore, are viewed as elements of different data sets.

In a similar fashion, this type of breakdown can be done from a structural or locational point of view. The relationship established between system related segments and locational or spatial elements can

Figure 3.3: Project Configuration Model Budget Phase

be used to properly sequence the erection process. The amount of information which can be attached to individual model segments will increase considerably as component detail increases. The following examples are representative of those data elements which can be related to the configuration:

(1) Planning/Scheduling	- Activities, events, work packages
(2) Estimating	- Quantities, cost, unit rates, cost codes, distribution curves
(3) Design Engineering	- Planned design documentation, drawings, specifications, Bill of Material
(4) Procurement	- Requisitions, purchase orders, vendor documentation
(5) Material Control	- Receiving of material, storage planning, personnel requirements planning
(6) Field Construction Field Engineering	- Development of installation and construction sequence and planning of labor and equipment resources

The type of information associated with the model is related primarily to planning and preparation for construction. About 3,000 to 6,000 segments are expected at this level for a typical nuclear power plant.

3.1.5 Definitive/Execution Phase

During this phase, the plant segments are separated into individual uniquely identified components. The basis for this expansion of the model is more detailed engineering design. Every component represents a well-defined and identified physical piece of the structure. For example, the following could be considered components:

Valves, spools, cables, raceways, concrete pours, welds, pipe sleeves, hangers, equipment, instruments, masonry walls, cuts, and conduits. (See Figure 3.4.)

Some of the components are identified by the designer, others by fabricators, vendors, or constructor. A large amount of information can be associated with every component at this level. The quantity of information will depend primarily on the user and what his information requirements are. Table 3.1 shows, in general, what type of information would be associated with every component. Some types of information are typical of all components. Other information will be specific to an individual component type. The model expands considerably during this period. It would not be unusual to have as many as 100,000 to 300,000 components depending on the level of detail of the breakdown.

The component level of the model is the most important in terms of control and management of nuclear projects. Some typical hierarchical levels relating the plant level to the component level are shown in Figure 3.5. A more detailed representation of various levels relating to concrete segmentation is shown in Figure 3.6. The first two phases of the model can be well handled with current methods. The component level (or definitive phase), however, renders current methods impractical. The component level of the model will provide true integration of usage by all participants. This portion of the model is very important in design, procurement, construction, startup and during operation of the plant. At this level, the plant becomes a giant puzzle with the components being pieces of the puzzle. As the component travels through individual functions, new information is added to each component.

Figure 3.4: Project Configuration Model Definitive Phase

TABLE 3.1: TYPICAL COMPONENT INFORMATION

IDENTIFICATION

Item Number
System Number
Component Type, Category
Startup System Number
Startup Subsystem Number
Referenced Components
Vendor Number
Hydro Test Code
Revision
Related Components (from,
to destination)
Description
Flush Code

ENGINEERING

Location - Building
Area
Zone
Floor (Elevation)
Bay, Wall (Section) Number
Rooms

Specification - Size, Class, Structure
Rating, Material
Schedule (Pipe)
Dimensions

Quantities - Length
Weight
Volume

DOCUMENTS

Drawing Numbers
Type of Drawings
Number of Drawings
- Design Documents
- Vendor Documents
- Mill Test Reports

PROCUREMENT

Requisitions
Purchase Orders
Expediting Dates
Vendor Identifications
Bill of Material Number

WAREHOUSING

Received Date
Material Receiving Report Number
Storage Location
Field Material Requisition Number
Issued Date
Spare Parts Interface
Heat Number
Storage Requirements

COST CONTROL

Cost Code
Actual Manhours
Unit Manhours (Actual)
Material Cost

QUALITY CONTROL

QC Status
Test Results
Acceptance Date
Personnel I.D.
QA/QC Class, Category
Receiving Inspection

PLANNING/SCHEDULING

Work Package I.D.
Scheduled Dates
Activity Codes
Actual Dates
Startup Activities

TABLE 3.1: TYPICAL COMPONENT INFORMATION (continued)

ESTIMATING

Estimated Manhours (Installation)
Work Activities
Unit Manhours (Estimated)

PRODUCTION CONTROL

Installation Status
Crew I.D.
Activities Performed
Erection Code
Craft Type of Work
Installed Quantities

FIGURE 3.5:
SYSTEM/AREA/COMPONENT RELATIONSHIPS

FIGURE 3.6:
EXAMPLE OF PCM SEGMENTS OF SEVERAL LEVELS

Conversely, some information is deleted and moved to project historical files. The model at this level will be capable of grouping the components into many different combinations. Organization of information for management might require combination by:

- (1) Component type
- (2) Component category
- (3) Location (building, floor, zone, room)
- (4) System
- (5) Start-up system/subsystem
- (6) Status (erection, availability)
- (7) QC codes
- (8) Sizes
- (9) Drawings
- (10) Responsibility, cost code, activity, etc.

3.1.6 Model Development

The development of this model must be a joint effort of all functional groups related to the project. Every group defines their requirements in terms of segmentation of the model during each individual phase. During each phase, the information which will be required and maintained by each group is established. Not every user and every group is involved from the beginning of the project, so the model will be dynamic and evolutionary in nature. It is expected that the segmentation will change during the lifetime of the project. At the beginning of the project a special group will have to be organized which will have

the responsibility of creating, controlling, and maintaining the integrity of the model during the lifetime of the project. Additional responsibilities of this group will be as follows:

- (1) To provide interface among individual users
- (2) To provide training in using the model
- (3) To provide system support in terms of the usage of the model
- (4) To evaluate the requirements of the users
- (5) To suggest the most economical and effective usage of the model

As mentioned earlier, the model will be developed gradually during the lifetime of the project, increasing in size and detail as new information becomes available. The three major phases mentioned previously will be more functional in nature, not necessarily representing precise time periods. It is obvious that some components can be identified fairly early in design (concept level), even though most of the other project segments will be identified at the budget level. From this point of view the building of the model will have to be very flexible, allowing different segments to be at different levels of detail at any given time.

3.2 Utilization of the Project Configuration Model (PCM) in Individual Project Functions

The configuration model can be effectively utilized by practically every group related to the project. Every user of the model will see only the image of the model most applicable to his needs and other

functions of the model will be transparent to him. The PCM will provide centralized modeling facility and the users can, in general, function and use the model independently of each other.

The model itself passes through evolutionary development in two major dimensions:

- (1) Level of detail
- (2) Usage by individual major groups (design, procurement, construction, start-up, operation)

Some of the major project level users of the PCM were indicated in Chapter I (Figure 1.2). User phases with activities supported by the model were previously shown in Figure 1.1. In the following sections, the Plant Configuration Model is briefly described in terms of individual users.

3.2.1 Design Engineering

The model is initiated by this group in conceptual form and is gradually refined reflecting progress of design. The model provides a systematic representation of the plant. It serves the following purposes:

- (1) Establishes good communication among individual design groups.
- (2) Allows association of design documents with the plant segments.
- (3) Provides a good tracking system for information related to individual components and structures.
- (4) Enables quantities to be developed gradually in parallel with plant design.

- (5) Provides a good communication tool to procurement, suppliers, and construction.
- (6) Forces designers to be more consistent and accurate since the model is easier to verify and audit than drawings or paper documentation.

Designers play a very important role in the development of uniform, well-defined numbering rules related to the model. The numbering system selected by the designer (supplier and vendors) is propagated through the life span of the project. Poorly defined and inconsistent numbering systems can cause the loss of millions of dollars during the lifetime of the project.

3.2.2 Purchasing/Expediting

Purchasing documentation is associated with segments or components of the PCM and expediting is monitored according to requirements established from the PCM segment. Typical supplier and vendor information might include manufacturer, vendor, vendor drawing numbers, vendor equipment/material identification, required dates, and promise dates. The model serves as a tracking mechanism for expediting and communication among Purchasing/Expediting and other groups.

3.2.3 Planning/Scheduling

Planning and Scheduling establishes the relationship between individual schedule activities and the individual segments of the PCM. These activities represent a logical sequence for assembling the PCM

segments and components so as to complete the project. As noted, the segments (and their subordinate components) represent the pieces of a giant puzzle. The schedule activities represent the sequence of putting the puzzle together. Every segment of the PCM will have one or more associated schedule activities. These activities will be unique to that PCM element. The duration of the activities will be determined by the scope of the PCM segment and other factors related to activities. The association of the schedule with the PCM provides schedules in which the scope of every activity as well as the logical sequence of plant erection is defined. The model will also serve as an excellent communication tool among individual schedules (e.g., design, procurement, construction/installation, start-up) as well as insuring compatability between individual levels of schedule - milestone, medium range, and short range. The equipment/material availability will be directly integrated into the schedule through PCM. The model will also be used to monitor progress in terms of the completion of the final product.

3.2.4 Estimating

Large numbers of definitive quantities are finalized during the engineering design effort. The PCM model provides a mechanism for entering estimated quantities associated with higher levels of the model prior to detailed engineering. These quantities include material and equipment being installed at the plant, as well as resources required for installation and erection. Again, the important point is

that these estimates are associated with a uniform Project Configuration Model. The conceptual estimate is prepared for the first level of model segments. Once the concept budget is defined, a budget estimate for the second level of precision is established. Finally, a definitive estimate for the lowest levels of PCM is generated. The established project chart of accounts will be assigned to elements (segments) of the Project Configuration Model. In a manner similar to the associating of schedule activities with PCM segments, several cost (estimating) accounts would be assigned to an individual segment. These accounts could also be associated with activities, but the reference system provided by the PCM eliminates this requirement.

3.2.5 Cost Control

The Cost Control function will also be performed in relation to PCM segments and categories. Since, during the labor cost control process, definitive segments and components are known in the field, the cost reporting is accomplished using these known elements. Labor manhours are reported against cost items such as pour numbers, welds, systems, hangers, structures, and rooms. These elements are easier to identify in the field than cost codes. Since cost codes have been associated with PCM elements, the translation to cost codes will be simpler and more accurate. Also, very significant benefits will accrue since productivity rates will be available in terms of final product elements or element categories.

3.2.6 Material Control

It is very important to establish a system for receiving materials and equipment which complements their placement sequence. That is, receipt and storage of materials should support the installation sequence by allowing storage in a common general work package grouping. The equipment/material identification used during procurement should be compatible with and support the documentation used in the erection and construction processes. This compatibility can be achieved by usage of PCM. The received material can be associated with PCM segments. Documentation such as material receiving reports, location in warehouse, inspection reports are related through the PCM segment linking procurement, receipt, and installation. The issuing of material is also recorded

in relation to the PCM. Several categories of equipment and material must be considered, to include:

(1) Equipment and material which is directly identifiable within the PCM (e.g., components procured with unique identification).

(2) Equipment and material which is procured in quantity (e.g., small valves) but for which unique identification is assigned when material is issued from warehouse.

(3) Bulk material included as part of the permanent plant without unique identification (e.g., reinforcing steel).

(4) Consumables - material used as a resource supporting construction.

(5) Spare parts.

3.2.7 Field Engineering

Since the Project Configuration Model is almost a direct transformation of drawings, the field engineering staff will not have any problems in working with the model. The model will be used primarily in the following ways:

(1) To incorporate detailing information from fabricators (spools, hangers, etc.) which generate a more detailed breakdown of the PCM.

(2) To support addition of as-built drawings and field run systems to the model.

(3) To monitor the availability of material/equipment for construction.

(4) To relate all documentation generated in the field to the PCM.

(5) To monitor engineering acceptability of plant construction progress using the model.

(6) To identify the sequence of construction and installation (i.e., support effort for the scheduling and construction effort). Field Engineering is responsible for the identification and support of further detailing of the model reflecting field use.

3.2.8 Field Construction

Field Construction will utilize the model as generated by other groups and will attach information related to the construction/erection needs of the project. This would include information required to:

(1) To support short range (task) scheduling of the construction or erection of a component (subcomponent).

(2) To identify resources (manpower, equipment, mechanical) required by the PCM segments.

(3) To monitor erection status.

(4) To monitor resource productivity and utilization.

(5) To identify requirements for QC inspection.

(6) To monitor availability of components for testing and turnover to start-up.

3.2.9 Project Management

Project Management will obtain information from the model primarily through the PCM based reports generated by other project groups on an exception basis. The model itself will have a strong impact on the

monitoring of information available to management. Since the model is jointly used by all project groups, the reports overlapping several users will be more consistently and easily prepared. The model will provide a mechanism to extract reports either in great detail or in a highly summarized format. Since the model will provide a very systematic and highly structured representation of the final project, management will be able to more intelligently control and monitor functions and characteristics related to the project.

3.2.10 Quality Control/Quality Assurance

The quality control functions almost always relate to individual components (spools, valves, instruments, concrete pours, cadwelds, etc.) and their associated individual work activities. The PCM will provide a natural representation of the plant for the QA/QC organization. Present models (scheduling and cost control) are almost unusable by this group since they do not support component level activity. The QC group determines the status of individual components, establishes required procedures, maintains the identification of inspectors or craft personnel, records traceability information relating to the material origin (heat numbers), and records the completion date for QC tests (concrete cylinder breaks, rebar tests, calibration).

3.2.11 Document Control/Records Management

Document Control will use the model to link design documentation (drawings, specifications), manufacturing documentation, and construction/

erection documents with the plant. The PCM provides a composite image of the hardware of the plant and its supporting documentation software. The model will simplify the association of documents with the plant. This relation will also support the:

- (1) Determination of generic document requirements for the plant
- (2) Auditing of actual generation of documents required during turnover and testing
- (3) Retrievability of documents in relation to the project segments and components.

3.2.12 Start-Up Phase of the Project

During the startup phase, the model will be used to scope boundaries for individual start up tests and monitor the completion status of components belonging to the defined start-up boundaries. Again the model establishes a basis for communication between the construction and start-up groups. Resource planning for the start-up and testing operation will be simplified through the relative simplicity of determining individual test boundaries. The model can also be used to monitor the status of start-up operations. Review of documentation will also be improved since the documentation for every start-up boundary will be easily identified.

3.2.13 Operation of the Plant

After completion of start-up, the model will be completed and can be utilized during operation of the plant. It constitutes a repository

of historical, readily retrievable information about the plant. It can also serve as an interface for the plant equipment reliability program. Spare parts can be directly tied to the model. The model can also support the planning of periodic maintenance and plant shutdowns.

Table 3.2 outlines major activities performed by the project management system. These activities result in the expenditure and transformation of resources to realize the plant configuration. The resources considered in this report are manpower, material, equipment, cost, and information. Therefore, the resources control segment is concerned with the management of these items. The operation control segment deals primarily with the methods by which resources are transformed into a final product. The operation control segment is concerned primarily with procedures, logic, sequence, methods, guidelines, and manuals. In contrast, the configuration control segment of the project control system deals with the product itself, its characteristics, status, volume, quantities, and dimensions. The formulation of the configuration control mechanism adds flexibility and ease of accountability to the overall project control system and encourages the participation of all project groups in improving project control.

TABLE 3.2:

RELATIONSHIP BETWEEN CONFIGURATION CONTROL (PROJECT CONFIGURATION MODEL), RESOURCES, AND OPERATION CONTROL

CONFIGURATION CONTROL	OPERATION CONTROL	RESOURCES CONTROL
Develop Project Configuration Model (PCM)	Develop Work Breakdown Structure (Work Activities)	
Level 1	Level 1	
Level 2	Level 2	
Level 3	Level 3	
Develop physical dimensions of the "PCM"		Develop scope of Work Packages (resources required to build the plant)
PCM Segments Level 1 (Scheduling support)	Develop Milestone Schedule	(Resources requirements) Time
PCM Segments Level 2 (Scheduling support)	Develop Integrated Project Schedule (Logic)	Resources loading of the Integrated Project Schedule (Time)
PCM Segments Level 3	Intermediate Project Schedule (Logic)	Intermediate Project Schedule (Time)
Detail PCM Segments Components/ Subcomponents	Short Range Schedule (Logic, sequence)	Short Range Schedule (Time)
Monitor and collect status by PCM Segments	Monitor and collect status by activities related to PCM	Analyze schedule variances
		Develop time-phased distribution of labor, material, and cost
		Perform Resources Leveling
Revise PCM Model: Engineering changes More detail breakdown	Revise Schedule (Logic)	Perform Schedule (Time)

TABLE 3.2 (CONTINUED)

RELATIONSHIP BETWEEN CONFIGURATION CONTROL (PROJECT CONFIGURATION MODEL), RESOURCES, AND OPERATION CONTROL

	CONFIGURATION CONTROL	OPERATION CONTROL	RESOURCES CONTROL
ESTIMATING		Develop Estimating guidelines	
	PCM will determine physical boundaries of Project Chart of Accounts	Project Chart of Accounts	
	PCM Segments Level 1		Develop Conceptual Project Estimate
	PCM Segments Level 2		Budget Estimate
	Detail PCM Segments Components/Subcomponents		Definitive Estimate
	Revision in PCM Model Engineering changes		Change order estimates (Engineering changes)
COST CONTROL			Change order estimate (Rework on deviations)
			Estimate revisions
	PCM Segments Level 3, Components/Subcomponents	Develop Cost Control program	Monitor and collect labor, material, and equipment cost
	Reporting of cost in relationship to PCM Segments Level 1, Level 2, Level 3, and Components/Subcomponents		Monitor productivity
			Forecast productivity
			Perform cost analysis
			Review and revise budgets

TABLE 3.2 (CONTINUED)

RELATIONSHIP BETWEEN CONFIGURATION CONTROL (PROJECT CONFIGURATION MODEL), RESOURCES, AND OPERATION CONTROL

	CONFIGURATION CONTROL	OPERATION CONTROL	RESOURCES CONTROL
PURCHASING/EXPEDITING		Develop Purchasing procedures	
		Develop Approved Vendor List	
	Responsibility assignment to PCM Segments (Subcontractors, vendors)	Administer contracts/subcontracts	
	PCM - Components/Subcomponents	Purchasing of uniquely identifiable components	Component Expediting
	Component categories of PCM	Purchasing of bulk material (Permanent plant)	Material Expediting
	Status of Purchasing and Expediting in relation to Plant Configuration Model	Purchasing of consumables	Expediting of delivery
WAREHOUSING	Identify received material/equipment with PCM	Receive, inspect, and maintain material/equipment	
	Identify issued material/equipment with PCM	Issue equipment/material Handle outbound shipments	
	Sequence of plant erection and expected material receiving		Forecast and plan (space and manpower)
	Identify spare parts with PCM		Control inventory Control spare parts

TABLE 3.2 (CONTINUED)

RELATIONSHIP BETWEEN CONFIGURATION CONTROL (PROJECT CONFIGURATION MODEL), RESOURCES, AND OPERATION CONTROL

	CONFIGURATION CONTROL	OPERATION CONTROL	RESOURCES CONTROL
PROJECT SERVICES	Sequence of plant erection and expected manpower requirements	Payroll	Personnel planning
		Accounts Payable	
	PCM Segments responsibility	Administer subcontracts	
FIELD ENGINEERING	Relate to PCM (resources and permanent plant material)	Procure and allocate material	
	Scope and content of PCM Segments	Prepare work assignment	
	Expansion of PCM into more detail according to field design and as-built conditions	Field Design	
	Associate Field Design documentation with PCM		Maintain and develop Field Design documentation
	PCM used for short and medium range scheduling	Support scheduling activities	
	Identify PCM segments and components accepted by engineering as complete	Monitor engineering acceptance of completion	
	Identify PCM Segments for turnover activities	Support turnover operation	Collection and verification of documentation generated during construction
	Audit of documents with PCM Segments		

TABLE 3.2 (CONTINUED)

RELATIONSHIP BETWEEN CONFIGURATION CONTROL (PROJECT CONFIGURATION MODEL), RESOURCES, AND OPERATION CONTROL

CONFIGURATION CONTROL	OPERATION CONTROL	RESOURCES CONTROL
	Perform work assignments	
Identify status of Segments and Components	Report status of work performed	
Sequence of PCM erection and context of PCM Segments		Resources requirements (equipment, material, manpower)
Sequence of PCM erection	Support short range scheduling	
	Monitor productivity	
	..Administrative requirements	
		Establish and maintain QA/QC personnel qualifications
	Specify and review construction inspection, testing points	
Associate inspection status with PCM. Plan for QA/QC requirements using PCM. Identify inspectors performing tests with components in required (welding).	Inspect for compliance to requirements, standards, practices	
	Define and schedule QA/QC audits	
Identify Quality related records with Segments and Components of PCM		Index, distribute and store Quality related records

TABLE 3.2 (CONTINUED)

RELATIONSHIP BETWEEN CONFIGURATION CONTROL (PROJECT CONFIGURATION MODEL), RESOURCES, AND OPERATION CONTROL

	CONFIGURATION CONTROL	OPERATION CONTROL	RESOURCES CONTROL
PLANT START-UP	Use PCM to plan and monitor the status of CVT Program	Conduct Construction Verification Test (CVT) Program	Prepare test procedures
	Use PCM to plan and monitor the status of POT Program	Conduct Preoperational Test Program (POT)	
	Use PCM to scope and execute IST Program	Conduct Initial Start-Up Test (IST) Program	
	Use PCM to support Plant Procedures Manual		Prepare Plant Procedures Manual
	Maintain status of turnover	Coordinate system turnover to operation	
DOCUMENT CONTROL	All design documentation must be related to PCM structure (audit)		Manage design documents Manage general project records
	All project generated documentation must be related to PCM structure (acceptance and audit)		Control QC documentation
		Coordinate usage of project reports and forms	Control project reports and forms

TABLE 3.2 (CONTINUED)

RELATIONSHIP BETWEEN CONFIGURATION CONTROL (PROJECT CONFIGURATION MODEL), RESOURCES, AND OPERATION CONTROL

<u>CONFIGURATION CONTROL</u>	<u>OPERATION CONTROL</u>	<u>RESOURCES CONTROL</u>
Usage of equipment should be associated with PCM Segments	Manage construction equipment shop	Construction equipment management
		Utilization
		Performance
		Small tools control
	Facilities management	Formwork management

3.3 Application Area Systems Layout Charts

Having introduced the major functional areas (e.g., design, purchasing/expediting, planning/scheduling, etc.) which must be considered in the design of an information management structure, the following sections present graphical layout charts relating application area and processes from the user's viewpoint. These charts represent a scoping of system/subsystem boundaries according to the Application Area Process Descriptions discussed in Chapter I. They provide a direct link between the user viewpoint and the system design viewpoint. The scoping generally follows traditional boundaries of systems used on major projects. From the system design point of view, these boundaries can be changed to establish the most effective system support in terms of hardware and software. The format of this scoping will be advantageous for the following reasons:

(1) It will allow modular development of the system according to implementation priorities.

(2) It will be possible to include existing systems (modules) in the overall network.

(3) Standard systems, such as the CPM scheduling processors, can be included as processing segments for the system.

Every chart presents primary systems for the application area which are represented as boxes with solid lines. Secondary systems are presented as boxes with dotted lines. Systems may service several processors as described in Chapter II or may support only one. A system for purposes

of this discussion is a computerized procedure which accesses, stores, controls, and updates information required by a process or several processes. This may be supplemented by certain manual procedures. The primary systems are specific to the application area and are the full responsibility of the users in this area. On the other hand, some of the features of secondary systems are used in the primary application area and generate return data to the secondary systems. In cases where it is meaningful, the systems have attached "Process Description" number in the format described on the Application Area Outline (Figure 2.11). Descriptions of referenced processes can be found by consulting the heirarchy charts of Exhibit II. The systems are linked systems. This relation might be:

- (1) Automatic data flow between two systems.
- (2) User retrieval of data from both systems simultaneously.
- (3) A segment of data in one system is directly compatible with a segment of data in other systems, so joint operation is potentially possible. Data retrieved from one system may be manually modified or reviewed and re-entered into the same system.

Every link must be reviewed and defined in much greater detail during the detail system design based on the specific application. The charts presented allow high flexibility in expansion of the design to more detailed levels. On some charts, the data (information) related to system is shown. This will aid in better understanding of the scope and purpose

of the system. Every chart is supported by a short narrative of the systems within the chart.

3.3.1 Primary Planning/Scheduling Systems

The Planning/Scheduling application area is described in the layout chart of Figure 3.7 and consists of the following primary systems or modules:

(1) Milestone Schedule - This system supports preparation of the milestone schedule and activities related to milestone schedule effort and identifies major events and resources. Major records within the system are activities and events with associated start dates, finish dates, probabilities, and resources. The system could be bar chart oriented and need not be processed by CPM processor.

(2) Manpower and Material Projection - This system provides a tool to forecast the distribution of major resources at the project such as individual crafts, key material (concrete, structural steel, lumber, piping) and consumables (fuel, electricity, etc.). The distribution curves for these items are maintained within the system as well as actual data collected to support future requirement forecasting.

(3) Work Breakdown Structure/Work Packages - This system supports scoping of work packages and aids in the assignment of responsibilities to individual project groups. It provides tracking of progress by a work package. Individual packages will consist of a segment or segments from the CPM, as well as related activities, drawings, and resources.

Figure 3.7: Planning/Scheduling PL

The WBS assists in the work scoping and control function.

(4) Medium and Short Range Schedule - This system supports maintenance and preparation of medium or short range schedules or special schedules. Again this system is not proposed as an automated or CPM oriented system, but will contain dates associated with individual activities. This system will, however, be directly related to CPM system and Work Package System.

(5) CPM Scheduling System - This system consists of a typical precedence or arrow oriented network processor such as MSCS, PROJECT/2, PMS IV, as described in Chapter II, Appendix A. In the overall configuration of the information management system, the role of this system will be primarily to provide the computerization required to compute dates and floats in schedule networks. This system will be used primarily for simulation purposes and will not be expected to contain more than 3,000 to 5,000 activities for any particular phase (engineering/procurement, construction, start-up). The networks for individual phases will be linked together.

(6) Network Graphic System - This system or module will produce a graphical representation of the scheduling network for presentation or debugging purposes. Network plotting systems such as EZPERT are typical of this module.

(7) Resource Allocation and Leveling - This system will be used as a tool in the evaluation of resource requirements as well as assisting in rescheduling work activities for more effective utilization of

resources. It is expected that this will be a standard program available with the CPM processor.

3.3.2 Primary Cost Control Estimating Systems

The primary systems contained within this cost oriented application area shown in Figure 3.8 are:

(1) Cost Control Systems - This system will be used to monitor cost as related to project activities. The system will provide support for control of costs related to material, labor, subcontracts, and equipment. General Ledger will be one module within this system. The system will be structured according to an established project chart of accounts and individual types of expenditures will be collected accordingly. The system will interface with other cost related systems such as payroll, accounts payable, and estimating.

(2) Chart of Accounts/FPC Code of Accounts - This system will support the Cost Control System and will be used to provide maintenance to project chart of accounts as well as FPC code of accounts if they are different. The subsystem will also provide integration among project chart of accounts and FPC code of accounts.

(3) Estimating System - This system will support development and periodic maintenance of the project estimate. The estimate will cover all cost categories and the system will directly interface with the Cost Control System to analyze variances between estimated cost and actual cost. The system will provide a control estimate for the project and must be capable of summary report at various levels of

COST CONTROL/ESTIMATING CC & ES

Figure 3.8: Cost Control/Estimating CC & ES

the cost hierarchy.

(4) Production Units Processing - This system contains target unit process and unit manhours for individual types of work or units of component. The component unit could be, for example:

- One foot of stainless steel pipe
- Diameter 3"
- Schedule 40
- QA Class 1
- In auxiliary building.

The system contains prices for erection of this unit, fabrication, and other associated activities. This system will be periodically modified according to experiences at the project. The system provides a basis for estimating, labor performance control (crews), cost control, and planning purposes.

(5) Cashflow System - A reliable cashflow projection capability for large projects is becoming increasingly important. This system provides this support. Several levels of cashflow projection will be supported to include weekly, monthly, quarterly, and total project. To provide this function, the system will interface with the following systems depending on what level of accuracy of cashflow is required: Personnel System, Payroll System, Accounts Payable, Procurement/Expediting, Cost Control, Estimating, and Scheduling.

3.3.3 Primary Project Services Systems

The primary systems required to support this application area are shown in Figure 3.9 and consist of:

(1) Personnel System - This system handles salaried personnel as well as craft personnel and provides information related to qualifications, experience, organization, as well as basic personnel data. The system has a related set of subsystems for controlled employees with Quality Control related skills, such as welders, cadwelders, QC inspectors, and employees handling radioactive material.

(2) Payroll System - This will consist of a typical software system capable of handling construction type projects with 3,000 to 4,000 employees. The system used should be able to handle salaried as well as craft employees. In addition, the system should be able to handle various incentive and bonus types of programs when implemented on the project.

(3) Accounts Payable - This module handles project related detailed clerical accounting functions for procurement as well as sub-contract payments. The following features should be available:

- (a) Consolidation of invoices
- (b) Cost code distribution
- (c) Cash and accrual accounting
- (d) Balance and edits
- (e) Checks preparation
- (f) Ledger account distribution

PROJECT SERVICES (PAYROLL, PERSONNEL, ACCOUNTING) PS

Figure 3.9: Project Services (Payroll, Personnel, Accounting) PS.

The system will support other systems such as cashflow, cost control, and vendor control.

3.3.4 Primary Mechanical Engineering & Mechanical Installation Systems

Primary systems required to support Mechanical Engineering and Field Control are shown in Figure 3.10 and include:

(1) Field Reporting Processing - This system is used to consolidate field reporting information related to manpower utilization, equipment utilization, erection progress, and field QC status. The system edits and verifies incoming information and creates transactions which will be used as an input to several other systems to include Payroll, Labor, Cost Control, Equipment Control System, Configuration Control System, and Production Units Processing.

(2) Crew/Employee Productivity and Performance - This system monitors and evaluates labor productivity at the project. The system can have several sub-systems dealing with individual types of productivity and performance evaluation. For example, the module can contain a Welder Performance Evaluation Subsystem which will be used specifically for welders, a Crew Productivity Evaluation Subsystem, and a Work Sampling System. Welder Performance will be used to monitor the performance of welders in terms of quantity of welding produced, accepted, and rejected. The information is kept for individual welds, welders, and the project as a whole. The work sampling subsystem can be used on a selective basis to determine how much time and resources are being expended in various pre-defined categories of a given operation.

MECHANICAL - ENGINEERING & FIELD CONSTRUCTION EM& FM

Figure 3.10: Mechanical - Engineering & Field Construction EM & FM

(3) Configuration Control System (CCS) - This system is the major operational entity within the PCM. Mechanical Engineering and Mechanical Field Construction utilize several subsystems dealing specifically with mechanical components. Subsystems within the CCS module include files dealing with spools, valves, welds, hangers, ductwork, mechanical equipment, instrumentation (mechanical), insulation (piping, equipment, ductwork), and painting (mechanical components). Every subsystem is autonomous and has its own set of input documents and typical output reports. Every subsystem contains a set of data which is typical for Configuration Control System at component level as well as specific information for every type of component. Tables 3.3 and 3.4 list some typical data elements characteristic of piping spools, valves, hangers, instrumentation, and welds. The Configuration Control System at component level will be one of the most valuable tools for detail handling of the large number of components at the project. Each subsystem will provide a comprehensive list of components with information ranging from design engineering through start-up and operation.

3.3.5 Primary Civil Engineering & Civil Installation Systems

Primary systems relating to the Civil area are shown in Figure 3.11 and include:

(1) Field Reporting Processing - This system performs the same functions in the Civil area as that described for Mechanical Engineering and Field Construction in the previous section.

TABLE 3.3

SAMPLE OF DATA ELEMENTS
TYPICAL TO PIPING COMPONENTS

DATA ELEMENTS	SPOOLS	VALVES	HANGERS SUPPORTS	WELDS	INSTRUMENTS
1. Unique Identification	X	X	X	X	X
2. PIS Number	X	X	X	X	X
3. Vendor ID	X	X	X		X
4. Building/Area	X	X	X	X	X
5. Elevation	X	X	X	X	X
6. Drawing Number	X	X	X	X	X
7. Scheduled to Receive	X	X	X		X
8. Received Date	X	X	X		X
9. QC Hold	X	X	X	X	X
10. Installed or Erected	X	X	X	X	X
11. Completion Sign Off	X	X	X	X	X
12. Cost Code	X	X	X	X	X
13. Start Up Number	X	X	X	X	X
14. ISO Number	X	X	X	X	X
15. Safety Class (ASME)	X	X	X	X	X
16. Material	X	X	X	X	X
17. Bill of Material Number	X	X	X		X
18. Vendor Part Number	X	X	X		X
19. Warehouse Location	X	X	X		X
20. Date Issued	X	X	X		X
21. Field Requisition Number	X	X	X		X
22. Hydro Test Code	X	X	X	X	X
23. Check Documentation Comp.	X	X	X	X	X
24. Engineering Hold	X	X	X	X	X
25. Contractor Cost Code	X	X	X	X	X
26. Contractor Schedule No.	X	X	X	X	X
27. Fabric. Work Package	X	X	X	X	X
28. Erection Work Package	X	X	X	X	X
29. Estimated Manhours	X	X	X	X	X
30. Actual Manhours	X	X	X	X	X

TABLE 3.4

SAMPLE OF DATA ELEMENTS SPECIFIC TO
INDIVIDUAL TYPES OF COMPONENTS

SPOOLS

1. Operating Temperature
2. Insulation Type
3. Insulation Thickness
4. End Preparation
5. Schedule/Thickness
6. Length
7. Diameter
8. Pressure Rating

VALVES

1. Upstream Unique Comp. No. (spool, valve, equipment)
2. Downstream Unique Comp. No. (spool, valve, equipment)
3. Manufacturer
4. Vendor Drawing No.
5. Type of Valve
6. Valve Mark No.
7. End Preparation
8. Vendor Valve No.
9. Weight
10. Pressure Rating

HANGERS/SUPPORTS

1. Hanger Type
2. Hanger Sketch No.
3. Weight
4. Hot/Cold Settings
5. Supported Spools

Figure 3.11: Civil Engineering/Civil Construction.

(2) Crew/Employee Productivity and Performance - This system controls Civil productivity in a fashion similar to that of the Mechanical productivity system presented in the previous section.

(3) Configuration Control System - Civil Engineering will use this system to handle components typical of civil construction, such as: concrete pours, earthwork, structural steel, masonry, embedments, special structures, roofing and siding, painting (structures), insulation (civil structures). The important task will be to uniquely identify components on drawings so all project groups can refer to the same identification structure. Unique identifications such as (a) masonry for a room number 145 and (b) embedments type TP-1 for a concrete pour TB-150 are required. Information maintained about every civil component will be similar in content to that described for mechanical components.

3.3.6 Primary Electrical Engineering & Electrical Installation Systems

Primary systems required to support this application area are shown in Figure 3.12 and include (1) Field Reporting Processing, (2) Crew/Employee Productivity and Performance, and (3) Configuration Control System (CCS). Electrical Engineering will use the CCS system to handle components related to electrical design and erection. The following subsystems are typical electrical components requiring control: cables, raceways, instrumentation, and equipment (electrical). These subsystems will be related (or will be subsets) of design engineering systems such as cable and raceway routing programs or instrumentation

ELECTRICAL - ENGINEERING & FIELD CONSTRUCTION FE & EE

Figure 3.12: Electrical - Engineering & Field Construction FE & EE

programs. These subsystems are closely integrated with mechanical subsystems to support start-up operations. Information maintained about every component will be similar to that described for mechanical components.

3.3.7 Primary Purchasing/Expediting Systems

The primary systems intrinsic to this application area are shown in Figure 3.13 and include:

(1) Subcontract Management - This system supports management and control of various subcontracts related to the project. It is used by subcontract administrators to monitor typical information related to every subcontract such as cost (e.g., estimate, payables) and major events such as system turnover and interface dates. The system will also maintain a list of all vendors and manufacturers related to the project with related information.

(2) Purchase Order Control - This system contains all information related to project procurement (engineering, construction) from requisitioning, to Purchase Orders and Change Orders. It maintains a complete history of all requisitions, Purchase Orders, and Change Orders with typical information related to every document. The system is closely related to other systems with needs for procurement information.

(3) Expediting System - This module monitors active and opened purchase orders and supports the expediting group. Purchase orders or items belonging to purchase orders have assigned delivery dates and

PURCHASING/EXPEDITING PE

Figure 3.13: Purchasing/Expediting PE

shipment dates. The system will generate reminders and support expediting information collection. It will be a subset of the Purchase Order System, Configuration Control System, and Material Control activity.

3.3.8 Primary Warehousing Systems

Primary systems relating to Warehousing are shown in Figure 3.14 and are as follows:

(1) Material Control System - Stock Material - This system handles all stock types of material received at the project. It is used for receiving of material, inventory control, stock material inquiries, and issuing of material to field. Some of the stock material will have to be uniquely identified at the time of issuance to the field. For example, valves received in bulk (50 piece lots) will have to be tagged with a unique number at issue preparatory to installation.

(2) Material Control System - Component Material - This system monitors materials which are received with a unique identification in relation to the designed plant. In this case the quantity will always be one and the item will be handled as a component which is assigned to a specific location in the plant at the time of receipt. The system will support basic warehousing functions such as receiving, storing, inventory, inquiries, and issuance to the field.

(3) Permanent Plant Equipment - Periodic Maintenance - Some of the components and equipment will have to be maintained during the

MATERIAL CONTROL - WAREHOUSING WG

Figure 3.14: Material Control - Warehousing WG

storage period in the warehouse as well as during erection. This maintenance is required prior to acceptance by the start-up group. Information handled during these processes will be supported by this system.

(4) Consumables - This subsystem is a sub-system of the Material Control System - Stock Material, but will contain only non-permanent material used on the project. This material will be used during construction, but will not become part of the plant.

(5) Min/Max Control System - This module is also a subsystem to the Material Control System - Stock Material and will be used for stock items which would have to be frequently reordered because of the quantity used and limited storage availability. Between 300-500 items can be monitored by this sub-system. Every stock item has an assigned minimum quantity, ordering period, and ordering quantity. The system provides periodic reports related to Min/Max status.

(6) Spare Parts - This system contains information related to spare parts required for equipment and components installed at the plant. The spare parts system supports the warehousing function. It also establishes proper relationships between spare parts and permanent plant equipment for easy retrievability of information during unexpected repairs and to support scheduled shutdowns and maintenance. The system is transferred to start-up and operation of the plant.

3.3.9 Primary Construction Equipment/Facilities Systems

Primary systems utilized by this application area are shown in Figure 3.15 and include:

(1) Facilities Management - This system is used as an information source related to effective utilization of facilities at the project. It is used to support operations in laydown yard areas, warehouse areas, and shops.

(2) Construction Equipment Inventory Control - This system is used to support inventory management of construction equipment at the project. The inventory control system is central to all other construction equipment management systems.

(3) Equipment Cost Control - This system supports all cost activities related to construction equipment which include capital cost as well as operational cost. The system interfaces closely with the Project Control System.

(4) Equipment Utilization and Performance - This system computes utilization and performance factors for construction equipment. It is also used to maintain a history of equipment utilization on individual project activities.

(5) Planning and Forecasting of Equipment - This system is closely interfaced with Planning and Scheduling systems to forecast and plan equipment requirements at the project.

(6) Small Tools Control - This system is specifically oriented to management of small tools. This includes warehousing, issuing, planning and cost allocation, and control of small tools.

Figure 3.15: Construction Equipment/Facilities EO

(7) Formwork/Scaffolding Management - Nuclear projects require a large amount of formwork and scaffolding which is utilized in many areas at the project. This system coordinates requirements, monitors utilization, and establishes proper cost allocation.

3.3.10 Primary Quality Control/Quality Assurance Systems

The primary system requirements of Quality Control/Quality Assurance are shown in Figure 3.16 and include:

(1) Welder Qualification - This system supports monitoring of welder qualifications to weld by accepted procedures. The system also maintains a history of welders at the project.

(2) QC Inspectors Control - This system is similar to welder qualification and monitors qualification of QC inspectors. It also maintains a history of inspectors at the project.

(3) Cadwelder Control - This system is basically the same as the welder control system and monitors cadwelder qualification.

(4) Concrete Cylinder Breaks - This system is used to evaluate statistical values related to structural testing of concrete at the project. The prediction of the structural behavior of concrete is based on comprehensive testing of 6 x 12 inch concrete cylinders. A proper evaluation of test data requires a large amount of statistical computation of values such as standard deviation, coefficient of variation, and required average strength. The system is based on the ACI "Recommended Practice for Evaluation of Field Concrete."

Figure 3.16: Construction Quality Assurance/Quality Control QA

(5) Aggregate Sieve Test - This system maintains sieve test data for concrete aggregates and computes required statistical data.

(6) Rebar Test - Rebar test data is maintained by this system. It also computes statistical values related to rebar testing.

(7) Cadweld Test - This system maintains cadweld test data and computes statistical values related to cadweld testing.

(8) Vendor Surveillance - The QA/QC group maintains a historical record of vendor related information and key information related to vendor audits and surveillance. This subsystem is used to collect this information and support inquiries.

(9) Nonconformance Trending - This system is used to monitor design deviations and nonconformances. Every deviation will be classified and entered into the system. The system monitors disposition of deviations and reports statistical data related to occurrences by classifications.

3.3.11 Primary Document Control Systems

Primary systems related to Document Control are shown in Figure 3.17 and are as follows:

(1) Design Document Control - This system controls development and issuance of design documents related to the plant. All design documents (drawings, bills of material, isometric drawings, field sketches, and specifications) are identified and maintained in this subsystem. The subsystem supports other systems such as (a) Work Breakdown Structure, (b) Configuration Control System, and (c) Scheduling

Figure 3.17: Document Control DC

Systems where information about design documents is required.

(2) Document Distribution Control - This subsystem functions as a supporting system to "Design Document Control" and assists in distribution of design documents. The system maintains a current list of receivers for every distributed document and supports replacement of documents with revisions.

(3) Field Generated Documents Related to Design - The documents contained in this system pertain to modification of plant design. These documents are part of the design documentation of the plant. Since they are dynamic in nature the control of their origination, follow-up, and affected areas is very important to the construction and/or fabrication effort.

(4) Project Records Management System - This system is one of the key systems at the project providing complete management support of project documents. The system encompasses several functions related to the management of records on the nuclear project. First, it defines the records requirement of every component, system, material, structure, or activity related to the project. Secondly, the system provides the means for classifying and identifying records which contain vital information such as: cross reference to structures, components, systems, activities, material, dates, originators, and responsibilities. Thirdly, this system provides automatic sorting, updating, and reporting of record information which gives accurate, up-to-date accountability for those records generated during the design, manufacture, test, operation, and maintenance of a nuclear

power plant. Finally, the system implements filing and microfilming techniques once a record is generated or received.

(5) Mill Test Reports - The purpose of this system is to provide unique traceability of material to a chemical and/or mechanical analysis. Mill test reports with Heat Numbers will be referenced to plant components and material used in construction/erection as well as purchase orders, vendors, and receiving reports.

(6) Procedures Control - Several hundred procedures are required to support the nuclear power plant design, construction, fabrication, start-up, and operation. This system provides a central repository for information related to development of these procedures, their relationship to plant segments or components, their interface with drawings, and the dependence of project activities on their status.

3.3.12 Primary Start-Up Systems

The primary systems required by the start-up application area are shown in Figure 3.18 and include:

(1) Start-Up Task Assignment - This system contains information pertinent to the acceptance of segments of the plant. It is closely related to the construction schedule and interfaces with the construction schedule via a start-up network which is normally processed automatically using a CPM processor. It maintains information relating to start-up packages such as component status (from the CCS) and start-up system boundaries.

Figure 3.18: Start Up Operation SU

(2) Plant Periodic Maintenance - This system establishes procedures for maintenance of accepted plant segments.

(3) Material Control - Spare parts status for accepted plant segments is maintained by this system.

(4) Plant Reliability Data - This system maintains data related to system acceptance and performance data.

(5) Plant Maintenance Management System - One of the major tasks performed by the Start-Up Team is the establishment of procedures for the maintenance of the plant during operation. This system defines maintenance procedures, schedules, replacement and inspection policies. Data relating to operational maintenance are contained in this system.

3.3.13 General System Layout Chart

In the preceding sections, systems required to support the 16 application areas defined in Chapter II have been identified. The systems provide a procedural link between the processes intrinsic to each application area and the data base consisting of data elements. This is shown conceptually in Figure 3.19. Systems structure the user's view of the data to be processed and the processes to be performed. They constitute the ultimate bridge between the user or practitioner with job site requirements and the systems expert charged with the efficient manipulation and presentation of data.

The systems presented do not represent an exhaustive inventory of all the systems needed on a nuclear power plant. They are, rather,

FIGURE 3.19: SYSTEM INTERFACE BETWEEN PROCESSES AND DATA BASE

a fairly representative set indicating the broad scope of activity which organizations are responsible for and therefore require either manual or automated methods to accomplish. Some of the systems such as those related to Quality Control come about as a result of regulatory and licensing requirements which must be met. Other systems, such as the warehousing systems, evolve naturally as a direct result of the need to bring order to the movement of material to the site. Some systems such as the scheduling system are generated to assist management in controlling the project. Whether mandatory or discretionary, the systems described in this section reflect the virtual minimum

number required to manage many aspects of engineering, procurement, construction and start-up given the existing complexity and magnitude of nuclear power stations.

A composite layout diagram emphasizing major system interfaces with the Configuration Control System is shown in Figure 3.20. Not all of the systems discussed are present. This chart does, however, present an overall layout of the Nuclear Power Plant Information Control System. The scoping is done mainly from the user point of view and the chart consolidates the set of individual charts prepared for every application area in the previous sections. Table 3.5 shows the interrelationships between systems, sub-systems, and application areas implied by the General Layout Diagram.

TABLE 3.5

APPLICATION AREA INTERFACE TABLE

PRIMARY USER CODE	DESCRIPTION TITLE OF SYSTEM/SUBSYSTEM	OTHER APPLICATION AREA USAGE (CODES)
PL	<u>Planning/Scheduling</u>	
	Milestone Schedule	
	Work Breakdown Structure	FE/EE, EQ, DC, CC & ES, EM & FM, FC/EC
	Medium/Short Range Schedule	EM & FM, FC/EC, FE/EE, EQ
	CPM Schedule	EQ
	Network Graphic System	
	Resource Allocation & Leveling	
	Manpower & Material Projection	CC & ES
CC & ES	<u>Cost Control/Estimating</u>	
	Estimating Cost System	PL, PS, EM & FM, FC/EC, EQ
	Cost Control System	PL, EM & FM, FC/EC, PE, WG, EQ
	Chart of Accounts	
	FPC Chart of Accounts	
	Production Units Processing	PL
	Cashflow System	PL, PS, PE
PS	<u>Project Services</u>	
	Personnel System	
	Payroll System	CC & ES
	Accounts Payable	CC & ES, PE, WG
EM/FM	<u>Mechanical Engineering - Field Construction</u>	
FC/EC	<u>Civil Engineering - Field Construction</u>	
FE/EE	<u>Electrical Engineering - Field Construction</u>	
	Configuration Control System	PE, WG, EQ, QA, QA-CL, DC, PL, CC & ES, QA-EL
	Field Reporting Processing	PL, CC & ES, PS, EQ
	Crew/Employee Productivity and Performance	PL, CC & ES

TABLE 3.5 (CONTINUED)

PRIMARY USER CODE	DESCRIPTION TITLE OF SYSTEM/SUBSYSTEM	OTHER APPLICATION AREA USAGE (CODES)
PE	<u>Purchasing/Expediting</u>	
	Subcontract Management	WG, DC, PS, EM & FM, FC & EC, FE/EE
	Purchase Order Control	PS, EM & FM, FC/EC, FE/EE, WG, EQ, DC
	Expediting System	EM & FM, FC/EC, FE/EE, WG, EQ
WG	<u>Material Control - Warehousing</u>	
	Material Control System - Stock	FE/EE, PE, EQ, QA, DC, CC & ES, PS, EM & FM, FC/EC
	Material Control System - Comp..	FE/EE, PE, EQ, QA, DC, CC & ES, PS, EM & FM, FC/EC
	PERMANENT PLANT	
	Equipment Periodic Maintenance	QA
	Consumables	CC & ES, PS, EM & FM, FC/EC
	Min/Max Control	FE/EE, EQ, EM/FM, FC/EC, PE
	Spare Parts	FE/EE, PE, EQ, DC, CC & ES, PS, EM & FM, FC/EC
EQ	<u>Construction Equipment/Facilities</u>	
	Facilities Management	WG, PL, FC/EC, FE/EE, PE
	Construction Equipment Inventory Control	PL, FC/EC, PE, QA
	Equipment Cost Control	PL, CC & ES, PS
	Equipment Utilization and Performance	PL, FE/EE
	Planning & Forecasting of Equipment	PE, PL, FC/EC, FE/EE
	Small Tools Control	WG, QA, PL, FC/EC, FE/EE, PE
	Form Work/Scaffolding Management	PL, FC/EC, FE/EE, PE

TABLE 3.5 (CONTINUED)

PRIMARY USER CODE	DESCRIPTION TITLE OF SYSTEM/SUBSYSTEM	OTHER APPLICATION AREA USAGE (CODES)
QA	Construction Quality Assurance/Quality Control	
QA-CL	QA/QC Supplement (Civil)	
QA-EL	QA/QC Supplement (Electrical)	
	Welder Qualification	PS
	QC Inspectors Control	PS
	Cadwelder Control	PS
	Concrete Cylinder Breaks	
	Aggregate Sieve Test	WG
	Rebar Test	WG
	Cadweld Test	
	Vendor Surveillance	WG, DC, PE
	Nonconformance Trending	EM & FM, FC/EC, DC
DC	Document Control	
	Design Documents Control	QA, EM & FM, FC/EC, FE/EE
	Document Distribution Control	
	Field Generated Documents Related to Design	EM & FM, FC/EC, FE/EE, QA, SU
	Project Records Management System	PE, WG, QA, EM/FM, FC/EC, FE/EE, SU
	Mill Test Reports	EM & FM, QA
	Procedure Control	PL, FE/EE, QA, DC, SU
SU	Start Up/Operation	
	Plant Reliability Data	
	Plant Maintenance Management System	DC
	Plant Periodic Maintenance Schedule	
	Start Up Task Assignment	
	Start Up Schedule	PL

3.4 Computerization of the Project Configuration Model

3.4.1 Configuration Control System

The development and implementation of the Project Configuration Model must be supported by a well-designed and comprehensive computerized system. It would not be practical to maintain a model of this complexity by any other means. The computerization of the model will provide interactive simultaneous access to information by many users in various locations. The most significant benefits will be better and faster communication between users, flexible manipulation of data into inquiries and reports, development of relationship between data records and data elements, uniform and systematic management of information for the whole project, handling of large amounts of data, and a more systematic approach to information management. The hardware and software supporting this model should have sufficient capacity to handle a large number of quick turn-around requests. These requests will include both inquiries and ad hoc reports. The user should be encouraged to work with the system on an inquiry basis. The system should be readily accessible to the user. The computerized methods should be transparent to the user, generating the impression that he is working with the Project Configuration Model rather than with a computer system.

3.4.2 The Contents of the PCM Data Base

Every segment of the PCM will be identified by a set of parameters which provides the identity of the segment in terms of location, system structure, material, and type of segment. These parameters also will provide pointers or ties among individual segments. The data structure

will be as follows:

PCM Segment	Segment Type	Building	Floor	System Number	Startup Number	
	Parent Segment	Related Segments				

Every PCM segment identified in this fashion will have attached to it records pertaining to individual project control functions or information records which will further define the characteristic of the PCM segment.

The following records or combination of these records would be typical:

Quantities and Volume

Component or Segment Number	Quantity Code	Quantity	Unit of Measure	Date of Estimate	

Scheduling Activities/Packages Associated with the Segment

Component or Segment Number	Activity Number	Work Package Number	Activity Description	Activity Type	Other Info. Related to Activity

Cost Code Relation

Component or Segment Number	Cost Code Number	Cost Code Type	Estimated Value	Actual Values	Other Information	

Design Engineering Data

Component or Segment Number	Document Number or Document Package Number	Document Type	Status of Documents	Schedule for Documents	

Engineering data will be specifically related to the segments and components of individual levels. This data will be selected according to the type of segment and/or component. Some typical examples of engineering related segments are given below.

Concrete Segments

Component Pointer	Concrete Pour Number	Concrete Class	Type of Structure	Amount of Concrete	Steel Req.	Special Information

Equipment Component

Component Pointer	Equipment Number	Equipment Type	Equipment Description	Model Number	RPM	Horse- power
		Electrical Equipment	Voltage	Current	Computer I/O Number	
		Mechanical Equipment	Operating Temperature			

Instrumentation Component

Component Pointer	Instrument I.E.	Instrument Type	Rack Number	Model Number	Seismic Class	Mounting
		Electrical	Input Range	Accuracy	Set Point	
		Pneumatic	Design Pressure	Temperature		

System Segment

System Number	System Description	Location of the System	QA Classification	System	Type

Procurement Information

Component or Segment No.	Material Type	Purchase Order No.	Requisition Number	Vendor Code	Status
	Delivery Date	Purchased Quantity	Unit of Measure	Received Quantity	
	Unit Price	Total Price			

Warehousing/Material Control

Component or Segment No.	Warehouse Stock No.	Location	Quantity Ordered	Quantity Received	Field Mat. Req. No.

Field Construction

Planning:

Segment or Comp. No.	Craft Act.Code	Start Date	Duration	Crew No.	Manhours	

Execution of Work:

Comp. or Segment No.	Erection Status	Manhours Expended	Erection Dwg. No.	Quantity Erected	

Document Control

Every document generated at the project should be referred to a segment or component of PCM.

Component or Segment No.	Document Type	Document Number	Date	Originator	File Location

Startup Information

Component or Segment	Startup Number	Startup Activities	Startup Status

3.4.3 Software Requirements

A comprehensive Data Base Management System (DBMS) will be needed as the basis for developing the PCM. The DBMS should be able to handle large amounts of data elements with fairly complex relational logic. The data base will be supported by a Data Element Dictionary providing support in manipulation of individual data elements. The data base organization might

have several forms according to the relationship among data. The data base should be accessible in batch mode as well as inquiry mode for update purposes as well as reporting purposes.

3.4.4 Hardware

The PCM should be easily accessible to users in many locations. Hardware should provide inquiry type of access to those locations with a small amount of hard copy output capability and also batch processing for several key locations. Network type of processing will be necessary to support all users. Different data substructures will be needed at certain locations. These partial copies of the data base will be backed up at one central data base on the host computer. Basically, the hardware should support on-line access (CRT), character printers, line printers, extensive disk storage capacity, plotting capability, data entry for several local stations and several key locations.

3.4.5 Project Configuration Model User Manual and Procedures

One very important aspect of PCM development will be the development of a comprehensive PCM user manual and procedures related to individual functions of the model. Most systems fail because of the lack of good documentation and user training. The user manual should define the overall philosophy and structure of the model, the context of the model, and the model interface characteristics. The manual or set of manuals should provide a comprehensive "cook-book" for every project user. The procedures, on the other hand, will outline the specific use of the PCM by individual groups for their functions and activities. The procedures will establish responsibilities, auditing requirements, validation steps,

methods for collection of data, and updating of the model. The procedural portion of the PCM documentation will provide a format for specific utilization of the model for individual activities and processes.

The development and implementation of this concept will help the future expansion into much more sophisticated model graphic processing. The graphic processing of the model will require geometric description of every component or set of components. This geometric data base will have a significant number of users primarily from designer and engineering points of view. The following activities could be supported using geometric modeling:

- (1) Graphic processing of the model
  - Plotting of drawings and sketches
  - CRT display of modeled segments and model sections
- (2) Modeling of sequence of erection, preparation of erection sketches
- (3) Space utilization modeling
  - Design purposes
  - Availability of space for construction and erection
- (4) Optimization of system runs (piping, cables, conduits)
- (5) Redundant system separation design and verification
- (6) Design interference verification and analysis

Chapter IV

System Implementation

4.1 Introduction

Utilizing the user-oriented concepts developed in Chapter 3, this chapter considers the problem of integrating the data base approach from the systems viewpoint. Several different elements in the form of both diagrams and narrative are presented. Specifically, the following systems design aids as developed during the Phase I activity are discussed:

- (1) Global architecture of the system
- (2) System interface diagrams
- (3) HIPO charts
- (4) Central system design-in-principle
- (5) Data base design-in-principle

Together, their elements constitute the design-in-principle of a computer-based information system which we recommend for the support of the construction of nuclear power stations. In order to understand this design it is necessary to understand the role of its various elements.

4.2 Global Architecture of the System

The global architecture of the system is an elaboration of the design concept chart given in Figure 2.11. It shows typical elements within the major system component areas (Figure 4.1). The user/system

FIGURE 4.1:

GLOBAL ARCHITECTURE of the SYSTEM.

interface, for example, will be made up, in part, of user materials, written user procedures, data entry documents and formats, and report formats. The system/data interface will include a data base management system, data dictionary software, and a report generator. The system itself will support many functions but will contain modules which either currently exist and can be acquired or must be designed and developed.

This conceptual layout of the system provides a starting point for the systems analyst in addressing the question presented at the end of Chapter 2 regarding "How are the books (data elements) stacked in the library (data base)?" The user viewpoint presented in Chapter III is important since it indicates the nature and function of the data with which he must deal. The systems analyst investigates the data elements with a view towards how best to lay out the data structure. Using the 1300 data elements defined with the methodology described in Figures 2.10-2.17 as a point of departure, systems analysts of the team* analyzed the processing characteristics of the information intrinsic to the application areas. Charts reflecting these characteristics were developed using the technique called HIPO.

4.3 HIPO Charting

The Hierarchy plus Input, Process, Output (HIPO) technique provides a means for the definition and description of application area

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*The effort was headed by Dr. R. A. Lewallen, Daniel International Corporation.

processes from the systems analyst viewpoint. The application area is described first in the form of the Hierarchy Diagram (see Chapter 2, Section 2.8) which indicates the functional and process structure of the application area. Developing the Hierarchy Diagram is a top-down procedure in which the analyst begins with an inclusive description of the entire application area and then breaks this single step view into a set of component processes, which, taken together, are still inclusive of all the functions contained in the application area.

The Hierarchy Diagram for the Planning/Scheduling application area is shown in Figure 4.2. The entire process is first described as a single block identified as PL/1.2 Planning and Scheduling. 1.2 simply identifies the block within the overall hierarchy consisting of all application areas. Block PL is then decomposed into sub-processes (functions) represented by blocks PL-1 through PL-9. Block PL-1 is decomposed into PL-1-01 through PL-1-03 and so on. The vertical arrangement of PL-1-01, PL-1-02, and PL-1-03 does not indicate a hierarchical arrangement but rather merely simplifies presentation.

The Planning/Scheduling Hierarchy Diagram corresponds directly with the Planning/Scheduling Application Area outline and Process Description Sheets (see Figures 2.12-2.16) contained in Appendix E. These work sheets constitute the system specifications. Thus PL-1, Develop Work Breakdown Structure, is also a function in the Planning/Scheduling specifications. As noted in Chapter II, hierarchy diagrams for all application areas are included in Exhibit II at the end of this volume. The hierarchy diagrams aid the analyst in identifying

Figure 4.2: Planning and Scheduling (Hierarchy Chart)

HIPO chart

Appl. Area: PLANNING/SCHEDULING

1

Figure 4.3:

top down information flow relationships and help to establish process borders, thus avoiding data overlay (redundancy) and improving the ability to aggregate information in a summary format at various hierarchical levels. This layout is a significant aid in developing HIPO charts for each application area.

The Hierarchy plus Input, Process, Output (HIPO) technique is an organized approach to the visual presentation of processes. The diagram in Figure 4.3 is a modified Overview Diagram for the Planning/Scheduling activity. The modification consists of the inclusion of multiple hierarchy blocks on a single diagram. Thus, block PL-1-01 on the Hierarchy Diagram becomes step 1 on the Overview Diagram. The Overview Diagram indicates that General Arrangement Drawings, Plant Description, and Draft of Work Scope are input to step 1 while a Level 1 Work Breakdown Structure (Milestone) is the output. Similarly, the input to the second process (Develop Level 2 Work Breakdown Structure) is given in the input column as:

- (1) Level 1 Work Breakdown Structure
- (2) General Arrangement Drawings
- (3) Preliminary System Drawings
- (4) General System Descriptions
- (5) Level 1 Work Scope (Total Project)

The input and output characteristics derive directly from the Process Description sheets of Chapter II and the Overview Diagram

corresponds directly with the Planning/Scheduling specifications contained in Appendix E. Overview Diagrams for all application areas are included in Exhibit III at the end of this volume.

Reviewing the methodology used to analyze the relationship of data elements to processes presented above, the sequence is as shown in Figure 4.4.

FIGURE 4.4: THE INTERFACE CHART DEVELOPMENTAL SEQUENCE

The construction of the process Interface Charts constitutes the last step in analysis prior to defining the Central System Design-in-Principle.

4.4 System Interface Diagrams

The system interface diagrams illustrate the interrelationships among the application area processes implicit in the plant configuration control concept. A typical Interface Chart for the Purchasing/Expediting (PE) application area is shown in Figure 4.5. Nine processes are shown. At the left, the process "Develop Approved Vendors Lists" (PE-1-02) utilizes an exogenous input referred to as SURVEY. This indicates that a survey of vendor qualifications has been accomplished. The output of this process flows to the Purchase Material and Equipment process (PE-1-03). Other inputs to this process include unspecified DESIGN and VENDOR processes as well as input from:

- (1) EE-3-01 QUANTITY TAKE-OFF
- (2) EM-4-01 Preparation of Requisition
- (3) WG-3-02 Maintain Min/Max Stock System
- (4) PE-1-04 Issue Bid Package Modifications

The process generates outputs to VENDORS as well as:

- (1) DC-2-02 Classify and Index Documents
- (2) DC-4-01 Control QC Documentation from Vendors and Warehouse Receiving
- (3) PE-2-01 Expedite Vendor Date Submittal
- (4) PE-3-01 Maintain Purchasing and Expediting Records
- (5) PE-2-02 Expedite Fabrication and Delivery
- (6) PE-2-03 Administer Contracts, Subcontracts
- (7) PE-1-04 Issue Bid Package Modifications

Figure 4.5: Purchasing Expediting (Interface Diagram)

The legend at the right of the chart gives descriptions for those processes external to the application area which interface with internal processes. Interface diagrams for all application areas are given in Exhibit IV.*

The interface diagrams provide extensive information on the routing of information between processes. They also provide a set of basic design documents which can be used for the data base layout. With this comprehensive "map" of data flows, the systems analyst is in a position to sketch out the Central System Design which will be used for structuring the Data Base Design-in-Principle.

4.5 Design in Principle

Several comments are necessary regarding the nature of a "design-in-principle." First, it is not a final or implementable design. As we have noted earlier, major design and implementation phases must follow this one if this design is to become a reality. Perhaps the design-in-principle is most analogous to an architect's preliminary sketches of a project. We are saying, in effect, that, conceptually, this is the best way to structure a system to meet the specifications which were developed in this phase and are presented in Appendix E. With regard to the actual implementation of these concepts in our system design and data base design, we are saying that this is a way in which the design concepts can be realized. At the moment we believe

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*Civil Engineering and Field Construction are not included in this initial design.

it to be the best way, but this will undoubtedly change as more information becomes available. Specifically, we expect that the process of moving toward implementation of our concepts in a real environment will force some changes if not entirely new designs. Finally, we must emphasize that the designs-in-principle are sketch-like both in lack of detail and in their partial coverage of the total application. We have covered what we considered to be the key areas and have stubbed in or omitted altogether those which we considered to be less critical. The intent is to communicate ideas - not detailed and self-contained solutions.

As indicated earlier, the overall system design consists of a data base, a set of operational systems which both draw from and support that data base, and a capability for dealing directly with the data base in creating special-purpose reports.

The Design in Principle Chart (Figure 4.6) is a typical system chart showing the interrelationship of inputs, outputs, files, computer processes, and directly-interfaced manual processes. In the upper left-hand corner of the chart, for example, a computer process labeled PCM Builder takes input in the form of General Arrangement Drawings and Plant Descriptions and produces the Plant Configuration Model (PCM) on direct-access storage. This model is accessed by a process labeled Milestone Schedule Builder in order to build a Milestone Schedule. The on-line symbol indicates that this is an iterative process where the human operator interacting with the system has Previous Milestone Schedules and Project Status available

Figure 4.6: Central System Design (In Principle)

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to him. Event Data and Site Required Data are input directly to the computer process. The PCM Schedule/Work Package Builder both supply information to the process and are updated by the process.

The System Design-in-Principle illustrates computer-based functions and their interface with the user. Manual processes other than those which directly interface with computer-based functions are not shown. The files shown on the system chart correspond to data base subschemas and they are elaborated in the data base design-in-principle. Where the on-line symbol is used on the diagram, this is intended to indicate an interactive relationship between the user and the system. The diagram represents a static view of the system. No attempt is made to show iteration. Schedule building is clearly an iterative process throughout the life of a project. Here, however, it is shown merely as a static relationship of interactive input and output subschemas and computer-based functional modules.

The operational systems presented are only a subset of those which would eventually be implemented. The systems selected are those which are felt to be most important in initializing a data base system. The chart obviously contains much less detail than would be necessary for implementation. The intention is merely to present a sketch of what will be needed to implement the central system design.

4.6 Data Base Design

The objective of this section is to describe the proposed structure of the data base, which is intended to contain most of the information used by the systems outlined in the central system design. The word "structure" is important, since it is envisioned that the data base design will provide the skeleton or framework which supports the majority of the data used by the construction project.

This method of data organization is distinctly different from traditional methods in which a data file is normally defined and used by a single system. This results in frozen program-data relationships and makes it difficult to share data files between different systems, which may not use all the same data items. With the data base approach, data is recognized as an entity in its own right; the data structures are established independent of any of the programs which will access them.

This independence of the data from the programs which use it offers the following advantages:

- (1) Data items may be added or deleted from data files without affecting the application programs.
- (2) Each application program may use its own set of data items from the same data file.
- (3) Data redundancy is reduced, since a data item which is used by more than one application program need appear only once in the data file.

(4) Requests for new reports can be satisfied more quickly, since the data required is more accessible.

The nomenclature and data structure diagrams used in this section follow the conventions established by the CODASYL Data Base Task Group (CODASYL is an acronym for the Conference on Data Systems Languages.) In the diagrams which follow, each block represents one record type in the data base. When implemented, each record type in the diagram will be replaced by many instances of the record type. (A personnel record is a record type; the personnel records for Bill Brown, Sam Smith, etc. are instances of the record type.)

An arrow drawn from one block to another denotes a set relationship. The block at the tail of the arrow contains the owner of the set; the block at the head of the arrow contains the members of the set. (For example, the following diagram depicts the set relationship "assignment" between record types department and employee. Instances of this set relationship might be: the accounting department and its employees, the purchasing department and its employees, etc.)

Exhibit V contains the subschemas of the data base design-in-principle. Figure 4.7 shows the schema, or overall logical view of the entire Project Configuration Model (PCM) data base. Set relationships have not been named. Due to the preliminary nature of this design-in-principle, changes in these relationships are likely. An arrow from one block to another indicates that we feel a relationship ought to exist between these two record types.

The subschemas in Exhibit V represent different logical views of the PCM data base as seen by the various application subsystems. For example, the Receiving Subschema (Figure 4.8) shows the PCM data base as viewed by the Receiving Subsystem. To this subsystem, the PCM data base consists of five record types and six set relationships.

No attempt has been made in this volume to show the data elements which comprise each record type (the data items which are grouped together in an instance of the record type). This type of detail would tend to obscure the relationships. This will be accomplished during the conceptual design phase of the project following Design in Concept. Suffice it to say that each record type probably represents 5 to 50 data elements with an aggregate length of 100 to 500 characters.

The data base, as presently defined, contains some 50 record types and 90 set relationships. Assuming that one million records are required with an average record length of 250 characters, this results in a storage requirement of some 250 million characters for each nuclear construction

Figure 4.7: Project Configuration Model (Overall Schedule)

FIGURE 4.8: PROJECT CONFIGURATION MODEL
(MATERIAL RECEIVING SUBSCHEMA)

project supported. While this is certainly a large data base, it is well within the state of the art of today's data base technology.

4.7 Implementation Considerations

Three primary topics are addressed in this and the following section. First, a statement indicating the point in the system development process which has been reached with the publication of this report is in order. The process of conceiving, designing, and implementing a computer-based information system is both complex and long. The reader needs to understand what has been accomplished to date and, perhaps more importantly, what remains to be done. This, in fact, is the second topic for consideration. The steps necessary to proceed from the point represented by this report to the actual operation of an installed information system are presented in overview. Finally, it is helpful to indicate some of the possibilities which should be considered during the implementation of the design-in-principle described in this report. It is important to emphasize that the options discussed will be possibilities only. The actual systems choices will be made after in-depth investigation and evaluation in the course of the processes described below.

In the introduction, the nature of a Design-in-Principle was discussed. Further discussion is relevant here since an understanding of this term is essential to an understanding of the remaining systems processes. In a project of the magnitude of Information Management for Nuclear Power Stations, it would be ill advised, if not impossible, to

proceed directly to the development of detailed designs of individual information systems. From the conception of this project it was apparent that development would have to occur in an iterative or cyclical fashion with ample provision for industry input at each stage. Furthermore, it seemed clear that an innovative and successful final design would be achieved by a top-down, general-to-specific approach. Thus, after examining current information processes involved in the construction of nuclear power stations, critical conceptual and structural flows were identified and a conceptual approach was initiated which would overcome these problems within the overall design concept presented earlier. With the top-down design concept as a guide, a conceptual framework or design-in-principle in terms of which the data integration can be viewed has been developed. The design-in-principle specifies the system in terms of components and their relationships at a general level. It defines, for example, system inputs, outputs, and data bases. It also distinguishes functions to be performed by the computer. It does not, however, attempt to specify hardware or software or even to indicate how computer-performed functions will be broken into specific programs or program segments. No attempt is made to project system costs, benefits, or time performance. It is hoped that the publication of this report will elicit substantial critical input from industry. With this comment and criticism in hand, both the design concept and the design-in-principle can be re-examined and improved. The revised design-in-principle becomes the starting point for the development of a general design and a corresponding

feasibility analysis. In the general design, both manual and computer functions will be elaborated in substantial detail.

While equipment will continue to be identified in generic terms, required capabilities will be specified in detail. It might be specified, for example, that terminals are required to support the estimating function and further that the terminals must have certain specific capabilities. A general study would not attempt to identify a particular terminal or vendor. Following completion of the general design, benefits resulting from the implementation can be projected. At this point, a careful hardware and software selection process can be initiated which would culminate in the specification and ultimately in the procurement of specific hardware and software components.

The next step would be one of detailed design. A subsystem or a set of subsystems would be selected from the general design and elaborated in extensive detail. This detailed design would become input to the programming and to the manual procedure development processes. Programming would be followed by testing and procedures manuals. User personnel would be trained, and, upon completion of a successful systems test, the subsystem installed. The subsystem process would be repeated as necessary until the general design was fully implemented.

4.8 Major Decision Areas

Perhaps the single most important set of decisions to be made following the decision to proceed with the design-in-principle will be those related to the selection of a hardware system. Here again the first step will be to investigate and settle upon an overall design concept. The design concept in this case will establish the relation or allocation of computer resources to functional processes. Most basically, should computer capability be centralized or decentralized? Should dedicated systems be located in each, or, at least, most of the application areas or should each project have one large facility reviewing all of the areas? An alternative concept would combine a central facility with smaller remote units in a network arrangement. Certain tasks could be performed by the remote unit while other tasks could be transmitted to the central facility for processing.

In the case of a large central facility, the question of processing mode will have to be resolved. Will processing be batch, on-line, or a combination of the two? If it is to be a combination, which functions will require on-line capability? Finally, we must consider whether the central facility should be located at the work site or at the constructor's or the owner's headquarters.

Decisions concerning software capability divide into those concerning data base software and non-data base software such as language compilers and operating systems. Data base software consists of these components:

- (1) Data Base Management System
- (2) Data Dictionary
- (3) Query Language

Organizational decisions are, of course, critical to the success of the project. Specific choices are dependent upon the environment within which the system is to be implemented, but general comments can still be made. It is clear, for example, that the successful implementation of information systems in any environment depends heavily on a commitment and involvement by user management. Commitment should be a precondition for the project itself, but involvement can be accomplished by organization. At the highest levels, involvement as well as guidance and coordination is provided by a steering committee composed of a senior project management staff. Within each subsystem area a similar steering committee may be appropriate. Placement of the system activity within or relative to the project organization is important also. Placement should be such that the authority of the systems project manager is commensurate with that of the project manager. While an ongoing data processor is frequently located under the project controls or the project services function, it is not felt that a similar placement is appropriate for a system of the scope and magnitude of the one which is proposed here. It is suggested that consideration be given to defining the systems function as a separate operation reporting directly to the project manager.

The staffing of the implementation effort will depend on the staging of subsystem implementation. In general, staffing the project

from general design onward with a wide array of systems as well as application area skills is suggested. At one extreme, the project staff should include systems specialists with very strong backgrounds in computer technology. At the other extreme, the staff should include persons widely experienced in the construction of nuclear power stations with some exposure to systems analysis. Other areas of staffing required include systems project management, computer systems architecture and hardware selection, data base design, data base management systems, human engineering, procedure writing, and programming.

Following general design, equipment selection, and a decision to proceed based on cost-benefit analysis, a detailed implementation plan must be developed. Such a plan would schedule the following processes for every subsystem to be implemented.

- Develop Budget

- Develop Project Control Mechanisms

- Detailed Design

- Additional Hardware or Software Procurement

- Site Preparation Plan

- Training Plan - Systems Personnel

- Training Plan - User Personnel

- Systems Personnel Training

- Programming

- Procedure Writing

- Site Preparation

Program Testing

System Testing

User Personnel Training

Conversion

System Evaluation

As was noted earlier, subsystem implementation should be phased.

There are several possible approaches to determining the order of phasing. First, subsystems could be implemented in order of importance. It may, for example, be decided that one of the configuration control subsystems is particularly crucial to the construction process and should be implemented first. Alternatively, subsystems could be implemented in order of increasing difficulty. The idea here would be to arrange the implementation process so as to adapt to the learning processes of both systems and user personnel. Finally, the order of subsystem implementation could be arranged in a way designed to present user personnel with a system evaluation. Under this approach, the first subsystem to be implemented would be one which is both useful and readily understandable to user personnel. When this subsystem has stabilized and user personnel are comfortable with it, a second subsystem which extends the system capabilities would be implemented. This procedure can then be repeated until all subsystems are implemented.

4.9 Conclusions and Future Work

The intent of this study has been (1) to study methods for the control of information during the construction and start-up of nuclear power plants, and (2) to identify those data elements intrinsic to nuclear power plants which must be maintained in a structured format for quick access and retrieval. This has laid the groundwork for the design of an integrated information management system which is responsive to the needs of the team charged with the construction management and control of a nuclear power station.

The power and flexibility of currently available central computer systems, combined with remote data entry terminals, makes implementation of such a system technologically feasible for the management of nuclear power station construction. The problems relative to information management and project control in nuclear power plant construction make such a system desirable for the following reasons:

(1) Numerous delays have been caused by the lack of prerequisite information and material. Frequently, these delays have been caused by the lack of a clear understanding of scope, responsibility, and commitments.

(2) Numerous instances of communication breakdowns have been noted between organizations, functional departments, and individuals involved in the development of nuclear power projects.

(3) In many cases, research and design work has been duplicated because it was not available to a certain organization at a specific time.

Mismanagement of information results in significant delays in completing nuclear projects and bringing them on line. The cost of delays in the operational dates of plants presently under construction is estimated as high as \$500,000 per day. Clearly, a reduction in these delays can result in significant savings for the utility user.

The scope of future work is shown graphically in Figure 4.9. As an initial activity in the next phase, comments and suggestions regarding the "design-in-principle" should be solicited from major utilities and service organizations within the nuclear power industry. These utilities would be asked to review the Phase I report and provide input regarding the improvement and extension of the concepts presented.

Based on this user review, a final conceptual design would be prepared to include suggestions from the user group. This will provide a definitive set of specifications which can be used for the detail design of individual application area modules. This conceptual design will include information regarding required categories of input, formats for output screens and reports, the modes of processing required, and precise information regarding interfaces between individual application area modules.

Implementation of the entire system will be in a sequential mode. That is, certain modules will be selected as the lead module or modules to be implemented within an actual project environment. This is consistent with the desire of utilities who have been contacted regarding the use of their projects as a "test bed" for the integrated system.

FIGURE 4.9: GRAPHICAL PRESENTATION OF THE PROPOSED SCOPE OF WORK

Therefore, a building block approach would be used. One or two selected modules will be carried through detail design and prepared for implementation within an operational project environment. After detail design is completed for the selected modules, one module will be chosen for pilot installation on an ongoing project. The procedures for testing and implementing the module selected will be coordinated with the utility providing a test site. The test environment will provide access to actual project data and allow evaluation of the improved speed of transmission and access to information provided by the integrated system. Following implementation of the first module, a second module will be installed. This process will continue until detail design and implementation of all application area modules presently defined have been site tested.

The system in its final configuration will be designed to transcend traditional organizational and departmental lines. This will allow users in one department to access knowledge generated outside their immediate area of activity. Such a system should eliminate overlap and redundancy, integrate all information channels, and create a single responsibility for the collection and maintenance of project related data.

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EXHIBIT I

PROJECT CONTROL SYSTEM CONCEPTS

EXHIBIT I

Project Control System Concepts

The concepts basic to a Project Control System (PCS) have been summarized as follows:

In order to MANAGE, one should be able to CONTROL
In order to CONTROL, one should be able to MEASURE
In order to MEASURE, one should be able to DEFINE
In order to DEFINE, one should be able to QUANTIFY*

The Clinch River Breeder Reactor Project (CRBRP) Control System is typical of a variety of project control system which have been developed to provide management with a means of controlling the high technology projects of today. Nuclear power projects are representative of this type of complex construction. Other nuclear construction activities utilizing Project Control Systems are;

- (1) Fast Flux Test Facility - Hanford, Washington.
- (2) Southern Company Services - Vogtle Nuclear Power Station
- (3) GPU Services - Three Mile Island Unit 2, Homer City Unit 3
- (4) Bechtel Corporation - PP&L Susquehanna Steam Electric Station
- (5) Daniel International - SNUPPS System - Callaway Plant Units 1 & 2

Various features of these systems are described in Appendix A (Volume III) to this report.

All of these system are based on the decision cycle or feedback loop shown in Figure 1.3 of Chapter I and the principles presented above.

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* D. Burchfield, "Systems Analysis in Management," Analytic Progress, January, 1970.

A short discussion of the CRBRP will aid in understanding what systems are typically of interest in a Project Control System (PCS) utilized to control nuclear power projects. As stated in Chapter 1, the many organizations which interface to realize the construction of a nuclear power plant have a wide range of views of the project. These views tend to emphasize those functions peculiar to a particular organization and its discipline. These views are not necessarily compatible and, therefore, lead to difficulties in talking about and communicating information regarding the same activity or element of construction. Realizing that this communications problem exists, the CRBRP first established a set of guidelines for the operation of all project organizations. This document is called the Management Policies and Requirements (MPR) and consists of the following sections:

- (1) Introduction
- (2) Management and Planning
- (3) Design and Development
- (4) Procurement
- (5) Manufacturing
- (6) Construction and Installation
- (7) Operation, Maintenance, Modifications
- (8) Quality Assurance
- (9) Licensing
- (10) Reliability

Although the MPR is not a set of procedures, it provides a guide for the development of procedures which facilitate communication and

coordination of common areas between project groups and organizations.

"The MPR addresses all aspects of the project. There are separate organizations within the Project Office to attend to these areas. The Engineering Department focuses upon design and development and on manufacturing; the Office of Public Safety addresses licensing and reliability. Procurement, construction, operation and quality assurance each have separate organizations."*

A great deal of emphasis in a PCS is placed upon the areas of planning, scheduling, cost control, estimating and progress reporting.

The key progress reporting element within CRBRP control is a computerized system called the Project Status and Control System. Various modules within this system maintain status on all principal design documents and equipment. All modules are interfaced with the project network (see Table I.1). All organizations can access this statusing system via computer terminals located at their sites. This expedites not only information access but also insures a timely system based on day to day or week to week updating.

The project is sub-divided into several hierarchical levels to expedite communication of information and the measurement of progress. The plant is broken into systems. Each system has an associated System Design Description (SDD). Below the SDD's, a set of Work Agreements establishes the scope and the basis for realizing the various systems.

"A work agreement contains a brief description of the work scope covered, a breakdown of the work into more manageable pieces called line items, a cash flow by fiscal year detailing the cost of each line item, and a near term schedule of milestones associated with each line item."**

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*David H. Smith, CRBRP Project Control,

**Ibid.

TABLE I.1: ELEMENTS OF THE PROJECT STATUS AND CONTROL SYSTEM

o Document Status

Overall Listing Approved Project Documentation,
Identifying Release Date (Schedule Or Actual) And
Revision Status, Data Type, And Cognizant Engineer

o Document Hold Status

Overall Listing Of Holds In Approved Documentation,
Identifying Responsible Individual And Date For
Release

o Equipment List

Identifies Type, Equipment Number, Quantity, Code
Classification, Location, Size, Weight, Radiation Zone,
Seismic Category And Atmosphere For All Deliverable
Equipment

o Equipment Schedule Status

Display Of Key Milestone Dates For Each Item On The
Equipment List. Includes Engr. Spec. Release, Drawing
Release, Purchase Order Placement, Shipment, Site
Need Date

o Network Hold

Provides Status Of Information Interfaces Between
Contractors Based On Level 2 Networks.

Some of the systems which are covered by SDD's and broken into work agreements are the Reactor System, Heat Transport System, and Reactor Service Building. The Reactor System is further sub-divided into Heat Removal System which itself is further divided into Steam Generator System. A hierarchical breakdown is shown in Figure I.1.

The physical structure of the project is tied to the project network via the line items within the work agreement. Each activity

FIGURE I.1: HIERARCHICAL STRUCTURE OF CRBRP PROJECT CONTROL

in the project control network (Level 2)* corresponds to a work agreement line item. On the CRBRP, both the designer, Burns and Roe, and the major reactor vendor, Westinghouse, maintain their own level 2 schedules using a computerized system.

As shown in Figure I.1, the Work Agreement line items are further broken down into Cost Accounts and Work Packages. Each work package is the base unit for budgeting and scheduling. Its "definition" provides the basis for "measurement." This measurement provides the required management visibility. This definition and quantification is an ongoing process which continues throughout the life of the project. Actual costs and progress are compared with the target values of the work packages. Comparisons allow management to identify exceptions from target and initiate the decision mode required to bring the project back on schedule.

This short discussion of PCS concepts hopefully has indicated the role played by the monitoring and measurement function in such systems. The key to good measurement is the timely acquisition and organization of data. This data must be readily accessible and retrievable. Therefore, the project information system is the key element of any Project Management System.

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*The Level 1 schedule is a milestone overview schedule for top management as discussed in Volume III, Appendix A to this Report (Chapters 1 and 2).

EXHIBIT II

OBJECT SYSTEM
HIERARCHY CHARTS

Construct Nuclear Power Station
HIERARCHY CHART

Construct Nuclear Power Station (Hierarchy Chart)

Planning and Scheduling (Hierarchy Chart)

Cost Control
HIERARCHY CHART

Cost Control (Hierarchy Chart)

Estimating
HIERARCHY CHART

Estimating (Hierarchy Chart)

Project Services
HIERARCHY CHART

Project Services (Hierarchy Chart)

**Purchasing
Expediting**
HIERARCHY CHART

Purchasing Expediting (Hierarchy Chart)

Warehousing (Hierarchy Chart)

Civil Engineering (Hierarchy Chart)

Civil Engineering and Field Control (Hierarchy Chart)

Mechanical Engineering (Hierarchy Chart)

**Mechanical
Construction**
HIERARCHY CHART

Mechanical Construction (Hierarchy Chart)

**Electrical
Engineering**
HIERARCHY CHART

Electrical Engineering (Hierarchy Chart)

**Electrical
Construction**
HIERARCHY CHART

Electrical Construction (Hierarchy Chart)

Construction Equipment/Facilities Management (Hierarchy Chart)

QA/QC (Hierarchy Chart)

Document Control
HIERARCHY CHART

Document Control (Hierarchy Chart)

Start-Up
HIERARCHY CHART

Start-Up (Hierarchy Chart)

EXHIBIT III

OBJECT SYSTEM
FUNCTIONAL OVERVIEWS
(HIPO'S)

HIPO chart

Appl. Area: PLANNING/SCHEDULING

1

I-III

HIPO chart

Appl. Area: PLANNING/SCHEDULING

2

INPUT

- PSAR AND FSAR QC LEVELS
- LEVEL 2 WORK SCOPE
- GENERAL ARRANGEMENT DRAWINGS
- PLANT DESCRIPTION
- LEVEL 1 WORK BREAKDOWN STRUCTURE
- EQUIPMENT CODES
- LABOR CODES
- MATERIAL CODES
- OVERHEAD CODES

- PRELIMINARY DRAWING LIST
- GENERAL SYSTEM DESCRIPTIONS
- PRELIMINARY SPECIFICATION LIST
- LEVEL 1 WORK SCOPE
- LEVEL 2 WORK BREAKDOWN STRUCTURE
- NRC REGULATIONS

PROCESS

4. DEVELOP LEVEL 1 WORK SCOPE

5. DEVELOP LEVEL 2 WORK SCOPE

OUTPUT

- LEVEL 1 WORK SCOPE (TOTAL PROJECT)

- LEVEL 2 DESIGN AND PROCUREMENT WORK SCOPE
- LEVEL 2 CONSTRUCTION WORK SCOPE
- LEVEL 2 TEST WORK SCOPE

III-2

HIPO chart

Appl. Area: PLANNING/SCHEDULING

3

INPUT

- PSAR
- SYSTEM FLOW DIAGRAMS
- GUIDES AND STANDARDS
- DRAWING LIST
- SPECIFICATION LIST
- COMPONENT LIST
- VENDOR DOCUMENT REQUIREMENTS
- LEVEL 2 DESIGN AND PROCUREMENT WORK SCOPE
- LEVEL 2 CONSTRUCTION WORK SCOPE
- LEVEL 2 TEST WORK SCOPE
- LEVEL 3 WORK BREAKDOWN STRUCTURE
- LIST OF ACCEPTANCE, PRE-OP, AND INITIAL STARTUP TESTS
- LIST OF TEST PROCEDURES
- LIST OF OPERATING PROCEDURES

PROCESS

6. DEVELOP LEVEL 3 WORK SCOPE

OUTPUT

- LEVEL 3 DESIGN WORK SCOPE (ASSIGNMENT OF DESIGN DOCUMENTS TO WORK PACKAGES)
- LEVEL 3 PROCUREMENT WORK SCOPE (ASSIGNMENT OF COMPONENTS TO WORK PACKAGES)
- LEVEL 3 CONSTRUCTION WORK SCOPE (ASSIGNMENT OF COMPONENTS AND BULK MATERIAL TO WORK PACKAGES)
- LEVEL 3 TEST WORK SCOPE (ASSIGNMENT OF TESTS AND PROCEDURES TO WORK PACKAGES)

III-3

HIPO chart

Appl. Area: PLANNING/SCHEDULING

4

HIPO chart

INPUT
○ LEVEL 3 WORK PACKAGES (DESIGN, PROCUREMENT, CONSTRUCTION, AND TEST)   ○ QUANTITY ESTIMATES (CONCEPTUAL AND BUDGET)   ○ TEST SEQUENCE   ○ ENGINEERING SPECIFICATIONS   ○ VENDOR INFORMATION SCHEDULE   ○ PURCHASE ORDER LIST   ○ DESIGN MANNING BY A/E
○ CONSTRUCTION ACTIVITY SCHEDULE   ○ TEST ACTIVITY SCHEDULE   ○ PROCUREMENT ACTIVITY SCHEDULE   ○ DESIGN ACTIVITY SCHEDULE
○ INTEGRATED PROJECT SCHEDULE (IPS) OR   ○ CONSTRUCTION, TEST, PROCUREMENT, OR DESIGN ACTIVITY SCHEDULE

Appl. Area: PLANNING/SCHEDULING

5

PROCESS	OUTPUT
10. DEVELOP TEST SCHEDULE	○ TEST ACTIVITY SCHEDULE (CPM MODEL)
11. DEVELOP PROCUREMENT SCHEDULE	○ PROCUREMENT ACTIVITY SCHEDULE
12. DEVELOP DESIGN SCHEDULE	○ DESIGN ACTIVITY SCHEDULE (CPM MODEL)
13. DEVELOP INTEGRATED PROJECT SCHEDULE	○ INTEGRATED PROJECT SCHEDULE (IPS) (MAY BE CPM MODEL)
14. DEVELOP INTERMEDIATE LEVEL SCHEDULE (THREE TO SIX MONTH PROJECTION AT WORK PACKAGE LEVEL)	○ FRAGNET OR BARCHART OF PORTION OF IPS OR ○ FRAGNET OR BARCHART OF CONSTRUCTION, TEST, PROCUREMENT, OR DESIGN SCHEDULE

HIPO chart

Appl. Area: PLANNING/SCHEDULING

6

HIPO chart

Appl. Area: PLANNING/SCHEDULING

7

HIPO chart

Appl. Area: ESTIMATING

1

HIPO chart**Appl. Area:** ESTIMATING

2

HIPO chart

Appl. Area: ESTIMATING

3

III-10

HIPO chart

Appl. Area: COST CONTROL

1

HIPO chart

Appl. Area: COST CONTROL

2

HIPO chart

Appl. Area: COST CONTROL

3

III-13

HIPO chart

Appl. Area: COST CONTROL

4

HIPO chart

Appl. Area: PROJECT SERVICES

1

HIPO chart

Appl. Area: PROJECT SERVICES

2

III-16

HIPO chart

Appl. Area: PURCHASING/EXPEDITING

1

HIPO chart

Appl. Area: PURCHASING/EXPEDITING

2

III-18

HIPO chart

Appl. Area: PURCHASING/EXPEDITING

3

INPUT

- NON-CONFORMANCE INFORMATION
- CONTRACTOR PAYMENT REQUEST
- ENGINEER'S ASSESSMENT OF CONTRACTOR'S PROGRESS
- PAID CONTRACTOR IN-VOICES
- BACKCHARGE COST ESTIMATE
- BACKCHARGE PAYMENTS
- DISCREPANCY DATA
- OUTBOUND SHIPPING REQUESTS

PROCESS

10. DETERMINE DISPOSITION OF EXCEPTION ITEMS

OUTPUT

- ADDITIONAL VENDOR DELIVERY EXPEDITING REQUIREMENTS
- APPROVED PROGRESS PAYMENT REQUESTS
- BACKCHARGE NOTICES
- CONTRACT FINANCIAL SUMMARY
- DISPOSITION OF RECEIVING DISCREPANCY ITEMS
- DISPOSITION OF OUTBOUND SHIPPING REQUESTS

61-111

HIPO chart

Appl. Area: WAREHOUSING

1

HIPO chart

Appl. Area: WAREHOUSING

2

HIPO chart

Appl. Area: WAREHOUSING

3

III-22

HIPO chart

Appl. Area: WAREHOUSING

4

HIPO chart

Appl. Area: CIVIL ENGINEERING

1

HIPO chart

Appl. Area: CIVIL ENGINEERING

2

HIPO chart

Appl. Area: CIVIL ENGINEERING

3

HIPO chart

Appl. Area: FIELD MECHANICAL ENGINEERING

1

HIPO chart

Appl. Area: FIELD MECHANICAL ENGINEERING

2

III-28

HIPO chart

Appl. Area: FIELD MECHANICAL ENGINEERING

3

HIPO chart

Appl. Area: FIELD MECHANICAL ENGINEERING

4

III-30

HIPO chart

Appl. Area: FIELD MECHANICAL ENGINEERING

5

INPUT

- SYSTEM DESIGN/PIPING AREA DRAWINGS
- RADIATION ZONE MAPS
- MARKED-UP P&ID'S FOR RADIOACTIVE LINES
- START-UP SYSTEM P&ID'S
- CONCRETE AND PENETRATION DRAWINGS
- H.V.A.C. DRAWINGS
- CABLE TRAY DRAWINGS
- HANGER DRAWINGS
- ELECTRICAL SUPPORT DRAWINGS

- OWNER'S SPECIFICATIONS
- DESIGN ARRANGEMENT DRAWINGS
- PIPING AND INSTRUMENT DIAGRAMS (P&ID'S)
- DESIGNER'S BILL OF MATERIAL
- VENDOR SHOP DRAWINGS
- SMALL PIPE LAYOUT DRAWINGS

PROCESS

14. PREPARE ISOMETRIC DRAWINGS (SMALL BORE)

OUTPUT

- ISOMETRIC DRAWINGS
- ENTRY IN ISOMETRIC DRAWING REGISTER

III-31

HIPO chart

Appl. Area: FIELD MECHANICAL ENGINEERING

6

11-32

HIPO chart

Appl. Area: FIELD MECHANICAL ENGINEERING

7

HIPO chart

Appl. Area: FIELD MECHANICAL ENGINEERING

8

HIPO chart**Appl. Area:** FIELD MECHANICAL ENGINEERING

9

HIPO chart

Appl. Area: FIELD MECHANICAL ENGINEERING

10

HIPO chart

Appl. Area: ELECTRICAL ENGINEERING

1

INPUT

- QC DISPOSITION
- FIELD DISPOSITION
- SPECIFICATIONS
- NRC CODES
- CORPORATE QA PROGRAM
- CODES SUGGESTED BY NRC

- AREA HOLDS
- SYSTEM STATUS
- MATERIALS AVAILABILITY
- MANPOWER AVAILABILITY
- PRODUCTIVITY
- ENGINEERING DISPOSITION REQUEST
- MATERIALS REPORT
- LETTERS FROM SUPPLIERS
- ENGINEERING REPORT
- QC STATUS
- AVAILABILITY OF EQUIPMENT

PROCESS

1. WRITE QA/QC PROCEDURES
2. SCHEDULE INSTALLATION WORK, REQUESTING EQUIPMENT, MATERIAL, AND MANPOWER

OUTPUT

- QA/QC PROCEDURES
- REPORT TO SCHEDULING
- PUNCH LIST
- PRIORITY SHEET
- ASSESSMENT OF PROGRESS
- MANAGEMENT STATUS REPORT
- EXPEDITING REQUESTS
- EQUIPMENT REQUISITION
- OVERTIME AUTHORIZATION
- AUTHORIZATION TO RENT NEEDED EQUIPMENT
- MIN-MAX LEVELS

HIPO chart

Appl. Area: ELECTRICAL ENGINEERING

2

HIPO chart

Appl. Area: ELECTRICAL ENGINEERING

3

HIPO chart

Appl. Area: ELECTRICAL ENGINEERING

4

III-40

HIPO chart

Appl. Area: CIVIL CONSTRUCTION

1

HIPO chart

Appl. Area: FIELD MECHANICAL CONSTRUCTION

1

III-42

HIPO chart

Appl. Area: FIELD MECHANICAL CONSTRUCTION

2

HIPO chart

Appl. Area: ELECTRICAL CONSTRUCTION

1

III-44

HIPO chart

Appl. Area: ELECTRICAL CONSTRUCTION

2

HIPO chart

Appl. Area: ELECTRICAL CONSTRUCTION

3

HIPO chart

Appl. Area: CONSTRUCTION EQUIPMENT/FAC.MGT

1

HIPO chart

Appl. Area: CONSTRUCTION EQUIPMENT/FAC.MGT

2

HIPO chart

Appl. Area: CONSTRUCTION EQUIPMENT/FAC.MGT

3

HIPO chart

Appl. Area: QA/QC

1

HIPO chart

Appl. Area: QA/QC

2

HIPO chart

Appl. Area: QA/QC

3

INPUT

- INSPECTION RECORD
- CADWELDER CERTIFICATION RECORD
- MATERIAL CERTIFICATION
- MATERIAL SOURCE
- CONCRETE POUR CARD
- DESIGN MIX CARD

- CONCRETE POUR CARD

PROCESS

8. INSPECT PLACEMENT OF CONCRETE

9. PERFORM POST-POUR INSPECTION

OUTPUT

- INSPECTION DOCUMENT
- NCR
- CADWELDER PERFORMANCE RECORD
- PRE-POUR CHECKLIST
- PRE-BATCHING TEST RESULTS
- CONCRETE BATCH ADJUSTMENTS
- TEST RESULTS DURING BATCHING
- POST-BATCHING TEST RESULTS
- SUMMARY OF CONCRETE BATCHED
- CONCRETE PLACEMENT INSPECTION
- SUMMARY OF CONCRETE PLACED

- POST-POUR INSPECTION
- COMPRESSION TEST RESULTS

HIPO chart

Appl. Area: QA/QC

4

HIPO chart

Appl. Area: QA/QC

5

INPUT

- NOTIFICATION OF WIRE INSTALLATION
- LOCATION CARDS ON EACH WIRE
- CIRCUIT INSTALLATION REPORT
- INSPECTION RECORD
- INSPECTION RECORD
- DOCUMENT STATUS
- DRAWING STATUS
- TURN-OVER SYSTEM
- SYSTEM SCHEDULE
- TESTING RECORD
- QA/QC TRACE INFORMATION

PROCESS

- 16. INSPECT WITH HIPOT OR MEGGER
- 17. TERMINATION INSPECTION
- 18. INSPECT COMPLIANCE WITH HOUSEKEEPING AND CONTROLLED ACCESS REQUIREMENTS
- 19. INSPECT CONSTRUCTION EQUIPMENT
- 20. CONDUCT FINAL INSPECTION PRIOR TO STARTUP TESTING
- 21. CONDUCT MATERIAL QUALITY TESTS

OUTPUT

- MEGGER TEST REPORT
- TERMINATION INSPECTION REPORT
- INSPECTION DOCUMENT
- NCR
- CONTROL ACCESS DOCUMENT
- INSPECTION DOCUMENT
- NCR
- TURNOVER CERTIFICATION
- TESTING DOCUMENT
- NCR

HIPO chart

Appl. Area: QA/QC

6

III-55

HIPO chart

Appl. Area: PLANT STARTUP/OPERATION

1

HIPO chart

Appl. Area: PLANT STARTUP/OPERATION

2

HIPO chart

Appl. Area: PLANT STARTUP/OPERATION

3

HIPO chart

Appl. Area: DOCUMENT CONTROL

1

HIPO chart

Appl. Area: DOCUMENT CCNTROL

2

INPUT

- DOCUMENT REGISTER
- DOCUMENT DISTRIBUTION REQUESTS
- APPROVED DESIGN DOCUMENT DISTRIBUTION
- DESIGN DOCUMENTS
- DESIGN RELATED DOCUMENTS
- RELATIONSHIPS BETWEEN DESIGN DOCUMENTS AND DOCUMENT CHANGES
- CODES/STANDARDS/REGULATIONS TO WHICH PROJECT COMMITTED
- GENERAL PROJECT DOCUMENTS
- GENERIC RECORDS REQUIREMENTS
- INDEXED GENERAL PROJECT RECORDS

PROCESS

4. ESTABLISH DOCUMENT DISTRIBUTION
5. DISTRIBUTE DESIGN DOCUMENTS
6. ESTABLISH GENERIC RECORDS REQUIREMENTS
7. CLASSIFY AND INDEX DOCUMENTS
8. MICROFILM, FILE, AND STORE RECORDS

OUTPUT

- APPROVED DESIGN DOCUMENT DISTRIBUTION
- UPDATED DESIGN DOCUMENT FILES (THROUGHOUT PROJECT)
- GENERIC RECORDS REQUIREMENTS
- INDEXED GENERAL PROJECT RECORDS
- UPDATE TO SPECIFIC RECORDS FILE
- MICROFILMED GENERAL PROJECT RECORDS (WORKING FILE)
- HARD-COPY GENERAL PROJECT RECORDS (BACK-UP FILE)

HIPO chart

Appl. Area: DOCUMENT CONTROL

3

HIPO chart

Appl. Area: DOCUMENT CINTRCL

4

EXHIBIT IV

OBJECT SYSTEM
INTERFACE DIAGRAMS

Planning and Scheduling (Interface Diagram)

Cost Control (Interface Diagram)

Estimating (Interface Diagram)

EXTERNAL INTERFACE LEGEND

CC-18-01 FORECAST CREW REQUIREMENTS
 EN-3-08 PREPARE WORK ASSIGNMENT
 FE-4
 FM-3
 PE-1-03 PURCHASE MATERIALS, EQUIPMENT & INSTALLATION
 PE-2-03 ADMINISTER CONTRACTS/SUBCONTRACTS
 WG-2-01 RECEIVE & INSPECT INCOMING SHIPMENTS
 WG-2-03 PREPARE RECEIVING REPORT (EACH SHIPMENT)
 WG-5-02 PREPARE AND ARRANGE RETURN SHIPMENT

Project Services
 INTERFACE DIAGRAM

Project Services (Interface Diagram)

Purchasing Expediting (Interface Diagram)

CC-0-07	MATERIAL VALUE OF CONSTRUCTION
CC-18-01	FORECAST LABOR REQUIREMENTS
CC-19-01	FORECAST MATERIAL REQUIREMENTS
CC-2-02	CLASSIFY AND INDEX DOCUMENTS
DC-0-02	CONTAINING DOCUMENTATION FROM WAREHOUSE
EE-1-01	MANPOWER SCHEDULING (ELECTRICAL)
EE-1-02	MATERIALS SCHEDULING (ELECTRICAL)
EE-2-01	PROCEDURES WRITING (ELECTRICAL)
EE-4-01	PROBLEM ASSESSMENT (ELECTRICAL)
EE-5-01	QUANTITY TAKE-OFF (ELECTRICAL)
EH-1-02	INCOMING TAKE-OFF (ELECTRICAL)
EH-1-02	INCOMING DOCUMENTS FROM WAREHOUSE (MECHANICAL)
EH-3-05	BILL OF MATERIAL (MECHANICAL)
EH-4-02	BULK PURCHASE INVENTORY (MECHANICAL)
EH-4-02	BULK PURCHASE INVENTORY (MECHANICAL)
EH-4-03	OFFSITE FABRICATED PIPING (INVENTORY)
EE-5-07	ENGINEERING CONSULTATION (MECHANICAL)
FE-4-XX	PRODUCTION (ELECTRICAL INSTA- LATION)
FITJ-3-01	COMPLETE WORK ASSIGNMENT (MECH- ANICAL)
FE-2-03	ADMINISTER CONTRACTS
PE-3-01	PURCHASING/EXPIRATION RECORDS
PE-3-02	DETERMINE DISPOSITION OF EXCEPTION ITEMS
PL-4-03	INTEGRATED PROJECT SCHEDULE (PROCUREMENT)
PL-4-04	INTEGRATED PROJECT SCHEDULE (CONSTRUCTION)
PS-1-01	PURCHASE ORDER INVOICES
PS-3-01	PERSONNEL SERVICES
QA-0-01	CONDUCT LAUNCH TO REQUIREMENTS (SHIPPING & RECEIVING)
QA-4-01	COMPLY MATERIAL QUALITY TEST

Warehousing

Warehousing (Interface Diagram)

Mechanical Engineering and Field Control (Interface Diagram)

Electrical Engineering and Field Control (Interface Diagram)

Construction Equipment/Facilities Management (Interface Diagram)

QA/QC (Interface Diagram)

Document Control (Interface Diagram)

Start-Up (Interface Diagram)

EXHIBIT V

DATA BASE
SYSTEM SUBSCHEMA

FIGURE V-1: PROJECT CONFIGURATION MODEL
(PCM BUILD SUBSCHEMA)

FIGURE V-2: PROJECT CONFIGURATION MODEL
(SCHEDULE/WORK PACKAGE PLANNING SUBSCHEMA)

FIGURE V-3: PROJECT CONFIGURATION MODEL
(REQUISITIONING SUBSCHEMA)

FIGURE V-4: PROJECT CONFIGURATION MODEL
(EXPEDITING SUBSCHEMA)

FIGURE V-5: PROJECT CONFIGURATION MODEL
(MATERIAL RECEIVING SUBSCHEMA)

FIGURE V-6: PROJECT CONFIGURATION MODEL
(WAREHOUSE INVENTORY SUBSCHEMA)

FIGURE V-7: PROJECT CONFIGURATION MODEL
(MATERIAL ISSUING SUBSCHEMA)

FIGURE V-8: PROJECT CONFIGURATION MODEL
(FIELD STATUS REPORTING SUBSCHEMA)

FIGURE V-9: PROJECT CONFIGURATION MODEL
(EQUIPMENT CONTROL SUBSCHEMA)

FIGURE V-10: PROJECT CONFIGURATION MODEL
(ESTIMATING SUBSCHEMA)

FIGURE V-11: PROJECT CONFIGURATION MODEL
(COST CONTROL SUBSCHEMA)

FIGURE V-12: PROJECT CONFIGURATION MODEL
(SUBCONTRACT ADMINISTRATION SUBSCHEMA)

FIGURE V-13: PROJECT CONFIGURATION MODEL
(DESIGN DOCUMENT CONTROL SUBSCHEMA)

FIGURE V-14: PROJECT CONFIGURATION MODEL
(RECORDS MANAGEMENT SUBSCHEMA)

FIGURE V-15: PROJECT CONFIGURATION MODEL
(STARTUP SUBSCHEMA)