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FOR
NUCLEAR POWER STATIONS
PROJECT DESCRIPTION

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PROJECT DIRECTOR: DANIEL W. HALPIN, PHD.

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VOLUME I

GEORGIA INSTITUTE OF TECHNOLOGY
SCHOOL OF CIVIL ENGINEERING
ATLANTA GEORGIA 30332

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INFORMATION MANAGEMENT FOR
NUCLEAR POWER STATIONS

PROJECT DESCRIPTION

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March 1978

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PROGRAM MANAGER: CHARLES A. THOMPSON

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ABSTRACT

A 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. Maintenance of the massive amount of data needed for control of a nuclear project during design, procurement, construction, start-up/testing, and operational phases requires a structuring which allows immediate update and retrieval based on a wide variety of access criteria. The objective of the research described has been to identify design concepts which support the development of an information control system responsive to these requirements. A conceptual design of a Management Information Data Base System which can meet the project control and information exchange needs of today's large nuclear power plant construction projects has been completed and an approach recommended for development and implementation of a complete operational system.

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FOREWORD

This report consists of five volumes numbered ORO-5270-1 through ORO-5270-5. Volume I (ORO-5270-1), entitled Project Description, briefly describes the purpose, approach, and results of the study. It contains no supporting material. An extensive description of the study appears in Volume II (ORO-5270-2) entitled System Design Concept. The appendices A through 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 this volume.

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.

ACKNOWLEDGEMENTS

The following persons were directly responsible for developing or coordinating portions of the project.

Eugene R. Armstrong - Daniel International Corporation

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1. Scope and Objective

The construction of nuclear power facilities poses new and complex logistic and management problems for project managers. The information flow at the project level is enormous and traditional methods of information handling are not adequate to meet the challenge of this new management environment. Central to the proper control of such massive projects is the concept of a single point of 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.

In order to further define the requirements of such a system, a study of the information structure required to support nuclear power plant construction has been 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 objectives were (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. The study established criteria for the design of an integrated information management system which is responsive to the needs of the team charged with the project management and control of the design, construction and start-up for a nuclear power station. The design criteria are referred to as a Design-in-Principle. Development of the Design-in-Principle requires the definition of a basic set of project application areas, functions, processes, and data elements.

2. Background and Need

Methods of information and project management which are quite adequate for \$10 - \$20 millions projects are not acceptable on \$100 - \$200

million projects. Similarly, management information systems which have proved acceptable on \$100 million projects can break down and 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 sub-contractors. 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.

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 2 below.

FIGURE 2: PROJECT CONTROL CYCLE

As noted by David H. Smith of Project Management Corporation in describing one 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.

In large and complex projects, various work phases typically overlap (Figure 1) 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 3. 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.

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.

FIGURE 3. DATA BASE INTERFACES WITH PROJECT ORGANIZATIONS

3. Data Base Approach

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

- (1) Provides the mechanism for organization of data in 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 defined and structured so as 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 all 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.

Such systems are capable of on-line information retrieval 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 on-line within a few minutes. For large and complex reports which require long print times overnight turnaround should be available.

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.

The organization of the data base should 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 should be developed to maintain the data in an organizational structure called a schema. The data elements can be thought of as books in a library. The layout of the library is the schema. 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 subschema or local layout plan of the data base containing the information he needs. The overall schema and associated subschema have mapping characteristics which structure the data and define their relationships. Figure 4 indicates the concept of relationships between data and application through a schema.

FIGURE 4: DATA BASE USER RELATIONSHIPS

4. Organization and Methodology

In order to establish the scope of the required information structure, 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 state of the study provides the basis for Appendices A - D contained in a separate volume.

4.1 Application Area Reports

An Application Area, as referred to in this study, 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 shows those application areas which were studied and their grouping within the application area groups.

TABLE 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

4.2 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 Definitions became the input to the second system design step of developing Application Area Specifications. The Application Area Specifications and their relationship to the Application Area Groups are given in Table 2. Specifications were not developed for Project Management and Design Procurement due

TABLE 2: APPLICATION AREA SPECIFICATIONS

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

to limited resources. Engineering/Quantity Take-Off was expanded 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.

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 5.

FIGURE 5: FUNCTION-PROCESS-DATA ELEMENT TECHNIQUE

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 overview of the functions contained in an application area or system. This technique is particularly helpful in communicating information regarding the application area functions and 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.

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. 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).

4.5 Project Configuration Model

The physical components of the project and their configuration in an operational nuclear facility is the common denominator to which all organizations can relate. The concept of a Project Configuration Model (PCM) is developed in Volume II of this report. 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. 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 for 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

4.6 Design in Principle

The Application Area Specifications, Data Element Descriptions, and the Project Configuration Model became the major input to the actual system design activity. Based on this information, a conceptual system design-in-principle and a data base design-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.

5. Conclusions and Recommendations

The study has concluded that a data base information management system can be developed to meet the needs for project control and information exchange on today's large nuclear power plant construction projects. The research team has studied the methods presently utilized on nuclear projects, identified functions, processes, and data elements which must be considered in defining an information management system, and developed conceptual System and Data Base Designs-in-Principle which can be used as the basis for development and implementation of a complete data base information management system for use in nuclear plant construction.

The approach recommended for further development is shown graphically in Figure 6. 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. Based on this user review, a final conceptual design can 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 current or planned nuclear power plant construction projects. This approach is preferred by several utilities who have been considering the use of their projects as a "test bed" for the integrated system. Therefore, a building block approach will 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 at an ongoing project. The procedures for testing and implementing the module selected will be coordinated with the utility providing a test site.

FIGURE 6: GRAPHICAL PRESENTATION OF THE PROPOSED SCOPE OF WORK

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.

Full implementation of the conceptual system developed under this DOE sponsored project would result in significant overall cost and time savings in the construction of nuclear power plants. A quantitative analysis of the potential savings which might be realized is beyond the scope of this study. Full implementation of this system is estimated to improve productivity of construction work forces by approximately five percent, resulting in significant cost savings and reducing construction time by up to five months.

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3. Crandall, K., "The Design of a Limited Interactive Management System for Construction Project Control," thesis presented to Stanford University, at Stanford, California, in 1970, in partial fulfillment of the requirements for the degree of Doctor of Philosophy.
4. Halpin, Daniel W., "Information Management for Nuclear Power Stations," Proceedings, Lawrence Symposium on Systems and Decision Sciences, Berkeley, California, October, 1977.

EXHIBIT I

Contents of Volume II and Appendices A-F

VOLUME II: System Design Concept (391 pages)

Chapter I	Project Development and Methodology*
Chapter II	Information Management System Description*
Chapter III	Project Configuration Model
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	References
Exhibit I	Project Control System Concepts
Exhibit II	Object System Hierarchy Charts
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Exhibit V	Data Base System Subschema

APPENDIX A: Project Control (162 pages)

Chapter I	Project Management
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Chapter III	Computerized Network Processors
Chapter IV	Project Services

*Portions of this Project Description are excerpted from these chapters of Volume II.

APPENDIX B: Material Control (210 pages)

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Addendum A	Application Area Outlines
Addendum B	Supporting Material for Material and Equipment Status System (MESS)
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Addendum D	Supporting Material for Stores Accounting System (SAS)
Addendum E	Supporting Material for Punch List
Addendum F	Supporting Material for Material Management Information System
Addendum G	Supporting Material for Numbering Systems

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Addendum B	Mechanical (Small Component) Input/Output Data
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Addendum G	Electrical (Bulk Material) Input/Output Data
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Addendum J	Application Area Outline - Methods Engineering

APPENDIX D: Plant Performance Compliance (152 pages)

Chapter I	Quality Assurance
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Addendum A	NRC Requirements Description
Addendum B	Sample Types of Permanent and Non-Permanent Records
Addendum C	Field Generated Document System Example Reports
Addendum D	Duke Power Company: Data Base Management Control and Engineering System
Addendum E	Duke Power Design Document List
Addendum F	Mechanical Instrumentation and Control List
Addendum G	Duke Power Station Equipment Number Structure

APPENDIX E: System Specifications (Approx. 600 pages)

Introduction

Part I Project Controls and Services

Part II Field Engineering and Material Management

Part III Field Construction Control

Part IV Specifications Compliance and Document Control

APPENDIX F: Data Element Descriptions (350 pages)

Introduction

Data Element Dictionary