NUREG/CR-5538
BNL-NUREG-52301
Vol. 1

Influence of Organizational Factors on Performance Reliability

Overview and Detailed Methodological Development

Prepared by
S. B. Haber, J. N. O'Brien, D. S. Metlay, D. A. Crouch

Brookhaven National Laboratory

Prepared for
U.S. Nuclear Regulatory Commission

AVAILABILITY NOTICE

Availability of Reference Materials Cited in NRC Publications

Most documents cited in NRC publications will be available from one of the following sources:

1. The NRC Public Document Room, 2120 L Street, NW., Lower Level, Washington, DC 20555
2. The Superintendent of Documents, U.S. Government Printing Office, P.O. Box 37082, Washington, DC 20013-7082
3. The National Technical Information Service, Springfield, VA 22161

Although the listing that follows represents the majority of documents cited in NRC publications, it is not intended to be exhaustive.

Referenced documents available for inspection and copying for a fee from the NRC Public Document Room include NRC correspondence and internal NRC memoranda; NRC bulletins, circulars, information notices, inspection and investigation notices; licensee event reports; vendor reports and correspondence; Commission papers; and applicant and licensee documents and correspondence.

The following documents in the NUREG series are available for purchase from the GPO Sales Program: formal NRC staff and contractor reports, NRC-sponsored conference proceedings, international agreement reports, grant publications, and NRC booklets and brochures. Also available are regulatory guides, NRC regulations in the *Code of Federal Regulations*, and *Nuclear Regulatory Commission Issuances*.

Documents available from the National Technical Information Service include NUREG-series reports and technical reports prepared by other Federal agencies and reports prepared by the Atomic Energy Commission, forerunner agency to the Nuclear Regulatory Commission.

Documents available from public and special technical libraries include all open literature items, such as books, journal articles, and transactions. *Federal Register* notices, Federal and State legislation, and congressional reports can usually be obtained from these libraries.

Documents such as theses, dissertations, foreign reports and translations, and non-NRC conference proceedings are available for purchase from the organization sponsoring the publication cited.

Single copies of NRC draft reports are available free, to the extent of supply, upon written request to the Office of Administration, Distribution and Mail Services Section, U.S. Nuclear Regulatory Commission, Washington, DC 20555.

Copies of industry codes and standards used in a substantive manner in the NRC regulatory process are maintained at the NRC Library, 7920 Norfolk Avenue, Bethesda, Maryland, for use by the public. Codes and standards are usually copyrighted and may be purchased from the originating organization or, if they are American National Standards, from the American National Standards Institute, 1430 Broadway, New York, NY 10018.

NUREG/CR-5538
BNL-NUREG-52301
Vol. 1
RX

Influence of Organizational Factors on Performance Reliability

Overview and Detailed Methodological Development

Manuscript Completed: September 1991
Date Published: December 1991

Prepared by
S. B. Haber, J. N. O'Brien, D. S. Metlay, D. A. Crouch

Brookhaven National Laboratory
Upton, NY 11973

Prepared for
Division of Systems Research
Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
Washington, DC 20555
NRC FIN A3956

ABSTRACT

This is the first of a two-volume report (Volume II to be published at a later date) that presents the results of a research project conducted by Brookhaven National Laboratory for the United States Nuclear Regulatory Commission, Office of Nuclear Regulatory Research. The purpose of the project was to develop a general methodology to be used in the assessment of the organizational factors which affect performance reliability (safety) in a nuclear power plant.

The research described in this report includes the development of the Nuclear Organization and Management Analysis Concept (NOMAC). This concept characterizes the organizational factors that impact safety performance in a nuclear power plant and identifies some methods for systematically measuring and analyzing the influence of these factors on safety performance.

This report is divided into two parts. Part I presents an overview of the development of the methodology, while Part II provides more details and a technical analysis of the methodological development. Specifically, the results of two demonstration studies, the feasibility of the methodology, and a specific application for which the methodology was developed are presented. Volume II presents the procedures for implementing the NOMAC methodology and applying the results to probabilistic risk assessment.

NRC SUMMARY

The Nuclear Regulatory Commission initiated research into methods for estimating how nuclear-plant organizational performance could influence risk parameters. The intent is to measure attributes of nuclear power plant organizations that are important to risk and develop techniques for systematically evaluating organizational performance. Techniques developed through this effort (e.g., data gathering instruments) must be practical for use in the regulatory process, consistent, and defensible. The emphasis is on techniques that are practical for investigating organizational effectiveness and is not on requirements or regulations.

Brookhaven National Laboratory has made significant progress in their studies of the influences of organizational factors on performance reliability. Their progress is reflected in this report as general descriptions of techniques. Further work remains to be done before the techniques can be demonstrated as feasible in a regulatory context, particularly the technique for coupling observable organizational performance to risk measures. The work reported here by Brookhaven National Laboratory has provide a sound starting point for gathering organizational performance information that might be incorporated into probabilistic risk assessments.

EXECUTIVE SUMMARY

The United States Nuclear Regulatory Commission (NRC) has long been interested in the performance of individuals at the nuclear facilities over which it has jurisdiction. While nuclear power plants have been designed through engineering disciplines to intercept and mitigate events that could cause adverse consequences, it has been clear from various safety-related incidents that human performance also plays a dominant role in preventing accidents. In recognition of this, the NRC has instituted research efforts to examine the relationship between personnel performance and plant safety using the methods and concepts of the social and behavioral sciences. In this report, organizational research is described that was carried out at operating fossil fuel and nuclear power plants.

The first step in the research program was to develop an organizational concept. A review of the literature led to the adoption of a concept (termed Nuclear Organization and Management Analysis Concept [NOMAC]) that is based on the dominant sociological theory of organizations. Under this concept, organizations are differentiated into five structural components: the *strategic apex*, which sets goals and ensures their satisfaction; the *middle line*, which mediates between the strategic apex and the operating personnel; the *technostructure*, which is responsible for the standardization of work; the *operating core*, which performs the basic work of the organization; and the *support staff*, which carries out tasks essential to the organization even though they are outside the normal work flow.

Depending on the relative size and importance of each of these components and on the method adopted for coordinating work, organizations take on different characteristics and pursue different behaviors. On the basis of discussions with people familiar with nuclear power plants, it was hypothesized that these organizations best fit the "machine-bureaucracy" type. This type of organization is characterized by large-sized units in the operating core, a functional basis for grouping personnel, centralized decision-making, and a sharp distinction between staff and line. Coordination occurs mainly through the standardization of work, that is, the implementation of procedures, policies, and programs. The technostructure at nuclear power plants is, therefore, expected to be well-developed and influential.

To "test" the validity of NOMAC and to determine whether the organizational behaviors it posits occur, three data collection methods were used. The first is *functional analysis*. This method provides a description of the organizational work flow and is obtained through examination of documentation, interviews, walk-throughs, talk-throughs, and observation of organizational activities such as meetings. The second is the *behavioral observation technique*. This method involves the observation of key managers as they carry out their tasks. Their behaviors are categorized using a predetermined scheme; their patterns of interaction and communication are also recorded. The third is the *organizational culture assessment*. This method requires that personnel complete a questionnaire consisting of items measuring various aspects of the organization's working environment and culture as well as other dimensions of organizational behavior. Each of the three methods supplement the information obtained from the others; all are necessary to obtain insights on the organization.

The three methods were first carried out at a fossil fuel plant. Each proved to be *practical*; i.e., each could be implemented, was comprehensible, and did not consume excessive resources. Each method was also considered *acceptable*; i.e., each could be conducted without undue disruption of normal plant routines. Although the functional analysis and organizational culture assessment appeared to be *useful* in generating data that were reliable and valid, the behavioral observation technique, as first implemented, was somewhat deficient in this respect. In particular, it was learned that the categorization scheme did not adequately reflect the set of behaviors observed. Furthermore, the manner in which behavior was scored and the approach to measuring patterns of interaction and communication required modification.

A second field test of the methods took place at an operating nuclear power plant. Prior to the start of this phase of the research, modifications to the behavioral observation technique were made. With these modifications, all three methods exhibited a relatively high level of practicality, acceptability, and usefulness. In sum, while certain issues remain open, NOMAC methods have proven to be valuable tools for understanding and explaining organizational behaviors at nuclear power plants.

Although this research was designed primarily to develop, refine, and evaluate a set of methods for understanding the influence of organizational factors on performance reliability, some interesting substantive findings were also obtained. At the fossil fuel plant, the organizational culture assessment revealed statistically significant differences between engineers and other personnel in their perceptions about the working environment. These were consistent with what would be expected given the former group's professional status.

At the nuclear power plant, the data collected using the behavioral observation technique documented the fact that different individuals, occupying the same role within the organization, had virtually identical behavioral profiles. The method also measured differences among functional and structural units with respect to behavior and patterns of interaction and communication. These findings tended to support the hypotheses derived from NOMAC. The organizational culture assessment also yielded some intriguing results. For example, although individuals from different units believed that their jobs exposed them to different levels of hazard, they had identical views as to the importance of safety considerations in the performance of their tasks. This suggests the existence of a pervasive and homogeneous safety culture. Although the results obtained thus far are promising, additional work needs to be undertaken to refine further the NOMAC methods so as to increase their validity in a nuclear power plant setting. Increased data collection is also needed for between-plant comparison purposes.

The information generated by the three methods can be put to use in a number of ways. First, it provided a means for postulating a set of organizational and managerial factors that might be related to the effective safety performance at a nuclear power plant. Five such factors were identified: communication, organizational culture, decision-making, standardization, and management attention, involvement, and oversight. Second, the methods might be used to provide insights to the inspection and evaluation activities currently undertaken by the NRC. These include the Systematic Assessment of Licensee Performance ratings, Diagnostic Evaluation Teams, Incident Investigation Teams, regional briefings, and NRC Senior Management meetings. Third, the methods might also be used as a starting point for gathering information that ultimately could be incorporated into probabilistic risk assessments. Hypothetical data were employed in this research to illustrate how this might be accomplished. Considerable work will still have to be undertaken before such a use of actual organizational data can be validated.

CONTENTS

CONTENTS (Continued)

CONTENTS (Continued)

LIST OF FIGURES

Page

Part I - Overview

Part II - Detailed Methodological Development

LIST OF FIGURES (Continued)

Part II - Detailed Methodological Development (Continued)

LIST OF TABLES

ACKNOWLEDGEMENT

The authors wish to thank the NRC technical monitors for the program, Joel Kramer and Thomas Ryan, for their detailed comments and guidance on all phases of this project. We would also like to extend our thanks to Frank Coffman of the NRC for his input and assistance on earlier drafts of this document.

This project could not have been successfully completed without the help and technical assistance of our external consultants: Henry Mintzberg, Judith Komaki, and Todd LaPorte. In addition, the High Reliability Organization Research Group at the University of California at Berkeley was critical in soliciting the demonstration sites from the Pacific Gas and Electric Company (PGE). PGE and the staff at the Pittsburg and Diablo Canyon Power Plants were also most gracious and cooperative hosts.

We further extend our gratitude to our colleagues at Brookhaven National Laboratory for their participation in our workshops and for their review, comments, and insights on many phases of this project. In particular, the support and guidance of Robert Hall and James Higgins is greatly appreciated.

Finally, we thank Kathleen Nasta for her excellent help in preparing the manuscript, several different times, in several different ways.

PART I:

OVERVIEW

1. PURPOSE OF WORK

The purpose of this research project, conducted for the United States Nuclear Regulatory Commission (U.S. NRC), Office of Nuclear Regulatory Research, was to develop a general methodology to characterize the organizational factors at a nuclear power plant (NPP) that affect safety performance, to systematically collect information on these factors, and to integrate that information into various types of ongoing NRC activities. This project responds to the need to develop an understanding of how organizational factors at a nuclear power plant directly and indirectly affect plant safety performance and how these factors might be observed, measured, and evaluated.

To achieve the research objective, a three-step process was used: (1) development of a descriptive concept of the human organization of a NPP, (2) identification of organizational and management functions and processes related to safety performance, and (3) the proposal and implementation of methods for measuring organizational and managerial factors (see Figure I.1.1). Those methods were then evaluated against three criteria. First, they had to be practical. The methods could not require excessive resources in order to be implemented, the skills needed to carry them out could not be so demanding so as to preclude their use, and the data obtained should be relatively easy to analyze. The methods also had to be acceptable. For them to satisfy this criterion, the methods had to be reliable, i.e., capable of being reproduced by different individuals and across time, they could not place excessive demands on the NPP organization, and the methods should yield information that managers felt was insightful. Finally, the methods had to be useful. For them to satisfy this criterion, they had to measure in a valid fashion the variables and relationships that they purported to measure, and they had to produce an accurate picture of the functional relationships within the plant, they had to provide data which would yield insights and information relevant to the goals of the project.

In the pages that follow, an overview of the work in this project is provided. The discussion begins with an examination into why the research was undertaken. It next details the development of the Nuclear Organization and Management Analysis Concept (NOMAC) of a NPP. The methods identified are then described along with a summary of the major findings obtained through their implementation at a fossil fuel plant and a NPP. The methods are then evaluated in terms of their practicality, acceptability, and usefulness. Finally, an example of how data produced by these methods might be utilized in a risk assessment is presented.

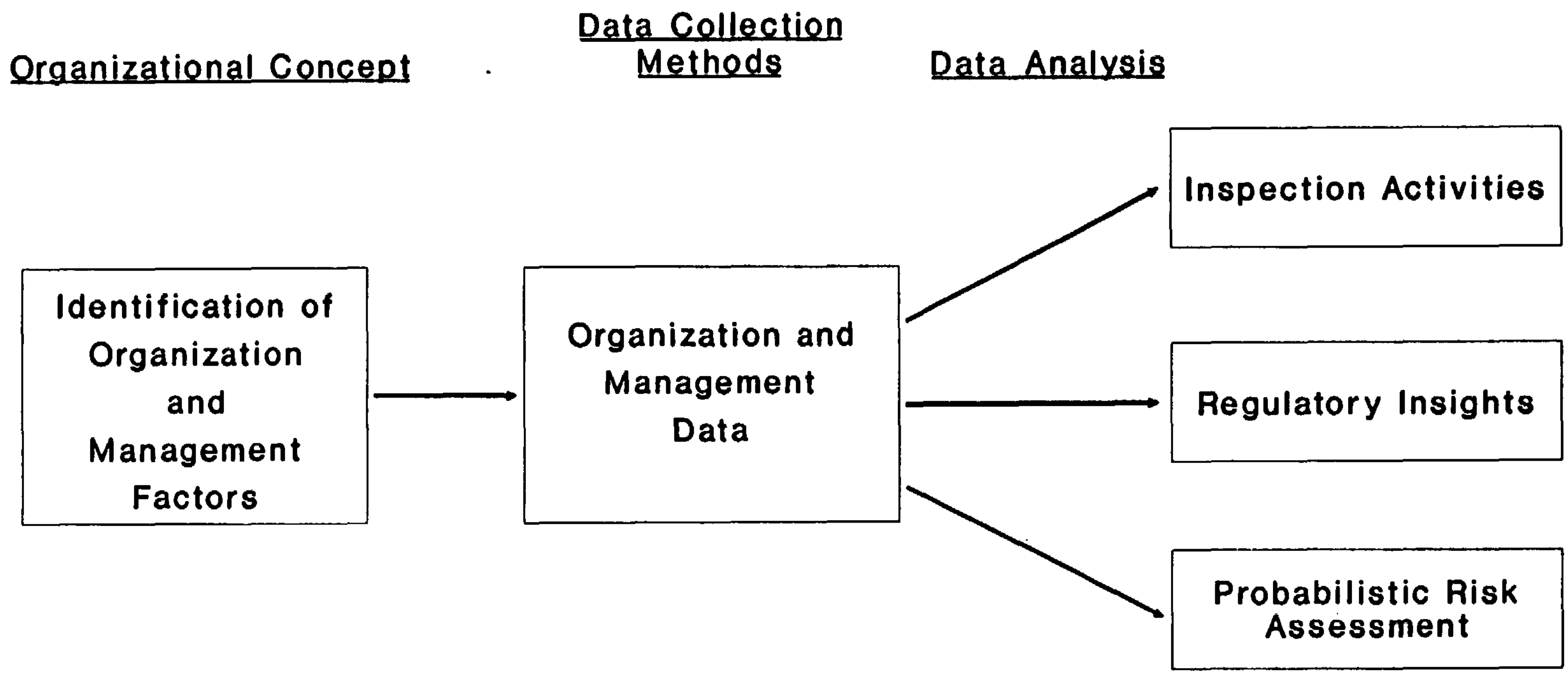


Figure I.1.1. Objectives of the BNL organization and management research project

2. BACKGROUND

There are many organizations in our society that depend on human performance to avoid incidents involving significant adverse consequences. As our culture and technology have become more sophisticated, the management of risk on a broad basis has become more and more critical. The safe operation of military facilities, chemical plants, airlines, mass transit and so on are substantially dependent on the performance of the organizations that operate those facilities.

The U.S. NRC has long been interested in the performance of individuals at the nuclear facilities over which it has jurisdiction. While NPPs have been painstakingly designed through engineering disciplines to intercept and mitigate events that could cause serious adverse consequences, it has been clear from various safety-related incidents at NPPs that human performance plays a dominant role in preventing adverse consequences from accidents. Numerous studies have been conducted by the U.S. NRC and its contractors in an attempt to assess how human performance affects NPP safety. These studies took on particular significance after the Three Mile Island accident in 1979.

During the last several years, there has been a growing interest in how organizational factors affect NPP personnel performance, and thus, plant safety. In recognition of this, the U.S. NRC has instituted research efforts to examine this relationship more closely employing the methods and concepts of the behavioral and management sciences. Brookhaven National Laboratory (BNL) was contracted by the U.S. NRC to develop scientifically valid and acceptable techniques to examine and assess the broad influence of organizational factors on NPP safety. The initial objective of the project was to identify methods, which had undergone substantial prior scrutiny, that could be used in observing and assessing the impact of organizational factors on NPP safety and that could provide products useful to U.S. NRC staff, NPP personnel, and PRA practitioners. The research, conducted by BNL, is described in this report. It identifies reliable, defensible methods to examine the organizational structure, culture, and management behaviors in a NPP.

Two additional points need to be noted. First, the development of both data collection and analysis techniques and the means for capturing and utilizing the results was pursued in parallel. This tact was adopted because it was important to ensure feedback between the effort to identify methods to collect data and the efforts to determine what forms of data would actually be most useful in contributing to NPP safety.

Second, this document focusses on methods which are still open to modification and not on substantive or evaluative findings. Consequently, the results of this research are primarily useful for further refining the methods tested, and should not be viewed as a complete or final source of information for correcting organizational and management factors examined in any specific NPP.

3. THE ORGANIZATIONAL CONCEPT

The first step in this project was to develop an approach to studying an organization that facilitated identification of the organization's structure and identification of key managerial and supervisory positions. Specifically for the NPP, the goal was to identify and describe those units that exerted either a direct or indirect impact on safety performance, and the group of supervisors and managers responsible for those influences.

The initial effort in this project was directed toward establishing an organizational structural concept which should satisfy three criteria: (1) the concept should be dynamic and process-oriented; i.e., should go beyond an organizational chart in that it should focus on functional relationships within the organization; (2) the concept should be empirically based and recognized in the scientific literature; and (3) the concept should be capable of reconfiguration to describe off-normal situations.

Based on an extensive computer and manual search of the literature, as well as consultation with experts in the area of organization and management, BNL was directed to a particularly applicable concept developed by Mintzberg (1979). That work was particularly useful for two reasons. First, it examined over 200 articles and books. Those studies constitute the core of the dominant sociological theory of organizations. Indeed, most of the relevant research arising from the literature search conducted by BNL was addressed in Mintzberg's work. Second, Mintzberg synthesized that literature into a comprehensive, generalized model of organizations. It was, therefore, used as the basis for developing an organizational structural concept for a NPP.

3.1 Mintzberg's Model

Mintzberg distinguishes different organizational structures based upon the roles played by five functional components of the organization and on the mechanisms for coordinating work among them. For a complete discussion of Mintzberg's work relevant to this project, see Appendix A. The personnel who perform basic work related to the production of products or services comprise the *operating core* (OC) of the organization (e.g., assemblers in an automobile factory, professors in an university, maintenance technicians in a NPP). The individuals charged with ensuring that the organization serves its mission in an effective way, and also serves the needs of those people who control or otherwise have power over the organization, belong to the *strategic apex* (SA) (e.g. the president of a company, the superintendent of a school system, the plant manger of a NPP). Personnel who are a chain of authority between the strategic apex and the operating core are part of the *middle line* (ML) of the organization (e.g., senior managers). Personnel who are responsible for and effect standardization within an organization comprise the *technostructure* (TS) (e.g. accountants, trainers, engineers). Finally, the individuals who provide support to the organization outside the operating work flow are the *support staff* (SUP) (e.g. cafeteria employees, custodial staff, security, payroll departments). As the characteristics and parts of each organization become more or less prominent, the shape of the basic organizational structure changes. Mintzberg identifies five structural types toward which most organizations (based on their characteristics) gravitate. Using the model provided in Mintzberg, the NPP, at least initially, is best described by the "machine bureaucracy" type and is depicted in Figure I.3.1.

The machine bureaucracy is typically characterized by large-sized units at the operating level, a functional basis for grouping of personnel, centralized power for decision-making, and a sharp distinction between line and staff (Mintzberg, 1979). An important functional unit in the machine bureaucracy is the technostructure, which is primarily responsible for standardizing the work within the organization.

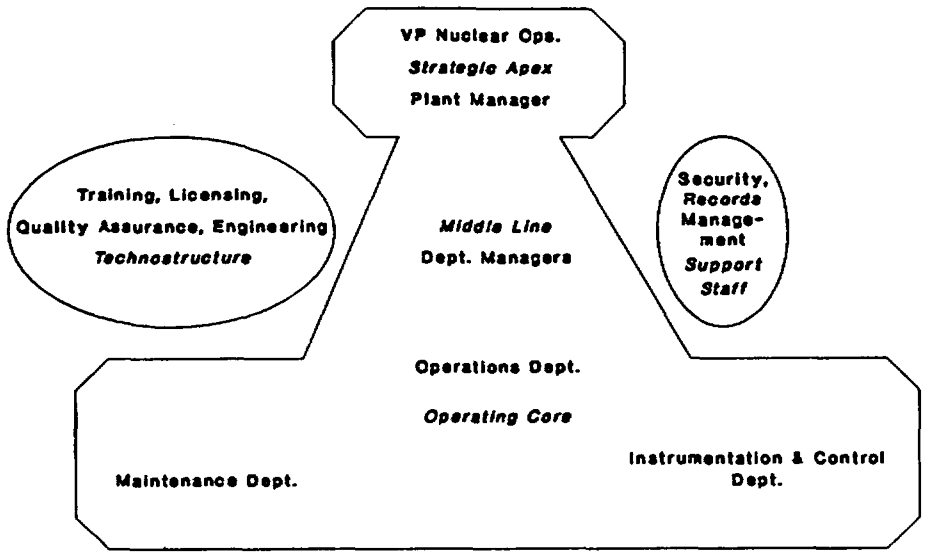


Figure I.3.1. Organizational structural concept of a NPP

Standardization can occur through the implementation of procedures, policies, or programs, and is a primary coordinating mechanism for work in the machine bureaucracy type. In the NPP, standardization is carried out by departments such as licensing, training, quality assurance, planning and scheduling, and engineering. In addition, the NPP is vertically centralized, with decision-making occurring primarily from the top down, and work units within the organization are grouped by function (e.g., maintenance, operations, instrumentation and control). These initial observations were used to further refine the NPP organizational structural concept.

The NPP organizational structural concept underwent extensive peer review by individuals with expertise in various NPP specialties. Additionally, academic experts reviewed the concept to ensure that it was not inconsistent in important ways from other organizational theories developed in the literature. Comments from both groups were considered and incorporated into subsequent revisions to the concept as necessary.

3.2 Identification of Key Organizational and Management Functions and Processes

If the NPP is best described by the "machine bureaucracy" organizational type, a primary process of the organization is the standardization of work. The key organizational and management functions can then be identified in terms of subprocesses of standardization: (1) design of standards (including procedures for operating the plant); (2) the application of standards (their conveyance to personnel performing the work); (3) the feedback on standards (communication and education about the adequacy of the standards); and (4) the modification of standards (adjustments made in the event of abnormal conditions) (Haber and O'Brien, 1988).

The initiation of standards for the organization is primarily performed by the strategic apex, the functional unit responsible for ensuring that the organization carries out its mission effectively. The development of standards occurs largely within the technostructure of the organization. Supervisors and managers within this organizational unit are critical in developing the policies and procedures comprising the standardization process. Middle line supervisors and managers are responsible for interpreting the standards, and the supervisors of the operating core (those individuals actually performing the work within the organization) ensure implementation of the standards. Feedback on the effectiveness of the standards should come from all parts of the organization. Evaluation of that feedback and its incorporation into amended standards is the responsibility of the strategic apex and supervisors in the technostructure. The modification of standards in the event of abnormal conditions is beyond the scope of this particular research project, but is being addressed in another project supported by the U.S. NRC Office of Nuclear Regulatory Research, entitled "Organizational Factors Research to Support Accident Management," (FIN B-5879).

3.3 Summary

The organizational structural concept of the NPP described above has been labeled the Nuclear Organization and Management Analysis Concept (NOMAC). It is a description of the human organization of a NPP. Its utility lies in the fact that it is a dynamic, interactive, and behavior-oriented characterization of the plant, emphasizing functional relationships between units. The identification of such a concept allows ideas generated by a particular characterization of the organization, in this case, a "machine bureaucracy," to be tested by the proposed methodology. For example, is there vertical centralization for decision-making? Does the technostructure play an important role in the NPP? Is the middle line interpreting standards for the operating core? These "hypotheses" generated by the concept also allow comparisons to be made between and within facilities with regard to organizational characteristics and management functions.

4. IDENTIFICATION OF METHODS

The next step in the research process was the identification of methods to measure and assess the "hypotheses" generated by the Nuclear Organization and Management Analysis Concept. Two criteria greatly influenced the choice of techniques to be used in this project. First, the methods identified and implemented had to be capable of broad-based use. Second, the methods chosen must have withstood substantial peer scrutiny and must have undergone extensive use. These two criteria greatly limited the number of methods that could be employed for this project.

In particular, methods currently used in the private sector did not seem appropriate. Most of the organization and management assessments performed by consulting firms use proprietary methods that are based mainly upon the experience of the particular individuals conducting the evaluation. The implementation of these methods and an understanding of their premises are generally not well-articulated or easily transferable. Thus, they were not considered well-suited for the U.S. NRC, which has a clear preference for methods that can be clearly standardized and documented so qualified individuals from any organization can conduct them. These concerns led to the selection of the methods described below to be implemented and evaluated for the purposes of this research project. As with the development of the organizational structural concept, extensive peer reviews of these methods were sought and obtained.

4.1 Nuclear Organization and Management Analysis Concept (NOMAC) Methods

To assess and evaluate NPPs with regard to organizational and management factors, three specific types of data collection methods were proposed. Although each method is described separately, it is important to note that a full understanding of the NPP organization can only be obtained from the insights provided by all three.

4.1.1 Functional Analysis

The first NOMAC method is a functional analysis. This method provides a description of the organizational work flow and is obtained primarily through documentation, interviews, walk-throughs, talk-throughs, and some observation of organizational activities such as meetings. The functional analysis provides: (1) a qualitative description of the human organizational structure of the plant, (2) the identification of key managerial and supervisory positions, and (3) information essential for resource allocation in the other data collection methods.

After the functional analysis has been completed and the organizational structural concept defined, the team conducting the research can begin collecting additional data. There are two other modes of data collection: (1) observation of managerial and supervisory behaviors, and (2) an assessment of organizational culture.

4.1.2 Behavioral Observation Technique (BOT)

The second data collection method is an observational technique. This technique assesses the frequency of certain management behaviors and identifies patterns of communication and interaction within the organization. A data collection method developed by Komaki, et al. (1986) was modified for this research project. Based upon the functional analysis of the NPP described earlier, selected supervisors and managers are observed during their workday. Trained observers accompany the individuals selected and record behaviors based on a developed categorization scheme. Each observation consists of 30 minutes and is conducted at different times of the day. The number of observation periods and individuals to be observed is decided upon after the functional analysis is complete.

4.1.3 Organizational Culture Assessment (OCA)

The third method is the use of a well-developed standardized questionnaire to assess the organizational culture/environment of the NPP. In particular, the questionnaire includes the Organizational Culture Inventory (OCI) (Human Synergistics, 1987), which has been used for assessing organizational culture and which has been tested in many different types of organizations, including high reliability organizations such as air traffic control facilities and military operations (e.g. naval aircraft carriers) (Roberts, personal communication, 1989). Twelve scales describing the environment of the organization comprise the OCI. Additional scales are also included in the questionnaire measuring such things as "safety" culture, job satisfaction, communication, cohesion, and hazardous nature of work. The questionnaire is a paper-and-pencil survey which can be administered in large groups to all levels within the organization.

4.2 Demonstration Studies

The next step was to identify a "test-bed" or demonstration site for the implementation of the methodology. The primary purpose of a demonstration study would be to assess the practicality, the acceptability, and the usefulness of the NOMAC methodology. Practicality has to do with how feasible it is for qualified individuals to implement the methods. Feasibility is related to the resources required for each method and the ease of method implementation. Acceptability has to do with whether the personnel performing the methods and evaluating the data and the facility staff comprehend the methods and results. Usefulness has to do with whether the methods yield results that provide insights and information relevant to the understanding of how organizational factors affect plant safety, whether the methods are broadly applicable, and whether the results are credible.

Efforts to obtain a demonstration site took longer than anticipated. The NRC requested that we not use a NRC-licensed facility in order to minimize perceptions that data collected from such a facility would be used in an evaluative manner. A Department of Energy (DOE) facility was pursued, and although management at the EBR-2 facility in Idaho desired to participate, it was unable to do so because of other requirements placed on it by DOE.

In discussing the need for a site with one of BNL's consultants, Dr. Todd LaPorte from the University of California at Berkeley, it was suggested that we consider collaborating with a Berkeley research group working with the Pacific Gas and Electric Company (PG&E) in California. PG&E management suggested that we initiate work at one of their larger fossil fuel facilities, the Pittsburg Power Plant. The suggestion to use a fossil fuel facility had also been made by the then Chairman of the Advisory Committee on Reactor Safeguards (ACRS). Pittsburg Power Plant, located in Pittsburg, California, was the initial demonstration site for the implementation of the NOMAC methodology in the summer of 1989.

4.2.1 Fossil Fuel Plant Demonstration Study

In the Pittsburg Power Plant (PPP) demonstration study, a functional analysis, the behavioral observational technique, and an organizational culture assessment were conducted. Valuable lessons were learned in implementing the methods in a power plant environment. A detailed discussion of this study is presented in Part II, Section 2, of this volume.

The functional analysis was implemented at the Pittsburg plant in accordance with the research design established prior to the field work. It yielded the qualitative description of the organization necessary to understand the work flow and functional relationships within the plant. Fourteen key managers and supervisors were identified for inclusion in the behavioral observational technique.

The most valuable information obtained from the fossil fuel plant study was the lessons learned concerning the behavioral observational technique. Based on the criteria discussed earlier: (1) the usefulness of this method for NOMAC was limited because of the behavioral categorization scheme initially employed. Behavioral categories more focused on the NOMAC "hypotheses" were developed for the method's use at a NPP. Additionally, the unit of analysis was changed from the original (Komaki, 1986) duration of behavior to its frequency; (2) the practicality of the method could be increased by reducing the number of trained observers; and (3) the acceptability of this technique was very positive. Facility management and staff adapted to the observers' presence rather quickly and on only one occasion were observers asked to leave because of the personal nature of a conversation.

The organizational cultural assessment was also conducted in cooperation with facility management. The surveys were administered during specially scheduled group sessions. A total of 179 questionnaires were completed and analyzed. The individuals surveyed were from the operations, maintenance, and engineering departments and represented approximately 64 percent of the total plant population. Statistically significant differences between departments at the plant were obtained on several of the Organizational Culture Inventory scales as well as on the communication scales. Differences were also obtained between managers and non-managers on many of the scales.

The success at the Pittsburg plant prompted PG&E management to offer the University of California at Berkeley and BNL research teams the opportunity to conduct similar research at the utility's nuclear facility, the Diablo Canyon Power Plant in San Luis Obispo, California. The second implementation of the NOMAC methodology was conducted at the Diablo Canyon plant in the fall of 1989.

4.2.2 Nuclear Power Plant Demonstration Study

The demonstration study at the Diablo Canyon Nuclear Power Plant (DCPP) allowed an examination of NOMAC and its associated methods, modified as a result of the fossil fuel study. In this way, the acceptability, practicality, and usefulness of the methods could be assessed in a nuclear setting. A detailed discussion of this study is presented in Part II, Section 3, of this volume.

The first method implemented in this study was the functional analysis. Interviews were conducted with upper management, organizational documentation was reviewed, and observations of certain organizational activities (e.g., meetings) were made. As in the fossil fuel plant demonstration study, the functional analysis provided a good description of the human organization of the nuclear power plant. Several "hypotheses" from NOMAC were also addressed. Consistent with some of the ideas formulated in NOMAC, the influence of standardization of work in this NPP was found to be very pervasive. However, the nature of decision-making in this NPP was sometimes collegial and not always vertically centralized. This insight represented a slight departure from the vertical centralization described by NOMAC. Finally, the functional analysis also helped to identify the supervisors and managers for inclusion in the behavioral observation technique.

Twenty-two supervisors or managers were observed, each for ten 30-minute periods. As noted above, the behavioral categories used in the observational technique were significantly modified for this demonstration study, with a new categorization scheme consisting of 37 behaviors employed. Using this new scheme, an inter-rater reliability of over 80 percent for this method was achieved prior to the collection of data. In addition, patterns of communication and interaction were tracked by recording the mode of communication as well as with whom the communication was occurring.

The new scheme of organizational and management behaviors developed for this demonstration study proved to be very useful. For the purpose of analyses, the 37 behaviors were grouped into six broader categories: decision-making (DM), planning and organizing (PAO), management attention and oversight (MAO), clarifying ambiguity (CA), solitary work (SW), and non-work related activity (NWR). Very little was observed during the course of the observations that could not be described by the behaviors contained within each group. In addition, differences were obtained among functional and structural units on several of the behaviors. Behaviors and communication variables were measured by the frequency of occurrence as well as with whom they occurred.

Table I.4.1 presents an example of the results obtained from the behavioral observational technique. Specifically, the pattern of interactions across organizational units in the NPP is described in this table. Two main points relevant to NOMAC are highlighted by these results: (1) the middle line spends the majority of its interactions with the operating core and the technostructure. NOMAC maintains that a key function of the middle line is the interpretation of standards. This role requires it to be the liaison between the developer of standards, the technostructure, and the implementer of standards, the operating core (the data suggests that this actually occurs as the middle line most frequently interacts with the operating core and technostructure); (2) as the initiator of standards in a primarily vertically centralized organization, the strategic apex must communicate its direction to the middle line in its role as interpreter of standards and as the link between the strategic apex and the operating core. The data is consistent with this NOMAC "hypothesis." The strategic apex interacts most frequently with the middle line.

Table I.4.1. Patterns of Interaction in a NPP

ORG. UNIT	RESPONDENT ORGANIZATIONAL UNIT						
	N[1]	OC	TS	SUP	ML	SA	EXTERNAL
Operating Core (OC)	1131	74.6[2]	13.2	2.9	4.2	0.5	4.6
Technostructure (TS)	838	11.2	59.2	6.2	2.3	2.0	19.1
Middle Line (ML)	354	39.5	32.2	8.5	10.2	5.4	4.2
Strategic Apex (SA)	638	13.0	14.4	8.2	34.0	11.9	18.5

[1] N = Total number of interactions observed.
[2] Numbers represent percentages of total interactions observed.

The third method, the organizational cultural assessment, was self-administered in the nuclear power plant demonstration study. The Organizational Culture Inventory (OCI) consisting of 12 cultural scales as well as commitment, cohesion, hazard, safety, routinization, job satisfaction, interdependence, and coordination scales were included in the questionnaire. Individuals from a representative sample of DCPP personnel were asked to complete the survey. The response rate was excellent at 84 percent (516/615 distributed).

Several of the scales yielded significant differences among departments as well as differences between managers and non-managers. The use of NOMAC organizational units was also useful in discriminating among groups within the plant. Figure I.4.1 depicts organizational unit differences on four of the OCI cultural scales. The engineering group was significantly different from some of the other groups on the approval, dependent, competitive, and perfectionistic OCI scales.

An interesting result obtained from the organizational culture assessment pertains to "safety" culture. Individuals from different departments within the NPP perceived their jobs as differentially hazardous as measured by the hazard scale. Despite these statistically significant differences, no differences were obtained across any of the departments or organizational levels on the "safety" scale. Moreover, the overall mean score for the NPP on the safety scale was high, apparently suggesting a homogeneously high regard for attention to safety within this organization.

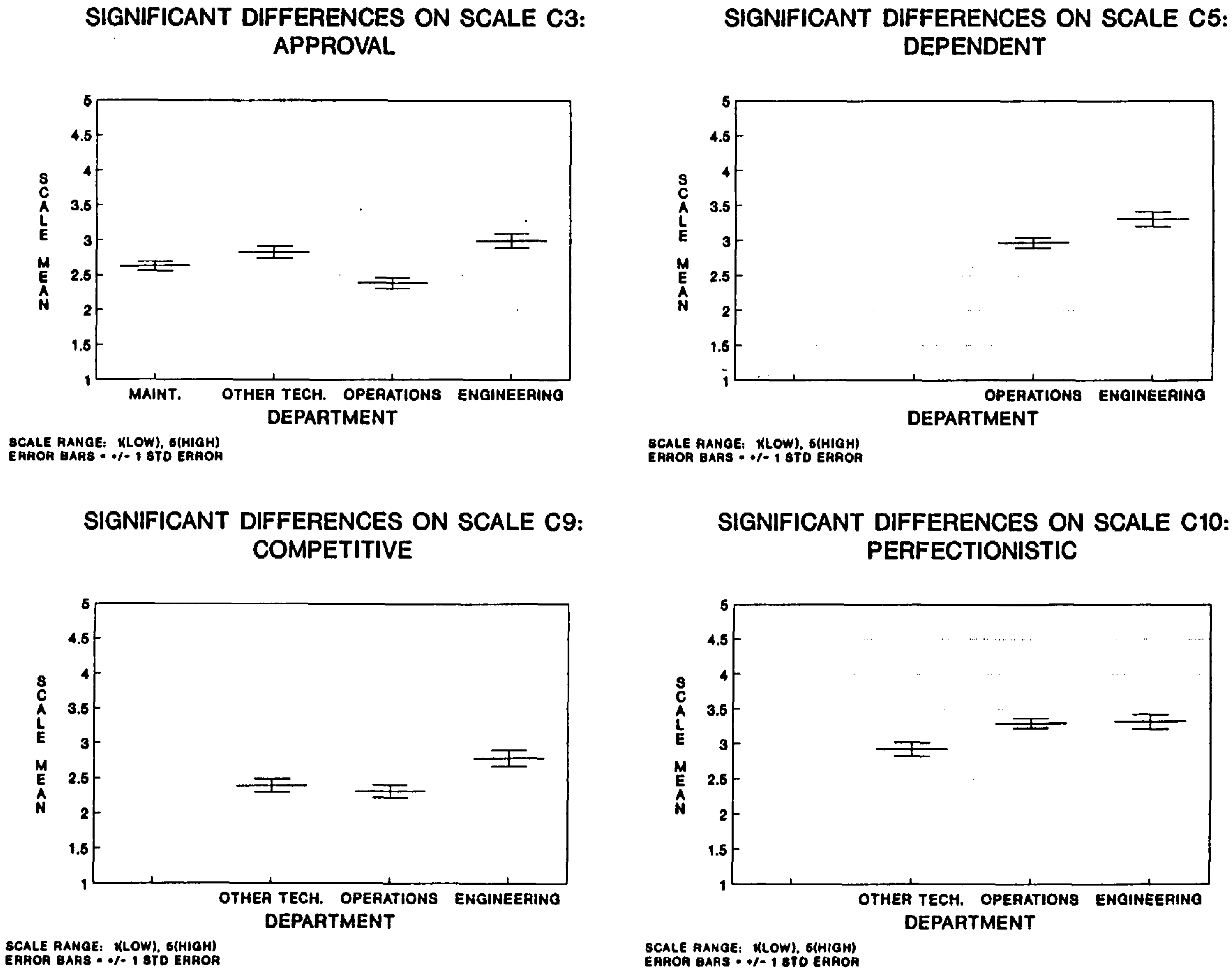


Figure I.4.1. Statistically significant differences on OCI scales

5. EVALUATION OF THE METHODOLOGY

As described earlier, the three general criteria used to evaluate the NOMAC methodology are practicality, acceptability, and usefulness. As a result of such an evaluation, insights into how to improve the methods and their application can be obtained. Furthermore, goals for future implementation of the methodology can be established.

5.1 Evaluation of Practicality

The results of the two demonstration studies indicate that the NOMAC methods can be implemented at a NPP. The methods can be carried out through procedures that are comprehensible to those implementing them. One of the methods, the behavioral observation technique, is more labor intensive than the other two methods. Issues that still need to be resolved for this method include how many individuals have to be observed, as well as the number of observations needed to collect useful information for NOMAC. The resolution of these issues is not likely to increase the level of effort associated with this method, and consequently, the resources required and demands on plant personnel to implement the technique are not expected to increase.

5.2 Evaluation of Acceptability

At both demonstration sites, the methods met with very positive acceptance. In fact, it was the "success" of implementation at the Pittsburg Power Plant that encouraged PG&E management to allow the Diablo Canyon study. Plant management and staff at both facilities viewed these studies as opportunities for feedback to learn more about themselves. Concerns over the behavioral observational technique, expressed prior to implementation, were unfounded. At both facilities, no one asked to participate in the observational technique refused. Personnel implementing the methods had little or no difficulty in meeting their schedules and collecting data.

5.3 Evaluation of Usefulness

The demonstration studies indicated that the methods provided insights and information useful for NOMAC. Differences observed in terms of behaviors, patterns of communication and interaction, and organizational culture were related to the structural and functional positions within the plant. The differences were also generally consistent with "hypotheses" derived from NOMAC. The quantitative methods were reliable and so the findings were independent of the investigators making them. The methods supplemented each other with regard to the type of information they obtained. The validity of the results obtained from the methods and their relationship to the NPP organization's safety performance needs to be further explored through additional data collection.

5.4 Conclusion

Based on their implementation at two power plants, for the purpose of NOMAC research and development, the NOMAC methods are likely with further research to satisfy the three criteria of evaluation: practicality, acceptability, and usefulness given the definitions described above. The methods were carried out in some cases by two individuals within a short space of time; they were relatively unintrusive and produced information that was consistent with the view of the plant held by its leaders. With respect to the regulatory perspective of these criteria, additional research will be needed to re-examine these definitions in terms of their application within a regulatory setting.

Some of the kinds of research issues remaining unsettled are: (1) What is the appropriate level of sampling of individuals for conducting the behavioral observation technique? (2) How many observation periods are necessary to capture adequately an individual's behavior and pattern of interactions and communications? (3) How can training for carrying out the technique be formalized and made effective so that the method's reliability can be maintained? (4) Are there additional dimensions of organizational culture that might be explored? (5) How can the link between organizational and managerial factors on the one hand and safety performance on the other be validated?

To address these issues, additional field work in at least two other NPPs is required. The research would be designed to accomplish two objectives. First, controlled experimentation would be built into the next stage of this project. Efforts would be made to discover how robust the behavioral observation technique is. The causes of inconsistencies between observers would be explored and reduced. Additionally, work might be done to identify other attitudes held by organizational personnel that could affect plant performance. Second, the new field work would replicate the effort undertaken at DCPP. By doing so, the relationship between organizational and managerial factors and safety performance could be better understood.

6. APPLICATIONS OF METHODOLOGY

While the primary product of the research conducted thus far is the development of a general methodology for systematically characterizing and collecting data on the organizational factors in a NPP that have an influence on safety performance, a secondary objective is to integrate that information into various types of evaluative activities. This section describes some of the potential applications of the methodology, recognizing that some of these activities may require additional modification of the data collection methods.

6.1 Identification of Organizational Factors

From the results obtained in the two demonstration studies and in particular, the initial validation of some of the NOMAC "hypotheses," certain organizational factors have been identified for further validation and investigation. These factors are communication, management attention, involvement, and oversight, organizational culture, decision-making, and standardization. These are found in the organizational theory literature and are reflected in NOMAC. Importantly, differences seem to exist on the factors across organizational units and levels, indicating their potential discriminative dimensions.

- Communication

  Communication among functional units within an organization is critical for effective operation. Communication is essential up and down the chain of command (vertical), laterally among units (horizontal), and between the organization and its constituents (e.g., NRC, state, and public). Communication can occur in different modes (face to face, written, telephone, electronic), and can be formal (scheduled meetings) or informal (spontaneous discussions). Communication is an important element of the other factors discussed below.

- Organizational Culture

  Culture is generally defined as the beliefs, perceptions, and expectations that individuals have about the organization in which they work and about the values and consequences that will follow from one course of action or another. Consequently, culture highly influences behavior within the organization.

- Decision-making (including problem-solving)

  Decision-making is a function which reflects an organization's values and culture and the ability of management to choose among competing alternatives. This function includes the ability of the organization to recognize and solve problems. The behaviors involved include identification and reporting of problems, analysis of root cause, selection and implementation of corrective actions, and learning from experience.

- Standardization of Work Processes

  The standardization of work processes in a NPP are the ways by which the organization coordinates its work. This is primarily accomplished by the high specificity of the content of work described for an individual. Standard operating procedures are an example of a standardization of work process. Policies and programs are also examples. Training, through the standardization of skills, is also considered a coordinating mechanism for work.

- Management Attention, Involvement, and Oversight

  These behaviors refer to management functions that enhance organizational awareness. Management must have its own level of understanding, involvement, and oversight of the work flow in the organization. At what level do managers participate in facility operations? To what degree do monitoring and reporting systems connect the managers with what is actually taking place in the organization? Does management seek to protect the objectives of the organization and attempt to thwart any interference of those objectives?

Two potential applications of the methodology could use these organizational factors as a preliminary basis for understanding the influence of organization and management in a NPP on safety performance.

6.2 Development of Insights for Regulatory Activities

The U.S. NRC is heavily involved in inspection and evaluation activities for the facilities over which they have jurisdiction. In particular, SALP (Systematic Assessment of Licensee Performance) ratings, Diagnostic Evaluation Teams, Incident Investigation Teams, NRC Regional briefings, NRC Senior Management meetings, and special inspection teams are routinely dealing with organization and management issues. Each of these activities uses their own subjective approach in assessing and evaluating organizational and management behaviors.

The methodology described in this report may provide a more systematic framework for assessing organizational and management influences in a NPP. The identification of organizational factors (described above) allows for a common language and perspective in describing those behaviors observed and believed to be important. The methods discussed in this report can provide a more objective and in some cases, quantitative means of translating those behaviors into useful information. They also can provide data on one point in time that is directly comparable to data collected using the same methods at another point in time.

The identification of the organizational factors believed to be important to safety performance has also been useful in research BNL is conducting for the U.S. NRC in the area of accident management. Specifically, the NOMAC methodology is being reviewed for its applicability to an emergency or accident situation in a NPP. Several of the organizational factors identified in this project are useful for understanding the response process to an abnormal situation in a NPP. The three NOMAC methods are also being considered for field research in the accident management project. (For a more detailed discussion of this research project, see Metlay et al., 1989.)

6.3 Integration into Probabilistic Risk Assessment

While much of the work regarding this project has focussed on the development and implementation of methods to collect data on organizational factors, another primary objective of the research project is to develop a way to then reflect the influence of these factors in reliability and risk-based analyses of NPPs. Work conducted by the University of California at Los Angeles (UCLA) under contract to BNL (Wu et al., 1989) identified a preliminary scheme for quantifying the impact of organizational factors in probabilistic risk assessment (PRA). A discussion of the subsequent process developed by BNL for integrating the data collected from the NOMAC methodology into a PRA is presented in Part II, Section 4, of this volume.

The work conducted by UCLA (Wu et al, 1989) suggested that the Success Likelihood Index Methodology - Multi Attribute Utility Decomposition method (SLIM-MAUD) (Embrey et al., 1984) would be a viable technique to utilize in the integration of organizational factors into PRA. The identification of the organizational factors described above and the type of data that can be collected from the NOMAC methods can be used to develop a rating matrix of the organizational factors believed to impact performance reliability at a NPP. The rating matrix is therefore developed on the basis of empirical data, consistent with the organizational factors identified by NOMAC.

After the ratings are developed, expert judges are used to weight the organizational factors with respect to their relative importance to different functional units within the NPP, e.g., operations, maintenance, instrumentation and control. After the weightings are complete, the results from the ratings and weightings are run through the SLIM program to obtain success likelihood indices (SLIs) for the different functional units. These SLIs can be used in a number of different ways to adjust the human error probabilities in the PRA.

The development of this process, although preliminary, is a significant alternative to traditional human reliability analysis. The use of data collected from a NPP, rather than just expert judgement, is an important step in reducing the uncertainty associated with human error probabilities. It is anticipated that future work in this research project will refine the process for integrating organization and management data into PRA.

7. CONCLUSION

In the development of a methodology to assess and evaluate the influence of organizational factors on performance reliability (safety), a criterion important to the U.S. NRC was to use scientifically tested and accepted concepts and methods. This research project has demonstrated that the human organization of a NPP can be described by such a concept in a way that is dynamic and process-oriented. This concept allows "hypotheses" to be generated and tested and is scientifically recognized and accepted. Similarly, methods can be identified to collect data on the organizational factors important to safety performance in a NPP that are also widely accepted and utilized in other industries.

This research also demonstrated that the NOMAC methodology can be implemented in different types of settings, including a NPP. The methods used were evaluated to be practical, acceptable, and useful for the goals of the project. Differences in behavior, patterns of communication and interaction, and organizational culture, were observed using the identified methods. More importantly, these differences were related to the structural and functional positions within the organization. The differences were also consistent with "hypotheses" derived from NOMAC.

Important to one of the objectives of this research is the initial demonstration of integrating data collected on organizational and management behavior into PRA. The process described in this report, although preliminary, is one of a few efforts which attempt to specify and use data which can be collected in a NPP and incorporated it into the human reliability analysis of PRA. In some ways, this research raises more questions than answers, but, this is the nature of research and the questions need to be asked and addressed by those interested in reliability and risk-based analyses.

Future work in this project needs to include continued refinement of the NOMAC methods for increased validity in the NPP setting. Increased data collection is also needed for more quantitative and comparative applications, including the continued development of the process for integrating organization and management data into risk assessment. Finally, thought has been given to how the methods described and implemented in this research project might be integrated into other regulatory activities addressing organization and management issues. The standardization of methods and consequently the data to be collected is an important step for the U.S. NRC to consider in its evaluation role.

8. REFERENCES

Embrey, D.E., Humphreys, P., Rosa, E.A., Kirwan, B., and Rea, K., "SLIM-MAUD: An Approach to Assessing Human Error Probabilities Using Structured Expert Judgement/Volume 1: Overview of SLIM-MAUD," NUREG/CR-3518, U.S. Nuclear Regulatory Commission, Washington, D.C., 1984.

Haber, S.B., and O'Brien, J.N., "Methods to Understand the Influence of Management Factors on Performance Reliability," in Trasactions of the Sixteenth Water Reactor Safety/Information Meeting, NUREG/CP-0096, U.S. Nuclear Regulatory Commission, Washington, D.C., 1988, 13-3.

Human Synergistics, Organizational Culture Inventory, Michigan: Human Synergistics, Inc., 1987.

Komaki, J.L., Zlotnick, S., and Jensen, M., Development of an operant-based taxonomy and observational index of supervisory behavior, Journal of Applied Psychology, 71, 1986, pp. 270-279.

Metlay, D.S., Haber, S.B., and Luckas, W.J., "Responding to Emergencies: How Organization and Management Make a Difference," in Transactions of the Seventeenth Water Reactor Safety/Information Meeting, NUREG/CP-0104, U.S. Nuclear Regulatory Commission, Washington, D.C., 1989. 1-3.

Mintzberg, H., The Structuring of Organizations, New Jersey: Prentice-Hall, 1979.

Wu, J.S., Apostolakis, G.E., and Okrent, D., "On the Inclusion of Organizational and Managerial Influences in Probabilistic Safety Assessments of Nuclear Power Plants," paper presented at the meeting of the Society for Risk Analysis, October 1989.

PART II:

DETAILED METHODOLOGICAL DEVELOPMENT

1. INTRODUCTION

Part II of Volume I provides more details and a technical analysis of the methodological development. Specifically, the results of the two demonstration studies, the fossil fuel plant (Section 2) and the nuclear power plant (Section 3) studies, are discussed in detail. Section 4 describes the specific application of integrating the NOMAC methodology and the data collected with probabilistic risk assessment.

2. FOSSIL FUEL PLANT DEMONSTRATION STUDY

2.1 Introduction

The U.S. Nuclear Regulatory Commission's (U.S. NRC) Office of Nuclear Regulatory Research contracted Brookhaven National Laboratory (BNL) to develop a method to assess organizational and managerial influences on safety performance in a nuclear power plant (NPP). The development of this methodology was described in Part I of this volume. Prior to implementation of the method at an operating NPP, the U.S. NRC determined that there had to be a demonstration study of the proposed methodology at an alternate facility in order to assess the practicality, acceptability, and usefulness of the methodology.

With the collaboration of a consultant on the project, Dr. Todd LaPorte of the University of California at Berkeley, a demonstration site for the study was found, a fossil fuel power plant operated by the Pacific Gas and Electric (PG&E) Company in Pittsburg, California. The data collection for the demonstration study at the Pittsburg Power Plant (PPP) began in June 1989 and was completed by the end of July 1989. The study was carried out in conjunction with researchers from the Institute for Governmental Studies at the University of California at Berkeley who are interested in the behavior of high reliability organizations (these are organizations that oversee technologies so hazardous that their operations must be nearly error-free).

PPP is a steam-electric plant which employs approximately 280 people and consists of seven generating units which run on gas and/or oil. The total megawatt electric output capability for the seven units is approximately 2090 megawatts. PPP is not part of the base load in the PG&E system which means that operation of the units depends on need. Consequently, operations at PPP must always be in a state of readiness, prepared to come on-line when power demands are high.

In early June 1989, an introductory meeting was held at PPP with all members of the research team present. Five senior managers of PPP also attended the meeting. The team members explained the purpose of the study, and they asked the managers to describe PPP and provide their views on how their departments fit within the overall organization. They were also asked to describe their own roles and responsibilities. The meeting provided the team with a good description of the plant and the systems and units operating within it. Additionally, the meeting provided a solid basis for conducting the first NOMAC method, functional analysis.

2.2 Functional Analysis

Functional analysis provides a description of the organizational work flow and is obtained primarily through interviews, documentation, and the observation of organizational activities such as meetings. Personnel considered critical to plant operations are also identified. The method provides a good qualitative description of the organization as well as a basis for indicating where resources should be allocated for additional data collection.

At PPP, organizational relationships were identified initially through the review of organizational charts and other documentation. Interviews were then conducted with the plant manager down through the organization to the first line supervisors and their subordinates. Approximately 25 semi-structured interviews were conducted. Efforts were made to understand the responsibilities of the individuals being interviewed, their unit, the responsibilities of other units in the organization that they interacted with, and the mechanisms of standardization and feedback. Cross-validation of responses using several different interviews was attempted whenever possible. Management briefings and meetings were also attended. The method provided a good qualitative description of the organization necessary to understand the work flow and functional relationships within the plant.

2.3 Behavioral Observation Technique

The behavioral observation technique used at PPP was based on the Operant Supervisory Taxonomy Index (OSTI) developed by Komaki et al. (1986), although significant modifications were made to the method by the BNL research team prior to implementation. Therefore, criticisms of the method as implemented at PPP and as discussed later in this chapter, should not be construed as criticisms of the OSTI.

The primary reason for modifying the OSTI was a difference in objectives between the studies conducted by Komaki and the study to be conducted by BNL. Komaki sought to develop a classification scheme whereby she could differentiate between effective and ineffective managers in different types of organizations than NPPs, e.g., banks, insurance companies. The BNL research team, at least initially, did not want to differentiate between managers but rather sought to identify a behavioral scheme relevant to a high technology organization.

One example of the modifications made to the OSTI for its use at PPP was the behavioral categories themselves. Table II.2.1 presents the categories and subcategories of the OSTI and the categories and subcategories utilized by BNL in the PPP study. The majority of changes made were in the form of additions, although a few deletions (e.g., "work-related" subcategory of "type") were also made. These modifications were made in order to capture a broader range of the activities that managers in different types of organizations appear to engage in.

A second modification to the OSTI affected the number of observations conducted and the amount of total observation time during the 30-minute observation period. The BNL research team completed ten 30-minute observations on each subject, while Komaki et al. (1986) maintained that at least twenty, 30 minute observations on every subject were necessary. Although the number of observations was reduced in the BNL study, the actual observation time increased. The BNL research team observed each subject for ten periods (one exception is a subject who was observed eight times due to the extensive amount of time that manager spent out of the office) for the full thirty minute period. Komaki et al. (1986) reported only observing for 300 seconds in each 30 minute period (i.e., for each minute of the observation period, 10 seconds were for observation, 40 seconds for recording verbatim and coding behaviors and 10 seconds getting the context of the next observational period). Thus, while Komaki et al. (1986) completed 20 observations on each subject, they actually only observed each subject for a total of 100 minutes, while the BNL research team observed each subject for a total of 300 minutes (with the one exception of the manager who was observed for a total of 240 minutes).

A description of the behavioral categories used at PPP follows after Table II.2.1.

2.3.1 Behavioral Categorization Scheme

Eight categories of behaviors were identified for the observational technique. Five of these categories were based on previous work by Komaki et al. (1986). The last three categories were not explicitly included in the taxonomy described by Komaki et al.(1986); however, similar information may have been captured in the comments recorded by observers in her studies. These categories were added

Table II.2.1. Comparison Between OSTI and BNL Taxonomy Used at PPP*

OSTI	BNL
I. Performance Consequences	**I. Performance Consequences**
A. Delivery	A. Delivery
1. Direct	1. Direct
2. Indirect	2. Indirect
B. Evaluation	B. Evaluation
1. Positive	1. Positive
2. Negative	2. Negative
3. Neutral	3. Neutral
II. Performance Monitoring	**II. Performance Monitoring**
A. Tense	A. Tense
1. Past	1. Past
2. Present	2. Present
B. Method	B. Method
1. Work Sampling	1. Work Sampling
2. Archival Records	2. Archival Records
3. Self-Report	3. Self-Report
4. Secondary Source	4. Secondary Source
	5. Questioning
III. Performance Antecedent	**III. Performance Antecedent**
A. Delivery	A. Delivery
1. Direct	1. Direct
2. Indirect	2. Indirect
B. Planning	B. Planning
1. Past	1. Past
2. Current	2. Current
3. Anticipated	3. Anticipated
C. Specificity	C. Specificity
1. Specific	1. Specific
2. General	2. General
3. Vague	3. Vague
D. Responsibility	D. Responsibility
1. Clear	1. Clear
2. Unclear	2. Unclear

*Courtesy of Komaki, 1986.

Table II.2.1. Continued*

OSTI		BNL	
	E. Type		
	1. Invited		
	2. Not Invited		
IV.	Own Performance		
	A. Content		
	1. Consequences		
	2. Monitoring		
	3. Antecedents		
V.	Work Related	IV.	Work Related
	A. Type		*A. Own Performance*
	1. Invited		*B. Idea Generation*
	2. Not Invited		*C. Decision Making*
	3. Not Speaking		*D. Problem Solving*
			E. Scheduling
			F. Check Knobs & Dials
			G. Status Report
			H. Paperwork
			I. Other
IV.	Non-work Related	V.	Non-work Related
VII.	Solitary Activity		
		VI.	*Mode of Communication*
			A. Verbal
			B. Phone-in
			C. Phone-out
			D. Written
			E. Electronic
		VII.	*Location of Behavior*
		VIII.	*Interaction With*

Note: Those categories in italicized print are those added by BNL.

*Courtesy of Komaki, 1986.

by BNL for the purpose of determining the patterns of communication (i.e., who interacted with whom and what mode of communication they used) as well as determining where certain behaviors typically occurred.

The first five behavioral categories were derived from Komaki et al. (1986), and are marked with an asterisk.

*I. Performance Consequences (PC)

This category describes a manager's indication of knowledge of a worker's performance. There are two subcategories of this behavior.

a. Delivery of Consequences: This describes the way in which the knowledge of performance was delivered to the person. It could be delivered directly (dir), so the person whom the subject is talking about is the one receiving the feedback, or indirectly (ind), so the subject is delivering information about a person's performance to someone else.

b. Evaluation of Performance: This category describes the subject's evaluation of the performance about which knowledge is being indicated. The subject can express performance consequences in positive (+) (subject evaluates person's performance in favorable terms); negative (-) (subject evaluates person's performance in negative terms); or neutral (0) terms (subject makes statement about person's performance but places no evaluative judgement on it).

*II. Performance Monitoring (PM): The subject being observed is attempting to gather information on another person's performance. Two subcategories are described:

a. Tense of Monitoring: This describes the act of monitoring in the context of time. A subject can monitor the past (pst) by inquiring into work that has already been completed or can monitor the present (pres) by observing work that is ongoing.

b. Method of Monitoring: This subcategory describes the way in which information is collected about performance. The subject can receive information about performance when someone volunteers information on their own performance, self report (SR). The subject can question (ques) a person about their performance. Direct observation of work can occur through work sampling (WS). A subject can refer to records (rec) (e.g., performance appraisals) to obtain performance information. Finally, a subject can obtain information from another person or a secondary source (2nd).

*III. Performance Antecedent (PA)

These behaviors describe the subject giving instructions or placing expectations on performance. Five subcategories are described:

a. Delivery of Antecedent: This subcategory is similar to delivery of consequences; direct (dir) indicates the antecedent was given directly to the person, while indirect (ind) indicates the antecedent was given to a different person than the one who will eventually carry out the instruction or meet the expectation (e.g., tell Jim to meet me in my office at 2:00 PM).

b. Antecedent Specificity: A specific (sp) antecedent gives the person clear guidance and direction on the actions that need to be taken. A general (gen) antecedent gives the person direction in terms of the desired outcome but does not provide specific direction on attaining that outcome. A vague (vg) antecedent provides neither goals or the behavior necessary to achieve the goals.

c. Responsibility for Antecedent: This subcategory describes whether specific responsibility for performing the antecedent is indicated, certain (cer), or whether the antecedent that needs to be performed is indicated but responsibility for action is not made clear, uncertain (unc).

d. Tense of Antecedent: This subcategory provides a time frame within which to describe the behavior. The subject can refer to a previously given antecedent, past (pst); a behavior that the subject expects to be performed in order to deal with a situation or problem that is ongoing, present (pres), or a behavior that the subject feels should be performed in order to prevent something from happening in the future or to help meet a goal or objective, anticipated (ant).

*IV. Work Related (WR)

This category consists of behaviors concerned with the subject's performance. Eight subcategories were developed by BNL for the purposes of this study to capture many behaviors not described by the other categories. These behaviors were not originally included in the work related category as described by Komaki et al. (1986).

a. Own Performance (OP): The subject refers to his/her own performance.

b. Idea Generation (IG): The subject engages in behavior that generates a variety of different thoughts on a particular problem or issue.

c. Decision Making (DM): The subject engages in behavior where the resolution of an issue is sought.

d. Problem Solving (PS): The subject is observed to be engaged in a process where the answer to a question or issue is sought.

e. Scheduling (Sched): The subject is observed making appointments and setting up meetings.

f. Check Knobs and Dials (CK&D): This behavior is a form of performance monitoring but is primarily concerned with plant status and not with the performance of others. Subject observes plant status by monitoring various indicators.

g. Status Report (STR): This behavior consists of the subject presenting the status of some issue to others or receiving information on the status of some issue (but not someone else's performance) from others.

h. Paperwork (PW): Consists of any solitary paperwork behavior (e.g., filling out forms).

i. Other (Oth): This category was used for any other work-related activities that did not fall into one of the previously identified categories.

*V. Non Work Related (NWR)

This category was used when the subject was observed to be engaged in any activity not related to work (e.g., social conversation).

VI. Mode of Communication (MODE)

This category described the way in which the subject communicated with the person they were interacting with. Five subcategories were coded:

a. Verbal (V): The interaction was face-to-face.
b. Phone In (PI): The subject received a phone call.
c. Phone Out (PO): The subject made a phone call.
d. Written (W): The subject interacted through a written medium (e.g., writing a memo).
e. Electronic (EL): The subject interacted through an electronic medium (e.g., electronic mail).

If the subject was engaged in solitary behavior, this category was left blank.

VII. Location of Behavior (LOC)

This category describes where the observed behavior occurred (e.g., office, hallway).

VIII. Interaction With (INT WITH)

This category describes who the subject was interacting with (e.g., superior, co-worker, subordinate, external to the plant).

These behaviors were recorded in terms of their duration, with the minimum definable time being one minute. Table II.2.2 is an example of a typical data sheet used in the behavioral observations. The abbreviations identified with each category in the text correspond to the abbreviations on the coding sheet. Space on the coding sheet was also allocated for information on the name and title of the subject being observed, the observer, the date of the observation, and the time the observation period began and ended. In addition, space was provided for the observer to take notes on the context of the interaction.

2.3.2 Training Observers

After the observers became familiar with the behavioral categories, training observations were conducted. In total, sixty training observations were conducted. These training observations consisted of two observers simultaneously observing a subject. Every attempt was made to remain as unobtrusive as possible. Each observer independently coded the subjects' behaviors for a half hour period. After the observation, the two observers met to discuss the coding of the behaviors. Discrepancies in coding were identified, and discussion took place about what the appropriate code for a behavior was.

Table II.2.2. Data Sheet for Behavioral Observations at PPP

Person/Title: ______________________ **Date:** ______________

Researcher: ______________________ **Time:** Begin ______ End ________

			MODE		PC	PA PC	PA	PA	PM PA	PM	WR		
M I N	LOC	INT. WITH	V PI PO W EL	PC PA PM WR NWR	+ - 0	dir ind	SP gen vg	cer unc	pst pres ant	SR ques REC WS 2nd	OP IG DM PS Sched	CK+D STR PW Oth	Cmts

These training observations also introduced the method and its purpose to the subjects. The observers informed each subject that they were free to request the observers to leave the room at any time. Additionally, the subjects had the option of not participating in the study if they so chose. The subjects were encouraged to ignore the observers and to carry on their work as usual.

2.3.3 Interrater Reliability Coefficient

In order to ensure that the four different observers were agreeing upon what they were observing, the last 18 of the training observations were used to compute an interrater reliability coefficient (IRRC). Paired comparisons were made between observers. The minutes of agreement and disagreement were then combined over all paired comparisons. There were 18 training observations. This yielded a total of 3240 minutes of observation. Of this total, agreement on behavioral categorization was obtained in 2495 of the 3240 minutes. Using the equation below,

IRRC = (# of minutes agreed upon/# of minutes observed) (100)

a 77 percent agreement was computed among the four observers. Due to the demonstration nature of this study, and the newness of the classification scheme used, this was an acceptable level of agreement, and the actual observations were initiated.

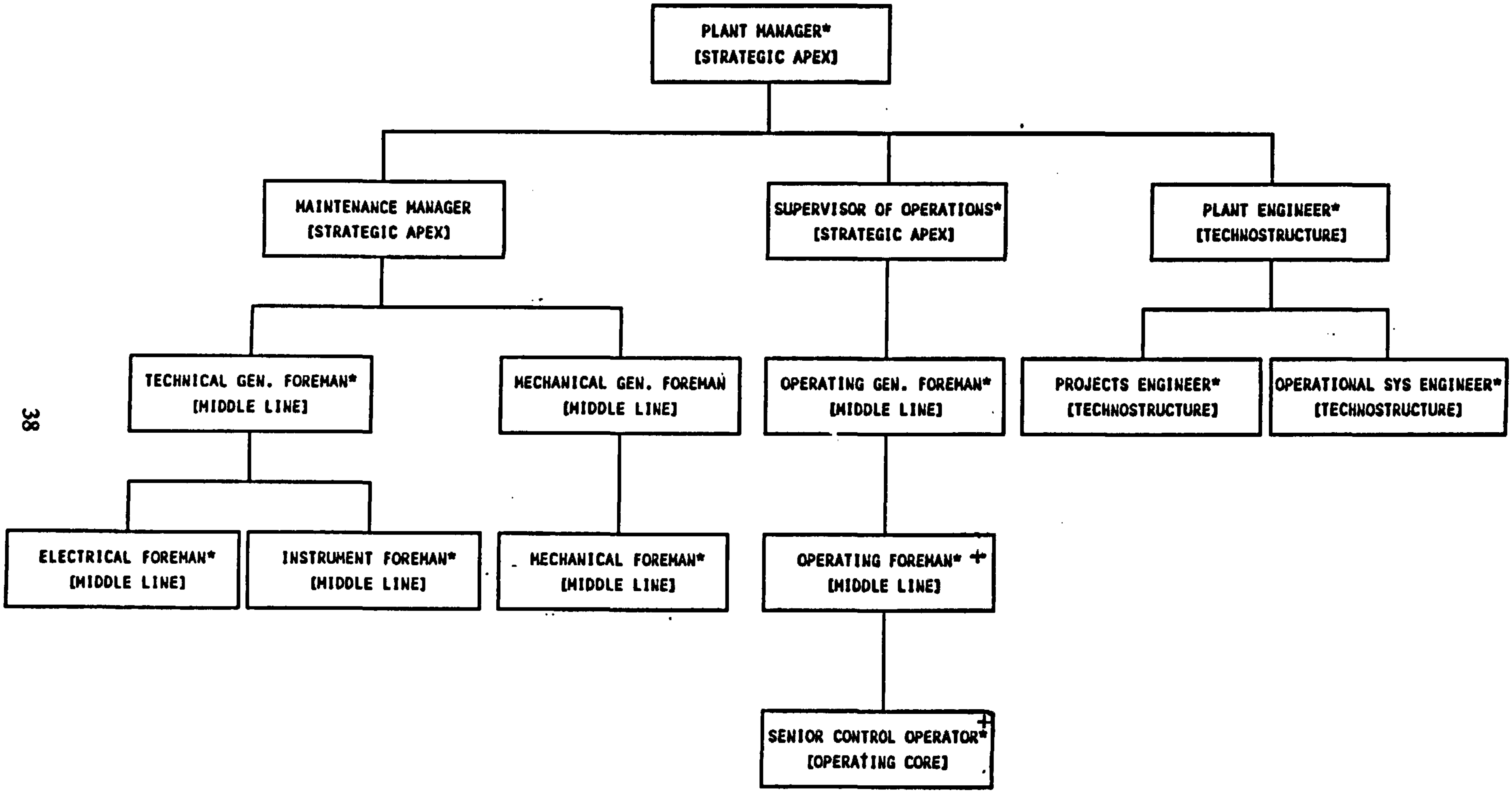
2.3.4 Observations

An initial list of 18 people selected for observation based on the functional analysis was reduced to 14 when four individuals were not accessible for a large portion of the study (i.e., vacation, training, business trips). Figure II.2.1 provides an overview of the individuals interviewed, their reporting relationships, their NOMAC identification, and their functional positions. Table II.2.3 provides the departments and NOMAC units of the subjects observed.

Table II.2.3. Distribution of Individuals Observed

NOMAC Unit	Number	Functional Unit	Number
Strategic Apex (SA)	2	Operations	6
Technostructure (TS)	3	Maintenance	4
Middle Line (ML)	7	Engineering	3
Operating Core (OC)	2	Other	1
Support Staff	0		

Observations were conducted at all times of the day, including swing and night shifts. Observation periods on each subject were divided among the four raters and in all cases but one, in which there were time restrictions, at least three raters made independent observations for each subject. For the one exception, two raters completed the ten observations.



*Indicates a position that was sampled for behavioral observation technique.
+Indicates two subjects in that position were observed.

Figure II.2.1. Functional organization of departments included in PPP demonstration study

2.3.5 Results

2.3.5.1 Overall Facility

The overall results of the behavioral observations are presented in Tables II.2.4 and II.2.5. Table II.2.4 presents the summary of the behavioral categories. The largest amount of time observed was in work related behavior (69.5 percent) Of the time engaged in work-related behavior, 30 percent was categorized as other, providing the first indication that the behavioral taxonomy used was not especially informative for this organization. The next largest category of work-related behavior was identified as problem solving, accounting for 28 percent of all work-related behavior.

The second largest category of behavior observed was performance monitoring (14 percent). The majority of this behavior occurred as a result of self-report (57 percent). However, an equivalent portion of the performance monitoring time was also spent in the combined behaviors of questioning (29 percent) and work-sampling (27 percent). Most performance monitoring took place in the present (25 percent).

Performance antecedent behaviors (9.6 percent)accounted for less time than performance monitoring. Most performance antecedents were given directly (81 percent) and tended to be specific (63 percent). It was also usually certain as to who should perform the actions (73 percent) and most performance antecedents referred to behaviors that were to take place in the future (50 percent).

Only a small percentage of the observed managers' time was spent engaged in performance consequences (1.1 percent). This percentage is less than that found by Komaki et al. (1986). In two separate studies, she found performance consequences to occur 4.9 and 5.3 percent of the total time observed. Of the total time spent in performance consequences, most were positive (23 percent) and were delivered directly (35 percent).

Table II.2.5 indicates that the mode of communication accounting for the largest percent of time was verbal communication (55.2 percent). Phoning out (9.9 percent) was used to a greater extent than phoning in (4.9 percent) for the individuals observed.

2.3.5.2 Department Profiles

Table II.2.6 presents the percentage of time the plant manager and managers in the departments of Operations, Maintenance, and Engineering, spent in the various behavioral categories. For all four groups, the majority of time was spent in work-related activities. However, the other categories of performance consequences, antecedents, and monitoring accounted for more time in some organizational groups than for others. For example, engineering managers spent 79 percent of their time and maintenance managers spent 71.3 percent of their time in work-related behaviors, while the plant manager and operations managers spent 65 and 64.3 percent of their time, respectively, in work-related behavior. The plant manager and operations manager's time was better captured by the performance behavioral categories (consequences, antecedents, monitoring) than either the engineering or maintenance manager's time was. For both the plant manager and engineering managers, the largest percentage of their work-related behavior occurred as problem solving (54 and 37.3 percent, respectively). However, both operations and maintenance managers spent the largest percentage of their work-related behavior as other (31 and 32.5 percent, respectively).

Table II.2.4. Summary of Behavioral Observations for PPP

Category		Average % of Time Engaged In
I.	Performance Consequences	1.1
	a. Positive	23.0
	b. Neutral	10.0
	c. Negative	13.0
	d. Direct	35.0
	e. Indirect	13.0
II.	Performance Antecedents	9.6
	a. Direct	81.0
	b. Indirect	4.0
	c. Specific	63.0
	d. General	23.0
	e. Vague	4.0
	f. Certain	73.0
	g. Uncertain	3.0
	h. Anticipated	50.0
	i. Past	3.0
	j. Present	27.0
III.	Performance monitoring	14.0
	a. Past	11.0
	b. Present	25.0
	c. Self-report	57.0
	d. Questioning	29.0
	e. Work-sample	27.0
	f. Records	3.0
	g. Secondary source	11.0
IV.	Work-related	69.5
	a. Own performance	4.0
	b. Idea generation	7.0
	c. Decision making	8.0
	d. Problem solving	28.0
	e. Scheduling	12.0
	f. Check knobs and dials	4.0
	g. Status report	19.0
	h. Paperwork	17.0
	i. Other	30.0
V.	Non-work Related	9.4

Notes:
Number of subjects observed = 14.
Numbers in column represent average percent of time spent in behavior.
Numbers do not total 100 percent due to multiple coding.
Numbers for subcategories below main categories represent percentage of main category.

Table II.2.5. Summary of Modes of Communication at PPP

Mode of Communication	% of Time Engaged In
Verbal	55.2
Phone In	4.9
Phone Out	9.9
Written	8.3
Electronic	3.3

Note:

Number of subjects observed = 14.
Numbers do not sum to 100 percent due to time spent in solitary activity.

Large differences existed within the performance monitoring category. The plant manager spent 35 percent of his time in performance monitoring, while engineering managers spent only 7 percent of their time in monitoring. While performance monitoring was most likely to occur through self-report, this trend was primarily evident in the maintenance and engineering departments. Both the plant manager and operations managers were somewhat more likely to use other means to gather performance information. The plant manager used questioning (72 percent) more than self-report (60 percent); while in operations, work-sampling (40 percent) and questioning (32.7 percent) were used slightly more often than self-report (30.8 percent). Engineering did the least amount of work-sampling (6 percent). Maintenance managers used records more than any other department (8.8 percent) and operations managers used secondary sources more than other departments (19.2 percent). All departments monitored performance in the present more than from the past.

The plant manager used performance antecedents more than any other department (26 percent). Operations, maintenance and engineering managers did not differ much in the percentage of time spent in performance antecedents (8.2 percent, 7.8 percent, and 9.3 percent respectively). All departments were more likely to give direct, specific, and clear performance antecedents.

While all departments spent a small amount of time providing performance consequences, the plant manager spent the most (4 percent). For all departments except maintenance, the performance consequences tended to be positive ones. Maintenance managers were more likely to give negative or neutral consequences than they were to give positive. In all departments, except operations, the consequences were likely to be direct; in operations, the consequences were more likely to be indirect.

Table II.2.7 shows that in all departments, verbal communications accounted for the largest percentage of time, with the plant manager spending the greatest percentage of time in verbal communications. Other differences between departments are seen in the written mode, with maintenance and engineering managers using this mode of communication to a larger extent than the plant manager or operations managers.

Table II.2.6. Summary of Behavioral Observations at PPP by Department

Behavioral Category		Plant Manager (n=1)	Ops. (N=6)	Maint. (n=4)	Eng. (n=3)
I.	Performance Consequences	4.0	0.5	1.0	1.3
	a. Positive	64.0	25.0	3.3	27.7
	b. Neutral	9.0	0.0	16.5	22.3
	c. Negative	0.0	8.3	21.8	16.7
	d. Direct	13.0	9.3	55.0	47.3
	e. Indirect	0.0	16.7	20.0	0.0
II.	Performance Antecedents	26.0	8.2	7.8	9.3
	a. Direct	89.0	83.5	81.8	67.3
	b. Indirect	0.0	4.2	1.5	7.7
	c. Specific	52.0	74.5	62.5	45.3
	d. General	42.0	22.3	19.8	23.7
	e. Vague	0.0	1.0	6.8	7.7
	f. Certain	55.0	83.8	73.3	56.0
	g. Uncertain	13.0	2.0	1.5	2.7
	h. Anticipated	18.0	36.5	66.8	65.7
	i. Past	0.0	0.0	1.5	11.7
	j. Present	34.0	43.8	19.5	2.0
III.	Performance monitoring	35.0	22.8	12.5	7.0
	a. Past	7.0	8.8	15.0	9.0
	b. Present	36.0	14.3	40.8	20.7
	c. Self-report	60.0	30.8	78.8	71.0
	d. Questioning	72.0	32.7	25.3	10.3
	e. Work-sample	16.0	40.0	26.5	6.0
	f. Records	0.0	2.0	8.8	0.0
	g. Secondary source	13.0	19.2	5.3	2.7
IV.	Work-related	65.0	64.3	71.3	79.0
	a. Own performance	1.0	2.5	6.0	3.3
	b. Idea generation	42.0	6.7	0.3	6.0
	c. Decision making	26.0	4.7	4.3	13.3
	d. Problem solving	54.0	22.2	21.5	37.3
	e. Scheduling	8.0	13.0	17.5	10.7
	f. Check knobs & dials	0.0	7.3	0.3	1.3
	g. Status report	22.0	24.7	16.0	12.0
	h. Paperwork	7.0	12.8	26.3	16.7
	i. Other	31.0	31.0	32.5	26.3
V.	Non-work Related	1.0	13.8	9.5	5.3

Notes:
Numbers in columns represent percentage of time engaged in behavior.
Numbers do not total 100% due to multiple codings.
Subcategories below main categories represent percentage of main category.

Table II.2.7. Summary of Modes of Communication by Departments at PPP

Mode of Communication	Plant Manager (n=1)	Operations (n=6)	Maintenance (n=4)	Engineering (n=3)
Verbal	80.0	58.0	46.8	52.7
Phone In	5.0	4.5	6.3	4.0
Phone Out	8.0	7.2	12.8	12.0
Written	0.0	2.8	15.0	13.0
Electronic	0.0	2.0	6.0	3.3

Note:

Numbers in columns represent percentage of time spent in communication mode.
Numbers do not sum to 100 percent due to amount of time spent in solitary activity.

2.3.5.3 NOMAC Profiles

Table II.2.8 presents summaries of the behavioral observations and modes of communication for the NOMAC units of strategic apex, technostructure, middle line, and operating core at PPP. The largest amount of time was spent in work related behaviors, with the middle line and operating core managers spending the greatest amount of time in work related other activities (32.4 percent and 36.5 percent respectively). The strategic apex and the technostructure spent the greatest amount of time in problem solving (46.5 and 37.3 percent, respectively). The strategic apex also spent a large amount of time in idea generation (30.5 percent).

The strategic apex and the middle line both spent the second largest amount of their time in performance monitoring (23.5 and 14.9 percent, respectively). Within the performance monitoring category, all groups used self-report to a large extent but the strategic apex used questioning more (58 percent) while the operating core managers used work sampling more (44 percent).

Interestingly, the operating core managers spent a large percentage of their time in non-work related behavior (27 percent). This is not totally surprising given that at PPP the operating core's main function is more passive plant monitoring than active control thereby allowing members of the operating core to have more time to spend in nonwork-related behavior.

Performance antecedents were used to the largest extent by the strategic apex (22 percent). All NOMAC units tended to give direct, specific, and clear antecedents. The strategic apex and the operating core were more likely to give antecedents in the present.

All groups spent minimal amounts of time engaged in performance consequences with the strategic apex being more likely than any other NOMAC unit to engage in that behavior (2.5 percent). The strategic apex was also most likely to give positive consequences, while the middle line and technostructure were more likely to provide negative consequences.

Table II.2.8. Summary of Behavioral Observations by NOMAC Unit at PPP

Behavioral Categories	Strategic Apex (n=2)	Techno-structure (n=3)	Middle Line (n=7)	Operating Core (n=2)
I. Performance Consequences	2.5	1.3	0.7	0.5
a. Positive	82.0	27.7	10.0	0.0
b. Neutral	4.5	22.3	9.4	0.0
c. Negative	0.0	16.7	19.6	0.0
d. Direct	32.5	47.3	31.4	0.0
e. Indirect	0.0	0.0	11.4	50.0
II. Performance Antecedents	22.0	8.7	7.0	6.5
a. Direct	93.5	67.3	82.0	83.0
b. Indirect	7.5	7.7	2.3	0.0
c. Specific	71.0	45.3	64.3	78.5
d. General	27.0	23.7	22.6	21.5
e. Vague	0.0	7.7	4.7	0.0
f. Certain	76.0	56.0	72.0	97.5
g. Uncertain	7.5	2.7	2.3	0.0
h. Anticipated	28.0	65.7	57.0	24.5
i. Past	0.0	11.7	0.9	0.0
j. Present	35.5	2.0	26.0	61.0
III. Performance monitoring	23.5	7.0	14.9	12.0
a. Past	7.0	9.0	11.3	13.5
b. Present	21.5	20.7	28.7	23.5
c. Self-report	44.5	71.0	55.1	42.5
d. Questioning	58.0	10.3	27.9	29.0
e. Work-sample	18.0	6.0	34.0	44.0
f. Records	1.0	0.0	6.4	0.0
g. Secondary source	27.5	2.7	10.0	12.5
IV. Work-related	67.5	79.0	69.4	57.5
a. Own performance	4.5	3.3	4.4	0.0
b. Idea generation	30.5	6.0	2.1	3.5
c. Decision making	17.0	13.3	5.3	0.0
d. Problem solving	46.5	37.3	19.9	20.5
e. Scheduling	11.0	10.7	14.6	3.0
f. Check knobs & dials	0.0	1.3	3.1	11.5
g. Status report	23.5	12.0	19.9	24.0
h. Paperwork	10.5	16.7	22.6	5.0
i. Other	23.5	26.3	32.4	36.5
V. Non-work Related	1.0	5.3	8.4	27.0

Notes:

Numbers in columns represent percentage of time spent in behaviors.
Numbers in columns do not total 100 percent due to multiple coding.
Numbers for subcategories below main categories represent percentage of main category.

All four NOMAC units, as seen in Table II.2.9, spent a large amount of time in verbal communications. Written communications were more likely to be carried out in the middle line (10.3 percent) or technostructure (13 percent) than in the other two NOMAC units.

Table II.2.9. Summary of Modes of Communication by NOMAC Units at PPP

Mode of Communication	Strategic Apex (n=2)	Techno-structure (n=3)	Middle Line (n=7)	Operating Core (n=2)
Verbal	77.5	52.7	47.0	65.5
Phone In	4.5	4.0	5.7	4.0
Phone Out	7.5	12.0	10.7	6.0
Written	0.5	13.0	10.3	2.0
Electronic	0.0	2.3	5.0	0.5

Note:

Numbers in columns represent percentage of time spent in communications mode.
Numbers do not sum to 100 percent due to the amount of time spent in solitary work activities.

2.3.6 Conclusions

As mentioned earlier in this section, one of the main objectives of this demonstration study was to evaluate the NOMAC methodology in terms of its practicality, acceptability, and usefulness. The practicality of the behavioral observational technique was clearly demonstrated. Some minor modifications were identified to increase its practicality. For example, although four observers were used in this study, it became apparent that the study could have been as easily implemented with only two. Moreover, while Komaki et al. (1986) suggested 20 observations on each subject, fewer observations in combination with more observation time were more consistent with the time constraints of the study, the desire to sample as many critical persons in as many critical positions as possible, and the type of organization being dealt with (e.g., managers frequently had to be searched for since they spent a lot of time away from their offices and out in the plant or in meetings).

The behavioral observational technique was highly acceptable. Initial concerns that the method may be too intrusive and disruptive proved untrue at PPP. Facility management and staff adapted to the observer's presence very quickly and on only one occasion were observers asked to leave because of the personal nature of the observation. In most instances, observers were able to enter a subject's office with no disruption to work routine. A few subjects would occasionally stop what they were doing to explain something to the observer, but for the most part work continued in an uninterrupted fashion.

This demonstration study did highlight the limited usefulness of the behavioral classification scheme even as modified by BNL for the PPP study of NOMAC. This was evident by the large number of behaviors coded as work-related in the subcategory defined as Other. This suggested that the classification was not as detailed as needed, nor was it able to capture the full range of behaviors which occurred in this particular organization.

Another issue relating to the usefulness of the behavioral observation technique utilized at PPP was the recording of behavior by duration. It became apparent at PPP that the amount of time a particular behavior was engaged in was not as critical as the fact that it occurred. In addition, duration did not necessarily equate with quality of the interaction. Consequently, it was decided that frequency and perhaps the content of behaviors observed, rather than time, would be a more meaningful indication of behavior.

2.4 Organizational Culture Assessment (OCA)

2.4.1 Administration of OCA

Organizational Culture Assessment (OCA) questionnaires were distributed to employees of PPP in the operations, maintenance, and engineering departments. A total of 179 questionnaires was completed. This represented approximately 73 percent of the total number of employees in operations, maintenance, and engineering. Response rates were 76 percent for the employees in the Maintenance Department, 86 percent in the Engineering Department, and 58 percent in the Operations Department. The lower percentage seen in the Operations Department was due to shiftwork.

Each OCA questionnaire administered at PPP consisted of the following: Organizational Culture Inventory (OCI) (Human Synergistics, 1987), Communications Survey (Roberts and O'Reilly, 1974), Safety Scale (Roberts, personal communication, 1989), Routinization Scale (Withey, Daft, and Cooper, 1983), and Organizational Commitment Scale (Mowday and Steers, 1979). Additionally, a demographics sheet was included to obtain background data on the respondents. This information included the length of time the respondent had been working at PPP, management level if applicable, job classification, and educational level. The questionnaires were administered by departments in group settings. Detailed descriptions of each scale, as well as the survey results are presented below.

2.4.2 Data Analysis

Overall means were computed for each scale listed above. A one-way analysis of variance was performed for each OCA scale using the scale score as the dependent variable and separate analyses using department and organizational level (management versus non-management) as the independent variables. Where the analysis of variance showed a significant difference among the group means, a Tukey HSD (Honestly Significant Difference) (Hays, 1988) procedure was applied to identify those means which were statistically different from each other. Only the pairs of group means found to be significantly different at the .05 probability level or less are reported.

2.4.2.1 Organizational Culture Inventory (OCI)

2.4.2.1.1 Description

The Organizational Culture Inventory (OCI) (Human Synergistics, 1987) is a diagnostic tool for measuring aspects of organizational culture that have an impact on the activities of members and on the organization's functioning. Respondents are asked to review 120 statements describing some of the thinking and behavioral styles members of an organization may be expected to adopt in carrying out their work and in interactions with others. They are asked to indicate to what extent they believe they're expected to exhibit those behaviors in order to be successful on the job. These statements, described in Table II.2.10, measure 12 different cultural styles. All of the styles measured by the OCI are related

Table II.2.10. Organizational Culture Inventory Scales

Scale	Name	Description
C1	HUMANISTIC-HELPFUL	Organization managed in participative and person-centered way. Members expected to be supportive, constructive, and open to influence in their dealings with one another.
C2	AFFILIATIVE	Organization places high priority on constructive personal relations. Members expected to be friendly, open, and sensitive to the satisfaction of their work group.
C3	APPROVAL	Organization where conflicts are avoided and personal relations are pleasant, at least superficially. Members feel they should agree with and gain approval of others.
C4	CONVENTIONAL	Organization that is conservative, traditional, and bureaucratically controlled. Members expected to conform, follow rules, and make a good impression.
C5	DEPENDENT	Organization that is hierarchically controlled and nonparticipative. Centralized decision-making leads members to do only what they are told and to clear all decisions with supervisors.
C6	AVOIDANCE	Organization that does not reward success but punishes failure. Negative reward leads members to shift responsibility to others and avoid being blamed for mistakes.
C7	OPPOSITIONAL	Organization where confrontation prevails and negativism is rewarded. Members gain status and influence by being critical and are encouraged to oppose the ideas of others.
C8	POWER	Non-participative organization structured on basis of authority in members positions. Members expect to take charge and control subordinates and respond to demands of superiors.
C9	COMPETITION	Organization where winning is valued and rewards are given for out-performing others. Members operate in a "win-lose" framework and work against peers to be noticed.
C10	PERFECTIONISTIC	Organization where persistence, hard work, and perfectionism are highly valued. Members feel they must avoid all mistakes, keep track of everything, and work long hours to attain specific objectives.
C11	ACHIEVEMENT	Organization that does things well and values members who set and accomplish their own goals. Members set challenging, realistic goals and plan and pursue them with enthusiasm.
C12	SELF-ACTUALIZE	Organization that values creativity, quality over quantity, tasks and individual growth. Members encouraged to gain satisfaction from their work, develop themselves and take on new activities.

Human Synergistics (1987).

to, and result from, organizational structural variables, reward systems, and managerial styles and philosophies that can be changed, at least to some extent, by those in leadership positions.

2.4.2.1.2 Overall Profile

The overall scores on the OCI for the entire sample of respondents at PPP are depicted in Figure II.2.2. The cultural styles are identified here by number and are described in Table II.2.10. The scores represent the mean scores for the entire population on a scale of 1 (not at all) to 5 (to a great extent).

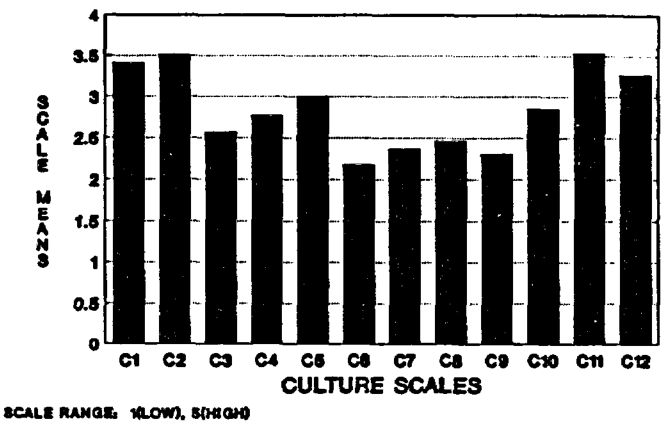


Figure II.2.2. Overall mean scores on OCI scales

The four cultural scales which PPP scored highest on are the Humanistic-Helpful, Affiliative, Achievement, and Self-Actualizing (C1, C2, C11, and C12) scales. These are considered to be constructive cultural styles (Human Synergistics, 1987). The scales PPP scored lowest on are Avoidance, Oppositional, Power, and Competition, (C6, C7, C8, and C9). This profile indicates that employees of PPP are generally satisfied with their jobs and are motivated to do what they do well. Task quality and individual creativity are desired and acknowledged. People are friendly and sensitive to others and members tend to accept rather than avoid responsibility.

2.4.2.1.3 Departmental Profiles

Comparisons of personnel from the Engineering, Maintenance, and Operations Departments revealed three scales in which the Engineering Department differed significantly from the Maintenance and Operations Departments. These differences are depicted in Figure II.2.3. Engineering is significantly lower than both maintenance and operations on the Avoidance (C6) and Power (C8) scales, but is significantly higher than both on the Achievement Scale (C11). This indicates that engineers are not as apt to avoid responsibility and shift blame for mistakes or to take charge of and attempt to control subordinates as are personnel in operations and maintenance. Engineers are also more achievement oriented. These differences are not surprising between professional and labor groups and in fact, were substantiated by comments obtained in the functional analysis interviews.

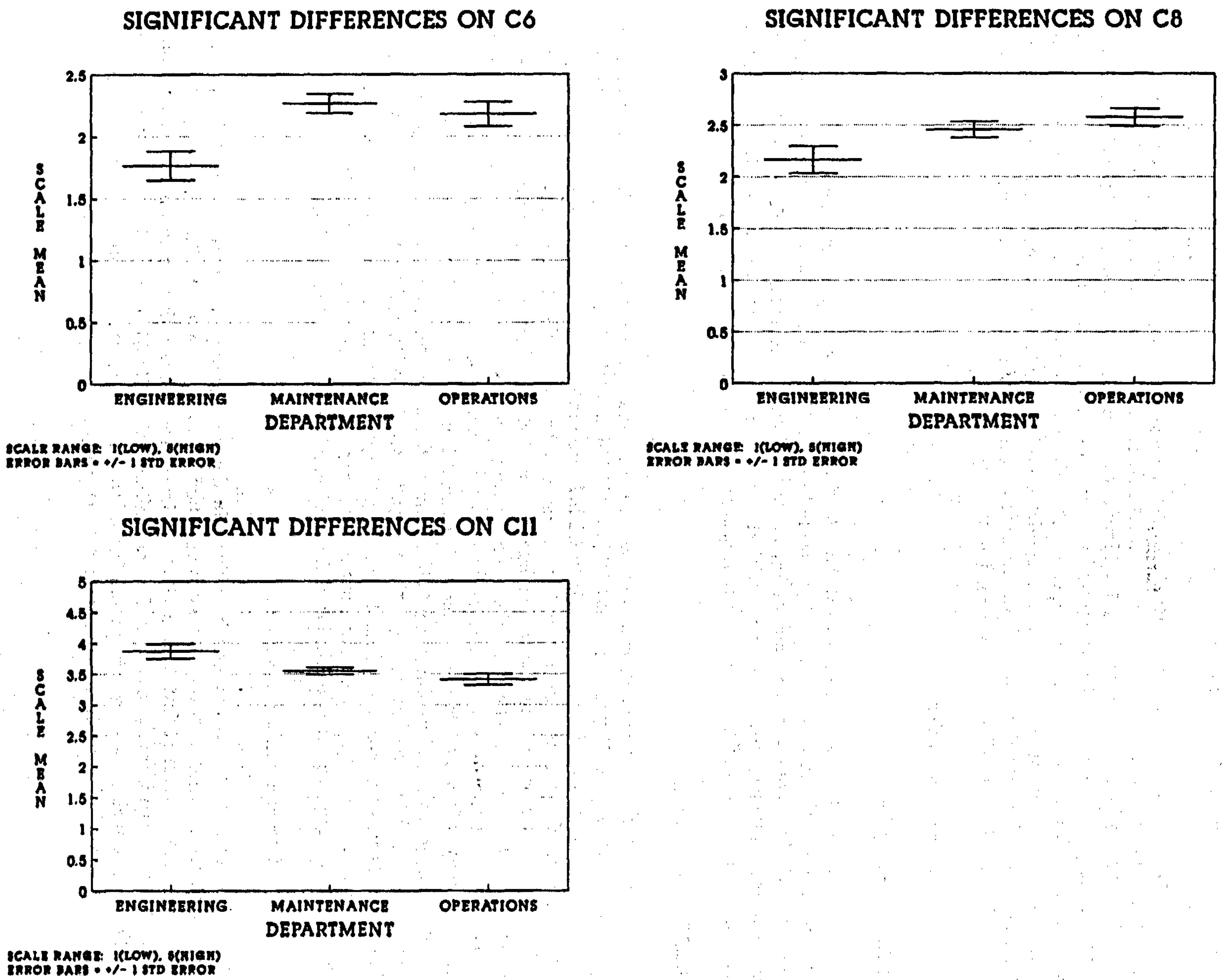


Figure II.2.3. Statistically significant differences between departments on OCI scales

2.4.2.1.4 Organizational Level Profiles

Comparisons between management and nonmanagement (Figure II.2.4) revealed significant differences between the two groups on four of the 12 OCI scales. Managers scored significantly higher on the Humanistic-Helpful, Affiliative, and Achievement scales (C1, C2, and C11) and significantly lower on the Avoidance scale (C6). These are not uncommon differences between such groups. Managers in many effective organizations are expected to encourage a participative and supportive work environment and to encourage people to communicate as well as to be achievement oriented. Managers of good organizations are also less likely to avoid responsibility and typically reward people for successes and not just punish for failures (Mintzberg, 1973).

2.4.2.2 Communication Scales

2.4.2.2.1 Description

Communications are necessary for the effective operation of any organization. However, the communications process cannot be easily measured. Included in the questionnaire administered to employees of PPP were the 12 communication scales developed by Roberts and O'Reilly (1974). This scale has been administered to various organizations and has been found to be reliable and valid in analyzing several facets of the communication process. The scales are described in Table II.2.11.

2.4.2.2.2 Overall Profile

The profile on the communication scales for the overall PPP organization is depicted in Figures 2.5 and 2.6. The scales in Figure II.2.5 for COM1 to COM4 and COM8 to COM12 are on a range from 1-7, while the scales in Figure II.2.6 (COM5 to COM7) are represented by percentage of total time for communication. Consistent with the profile that emerged from the OCI, the communication scale that received the highest value is the desire for interaction (COM4). Employees of PPP generally enjoy interacting with other members of their work group and actually seek such interactions out. Additionally, members of this organization tend to summarize information before they pass it on to others (COM9). They also do not exhibit a high amount of gatekeeping since they pass much of the information they receive on to others (COM10). Among the scales that PPP personnel tended to score lower on were Information Processing (COM11), Influence (COM2), and Mobility (COM3). Figure II.2.6 indicates that the majority of total time at work spent with others is spent with individuals in lateral positions (COM7). The least amount of time is spent with subordinates (COM6). Time spent with superiors is approximately one-third of the total time spent with others (COM5 and COM7).

2.4.2.2.3 Departmental Differences

Significant differences among individuals in the Engineering, Maintenance, and Operations Departments were found on two of the communication scales (see Figure II.2.7). Engineers exhibited significantly greater trust (COM1) than either maintenance or operations personnel. Additionally, engineers scored significantly lower on the transmittal scale (COM10) than either maintenance or operations personnel, indicating they passed less information on to others. No significant differences were found between the maintenance and operations groups.

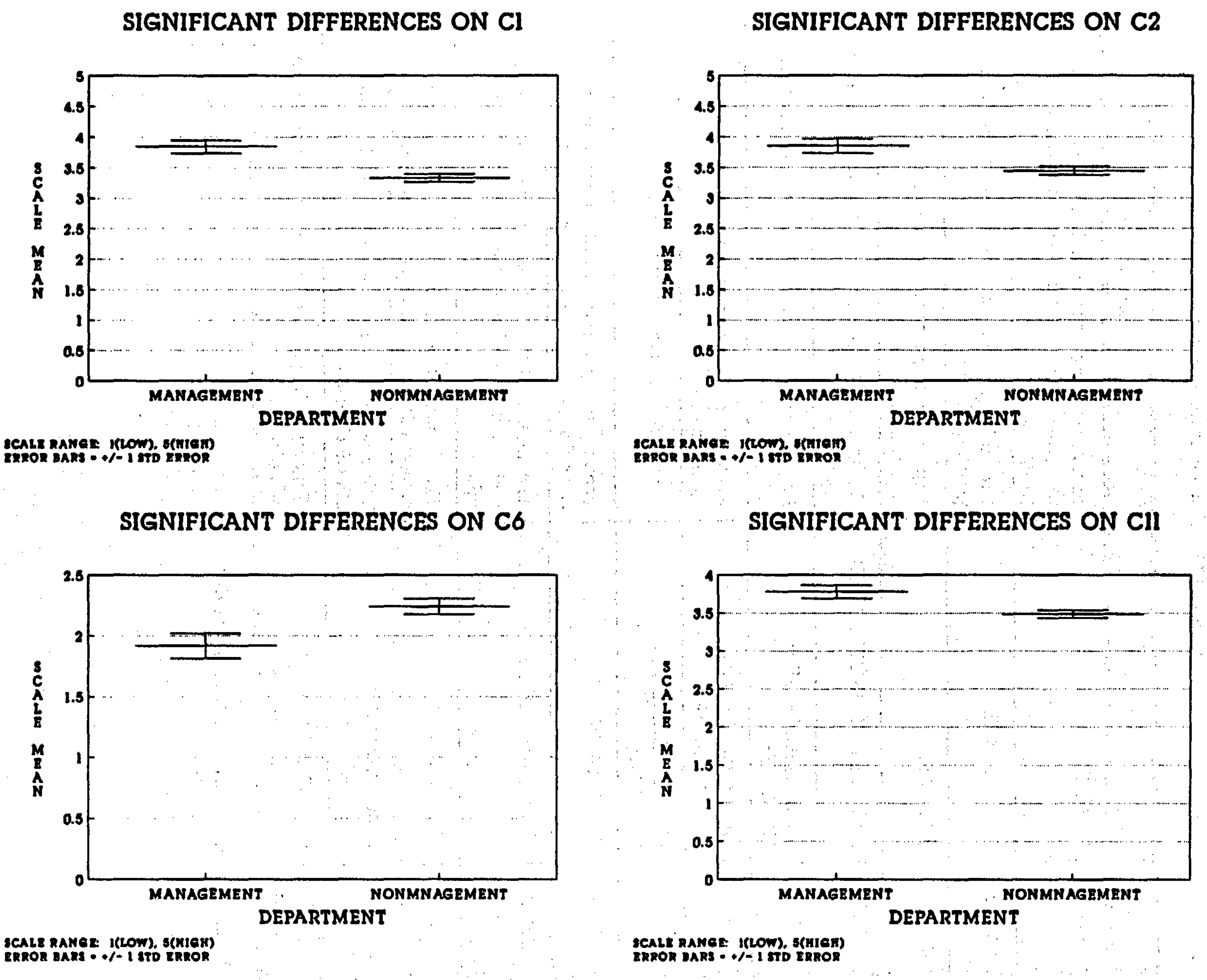


Figure II.2.4. Statistically significant differences between organizational levels on OCI scales

Table II.2.11. Communication Scales

Scale	Name	Description
COM1	TRUST	Freedom to discuss the problems and difficulties in a job with immediate supervisor without jeopardy.
COM2	INFLUENCE	Perception of immediate supervisor's ability to promote career.
COM3	MOBILITY	Importance to progress upward within the organization.
COM4	DESIRE FOR INTERACTION	Desirability of frequent contact with others in the organization.
COM5	DIRECTIONALITY/ UPWARD	Percentage of time at work spent with superiors.
COM6	DIRECTIONALITY/ DOWNWARD	Percentage of time at work spent with subordinates.
COM7	DIRECTIONALITY/ LATERAL	Percentage of time at work spent with peers.
COM8	ACCURACY	Perception of the accuracy of information received from other organizational levels.
COM9	SUMMARIZATION	The amount of the total amount of information that is summarized before being passed on to others.
COM10	TRANSMITTAL	The amount of the total amount of information received at work that is passed on to others.
COM11	INFORMATION PROCESSING	The amount of information received that can be effectively used.
COM12	SATISFACTION	General feeling about the communications in an organization.

Modified from Roberts and O'Reilly (1974).

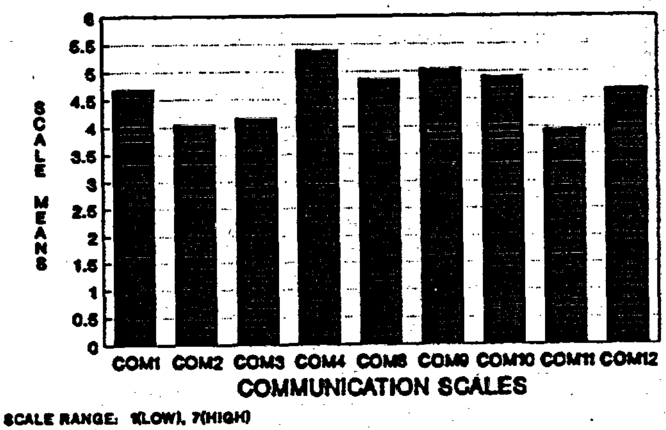


Figure II.2.5. Overall mean scores on communication scales

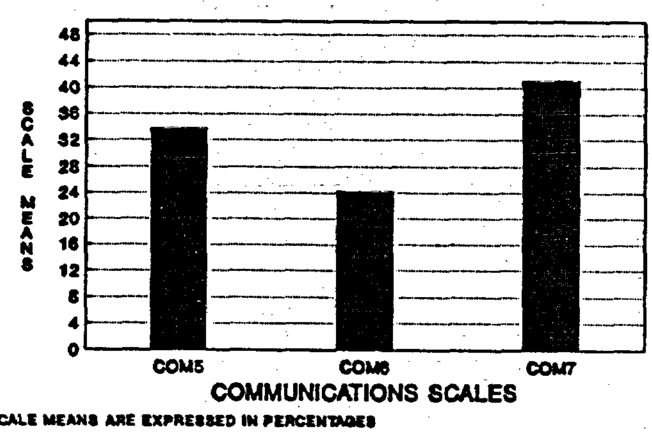


Figure II.2.6. Overall mean scores on communication scales

2.4.2.2.4 Organizational Level Differences

Significant differences among managers and nonmanagers appeared in six out of the 12 communication scales. Managers scored significantly lower than nonmanagers on both the Trust (COM1) and Directionality-lateral (COM7) scales. Managers scored significantly higher than nonmanagers on the Influence (COM2), Desire for Interaction (COM4), Satisfaction (COM12), and Directionality-downward (COM6) scales (see Figures 2.8 and 2.9).

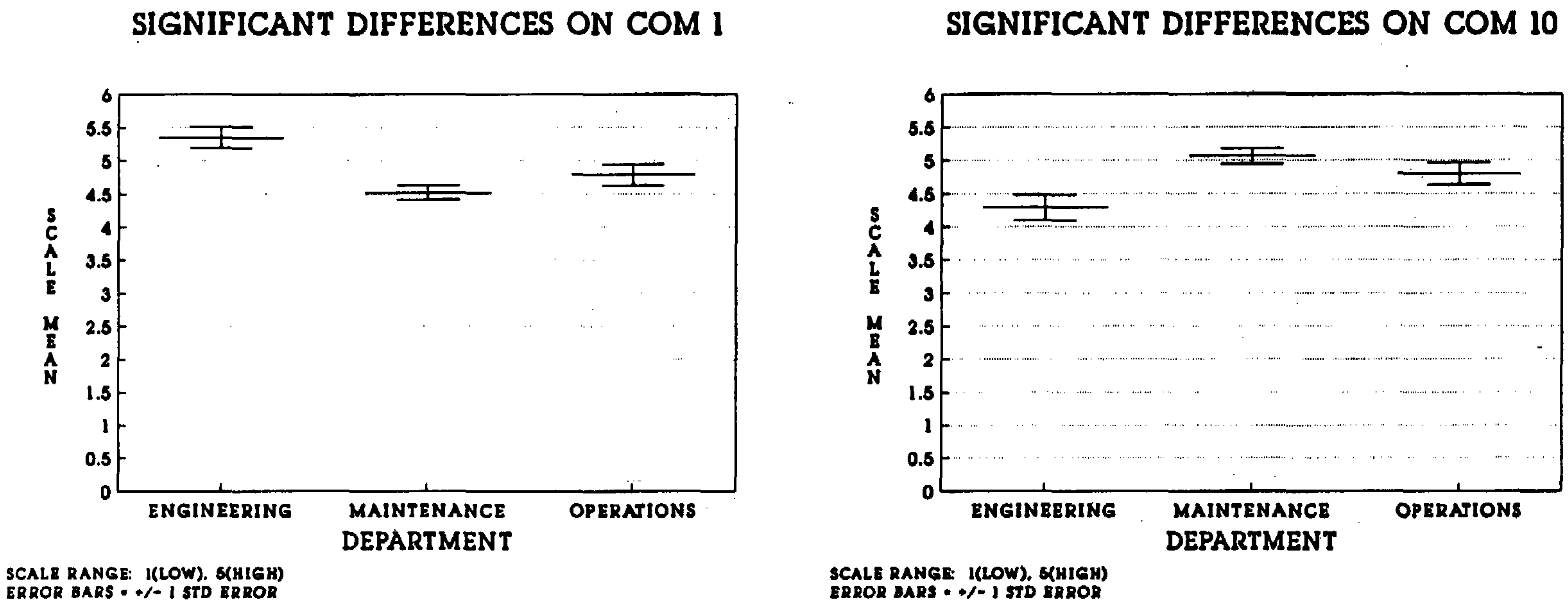


Figure II.2.7. Statistically significant differences between departments on communication scales

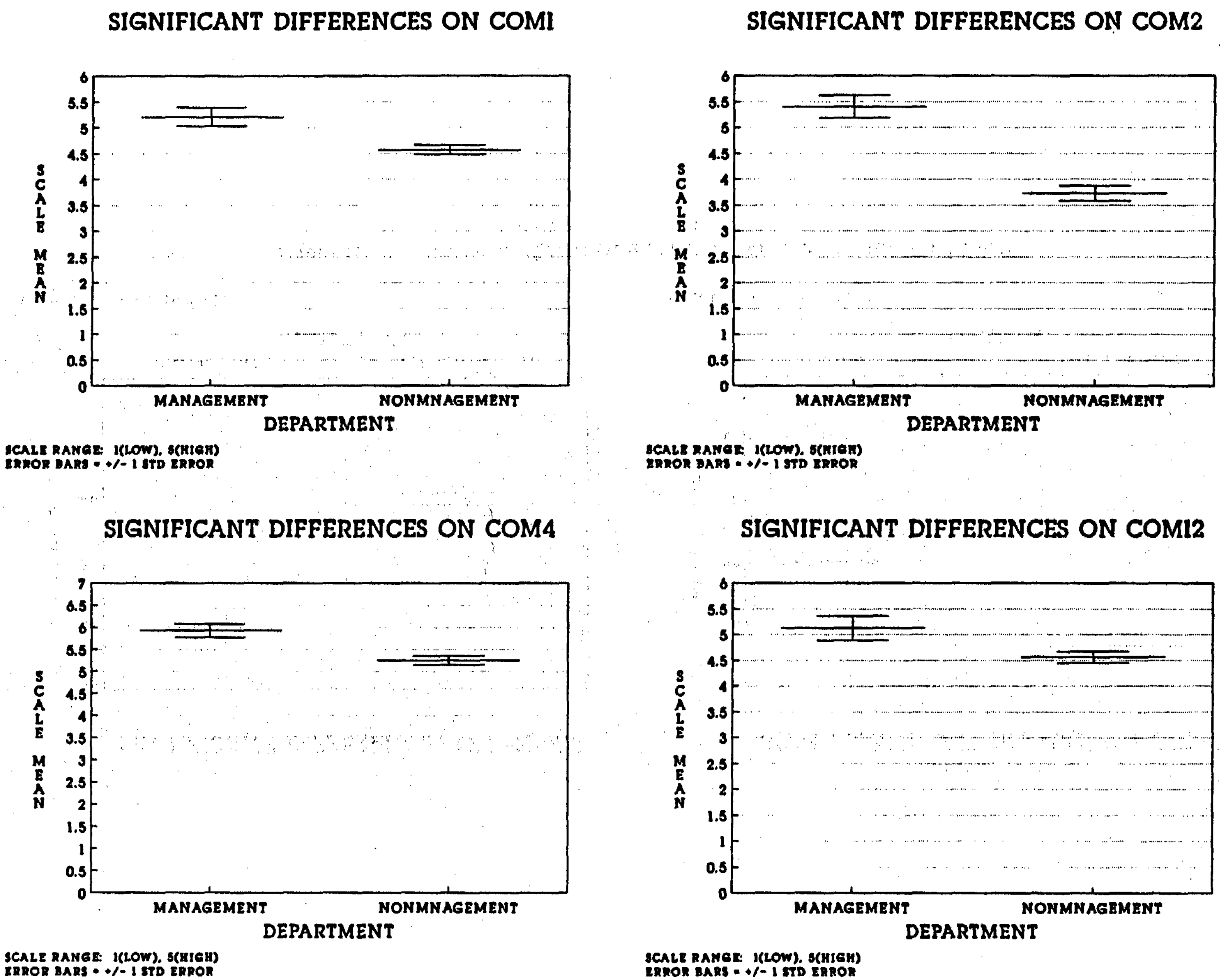


Figure II.2.8. Statistically significant differences between organizational levels on communication

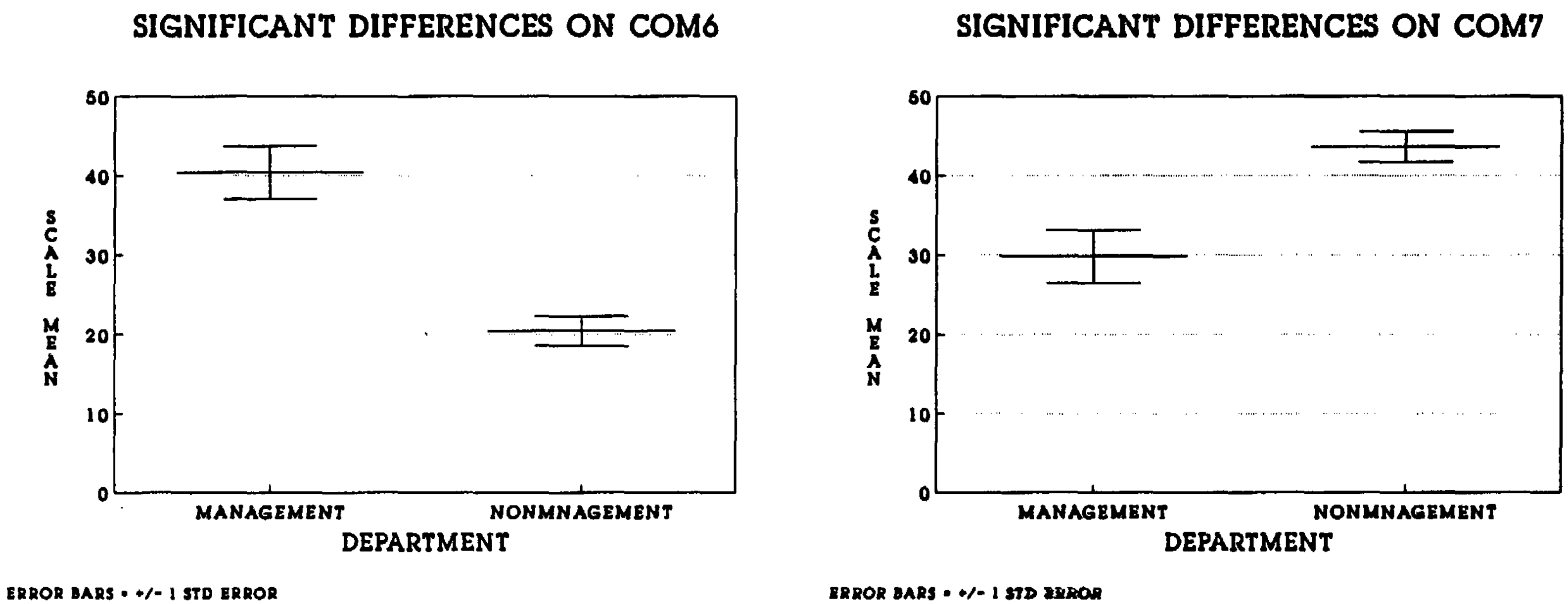


Figure II.2.9. Statistically significant differences between organizational levels on communication (scales 5-7)

2.4.2.3 Safety Scale

2.4.2.3.1 Description

The Safety scale is currently being developed by researchers at the University of California at Berkeley (Roberts, personal communication, 1989) to be used in organizations where the consequence of making a mistake is very high (e.g., naval aircraft carriers, air traffic control centers). The scale is designed to assess an individual's perception of the importance of acting safely to individual success in an organization. The scale administered at PPP consisted of 19 items whose scores ranged from 1 (does not help at all) to 5 (helps a great deal).

2.4.2.3.2 Results

The overall Safety scale mean at PPP was 3.95, indicating a high regard for attention to safety at the facility. There were no statistically significant differences among the Operations, Engineering, and Maintenance Departments. However, managers at PPP scored significantly higher on the Safety scale than did nonmanagers (see Figure II.2.10).

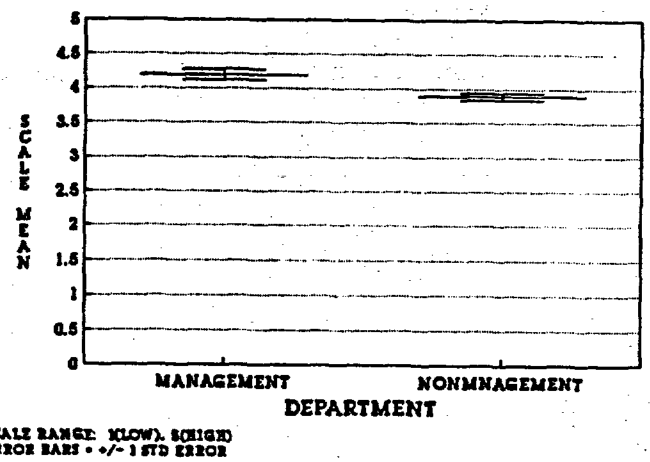


Figure II.2.10. Statistically significant differences on safety scale between organizational levels

2.4.2.4 Routinization Scale

2.4.2.4.1 Description

The Routinization scale was developed by Withey, Daft, and Cooper (1983). The scale consists of five questions whose scores are added together to produce a scale ranging from 5 (very low routinization) to 35 (very high routinization). The scale measures how repetitive individuals perceive their day-to-day work is.

2.4.2.4.2 Results

The overall mean score on the Routinization scale at PPP was 22.14, indicating that individuals perceived their work was moderately repetitive. Differences also existed among departments and between managers and non-managers (see Figures 2.11 and 2.12). Each department was significantly different from every other, with Engineering perceiving their work to involve the least amount of routinization, and Operations perceiving the highest amount of routinization. Additionally, managers perceived their work to be significantly less routinized than nonmanagers.

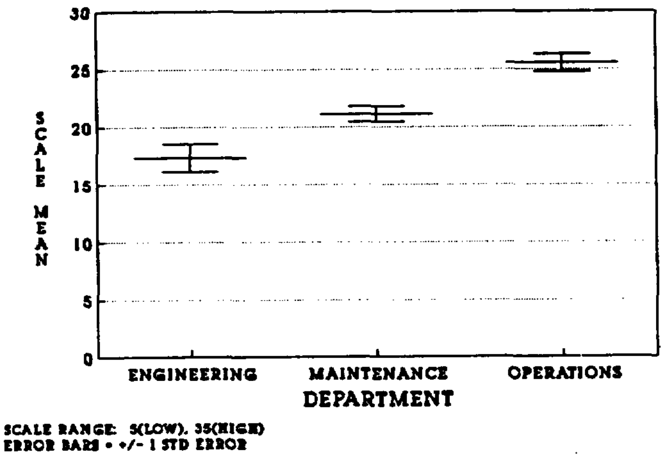


Figure II.2.11. Statistically significant differences between departments on routinization scale

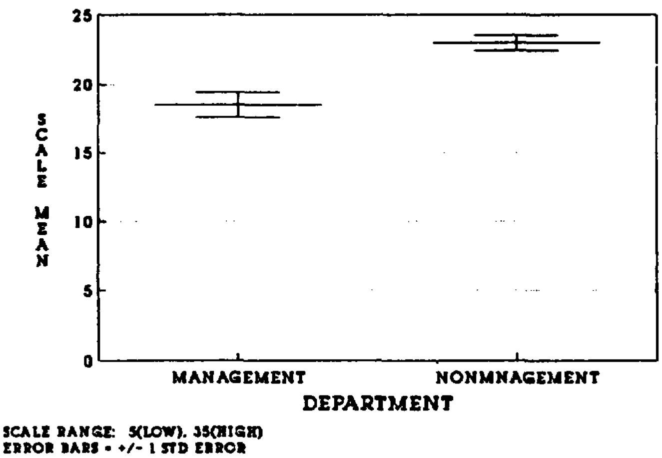


Figure II.2.12. Statistically significant differences between organizational levels on routinization levels

2.4.2.5 Organizational Commitment Scale

2.4.2.5.1 Description

The Organizational Commitment scale was developed by Mowday and Steers (1979) and consists of three items. Scores on the items are added to produce a scale ranging from 3 (low organizational commitment) to 21 (high organizational commitment). The scale measures the degree to which individuals belonging to an organization feel that they are really a part of that organization.

2.4.2.5.2 Results

The overall mean score on this scale was 13.82 indicating that a moderate degree of organizational commitment exists among employees at PPP. Analysis by departments and organizational levels revealed significant differences in both. Engineers were significantly more committed to PPP than maintenance workers (see Figure II.2.13). Additionally, managers were significantly more committed to PPP than nonmanagers (see Figure II.2.14).

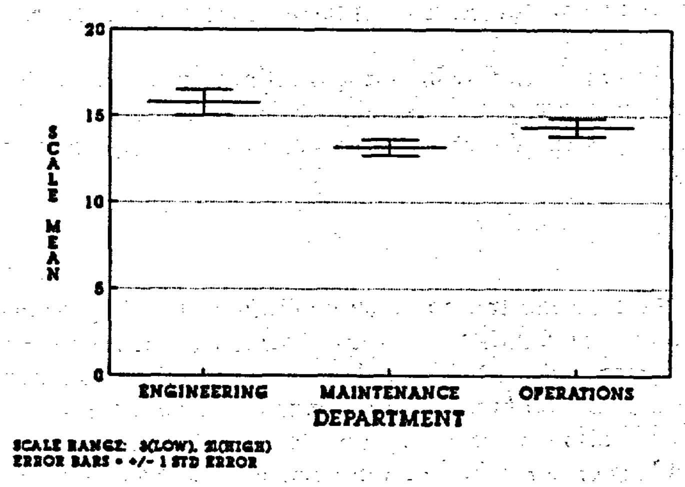


Figure II.2.13. Statistically significant differences between departments on commitment scale

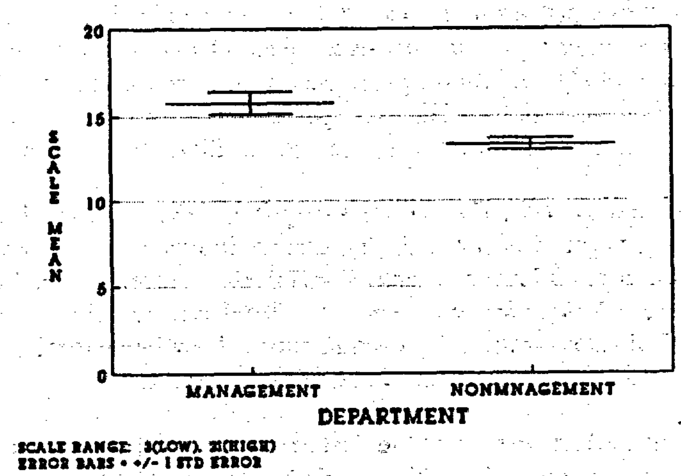


Figure II.2.14. Statistically significant differences between organizational levels on commitment scale

2.4.3 Conclusions

The acceptability, practicality, and usefulness of the OCA were also evaluated. The acceptability of this method was demonstrated by the high response rate achieved at PPP. Employees were willing to complete the questionnaire and management provided support in achieving a good response rate. PPP management indicated that the OCA would provide useful information for them in understanding employees' opinions on organizational cultural issues.

The OCA method was also highly practical. A large number of PPP employees could be sampled which was not feasible through the use of the other two NOMAC methods. The OCA, therefore, provided a broader basis for generalizing the results obtained in the functional analysis and the behavioral observational technique, at least in those areas covered by the questionnaire.

The OCA also allowed further definition and refinement of research issues uncovered by the other methods. (e.g., communication patterns) and provided a specific terminology with which to discuss the findings. The questionnaire was also able to discriminate effectively between groups like department and organizational level.

2.5 Conclusions

The fossil fuel plant demonstration study conducted at PPP provided, for the most part, a successful implementation of the NOMAC methods. Moreover, important lessons were learned. The use of four individuals to carry out the behavioral observation technique turned out to be impractical; employing fewer people for that job in the future seemed to have the advantage of not only reducing training length and costs, but also for improving consistency. Those benefits were believed to outweigh the additional time it would take to conduct a given number of observations. In addition, the measuring the duration of behavior met with practical difficulties. Plans were made to use an alternative, more appropriate approach, measuring the frequency of behavior.

The NOMAC methods proved more acceptable than was initially expected. In particular, the behavioral observation technique was not intrusive. Facility management and staff adapted to the observers' presence rather quickly, and on only one occasion, were observers asked to leave because of the personal nature of the conversation. PGE management considered the research so acceptable that they invited the team to continue its efforts at its nuclear facility, Diablo Canyon.

Finally, two of the methods, the Functional Analysis and the Organizational Culture Assessment proved to be useful. They generated substantial quantities of information that were valid and potentially revealing of the link between organizational factors and performance. A third method, the behavioral observation technique, needed modification. The behavioral classification scheme employed was not appropriate for an electrical power-producing organization. New behavioral categories would have to be adopted prior to the beginning of the next phase of the research.

Considering that this effort was really the first attempt to gather quantitative information about organizational behavior at a power plant, the implementation of the methods at PPP was quite encouraging. The problems identified were not insurmountable, and fairly straightforward adjustments were needed. Moreover, just working at PPP provided invaluable field experience and understanding of how power plant organizations functioned.

3. NUCLEAR POWER PLANT DEMONSTRATION STUDY

3.1 Introduction

Over a period of approximately four months, two individuals from Brookhaven National Laboratory (BNL) and a four-person team from the University of California, Berkeley (UCB) conducted field research at the Diablo Canyon Power Plant (DCPP) operated by the Pacific, Gas and Electric Company (PG&E) in California. The purpose of the research for the BNL team was to carry out another demonstration study of the NOMAC framework and data collection methods. This section describes the results of that study.

3.2 Functional Analysis

3.2.1 Implementation

The first step in carrying out the functional analysis at DCPP was to understand the formal structure of the facility. Organizational charts and documentation furnished an overview of the reporting relationships. Once the formal structure was delineated, it was then necessary to find out whether that representation corresponded to the way work was actually conducted.

Interviews were conducted from the top down with the assistant plant managers and department heads. The BNL researchers informed plant personnel of their general interest in high reliability organizations and emphasized that they were engaged in organizational research not organizational evaluation. The interviews also provided opportunities for plant personnel to ask questions about the project. At the end of interviews with the top managers of the facility, they were asked who among their subordinates should be contacted. Usually three or four additional individuals were identified. Approximately twenty individuals were interviewed in this phase of the project.

In an attempt to ensure that the information collected was not biased or incomplete, several cross-checks were incorporated into the functional analysis. Where feasible, individuals who occupied the same or similar positions were contacted. In the few instances where reports conflicted, attempts were made to reconcile the differences. DCPP documents were also relied upon to assess the "information" gathered from interviews.

The data collected in interviews and from a review of documentation was supplemented by observing a number of organizational activities. The start of this study also coincided with a refueling outage in one of the units. Thus, it was possible to investigate organizational behavior at DCPP from a variety of perspectives. A broad range of meetings were observed by the research team including:

- Plant Safety Review Committee evaluating changes in normal operating procedures and procedures governing the conduct of the outage.
- Technical Review Group discussing an unexpected loss of communications capability.
- Plant Manager's meeting reviewing the status of the outage.
- Conference call with Westinghouse on resolving problems with flux thimbles.
- Shift turnover for operators.

- Status briefing on the outage.
- Maintenance scheduling session.
- High Impact Team managing a flux thimble tube problem.
- Technical Review Group discussing the unanticipated reactor trip.
- Conference calls with NRC staff in Region V and in Washington, D.C.

Together, the interviews, documentation, and the observation of organizational activities created a sense of how the organization functioned, what challenges it faced, and how it responded to those challenges. The functional analysis also established the basis for selecting individuals for the behavioral observation technique.

3.2.2 Results

The functional analysis yielded a number of insights about the behavior of the DCPP organization. Of greatest relevance were the findings that related to the long-term objectives of this project, linking organizational factors to safety performance. In particular, it was learned that there was a powerful drive at DCPP to standardize work. It was also discovered that decision-making involved a broad range of individuals and was often highly collegial.

One of the central elements of NOMAC is the notion of standardization of work, whereby the contents of tasks are specified in considerable detail through procedures, policies, or other forms of guidance. If well-designed and implemented, these standards can increase organizational effectiveness and performance. At DCPP, management sought to rely on this strategy of coordination and control to a great extent. In fact, there seemed to be a continual drive to expand the boundaries of activities that were standardized.

The commitment to standardization could be seen in several processes related to procedure writing. It is not unusual for there to be guidelines for preparing procedures of all kinds. DCPP had procedures of this type but was also embarking on two new initiatives to standardize the procedures that govern the preparation process. The first was an effort to devise a single format that would be applied to procedures generated by all the departments within the plant. The second was an attempt to design a new cover sheet that would accompany a new or modified procedure through the approval process.

The approval process for procedures was also quite elaborate at DCPP. Rules were in place to ensure that new or modified procedures would be scrutinized at least twice by independent reviewers before they were reviewed by an assistant plant manager. Then the procedures were placed on the agenda of the Plant Safety Review Committee (PSRC). Despite the large number of items on the agenda, DCPP managers focused long and hard on each procedure during the final stage of the approval process.

Monitoring the standardization of work was an intricate process as well. The process starts with an action request (AR), the template on which organizational personnel report difficulties, seek action, implement changes, and track corrective measures. (The DCPP unit assigned the AR may issue an action evaluation (AE), which is a request for assistance from some other unit.) Some ARs lead to a quality evaluation (QE), which documents a quality problem that must be reviewed by quality assurance.

QEs detail the root cause analysis and the corrective actions for a significant event (one that could potentially impact or challenge the performance of plant safety systems or jeopardize personnel safety). QEs also describe the resolution of audit findings made by quality assurance. When a quality problem is evaluated and a determination is made that deviations from the Final Safety Analysis Report, the Technical Specifications, commitments made to the NRC, or established regulations exist, the issue is addressed through a non-conformance report (NCR).

The NCR designation often initiates a formal inquiry by an event investigation team (EIT). The plant manager appoints its members, but they are responsible to the corporate vice-president for nuclear power generation. The EIT follows an event response plan (ERP) that lays out the methodology of the investigation, prepares a root-cause analysis, and explores the safety implications of the problem. The EIT's implementation of the ERP provides input into the writing of the NCR. A technical review group (TRG) is assembled to assess the investigation, the root-cause and safety studies, and the proposed remedial measures. One person from quality assurance and another from the off-site safety review group are always members of the TRG. Conclusions reached are referred to the PSRC for review and certification.

The management information system technology at DCPP plays an important role in the drive to extend standardization. It is possible to learn about the maintenance history of components, to discover the status of a work order, to determine the set of procedures that referred to a particular valve or pump, or to ascertain the pressure and temperature at various locations within the reactor vessel using the system. Management's interest in pushing the boundaries of standardization probably contributed to its decision to purchase and support the information system. At the same time, having the system facilitated the drive toward formalization. Importantly, the technology is not yet fully utilized and resources are not likely to emerge as a constraint on increasing standardization.

One purpose of standardization is to pre-form or program many decisions, especially those that are routine or can be well anticipated. Even in an organization as highly standardized as DCPP, however, there are significant choices to be made that cannot be anticipated. The opportunity to offer substantial inputs to the choices at DCPP was broadly distributed throughout plant. The decision to replace weakened flux thimble tubes illustrates this.

After the DCPP Unit 1 outage was under way, excessive wear was discovered in the flux thimble tubes. A decision had to be made about how to respond, and none of the options were straightforward. A meeting was called by one assistant plant manager to decide what course to adopt. Several department heads as well as the scientists who were familiar with the data were present. In addition, a conference call was set up with the PG&E corporate engineering staff and technicians from the Westinghouse Research and Energy Center. After extended discussion on several issues, a consensus in favor of exchanging as many tubes as possible emerged. After conferring with upper management, that decision was eventually adopted.

It should not be inferred from this illustration that choices at DCPP were totally decentralized or that hierarchical position was not important in decision-making. Rather the suggestion is that, at least in matters where technical expertise counted, people who had something to say were able to say it and were seriously listened to. Decision-making at DCPP is not always authoritative but rather was often broadly based and collegial.

3.2.3 Evaluation

3.2.3.1 Practicality

The extensive use of functional analysis in the study of organizations stands, in principle, as evidence of the method's practicality. The Diablo Canyon demonstration study can be used as an example to further counter any concerns. For instance, the study established that researchers did not interfere with the conduct of activities at the facility and that they did not increase operational hazards. The researchers were also sensitive to issues that the facility might be confronting and did not increase their burden at those particular times. The resource demands for conducting a functional analysis are variable, but not excessive, and can be managed by as few as two individuals.

3.2.3.2 Acceptability

Individuals who are sensitive to the circumstances that surround any NPP in today's political and regulatory environment ought to be able to conduct their work without being too intrusive. Clearly this was the case at DCPP. Additionally, the interview process conducted during the functional analysis is very familiar and acceptable to most plant management and staff by virtue of their experience with it through other activities.

3.2.3.3 Usefulness

In discussing the functional analysis, there is much controversy about what sort of inferences might be drawn from the information collected. The method cannot be subjected to statistical tests to determine the validity of its findings, and there is a danger that the findings derived from functional analysis will be subjective and not amenable to replication. However, functional analysis can be used to select individuals for the behavioral observation technique. Functional analysis can also be used to generate insights about the connection between organizational and management influences and safety performance. Finally, functional analysis can be used in conjunction with other techniques to supplement details that may not be captured by more "systematic" approaches such as surveys.

3.3 Behavioral Observation Technique

3.3.1 Method Modification

The behavioral observation technique modified from Komaki et al. (1986), prior to use at the Pittsburg Power Plant (PPP) was further modified before implementation in the Diablo Canyon Power Plant (DCPP) demonstration study. In particular, three substantial changes were made. First, the behavioral categories in the taxonomy were changed; second, patterns of interaction and communication were more fully recorded; and third, instead of measuring the duration of each behavior, frequency was recorded. In each case, the changes were made to bring the methodology into greater conformity with the framework underlying the Nuclear Organization and Management Analysis Concept (NOMAC).

NOMAC derives from the structural/functional and contingency theories (Mintzberg, 1979). Processes such as decision-making, communication, and work standardization and their implications for organizational design are the critical variables in understanding the organization. Equally important are the questions of how culture is established and integrated within the organization.

The results from the demonstration study at PPP raised questions concerning the usefulness of the behavioral observation technique for NOMAC. Although some interesting results were obtained, most were in categories not well-delineated (e.g., "work-related/other"). Thus, it made sense to alter the conceptual foundation of the method but not necessarily the technique itself.

Considerable efforts were devoted to developing a fuller set of behaviors. The list of them, sorted into six broad classifications, is presented in Table II.3.1. Also included in Table II.3.1 are the communication variables which are used during the observations. For the most part, the behaviors chosen were based on the experience of personnel who had worked at commercial nuclear power plants. It should be noted, however, that the final grouping of categories is consistent with that used by Kaufman (1981) in his study of federal bureau chiefs. The meaning of these behaviors is generally self-explanatory but is described in Table II.3.2.

Since the NOMAC framework involves supervisors dealing with peers, superiors, and individuals in other units as well as within their own unit, it was important to modify the taxonomy for use at DCPP. Eight questions had to be answered in order to fully describe patterns of interaction and communication. First, was the subject (i.e. the individual being observed) dealing with someone in the same functional unit, in another unit, or from outside the organization? (Individuals were considered to be in the same unit if they had the same department manager.) Second, what was the relative organizational position of the person with whom the subject was dealing? Third, what was the NOMAC classification of the person with whom the subject was dealing? Fourth, what was the mode of communication employed by the subject? (The possibilities include face-to-face, written, electronic, and telephone: placing the call, receiving the call.) Fifth, did the subject interact with a person directly or through intermediaries? Sixth, did the subject communicate with a person in a formal setting (i.e., a meeting that had been previously scheduled) or in an informal setting? Seventh, was the communication clear or was it ambiguous? Eighth, what was the affective tone of the communication; positive, negative, or neutral? To collect the most detailed information possible, answers for the eight questions were sought for each observed behavior.

In the observational technique used at PPP, the dependent variables represented how much time managers spent engaged in each behavior. From the perspective of NOMAC, this is not appropriate. The importance of the processes and behaviors observed is not necessarily reflected in how long they occur. A decision to adopt a new procedure may, for example, only take a few seconds of time during a senior management meeting, yet the choice can have enormous ramifications for organizational performance. Conversely, behavior that takes a long time may be of marginal significance. A choice was made to modify the methodology to measure the frequency of each behavior regardless of its duration. This change was more consistent with NOMAC and had the practical advantage of allowing an observer to focus better on what was occurring.

An additional modification to the method was the introduction of the notion of an "event", a set of behaviors associated with a single issue or problem. A manager might engage a subordinate in discussion of a particular maintenance routine. The former might ask questions, clarify matters, and relay organizational policies. The latter might provide information, suggest ideas, and question priorities. As long as each of those behaviors centered on one specific topic, they were "bracketed" for subsequent analysis. If the topic of conversation shifted, the observers would note that a second "event" had commenced. As discussed later in this section, this notion of event was not very useful in the final analysis of the observational data. Further consideration of this type of categorization is required prior to its useful implementation.

Table II.3.1. Suggested Taxonomy for Behavioral Observation Technique

DECISION-MAKING/PROBLEM SOLVING

- Generation of alternatives
- Generation of alternatives in the context of decision-making
- Resolution of technical issues
- Resolution of technical issues in the context of decision-making
- Resolution of value trade-offs
- Resolution of value trade-offs in the context of decision-making
- Failure to resolve technical issues
- Failure to resolve technical issues in the context of decision-making
- Failure to resolve value trade-offs
- Failure to resolve value trade-offs in the context of decision-making
- Informal problem-solving
- Informal decision-making
- Formal problem-solving
- Formal decision-making
- Proactive problem-solving
- Proactive decision-making
- Reactive problem-solving
- Reactive decision-making
- Individual problem-solving
- Individual decision-making
- Collegial problem-solving
- Collegial decision-making
- Identifying problems
- Conflict resolution

MANAGEMENT ATTENTION AND OVERSIGHT

- Delegation of responsibility
- Monitoring work
- Receiving a status report
- Questioning a status report
- Networking
- Career development

CLARIFYING AMBIGUITY

- Clarifying ambiguity
- Giving a status report
- Informing subordinates of organizational policies
- Consulting

PLANNING AND ORGANIZING

- Planning and organizing

SOLITARY WORK

- Solitary work

NON-WORK-RELATED ACTIVITY

- Non-work-related activity

COMMUNICATION

- Formal, informal
- Mode: Face to face, written, electronic, phone in, phone out
- Respondent unit identification

Table II.3.2. Explanation of Behaviors

Decision-Making/Problem-Solving

Generation of Alternatives: Exchange about possible courses of action r options that might be adopted.

Generation of Alternatives/Decision-Making: Exchange about possible courses of action or options that might be adopted accompanied by the selection of one alternative.

Resolution of Technical Issues: Conclusion reached about some problematic empirical issue.

Resolution of Technical Issues/Decision-Making: Conclusion reached about some problematic empirical issue accompanied by the selection of an option or course of action.

Resolution of Value Trade-offs: Agreement reached on how competing priorities are to be balance.

Resolution of Value Trade-offs/Decision-Making: Agreement reached on how competing priorities are to be balanced accompanied by the selection of an option or course of action.

Failure to Resolve Technical Issues: Inability to reach conclusions about problematic empirical issues.

Failure to Resolve Technical Issues/Decision-Making: inability to reach conclusions about problematic empirical issues in the course of selecting an option or course of action.

Failure to Resolve Value Trade-offs: Disagreement on how competing priorities are to be balanced.

Failure to Resolve Value Trade-offs/Decision-Making: Disagreement on how competing priorities are to be balanced in the course of selecting an option or course of action.

Informal Problem-Solving: Searching for ways of addressing a problem in an unstructured setting.

Informal Decision-Making: Selecting a course of action in an unstructured setting.

Formal Problem-Solving: Searching for ways of addressing a problem in a structured setting.

Formal Decision-Making: Selecting a course of action in a structured setting.

Proactive Problem-Solving: Searching for ways of addressing a problem in anticipation of it occurring.

Proactive Decision-Making: Selecting a course of action prior to being forced to do so by events or pressures.

Reactive Problem-Solving: Searching for ways of addressing a problem in response to events or pressures.

Reactive Decision-Making: Selecting a course of action in response to events or pressures.

Individual Problem-Solving: Searching for ways of addressing a problem without involving others.

Individual Decision-Making: Selecting a course of action without involving others.

Collegial Problem-Solving: Searching for ways of addressing a problem in conjunction with others.

Collegial Decision-Making: Selecting a course of action in conjunction with others.

Table II.3.2. Continued

Identifying Problems: Recognizing that these are issues that will need to be addressed.

Conflict Resolution: Mediating or facilitating the resolution of disagreement over empirical questions or priorities.

Management Attention and Oversight

Delegation of Responsibility: Informing a subordinate of duties that otherwise might be performed by the subject.

Monitoring Work: Determining whether a subordinate's tasks have been carried out.

Receiving a Status Report: Being provided with information about performance.

Questioning a Status Report: Probing the meaning of information obtained about performance.

Networking: Contacting others in the organization to obtain information and to share ideas.

Career Development: Assisting subordinates in understanding the requirements of their jobs and how they might better achieve them.

Clarifying ambiguity

Clarifying Ambiguity: Answering questions about unclear policies, procedures, or tasks.

Giving a Status Report: Informing others about performance.

Informing: Transmitting information from superiors about organizational policies, procedures, or tasks.

Consulting: Servicing as a source of information for others.

Planning and Organizing

Planning and Organizing: Scheduling, setting up and establishing the order of tasks.

Solitary Work

Solitary Work: Tasks undertaken in isolation.

Non-Work Related Activity

Non-Work Related Activity: Tasks that do not contribute to organizational work flow.

3.3.2 Implementation

Based upon the functional analysis, 22 managerial and/or supervisory positions were identified for behavioral observation. They represented a broad cross-section of the DCPP organization in terms of their hierarchical level, NOMAC classification, and functional responsibilities. Figure II.3.1 shows the positions of those included in the sample. Ten of those selected had already been interviewed as part of the functional analysis. Most of the remaining twelve were either first or second line supervisors. Since several individuals held those positions, the BNL researchers spoke with the departmental managers in order to determine which specific individuals should be observed. In many cases, the departmental managers arranged a follow-up meeting with those individuals. All 22 individuals were briefed about the research that was being conducted, the behavioral observation technique, and what they might expect if they agreed to participate. Several points were stressed. First, if they felt in anyway uncomfortable about the project, they could decline without any repercussions. Second, the purpose of the study was not to evaluate them but to learn how organizations like DCPP operated. Third, they should make every effort not to interrupt or alter what they were doing just because an observer entered their office. Fourth, if, during the course of an observation, they wanted the observers to leave for any reason, they had only to ask. Fifth, if they felt that the technique was interfering with their work, the observations would be discontinued. Significantly, each of the twenty-two persons identified agreed to participate, and none dropped out.

To observe the full spectrum of activity at DCPP, observations were spread out over the entire working day. (It should be noted that all the observations were carried out between 8:00 AM and 4:00 PM. For logistical and practical reasons, no one from the back shifts was included in the sample.) Figure II.3.2 indicates that the observers did sample activities fairly well throughout the day. It also shows that observations were divided fairly evenly between the two observers.

Nine training sessions were conducted prior to the actual observations. During those times, both observers shadowed several individuals who would not be included in the actual sample. After each training session, the observers compared their findings and discussed discrepancies in categorization. As Figure II.3.3 illustrates, inter-rater reliability rose steadily over the course of the training, and by the end of training, it passed the 80 percent level, an acceptable level for new measures (Miller, 1980), especially one such as the behavioral categorization scheme that has so many response categories. It will be recalled that the inter-rater reliability coefficient is calculated by the following equation:

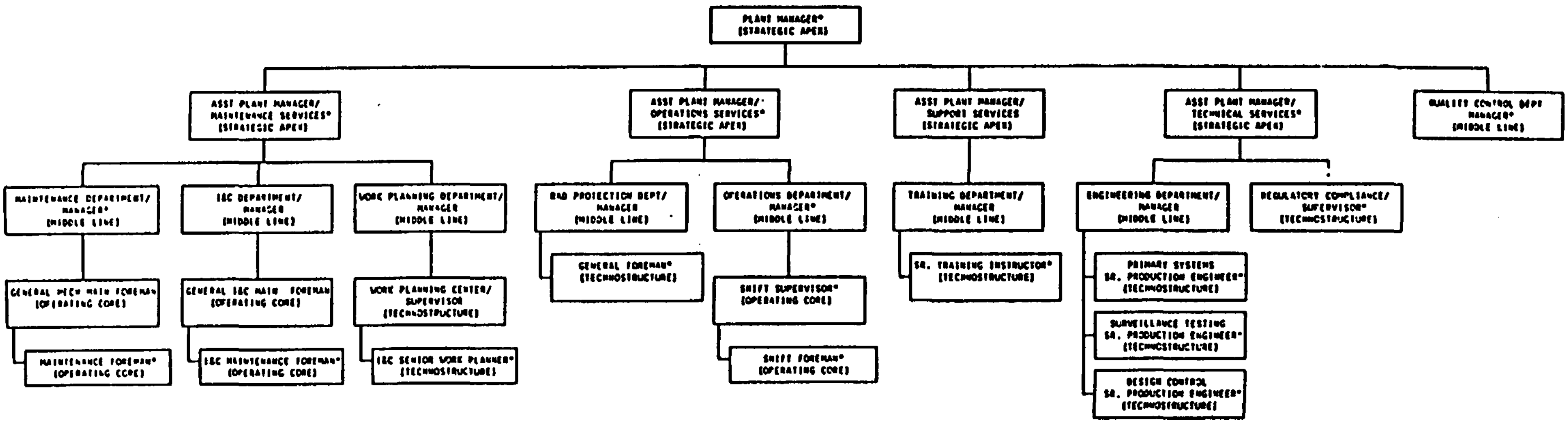
IRRC = (# of categories agreed upon/# of categories observed) (100)

3.3.3 Results

3.3.3.1 Methodological Findings

There are two broad categories of methodological issues that need to be discussed for the behavioral observation technique. The first revolves around the issues of access and intrusiveness. The second involves issues of the design of the technique, sampling strategies, and measurement reliability.

Access to individuals at DCPP was not limited, and each of the 22 individuals approached for this data collection agreed to participate. However, because observations were conducted as randomly as possible, individuals were not always available when the observers wanted to find them. Only rarely were efforts made to track them down out of a concern that the spontaneity of the observation might be compromised. Consequently, there were a number of times an observation was attempted but could not be completed.



*INDIVIDUALS OBSERVED

Figure II.3.1. Sample of individuals for observation

(Number of Observations)

SUBJECT	OBSERVATION TIME				OBSERVER	
	8-10 AM	10-12 AM	12-2 PM	2-4 PM	1	2
1	1	3	3	3	5	5
2	3	4	2	1	6	4
3	3	3	1	3	5	5
4	3	5	0	2	5	5
5	3	2	0	5	3	7
6	3	4	3	0	5	5
7	3	3	1	3	5	5
8	3	3	4	0	4	6
9	2	2	1	5	6	4
10	1	3	2	4	3	7
11	5	0	2	3	4	6
12	3	2	2	3	4	6
13	3	6	0	1	3	7
14	2	4	1	3	5	5
15	3	3	3	1	5	5
16	3	3	3	1	4	6
17	3	2	3	2	5	5
18	3	0	1	6	7	3
19	3	2	2	3	5	5
20	1	1	2	1	3	2
21	1	5	2	2	5	5
22	1	3	0	1	3	2
TOTAL	56	63	38*	53	100	110

*TOTAL REDUCED DUE TO LUNCH BREAK

Figure II.3.2. Sampling of subjects for observational technique

The level of the "Hawthorne effect" (where the act of observation alters that which is being observed) depended on the number of observations that had been conducted and on the individual involved. During the first couple of observations, it was not uncommon for the individual to interrupt conversation and explain to others why the observer had just come in unannounced. As more observations were conducted, people grew more familiar with the method, and little attention was paid to the observer. Individuals' reactions did, however, vary over the course of any given observation period. Approximately one-third of those being observed almost never altered their behavior once the observer entered. Roughly one-half of the individuals engaged the observers in conversation from time to time. Sometimes they did so to explain what was happening. For instance, one foreman described how his crew was organized. Another individual detailed how a particular procedure was being implemented. Individuals also commented on interactions that had been completed. Those conversa-

TRAINING PERIOD	NUMBER CODED	NUMBER CODED CORRECTLY	INTER-RATER RELIABILITY
1	13	7	54%
2	5	2	40%
3	17	8	47%
4	23	16	70%
5	28	13	46%
6	8	7	88%
7	25	16	64%
8	22	17	77%
9	28	24	86%

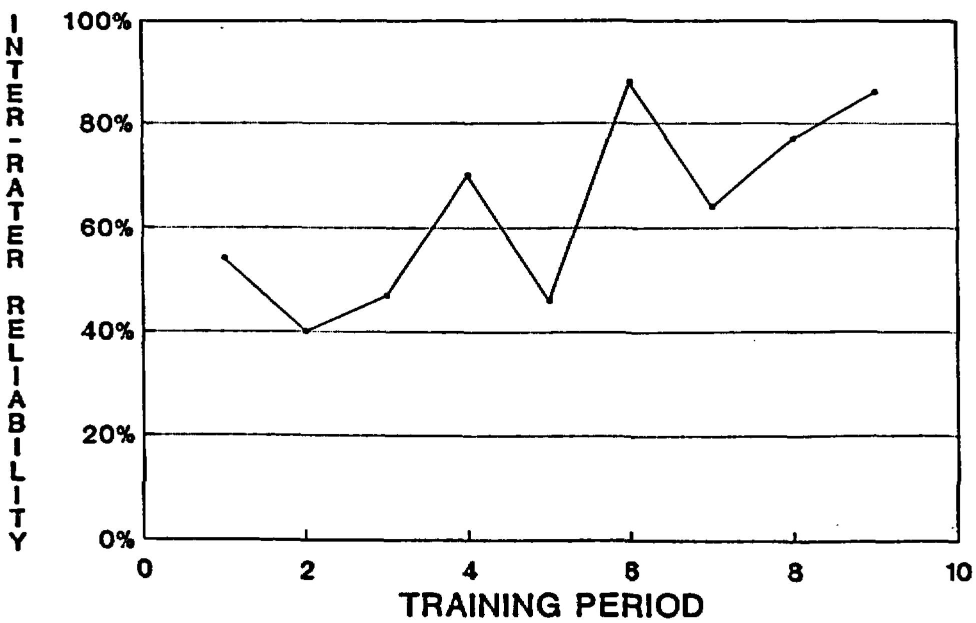


Figure II.3.3. Inter-rater reliability

tions often provided a context for what was transpiring as well as insights into the organizational dynamics of the plant. Less frequently, those being observed asked the observer questions and solicited opinions. Only a few individuals sought to carry on a running dialogue with the observer.

In retrospect, the observers' inability to constantly maintain their detached, "fly-on-the-wall" role is not surprising. They deliberately sought to promote candor and openness with personnel at the facility. At the close of many sessions, they asked questions themselves about what had occurred, and their mere presence at DCPP over a course of nearly four months meant that they would run into several of these individuals outside of the observational periods and carry on discussions.

The behavioral observation technique could conceivably lead to incorrect inferences because individuals avoid considering sensitive matters in the presence of the observers. It is difficult to quantify how much of a problem this was at DCPP. Both observers, however, were struck by their subjects' openness. Only twice were they asked to leave once an observation started. In the first instance, the individual was at a meeting where the performance of others was being criticized. In the second instance, the individual was trouble-shooting an electrical ground that was on the outage's critical path. A senior manager felt that the observer was adding to the already considerable stress. Importantly, the individuals who asked the observers to leave later sought to explain the situation.

It will be recalled that the behavioral taxonomy was substantially altered and a number of new variables were developed prior to implementing the method at DCPP. One concern was that the new design of the taxonomy might not adequately capture the range of activities at the facility or that the behaviors might not be readily observable. Other concerns involved appropriate sampling strategies and the technique's reliability. Each of these issues is considered in turn.

DESIGN: Nearly 3,800 behaviors were recorded over the course of 210 observation periods at DCPP. The overall frequency distribution of the variables evaluated is presented in Table II.3.3. Initially coded into 37 categories (see Table II.3.1), the behaviors were later grouped for ease of analysis and presentation into six sets: decision-making (DM); planning and organizing (PAO); management attention and oversight (MAO); clarifying ambiguity (CA); solitary work (SW); and non-work related (NWR). The six groups were observed at different frequencies. Management attention and oversight (43 percent) was observed nearly twice as frequently as clarifying ambiguity (25 percent), which, occurred approximately twice as frequently as decision-making (14 percent) or solitary work (12 percent). Planning and organizing and non-work related behaviors occurred much less often, not exceeding 5 percent. Neither observer experienced problems assigning a behavior to a category, and more significantly, they were able to place nearly all activities observed within the 37 categories. It would appear that the new taxonomy is almost completely exhaustive.

For each observed behavior, the mode of communication involved was also noted. There were five categories and by far the most frequent was face-to-face, which accounted for slightly over 70 percent of the total communications observed. Telephone conversations occurred approximately 23 percent of the time; roughly half were initiated by the individual being observed. Nearly 6 percent of interactions involved electronic/written communications and occurred in conjunction with the solitary work behavioral category.

Each time the individual being observed interacted with another individual, the respondent, three types of information were collected about the respondent. The first type was the respondent's functional unit. In nearly 60 percent of the cases, the individual interacted with someone from their own unit. The

Table II.3.3. Distribution of Observational Variables

Behaviors	**(N = 3774)**
Decision-Making (DM)	14.5%
Planning & Organizing (PAO)	3.5%
Management Attention & Oversight (MAO)	43.2%
Clarifying Ambiguity (CA)	25.6%
Solitary Work (SW)	11.7%
Non-Work-Related (NWR)	1.5%
Mode of Communication	**(N = 3490)**
Face-to-Face (FTF)	70.9%
Electronic/Written (E/W)	5.6%
Phone In (PI)	10.5%
Phone Out (PO)	11.5%
Phone Uncertain (PU)	1.6%
Respondent Unit	**(N = 2794)**
Same	59.8%
Other	27.8%
External (EXT)	12.4%
Respondent Level	**(N = 2519)**
Superior (SUP)	8.7%
Same	15.2%
Subordinate (SUB)	76.2%
Respondent NOMAC	**(N = 2961)**
Operating Core (OC)	39.2%
Technostructure (TS)	28.7%
Support (SUP)	5.6%
Middle Line (ML)	10.8%
Strategic Apex (SA)	4.0%
External (EXT)	11.7%
Formality	**(N = 3273)**
Formal	16.3%
Informal	83.7%
Directness	**(N = 3160)**
Directness	98.2%
Indirectness	1.9%

second type of information collected concerned the respondent's level in the hierarchy. The individuals being observed dealt with individuals who held a superior position about 9 percent of the time, with their peers approximately 15 percent of the time and the overwhelming frequency of interactions occurred with subordinates, including those not directly reporting to them. The final type of information recorded for respondents was their NOMAC unit. There were six categories: operating core (OC); technostructure (TS); support (SUP); middle line (ML); strategic apex (SA); and external (EXT). Personnel from the operating core, the largest component of DCPP, were involved approximately 40 percent of the time in the interactions observed. The technostructure personnel were involved in approximately 29 percent of the interactions and personnel from the middle line were involved approximately 11 percent of the time in the interactions observed.

Two other variables associated with the context of the interactions were recorded during the observational periods. The first was the level of formality In particular, it was noted whether the behavior occurred in a formal situation, such as scheduled meetings, or in an informal one. Five times as many behaviors took place in informal situations than in formal ones. A portion of this difference, however, is attributable to the observers' decision not to begin an observation when the individual was in a meeting since the observee often simply listened or perhaps answered a few questions in that situation. The second context variable was the level of directness. The purpose for including this measure was to find out what fraction of activity transpired directly and what fraction took place through intermediaries. The results indicate that directness completely dominates the context of interactions. Very little variance was found in this variable.

As noted above, two other variables relating to the quality of the communication were originally incorporated into the technique, degree of ambiguity, and affective tone of the interaction. It became clear both were difficult to measure without the observers inferring a great deal. Therefore, the two variables were dropped from the technique early in the study.

<u>SAMPLING:</u> In any organization, the same role and position will be occupied by a number of individuals. When that situation was encountered at DCPP, managers were asked to select individuals for the behavioral observation technique. The question arises whether the choice of different individuals would have yielded different results. To secure at least a partial answer, two first-line instrumentation and control (I&C) foremen, three operations shift foremen, and two operations shift supervisors were compared. The results obtained from those individuals are presented in Tables II.3.4, II.3.5, and II.3.6, respectively. In the case of the I&C foremen (Table II.3.4), there was remarkable agreement in the distribution of behaviors. In no case were the deviations greater than 5 percent. On all of the other variables, however, the differences were much greater. The two foremen were dissimilar in their patterns of communication, and with whom they interacted (respondent's unit and NOMAC unit). This may not be a fair comparison because the functional roles of these two foremen were quite different which could explain many of the differences observed.

There were few similarities in the distribution of variables among the shift foremen in the control room (Table II.3.5). Decision-making and clarifying ambiguity behavioral categories differed by 10 percent or more. Management attention and oversight, as well as solitary work differed by 6 percent or more. The first two foremen were similar in their modes of communication but differed from the third substantially. The same pattern was repeated with respect to respondent unit and NOMAC unit. When it came to respondent level, however, the pattern shifted and the first foreman differed from the other two, dealing mostly with subordinates.

The two shift supervisors were probably the most similar in their behavior and patterns of interaction and communication (Table II.3.6). With the exception of the management attention and oversight category, the supervisors engaged in virtually the same activities. They also interacted almost identically with people in their own unit and with other NOMAC units. The supervisors diverged when

Table II.3.4. Comparison of I&C Maintenance Foremen

	Subject 1	Subject 2
Behaviors	(N = 216)	(N = 148)
Decision-Making (DM)	9.7%	14.9%
Planning & Organizing (PAO)	7.4%	2.7%
Management Attention & Oversight (MAO)	31.9%	31.1%
Clarifying Ambiguity (CA)	31.9%	34.5%
Solitary Work (SW)	14.8%	16.9%
Non-Work-Related (NWR)	4.2%	0.0%
Mode of Communication	(N = 207)	(N = 133)
Face-to-Face (FTF)	77.3%	69.9%
Electronic/Written (E/W)	12.6%	7.5%
Phone In (PI)	6.3%	14.3%
Phone Out (PO)	3.9%	6.8%
Phone Uncertain (PU)	0.0%	1.5%
Respondent Unit	(N = 176)	(N = 118)
Same	77.8%	57.6%
Other	20.5%	28.0%
External (EXT)	1.7%	14.4%
Respondent Level	(N = 173)	(N = 79)
Superior (SUP)	5.2%	2.5%
Same	26.6%	3.8%
Subordinate (SUB)	68.2%	93.7%
Respondent NOMAC	(N = 175)	(N = 118)
Operating Core (OC)	79.4%	58.5%
Technostructure (TS)	18.3%	27.1%
Support (SUP)	0.6%	0.0%
Middle Line (ML)	0.0%	0.0%
Strategic Apex (SA)	0.0%	0.0%
External (EXT)	1.7%	14.4%
Formality	(N = 184)	(N = 121)
Formal	0.5%	15.7%
Informal	99.5%	84.3%
Directness	(N = 155)	(N = 121)
Directness	97.4%	100.0%
Indirectness	2.6%	0.0%

Table II.3.5. Comparison of Shift Foremen

	Subject 1	Subject 2	Subject 3
Behaviors	(N = 191)	(N = 148)	(N = 98)
Decision-Making (DM)	4.7%	14.9%	8.1%
Planning & Organizing (PAO)	5.2%	2.7%	1.0%
Management Attention & Oversight (MAO)	44.0%	31.1%	50.0%
Clarifying Ambiguity (CA)	29.3%	34.5%	19.4%
Solitary Work (SW)	14.7%	16.9%	14.3%
Non-Work-Related (NWR)	2.1%	0.0%	0.0%
Mode of Communication	(N = 168)	(N = 133)	(N = 85)
Face-to-Face (FTF)	73.8%	69.9%	89.4%
Electronic/Written (E/W)	4.8%	7.5%	0.0%
Phone In (PI)	16.1%	14.3%	9.4%
Phone Out (PO)	4.8%	6.8%	0.0%
Phone Uncertain (PU)	0.6%	1.5%	1.2%
Respondent Unit	(N = 149)	(N = 118)	(N = 76)
Same	58.4%	57.6%	76.3%
Other	36.2%	28.0%	23.7%
External (EXT)	5.4%	14.4%	0.0%
Respondent Level	(N = 135)	(N = 79)	(N = 80)
Superior (SUP)	1.5%	2.5%	23.8%
Same	7.4%	3.8%	12.5%
Subordinate (SUB)	91.1%	93.7%	63.8%
Respondent NOMAC	(N = 149)	(N = 118)	(N = 80)
Operating Core (OC)	76.5%	58.5%	83.8%
Technostructure (TS)	11.4%	27.1%	7.5%
Support (SUP)	6.7%	0.0%	3.8%
Middle Line (ML)	0.0%	0.0%	0.0%
Strategic Apex (SA)	0.0%	0.0%	5.0%
External (EXT)	5.4%	14.4%	0.0%
Formality	(N = 159)	(N = 121)	(N = 83)
Formal	0.6%	15.7%	0.0%
Informal	99.4%	84.3%	100.0%
Directness	(N = 159)	(N = 121)	(N = 83)
Directness	98.7%	100.0%	100.0%
Indirectness	1.3%	0.0%	0.0%

Table II.3.6. Comparison of Shift Supervisors

	Subject 1	Subject 2
Behaviors	(N = 262)	(N = 151)
Decision-Making (DM)	7.6%	11.9%
Planning & Organizing (PAO)	4.2%	9.9%
Management Attention & Oversight (MAO)	51.9%	38.4%
Clarifying Ambiguity (CA)	31.3%	30.5%
Solitary Work (SW)	4.6%	9.3%
Non-Work-Related (NWR)	0.4%	0.0%
Mode of Communication	(N = 256)	(N = 136)
Face-to-Face (FTF)	60.2%	75.7%
Electronic/Written (E/W)	3.1%	3.7%
Phone In (PI)	17.2%	9.6%
Phone Out (PO)	18.4%	8.1%
Phone Uncertain (PU)	1.2%	2.9%
Respondent Unit	(N = 208)	(N = 124)
Same	56.7%	57.3%
Other	40.9%	38.7%
External (EXT)	2.4%	4.0%
Respondent Level	(N = 197)	(N = 119)
Superior (SUP)	21.3%	10.9%
Same	19.8%	4.2%
Subordinate (SUB)	58.9%	84.9%
Respondent NOMAC	(N = 210)	(N = 124)
Operating Core (OC)	71.0%	71.8%
Technostructure (TS)	10.5%	9.7%
Support (SUP)	2.9%	5.6%
Middle Line (ML)	12.4%	8.9%
Strategic Apex (SA)	1.0%	0.0%
External (EXT)	2.4%	4.0%
Formality	(N = 245)	(N = 131)
Formal	6.5%	0.0%
Informal	93.5%	100.0%
Directness	(N = 245)	(N = 131)
Directness	98.8%	98.5%
Indirectness	1.2%	1.5%

it came to their modes of communication; the first using the telephone much more often than the second, who engaged in more face-to-face interactions than the first.

Notwithstanding these differences, the behavioral profiles of individuals holding identical functional positions are remarkably similar. The differences on the other variables are, however, greater. This finding, together with impressions gathered during the observations themselves, suggests a hypothesis related to sampling. Differences on a particular variable category among individuals occupying the same position are probably a function of two factors: the individual and the particular set of events and circumstances that arise as the observations were being made. This is clearly an area for further research in the use of this technique. One solution may be to increase the number of observations conducted. Another may be to increase the number of individuals observed in certain functional roles.

> <u>RELIABILITY:</u> The reliability of the behavioral observation technique in terms of multiple observers working at the same time was discussed earlier in this section where it was noted that inter-rater reliability had achieved over 80 percent by the end of the training period. The reliability of the technique in the sense of multiple observers over time, however, was of some concern. This issue did not emerge until after the observations had been completed. As part of the preliminary data analysis, the number of behaviors recorded per observation was calculated for each observer. For the first observer, the mean score across all subjects was 22.47 behaviors; for the second, it was 13.85. The confidence interval for the difference of means with an alpha = 0.05 was 2.24, indicating that the observer differences were not due to chance. Most of the difference arose because the observers seemed to code three behavioral categories differently: giving a status report; receiving a status report; and questioning a status report. One observer tended to code multiple instances of those categories, while the other merged several instances together. To test that explanation, the number of behaviors per observation was recomputed excluding those three categories. Now, the first observer had a mean score of 9.85 behaviors; the second had 7.87. The confidence interval for the difference of means with an alpha = 0.05 was 1.42. The null hypothesis that the differences were due to chance still could not be accepted, but the magnitude of the differences was considerably smaller.

In Figure II.3.4, the frequency of each behavioral category group for each observer is presented. The largest deviation is for managerial attention and oversight, the group where two of the three problematic categories (status report receiving and questioning) were placed. It also is important to note that the decision-making, solitary work, and non-work related category groupings only differed marginally across observers. Nonetheless, the weak reliability on some groupings remained a concern, and when statistical analyses were performed, corrections for the differences between observers were made. The reliability on the interaction and communication variables was considerably greater. Figures II.3.5 through Figure II.3.8 depict that data.

3.3.3.2 Substantive Findings

It must be reiterated that this method is still in devęlopment and most of the effort in this study, therefore, was directed toward understanding and refining the methodology. Nonetheless, some substantive findings can be reported.

Individuals were chosen for observation because they represented a wide range of key organizational positions. It was possible, therefore, to examine whether their functional role or location within the NOMAC structure affected their behaviors or patterns of interaction and communication.

Many of the findings obtained are not surprising, but it is the ability to actually quantify differences hypothesized by NOMAC that provides evidence of the "construct" validity of this method.

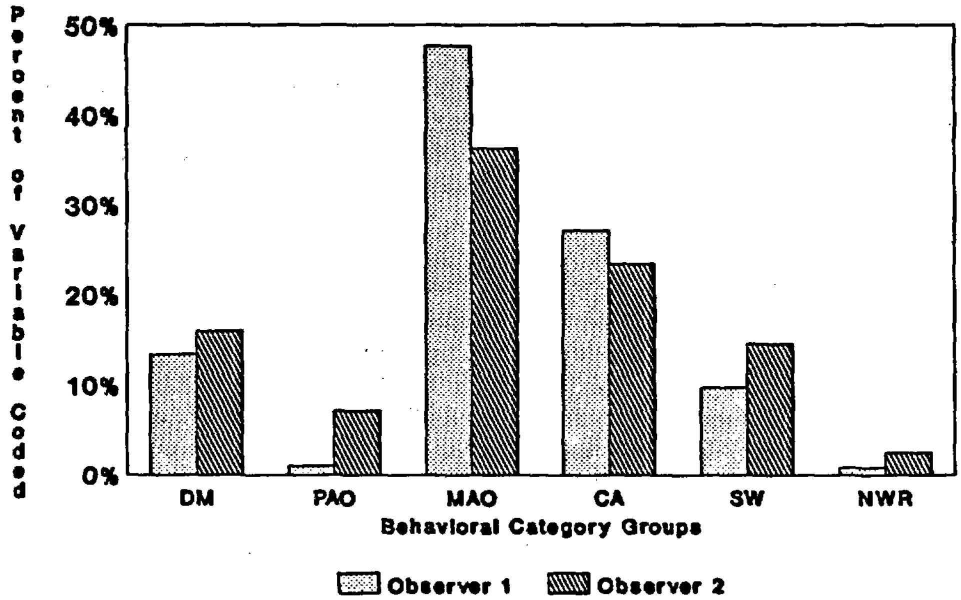


Figure II.3.4. Comparison of behaviors

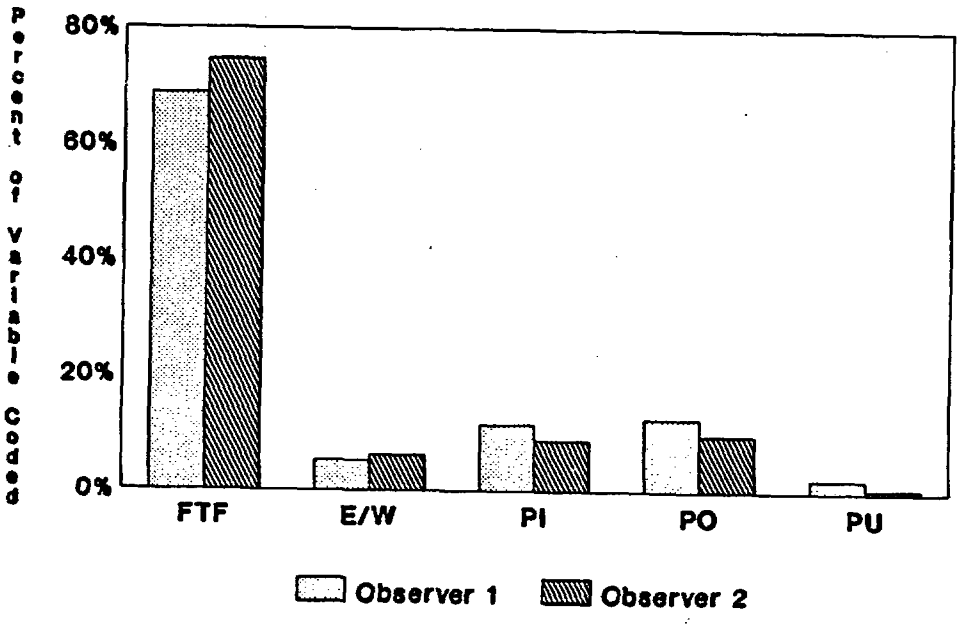


Figure II.3.5. Comparison of modes of communication

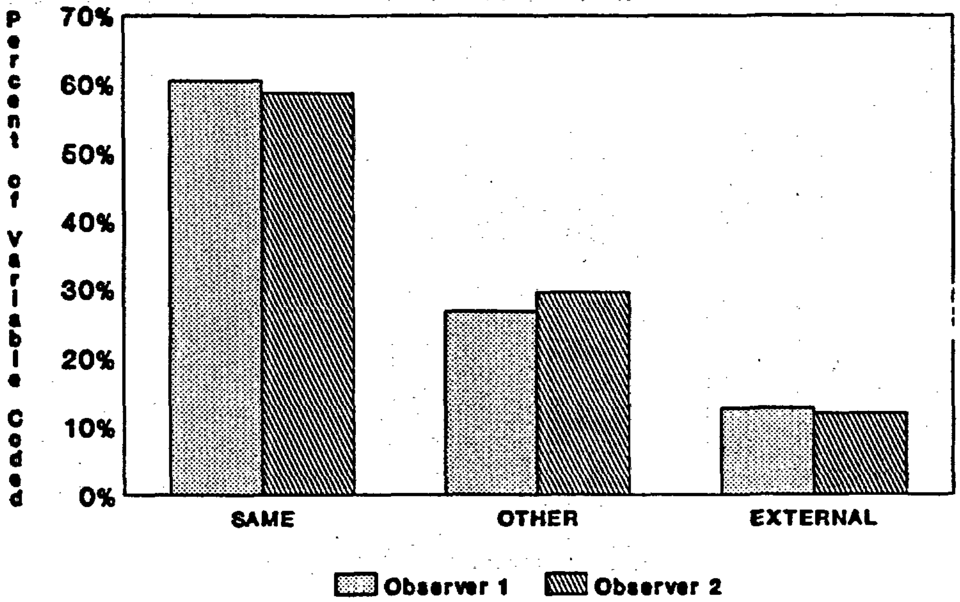


Figure II.3.6. Comparison of respondent unit

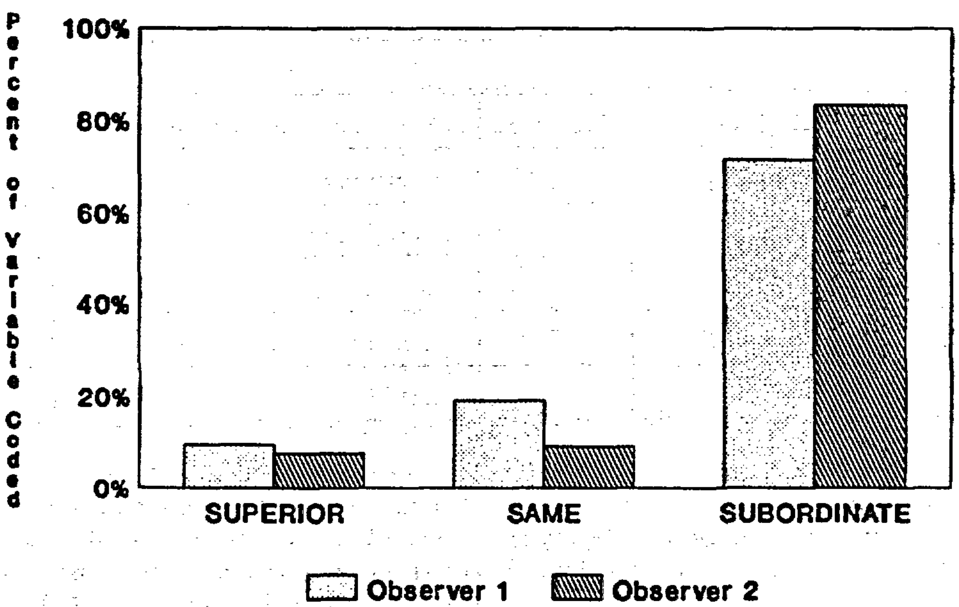


Figure II.3.7. Comparison of respondent levels

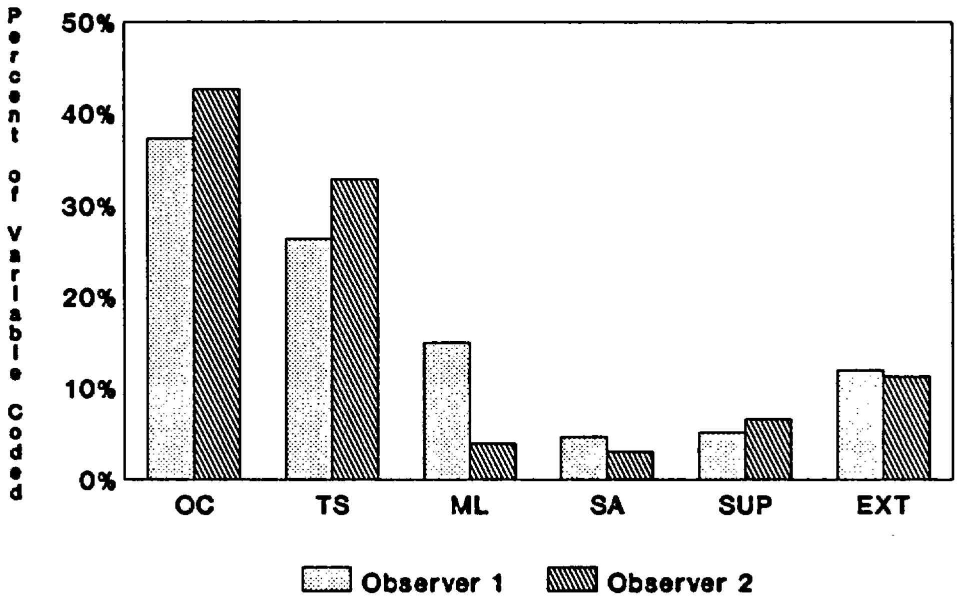


Figure II.3.8. Comparison of respondent NOMAC

Individuals were grouped into their functional unit, i.e., maintenance, operations, engineering, other technostructure (e.g., regulatory compliance, health physics, and quality control), and plant manager, and their position within the NOMAC structure. Table II.3.7 depicts the distribution of individuals observed by functional and NOMAC units.

Table II.3.7. Distribution of Individuals Observed

NOMAC Unit	Number	Functional Unit	Number
Strategic Apex (SA)	4	Operations	7
Technostructure (TS)	7	Maintenance	5
Middle Line (ML)	3	Engineering	3
Operating Core (OC)	8	Other Technostructure	6
		Plant Manager	1

Analyses of variance were carried out to ascertain whether those independent variables accounted for differences in behavior and patterns of interaction and communication. Frequency counts were obtained for each behavioral category grouping and for each category of the variables measuring patterns of interaction and communication. As noted above, it was discovered upon completion of the study that the observers differed significantly in the amount of behaviors they coded; i.e., one observer always coded more behaviors than the other. Consequently, the frequency counts were normalized. A repeated measures analysis of variance was performed that provided information on how the independent variable, the observer, and the interaction between independent variable and observer affected the dependent variable. (Since there was only one plant manager, no variation existed within this functional unit and it had to be dropped from the analyses of variance. Because the plant manager belonged to the strategic apex along with three of his assistant plant managers, he could be included in the NOMAC unit analysis.) Differences attributable to the functional and structural variables are reported if they were found to be statistically significant at the 0.05 probability level or less.

BEHAVIORAL CATEGORIES: Table II.3.8 presents the relationship between functional unit and observed behavior. The frequency distributions for four out of the six category groupings are very similar. This suggests that, regardless of function, personnel at DCPP were engaged in roughly the same sort of behavior. The only statistically significant difference was found between the engineering supervisors who engaged in more solitary work than did the other technostructure (i.e., regulatory compliance, training, health physics, and quality control managers). It should also be noted that the plant manager's frequency of management attention and oversight behavior was substantially higher than any of the other functional units.

Table II.3.8. Relationship Between Functional Unit and Behaviors

	BEHAVIOR						
FUNCTIONAL UNIT	N[1]	DM	PAO	MAO	CA	SW	NWR
Maintenance	1123	16.7%	3.7%	38.3%	26.7%	12.9%	1.8%
Operations	1233	13.9%	4.2%	46.2%	26.4%	8.8%	0.4%
Engineering	426	16.0%	2.3%	31.9%	23.7%	22.8%[2]	3.3%
Other Techno.	764	11.6%	3.7%	45.8%	26.3%	10.3%	2.2%
Plant Manager	228	13.2%	0.4%	62.7%	17.5%	5.7%	0.4%

[1] N = Total number of behaviors observed.
[2] ENG > OTHER TECHNO., $p < .05$.

Table II.3.9 presents the relationship between NOMAC unit and behavior. Again, the similarities on four out of the six category groupings is worth noting. There are also two statistically significant differences; the strategic apex engaged in more managerial attention and oversight behavior than individuals in the technostructure; and individuals in the operating core clarified ambiguity more often than individuals in the technostructure or the strategic apex. The first relationship follows directly from NOMAC, while the second may emerge because managers in the operating core must explain problems and solutions to their subordinates more than managers in the technostructure.

MODES OF COMMUNICATION: The relationship between functional unit and modes of communication is presented in Table II.3.10. Across all units, the amount of face-to-face communication is extremely high. There appears to be little difference in terms of how frequently communications occurred over the telephone. Managers in engineering, however, differed significantly from their colleagues in terms of their reliance on the electronic/written mode. There was a corresponding decline in the level of their face-to-face interactions. The explanation for this difference is relatively straightforward. Engineers are intensely involved with design changes and with the development of procedures. Both of these functions are performed at DCPP using the sophisticated on-line management information system. The data presented in Table II.3.11 indicates that even when engineering supervisors are included in a unit with managers from other groups in the technostructure, the difference in frequency of face-to-face interactions persists.

Table II.3.9. Relationship Between NOMAC Unit and Behaviors

	BEHAVIOR						
NOMAC UNIT	N[1]	DM	PAO	MAO	CA	SW	NWR
Operating Core	1393	10.3%	5.0%	41.3%	30.8%[3]	11.1%	1.4%
Technostructure	1055	14.8%	3.6%	38.6%	26.4%	14.9%	1.8%
Middle Line	494	14.6%	1.8%	41.3%	23.5%	17.0%	1.8%
Strategic Apex	832	20.9%	1.9%	53.1%[2]	17.3%	10.6%	1.1%

[1] N = Total number of behaviors observed.
[2] SA > TECH, $p < .05$.
[3] OC > SA, TECH, $p < .05$.

Table II.3.10. Relationship between Functional Unit and Modes of Communication

	MODE OF COMMUNICATION					
FUNCTIONAL UNIT	N[1]	FTF	E/W	PI	PO	PU
Maintenance	1046	72.9%	7.6%	8.1%	9.4%	1.9%
Operations	1148	73.5%	3.0%	12.5%	9.5%	1.6%
Engineering	393	53.7%	17.8%[2]	16.0%	11.2%	1.3%
Other Techno.	690	71.6%	1.0%	7.1%	18.6%	1.7%
Plant Manager	213	76.5%	1.4%	11.7%	10.3%	0.0%

[1] N = Total number of communications observed.
[2] ENG > MAINT, OP, OTHER TECHNO., $p < .05$.

RESPONDENT UNIT: Data presented in Table II.3.12 details the relationship between functional unit and respondent unit. With the exception of the plant manager, supervisors in all of the other functional units dealt more frequently with individuals in their own unit than with individuals from outside their unit. (The plant manager's high frequency of interaction with external actors is an artifact of the coding scheme. Since the plant manager is not considered a separate functional unit, but actually a member of each group, interactions with other groups were not applicable.) The only statistically significant difference was among operations personnel who tended to deal with other functional units in the plant more than individuals from engineering or from other technostructure (i.e., regulatory compliance, training, health physics, and quality control). When the individuals were grouped according to their NOMAC unit, that difference disappeared, suggesting that when individuals in operations dealt with personnel from other units, they did so mostly with those from maintenance.

Table II.3.11. Relationship between NOMAC Unit and Modes of Communication

	MODE OF COMMUNICATION					
NOMAC UNIT	N[1]	FTF	E/W	PI	PO	PU
Operating Core	1286	70.8%	5.8%	14.4%	8.2%	0.9%
Technostructure	980	63.7%	8.9%	10.2%	15.5%	1.7%
Middle Line	442	70.4%	6.8%	7.0%	15.2%	0.7%
Strategic Apex	782	80.6%[2]	0.4%	6.3%	9.8%	2.9%

[1] N = Total number of interactions observed.
[2] SA > TECH, $p < .05$.

Table II.3.12. Relationship Between Functional Unit and Respondent Unit

	RESPONDENT UNIT			
FUNCTIONAL UNIT	N[1]	SAME	OTHER	EXT
Maintenance	850	68.4%	24.5%	7.2%
Operations	964	55.1%	40.4%[2]	4.6%
Engineering	304	62.8%	18.8%	18.4%
Other Techno.	764	56.6%	19.1%	24.3%
Plant Manager	38	18.4%	2.6%	78.9%

[1] N = Total number of interactions observed.
[2] OPS > ENG, OTHER TECHNO., $p < .05$.

RESPONDENT LEVEL: As the data presented in Table II.3.13 indicates, managers from all functional units interacted most frequently with subordinates. The only statistically significant difference that emerged was that engineering supervisors worked with subordinates less frequently than did managers in operations or maintenance. A possible explanation for this finding might be found in the fact that the observed engineers had fewer subordinates than did their counterparts. Yet, data presented in Table II.3.14 does not support this explanation since all supervisors in the technostructure dealt less frequently with subordinates. These results are, however, generally consistent with NOMAC. The technostructure is the most professional, knowledge-based part of the organization. For individuals in such units interactions with peers should be more pervasive than with superiors or subordinates.

RESPONDENT NOMAC UNIT: Data on the relationship between functional unit and respondents' NOMAC unit are presented in Table II.3.15. With one exception, managers in each functional unit dealt mainly with personnel from the same NOMAC unit. The plant manager did not show as strong a relationship. Table II.3.16 presents data on the relationship between NOMAC unit and respondents' NOMAC units. Managers in the operating core and technostructure interacted most frequently with those in their own NOMAC units. The middle line interacted primarily with the operating core and the technostructure, consistent with their interpreter of standards role as defined in NOMAC. Most of the interactions occurring with individuals external to the organization are concentrated in the strategic apex and the technostructure. NOMAC does suggest that external influences would occur in those units and that they would play a significant boundary-spanning role for the organization.

Table II.3.13. Relationship Between Functional Unit and Respondent Level

	RESPONDENT LEVEL			
FUNCTIONAL UNIT	N[1]	SUPER	SAME	SUB
Maintenance	766	9.8%	14.6%	75.6%
Operations	914	12.5%	12.7%	74.8%
Engineering	339	8.4%	40.2%	51.4%[2]
Other Techno.	469	2.3%	14.5%	83.2%
Plant Manager	156	0.0%	0.0%	100.0%

[1] N = Total number of interactions observed.
[2] ENG < OPS, MAINT., $p < .05$.

Table II.3.14. Relationship Between NOMAC Unit and Respondent Level

	RESPONDENT LEVEL			
NOMAC UNIT	N[1]	SUPER	SAME	SUB
Operating Core	1033	12.7%	13.0%	74.3%
Technostructure	626	8.9%	27.0%	64.1%[2]
Middle Line	339	6.2%	15.9%	77.9%
Strategic Apex	521	1.9%	4.8%	93.3%

[1] N = Total number of interactions observed.
[2] TECH < OC, SA, $p < .05$.

<u>FORMALITY AND DIRECTNESS:</u> As Table II.3.17 suggests, there are some differences in the first context variable, formality, among managers of the various NOMAC units. There was a statistically significant difference between the strategic apex and the other three NOMAC units. For the second context variable, no significant differences are report. The variance on both of these contextual variables was so small, the differences obtained can only be of marginal substantive importance in this study.

Table II.3.15. Relationship Between Functional Unit and Respondent NOMAC Unit

	RESPONDENT NOMAC UNIT						
FUNCTIONAL UNIT	N[1]	OC	TS	SUP	ML	SA	EXT
Maintenance	860	51.2%	23.1%	4.8%	9.5%	4.3%	7.1%
Operations	976	62.1%[2]	13.3%	4.8%	13.3%	1.9%	4.5%
Engineering	304	12.2%	62.2%	2.6%	1.3%	3.3%	18.4%
Other Techno.	637	7.8%	48.2%	8.3%	9.4%	2.0%	24.2%
Plant Manager	184	15.2%	14.1%	9.8%	23.4%	21.2%	16.3%

[1] N = Total number of interactions observed.
[2] OPS > ENG, OTHER TECHNO., $p < .05$.

Table II.3.16. Relationship Between NOMAC Unit and Respondent NOMAC Unit

	RESPONDENT NOMAC UNIT						
NOMAC UNIT	N[1]	OC	TS	SUP	ML	SA	EXT
Operating Core	1131	74.6%[2]	13.2%	2.9%	4.2%	0.5%	4.6%
Technostructure	838	11.2%	59.2%	6.2%	2.3%	2.0%	19.1%
Middle Line	354	39.5%	32.2%	8.5%	10.2%	5.4%	4.2%
Strategic Apex	638	13.0%	14.4%	8.2%	34.0%	11.9%	18.5%

[1] N = Total number of interactions observed.
[2] OC > TECH, ML, SA, $p < .05$.

Table II.3.17. Relationship Between NOMAC Unit and Formality

	FORMALITY		
NOMAC UNIT	N[1]	FORMAL	INFORMAL
Operating Core	1211	3.1%	96.9%[3]
Technostructure	882	15.6%	84.4%
Middle Line	409	14.9%	85.1%
Strategic Apex	771	38.4%[2]	61.6%

[1] N = Total number of interactions observed.
[2] SA > OC,ML, TECH, $p < .05$.
[3] OC > TECH, $p < .05$.

EVENT ANALYSIS: In the modification of the behavioral observation technique, the concept of an event emerged. Behaviors that revolved around a particular issue or topic during an observation were bracketed. The rationale for doing this was to determine if certain behaviors are associated with other behaviors during the course of a specific event. Moreover, there might be differences found in terms of the patterns of interaction and communication occurring within given events. To explore these possibilities, an event's behaviors and associated variables were preserved when the data were analyzed.

The raw data sheets revealed that the two observers characterized an event somewhat differently, and therefore, the analysis that was performed examined all events together as well as the set of events designated by each observer. A large number of techniques were employed to analyze events including frequency distributions, counts, and correlations. Regardless of whether all events or subsets thereof were considered and regardless of what methods were employed, it was not possible to learn anything using events as the unit of analysis that could not also be learned by using individual behaviors and their associated interaction and communication variables.

3.3.4 Evaluation

3.3.4.1 Practicality

The field test of the behavioral observation technique at DCPP did demonstrate that the method could be implemented. It was possible to obtain agreement from organizational personnel to implement the technique, and individuals were helpful in answering questions about whom they interacted with. However, the issue of access is critical in implementing the behavioral observation technique. The discussion of this issue with respect to the functional analysis is also relevant here. Although this issue was not a problem at DCPP, it must be considered and negotiated in future studies.

Another practicality consideration is the level of resources that must be committed in implementing the behavioral observation technique. Based on the experience at DCPP, it was possible for one observer to conduct between seven and ten sessions per day. It is unlikely that that figure can be increased substantially. At this stage, it is unclear how many observations would have to be completed to obtain a representative picture of supervisory activity. This is obviously a research issue to be considered for future studies. Another question is how many individuals must be sampled under this method. The data collected thus far do not provide clear answers. Although there were similarities recorded when individuals sharing the same role and position were observed, there were also differences, especially with respect to the interaction and communication variables. In the course of development, future research can be directed toward establishing a satisfactory sampling level to resolve these issues.

3.3.4.2 Acceptability

The Diablo Canyon study also demonstrated that the behavioral observation technique did not create much of a "Hawthorne effect." The observers were unobtrusive and the subjects of behavior did not seems to change because of the observers' presence. Moreover, concern that only limited organizational activity would be observed and that sensitive matters would not be discussed proved to be unwarranted. Observers were not asked to leave during several "sensitive" interactions during the course of the study. It was, however, learned after the observations were completed that some plant personnel chose not to speak with the subjects when the observers were present, thinking they were engaged with the observers. This could be discussed with plant personnel prior to data collection at future sites.

The technique's reliability needs some improvement for it to be considered an acceptable method to other users. Although the observers achieved substantial inter-rater reliability by the end of the training sessions, some problems were still encountered. Observers scored some multiple instances of a behavior differently, and they adopted divergent rules for coding events. These difficulties are quite manageable, primarily through increasing the number of training sessions. The field experience with the technique highlighted areas of particular vulnerability, and they can be targeted in future training.

3.3.4.3 Usefulness

A critical question is whether the behavioral observation technique can be used to link organizational factors to NPP safety performance. At this stage of the research, no definitive answer is possible because only one facility has been studied. No variation on the dependent variable, safety performance, was examined in this study for the independent variables, organizational factors, to explain. However, with continued validation of the methods, the necessary relationship to those dependent variables can be made.

The method thus far has measured only the frequency of the behavioral, interaction, and communications variables. Certain behaviors do occur more often than others; managers located in a given part of the organization interact more frequently with particular individuals, and some modes of communication are preferred over others. A systematic understanding of the content and quality of the behavior still needs to be understood. For example, when a manager clarifies ambiguity about a procedure or technical question, how well does he accomplish that task? When an individual from the operating core deals with someone from the technostructure, does this necessarily mean that the two units are coordinating their actions or learning from each other? An effort was made during the observations to record some of the substantive context in which the behaviors took place, but those notes failed to fully capture the meaning of the interactions.

The model that underlies the behavioral observation technique posits that organizational factors and managerial behaviors depend on each other. They, in turn, influence organizational effectiveness, which impacts safety performance. To establish a causal association between the independent and dependent variables, organizational effectiveness has to be further operationalized. This was not done as part of this phase of research and needs to be addressed in the future.

3.4 Organizational Cultural Assessment

3.4.1 Implementation

An organizational cultural assessment (OCA) was performed at the Diablo Canyon Power Plant (DCPP) utilizing a questionnaire that queried employees on six different topics including, organizational culture, cohesiveness, commitment, hazardous nature of work, safety, and routinization. A description of each of the scales used to assess these subjects is discussed below.

The questionnaire was self-administered by departments. A total of 615 questionnaires were distributed, and 515 were returned and analyzed. This represented a 83.9 percent response rate. By department, the number of responses were:

Support Services	127
Technical Services	93
Operations	125
Maintenance	170

3.4.2 Results

Overall means were computed for each scale listed above. A one-way analysis of variance was performed on each OCA scale using the scale score as the dependent variable and separate analyses using department and organizational level (management and non-management) as the independent variables. Where the analysis of variance showed a significant difference among the group means, a Tukey HSD (Honestly Significant Difference) (Hays, 1988) procedure was applied to identify those means that were statistically different from each other. Only the pairs of group means found to be significantly different at the .05 probability level or less are reported.

3.4.2.1 Organizational Culture Inventory (OCI)

3.4.2.1.1 Description

The Organizational Culture Inventory (OCI) (Human Synergistics, 1987) is a diagnostic tool for measuring aspects of organizational culture that have a large impact on the activities of members and the functioning of the organization. Respondents are asked to review 120 statements which describe some of the thinking and behavioral styles that members of an organization may be expected to adopt in carrying out their work and in interacting with others. These statements measure 12 different cultural styles, some of which are indicative of a positive and supportive environment, while others are useful in identifying potentially dysfunctional environments. All of the styles measured by the OCI are related to, and result from, organizational structural variables, reward systems, managerial styles and philosophies, and other factors that can be changed, at least to some extent, by those in leadership positions. The 12 organizational culture styles are described in Table II.3.18.

3.4.2.1.2 Overall Profile

The overall scores on the OCI for the entire sample of individuals responding in the Diablo Canyon demonstration study are depicted in Figure II.3.9. The cultural styles are identified by number and are described in the preceding section. The scores represent the mean scores for the entire population on scales ranging from 1 (not at all) to 5 (to a great extent).

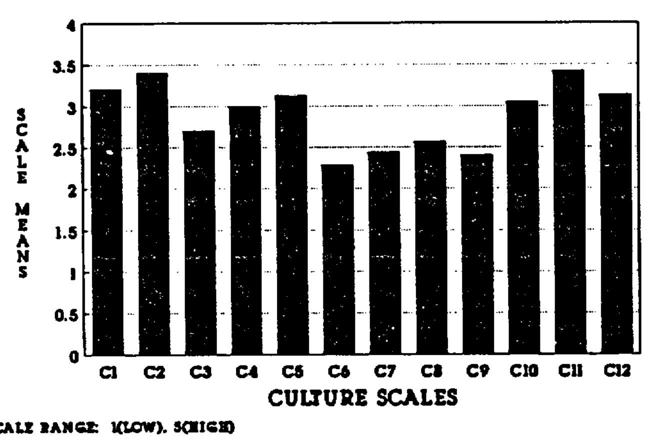


Figure II.3.9. Overall mean OCI scores on culture scales

Table II.3.18. Organizational Culture Inventory Scales

Scale	Name	Description
C1	Humanistic-Helpful	Organization managed in participative and person-centered way. Members expected to be supportive, constructive, and open to influence in their dealings with one another.
C2	Affiliative	Organization places high priority on constructive personal relations. Members expected to be friendly, open, and sensitive to the satisfaction of their work group.
C3	Approval	Organizations where conflicts are avoided and personal relations are pleasant, at least superficially. Members feel they should agree with and gain approval of others.
C4	Conventional	Organization that is conservative, traditional, and bureaucratically controlled. Members expected to conform, follow rules and make a good impression.
C5	Dependent	Organization that is hierarchically controlled and nonparticipative. Centralized decision-making leads members to do only what they're told and to clear all decisions with superiors.
C6	Avoidance	Organization that does not reward success but punished failure. Negative reward leads members to shift responsibility to others and avoid being blamed for mistakes.
C7	Oppositional	Organization where confrontation prevails and negativism is rewarded. Members gain status and influence by being critical and are encouraged to oppose the ideas of others.
C8	Power	Non-participative organization structure on basis of authority in members positions. Members expect to take charge and control subordinates and respond to demands of superiors.
C9	Competition	Organization where winning is valued and rewards are given for outperforming others. Members operate in a "win-lose" framework and work against peers to be noticed.
C10	Perfectionistic	Organization where persistence, hard work, and perfectionism are highly valued. Members feel they must avoid all mistakes, keep track of everything, and work long hours to attain specific objectives.
C11	Achievement	Organization that does things well and values members who set and accomplish their own goals. Members set challenging realistic goals and plan and pursue them with enthusiasm.
C12	Self-Actualize	Organization that values creativity, quality over quantity, tasks and individual growth. Members encouraged to gain satisfaction from their work, develop themselves and take on new activities.

(From Human Synergistics, 1987)

The organizational profile that emerges is one best described by the constructive styles on the OCI, humanistic, affiliative, achievement, and self-actualizing (C1, C2, C11, C12). The population is also conventional (C4) and perceives itself to be hierarchically managed and controlled (C5). It does not perceive an over-reliance on punishment and consequently does not avoid responsibility (C6). This is also an organization where persistence, hard work, and perfectionism are highly valued (C10).

3.4.2.1.3 Departmental Profiles

Comparisons among the four different groups at Diablo Canyon revealed three OCI scales on which the groups were statistically significantly different from each other. These results are presented in Figure II.3.10.

The Support Services group, which includes departments such as General Services, Training, Security, Emergency Planning, and Document Services, scored significantly higher than the Operations group on the Affiliative (C2) and Approval Scales (C3) and lower on the Perfectionistic (C10) Scale. The Technical Services group, which includes the Engineering and Regulatory Compliance Departments, scored higher than the Operations and Maintenance groups on the approval (C3) scale as well. These are not unexpected differences for service and support type groups that are dependent on the approval and cooperation of other groups to accomplish their objectives.

When departments were reanalyzed using functional groupings as described by NOMAC additional differences were observed in organizational culture profiles. Figure II.3.11 presents these results. Engineers scored significantly higher than individuals in the Operations and Maintenance Departments on the Approval (C3) Scale, higher than Operations on the Dependent (C5) Scale, and higher than Operations and Other Technostructure groups on the Competitive (C9) Scale. Operations and Engineering personnel were significantly higher than individuals in the Other Technostructure Departments on the Perfectionistic (C10) Scale. Of interest in this analysis is that fact that using the functional units described by NOMAC provided additional and interesting information concerning a particular unit within the organizational structure.

3.4.2.1.4 Organizational Level Profiles

Figure II.3.12 depicts the statistically significant differences between management versus bargaining unit personnel on the OCI scales. Managers at Diablo Canyon scored higher on the Humanistic (C1), Affiliative (C2), Competitive (C9), and Achievement (C11) Scales than bargaining unit personnel. Only on the Conventional (C4) Scale did managers score lower than bargaining unit employees. When individuals from the engineering groups were separately identified for organizational level comparisons (engineers are not bargaining unit employees and all engineers are not managers), additional differences emerged as depicted in Figure II.3.13. Engineers scored higher on the Approval (C3) Scale than either managers or bargaining unit personnel, were similar to bargaining unit individuals on the Conventional (C4) Scale, higher than managers on the Dependent (C5) and Avoidance (C6) Scales and higher on the Competitive (C9) and Achievement (C11) Scales than bargaining unit individuals. These results are consistent with those described above for engineering when functional units were compared.

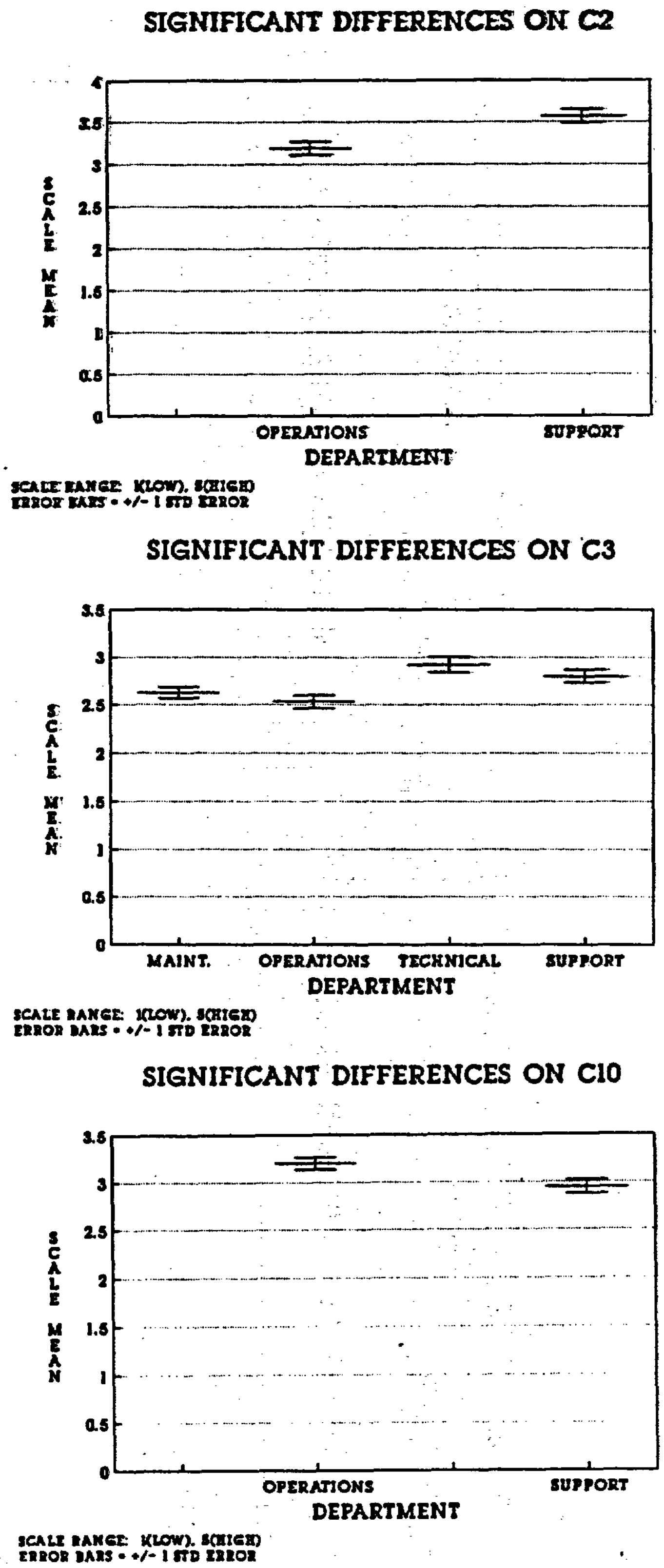


Figure II.3.10. Statistically significant differences between departments on OCI scales

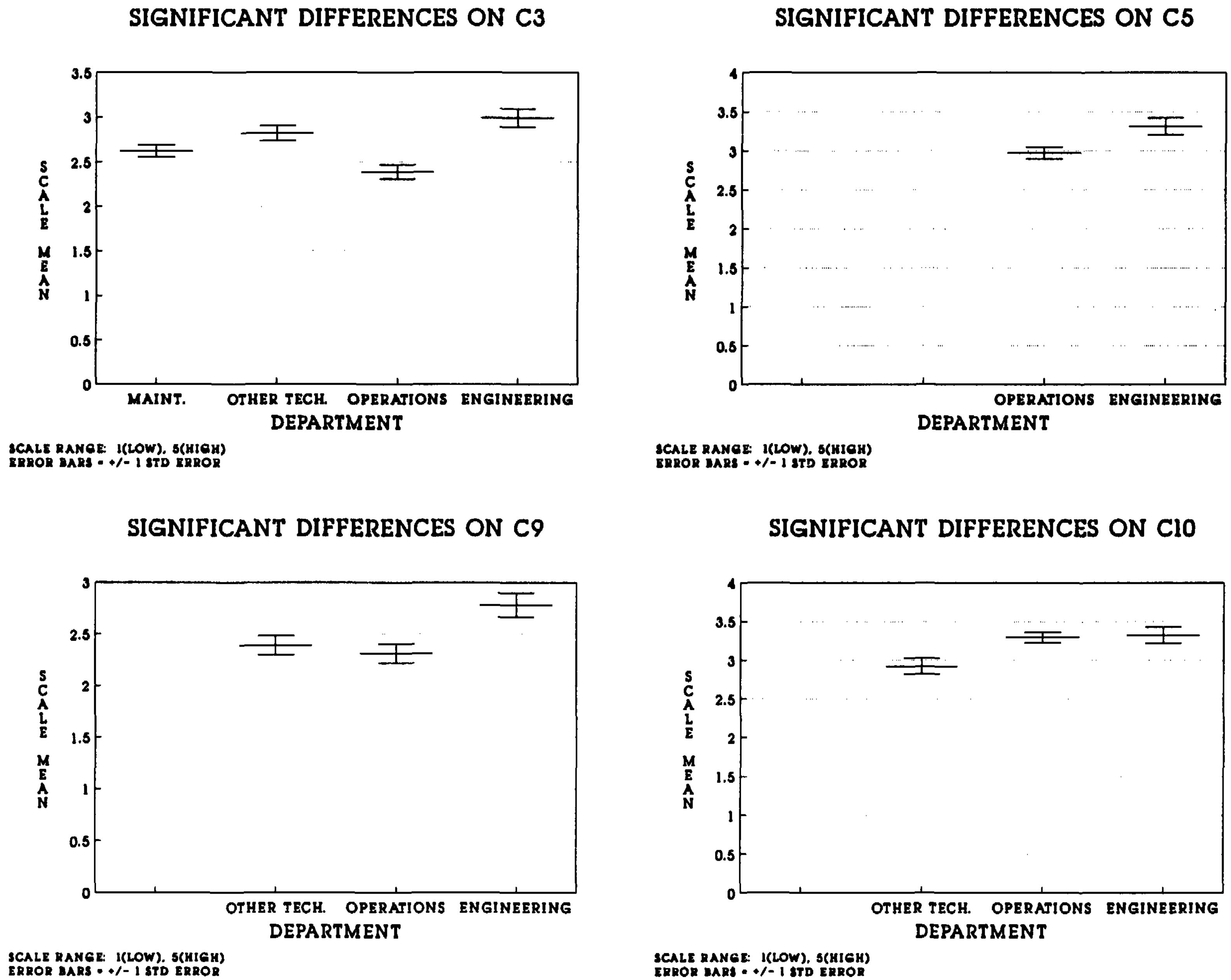


Figure II.3.11. Statistically significant differences on OCI between functional units (per NOMAC definition)

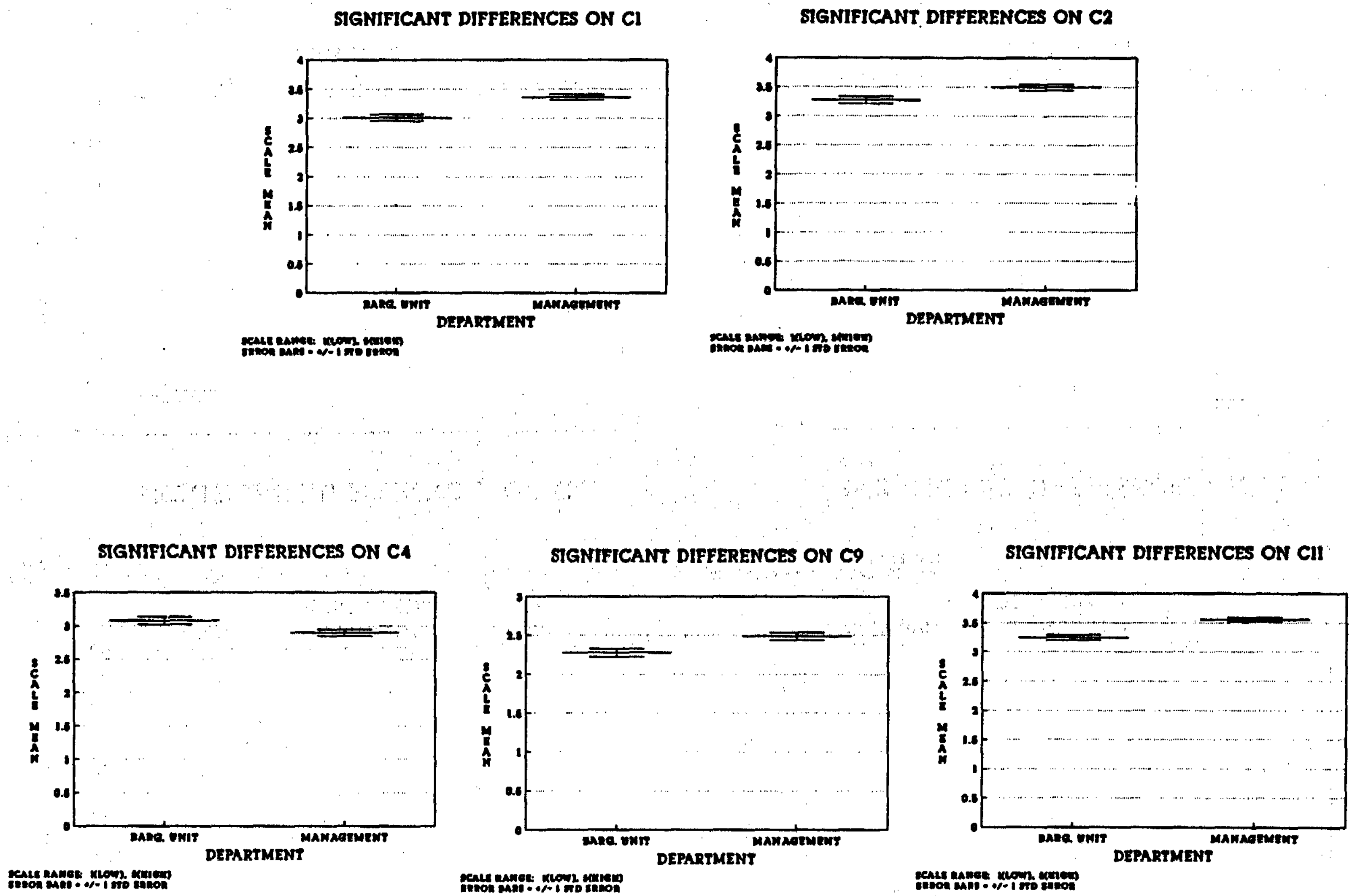


Figure II.3.12. Statistically significant differences on OCI between bargaining unit and management

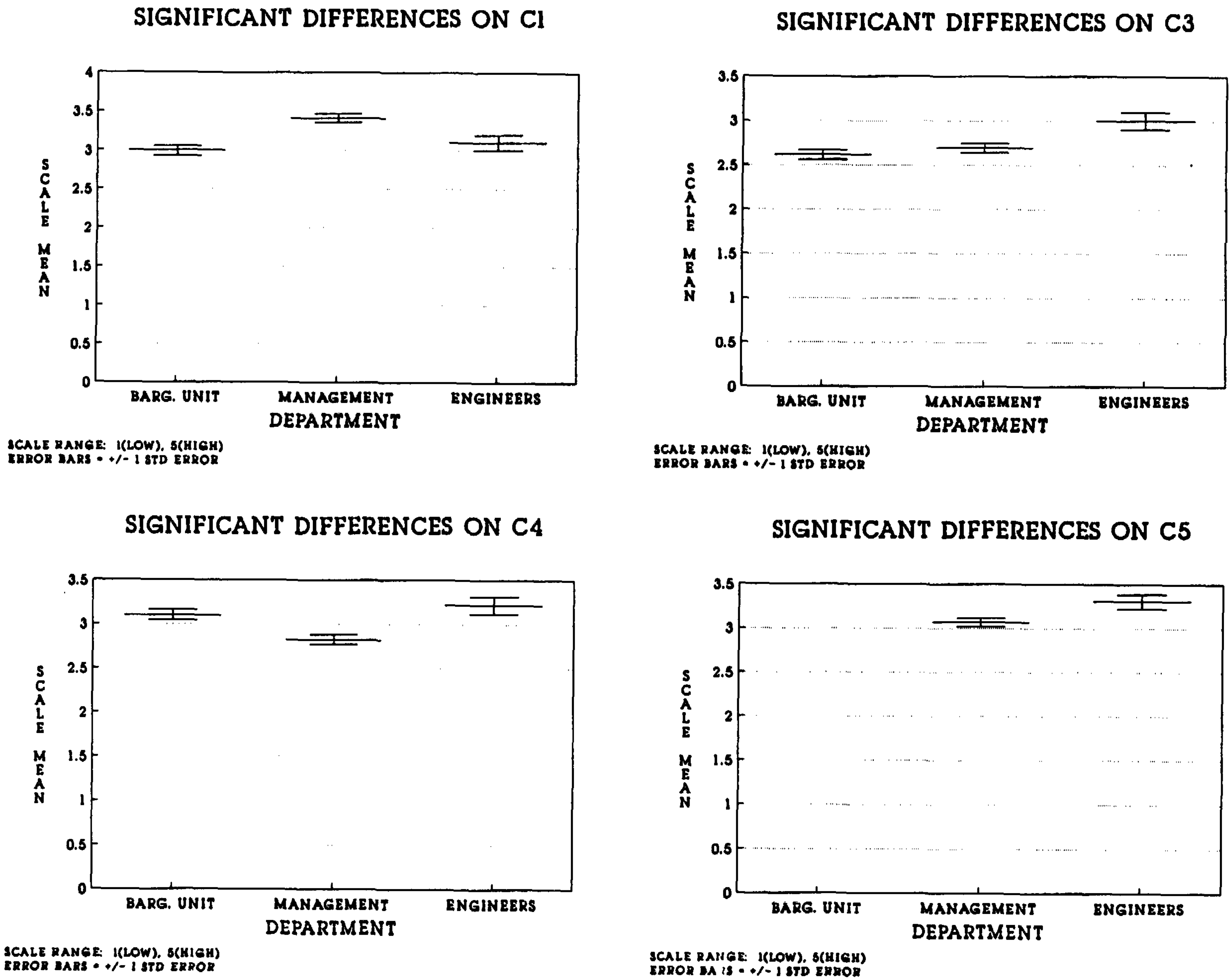
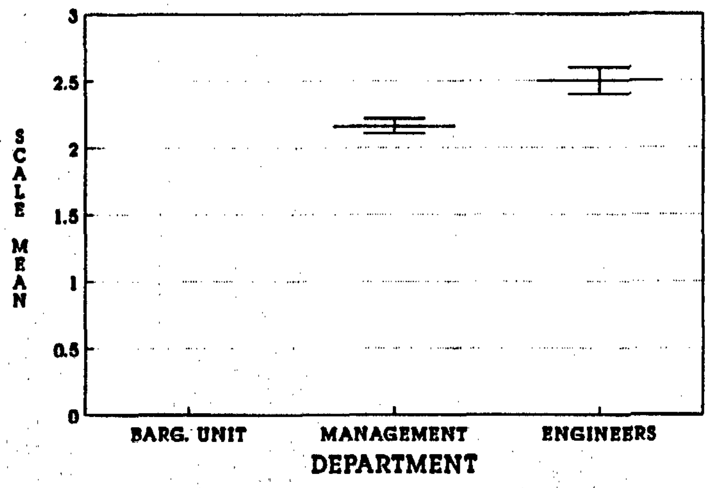


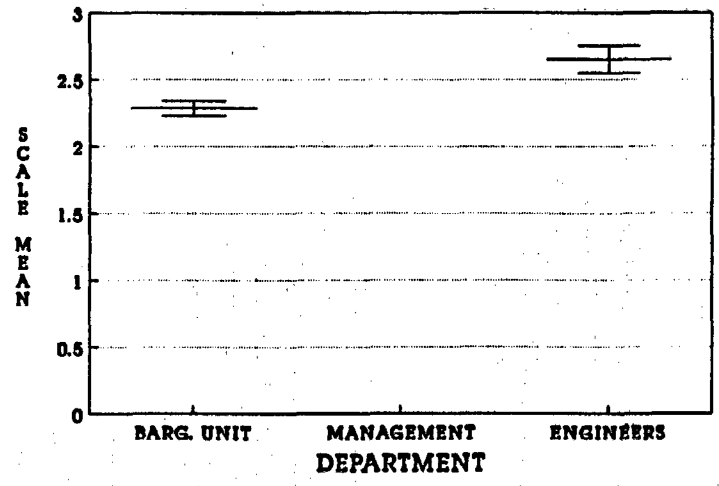
Figure II.3.13. Statistically significant differences on OCI between management, engineers, bargaining unit

SIGNIFICANT DIFFERENCES ON C6



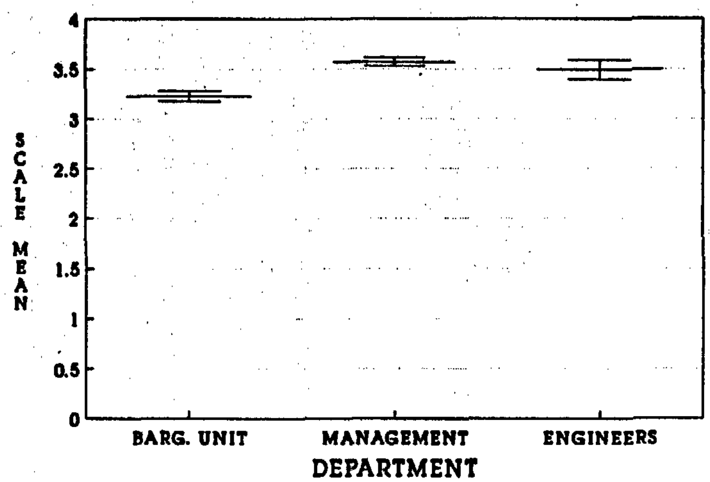
SCALE RANGE: 1(LOW), 5(HIGH)
ERROR BARS = +/- 1 STD ERROR

SIGNIFICANT DIFFERENCES ON C9



SCALE RANGE: 1(LOW), 5(HIGH)
ERROR BARS = +/- 1 STD ERROR

SIGNIFICANT DIFFERENCES ON C11



SCALE RANGE: 1(LOW), 5(HIGH)
ERROR BARS = +/- 1 STD ERROR

Figure II.3.13. Continued

3.4.2.2 Cohesiveness

The Cohesiveness Scale is defined as the relative strength of an individual's identification and involvement in a particular work group (K.H. Roberts, 1990, personal communication). The range on this scale is from a low score (weak cohesiveness) of 1 to a high score (strong cohesiveness) of 7. The only significant difference that emerged was in the organizational level comparison. Managers exhibited a slightly higher cohesiveness score than bargaining unit employees (see Figure II.3.14).

3.4.2.3. Commitment

The Commitment Scale is very similar to the cohesiveness scale except that it is defined as the relative strength of an individual's identification with and involvement in a particular organization (K.H. Roberts, 1990, personal communication). This commitment extends to the goals of the organization and the desire to maintain membership in the organization to facilitate these goals. The range on this scale is from a low score (low commitment) of 1 to a high score (high commitment) of 7. No statistically significant differences were obtained on this scale for the Diablo Canyon sample.

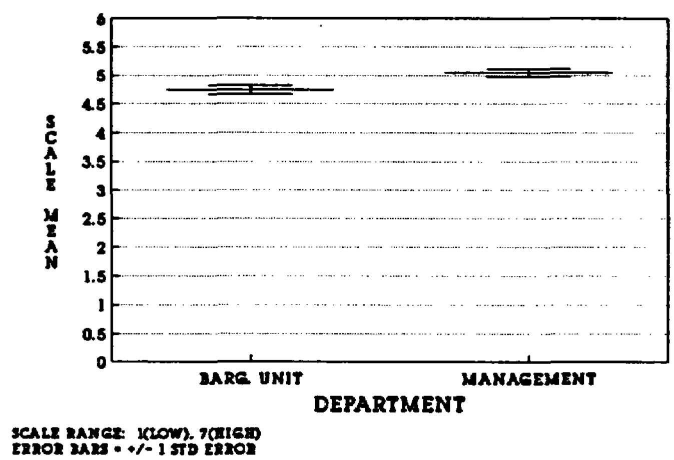


Figure II.3.14. Statistically significant differences between management, engineers, bargaining unit on cohesion scales

3.4.2.4 Hazard

The Hazard Scale is used to identify people's perception of the hazardous nature of their work (K.H. Roberts, 1990, personal communication). The scale can range from a low score (not hazardous) of 1 to a high score (very hazardous) of 7. Among departments, Operations had significantly higher hazard scores than any of the other groups (see Figure II.3.15). In addition, Maintenance had higher hazard scores than the Technical and Support Services groups. These results are not surprising within the environment of a nuclear power plant.

Similar results are obtained when the groups are analyzed by functional unit as defined by NOMAC. Figure II.3.16 depicts these results. In comparing organizational level hazard scores, the results are consistent with those already reported. Figure II.3.17 illustrates that bargaining unit employees have significantly higher scores than both managers and engineers and managers also scored significantly higher than engineers on the Hazard Scale.

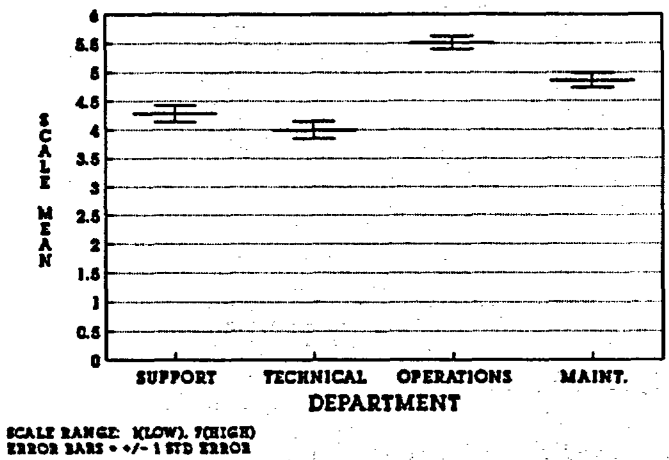


Figure II.3.15. Statistically significant differences between departments on hazard scale

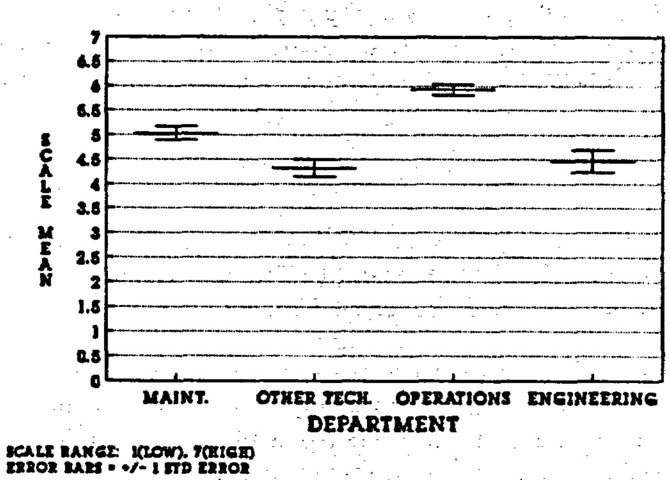


Figure II.3.16. Statistically significant differences between functional units (as defined per NOMAC observations) on hazard

3.4.2.5 Safety

The Safety Scale is being developed by researchers at the University of California at Berkeley (K.H. Roberts, 1989, personal communication) to assess an individual's perception of the importance of safety to success in an organization. Safety is defined as operating reliably where the consequence of making a mistake is high. Organizations typically viewed as high reliability operations are nuclear reactors, naval aircraft carriers and air traffic control centers. Data for this scale now exists from several of those organizations (Roberts, 1990, personal communication). The scale as administered at DCPP consisted of 40 items that range from 1 (does not help at all) to 7 (helps a great deal).

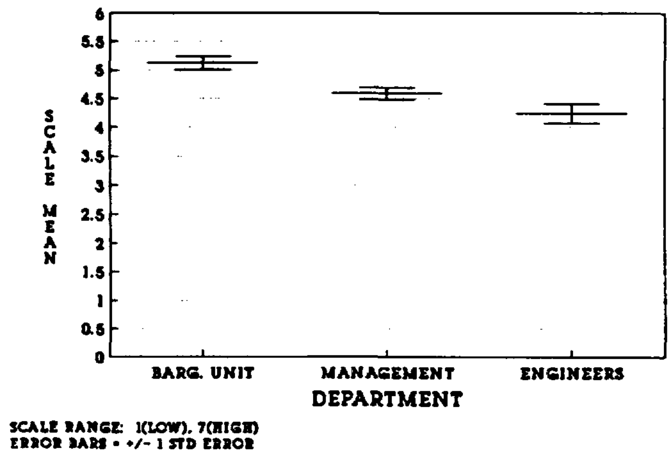


Figure II.3.17. Statistically significant differences between management, engineering, and bargaining unit on hazard

The overall mean score on the Safety Scale at Diablo Canyon was high, 5.68, but no statistically significant differences were obtained across any of the departments or organizational levels. This is an especially interesting result considering the different perceptions of hazardous nature of work among groups in the same sample. This seems to be indicative of a homogeneously high regard for attention to safety in this plant.

3.4.2.6 Routinization

The Routinization Scale was developed by Withey, Daft, and Cooper (1983). The scale consists of five questions that range from 1 (low routinization) to 7 (high routinization). The scale measures the amount of repetition people perceive in their work on a day to day basis.

Departments at Diablo Canyon varied in their Routinization Scale scores. Support Services, Operations and Maintenance all scored significantly higher than the Technical Services group on this scale (see Figure II.3.18). It should be remembered that the Technical Services group is comprised largely of engineers who would not be expected to perceive their work as routine as some of the other groups. Figure II.3.19 demonstrates this point more clearly when the groups are compared as functional units. The same trend is seen in Figure II.3.20, which compares managers, bargaining unit personnel and engineers. Again, engineers scored significantly lower than both managers and bargaining unit personnel. Bargaining unit personnel were significantly higher than managers on this scale.

3.4.3 Conclusions

The acceptability, practicality, and usefulness of the organizational culture assessment were evaluated from the results obtained in the Diablo Canyon demonstration study. The acceptability of this method was demonstrated by the high response rate achieved at the plant. A good distribution of organizational units were sampled, which allowed data to be collected from many more individuals than is possible with the other two NOMAC methods. The scales administered also provided information to supplement that collected in the functional analysis and behavioral observation technique. The OCA method was also highly practical. At Diablo Canyon the questionnaires were self-administered thereby requiring minimal resources on the part of the research team for implementation.

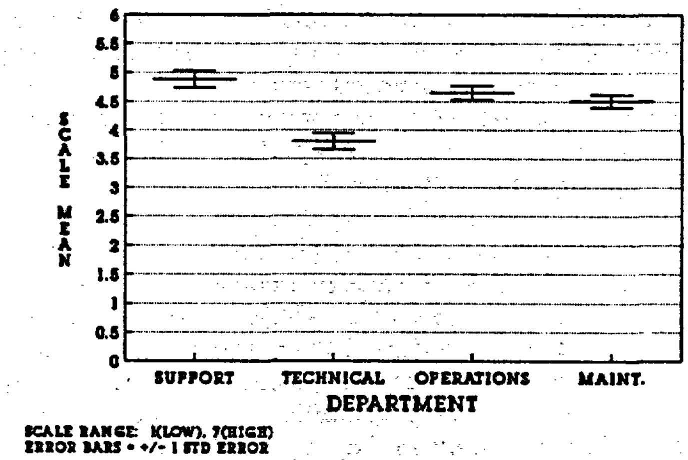


Figure II.3.18. **Statistically significant differences between departments on routinization**

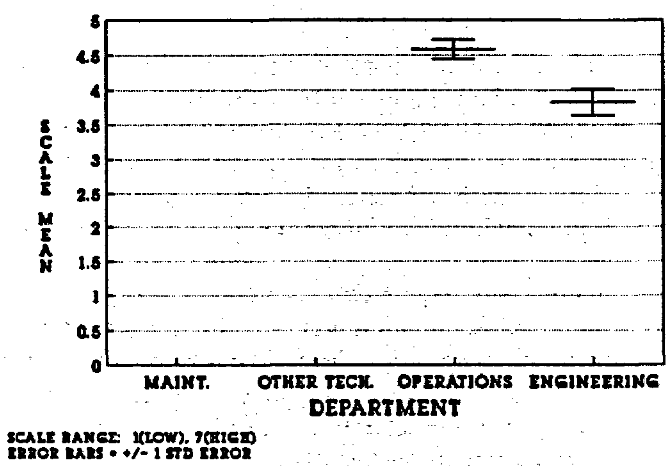


Figure II.3.19. **Statistically significant differences between functional units (as defined per NOMAC observations) on routinization**

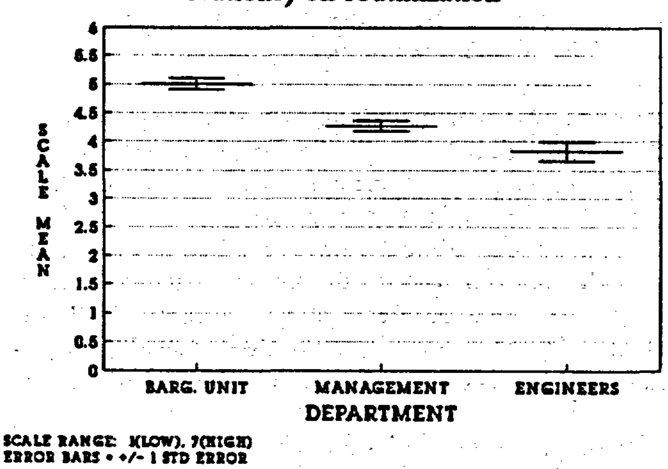


Figure II.3.20. **Statistically significant differences between management, engineers, and bargaining unit on routinization**

The usefulness of the OCA is highlighted by the results obtained. Scales could discriminate between departments and organizational levels. NOMAC organizational units could also be used to differentiate groups on many of the measures. Culture scales provided insights into the differences between organizational units and how they matched with the overall organizational profile. Despite perceived differences in the hazardous nature of the work among different groups, no differences across the organization on safety culture were found. This is perhaps indicative of a homogeneously positive attitude towards safety throughout the organization.

The organizational culture assessment was implemented in the Diablo Canyon demonstration study without major modification from the Pittsburg demonstration study. Some of the scales were switched, largely because of the research needs of the University of California at Berkeley group. The scales on the Organizational Culture Inventory, Safety, Commitment, and Routinization were all repeated and comparisons can be made between the two organizations. This aspect of the method will be very useful if comparisons between similar organizations need to be made, or if comparisons within the same organization across different points in time need to be made.

3.5 Conclusions

If the demonstration study at PPP was perceived as a qualified success, the study conducted at DCPP was a virtually complete one. The achievements of the first effort were repeated in the second. In particular, acceptability remained quite high. Plant personnel almost never found the presence of outside observers to be objectionable or disruptive. Cooperation between DCPP staff and the research team was high. Furthermore, the Functional Analysis and the Organizational Cultural Assessment continued to be judged as both practical and useful from a research perspective.

As importantly, there were clear improvements in the quality of data collected through the behavioral observation technique. The expectation was that the adjustments made to the method as a function of the lessons learned at PPP would achieve their objectives; that proved to be the case. Employing only two observers instead of four permitted shorter training time and yet greater consistency. The new behavior categorization scheme captured organizational behaviors accurately and exhaustively. Measuring frequency of activity rather than duration seemed increasingly appropriate as the research progressed. In fact, senior plant managers at DCPP were given a briefing on the substantive findings from the observations. Their reaction was that the results both in aggregate and in terms of the differences related to the subject's organizational position were strongly consistent with their intuitive understanding of the plant's operation.

There are still important research questions that have yet to be answered fully. Can the practicality of the behavioral observation technique be further improved by reducing the number of individuals sampled and/or the number of observation periods conducted? Would the utility of the method then be compromised? There is evidence from the research conducted thus far that methodological problems are possible without losing valuable information. Are there additional attitudinal dimensions that might be probed using the Organizational Cultural Assessment? Can the link between organizational factors and safety performance be more tightly drawn? This is a difficult, but critical, question to address. The answers to many of these questions are still not fully defined, but none of them appear insurmountable. The progress made to date in this study is a good place to begin.

Additional data collection studies would answer some of these questions while also increasing the database on the organizational factors believed to be important for safety performance. The link between the organizational data collected and other performance indicators currently assessed by the

NRC would help close the link between organizational factors and safety performance. Modifications to the methods would also allow their use or generalizability to other ongoing NRC evaluation and assessment activities.

4. APPLICATION OF NOMAC METHODOLOGY TO PROBABILISTIC RISK ASSESSMENT

4.1 Introduction

While much of the work in this project has focussed on the development and implementation of methods to collect data on organizational and management factors in a systematic and reliable way, one of the objectives of this research project is to develop a way to reflect the influence of these factors in reliability and risk-based analyses of nuclear power plants (NPPs). The methods in the NOMAC methodology might be used as a starting point for gathering information that could be incorporated into probabilistic risk assessment. Work conducted by the University of California at Los Angeles (UCLA) under subcontract to Brookhaven National Laboratory (BNL), identified a preliminary scheme for quantifying the impact of organizational factors in probabilistic risk assessments (PRA). This section discusses the process developed by BNL, subsequent to the UCLA work, for integrating the data collected from the NOMAC methodology into a PRA. Finally, a test case using hypothetical data, conducted at BNL, and a discussion of the issues surrounding further use of the process are presented.

The work conducted by UCLA (Wu, et al., 1989) suggested that the Success Likelihood Index Methodology-Multi Attribute Utility Decomposition Method or SLIM-MAUD (Embry, et al., 1984) might be a viable technique to utilize in the integration of organizational and management factors into PRA. SLIM-MAUD is a PC-based program originally designed to systematize expert judgements on the likelihood of success or failure of various human activities within a NPP. The SLIM-MAUD process is essentially a two-step process whereby expert judgment is used to both rate and weight the factors affecting performance that are being assessed. While the program was originally designed to assess the probability of success or failure of human actions, it was believed that minor modifications to the process could be easily incorporated to assess feasibility for use in integrating organizational and management factors into PRA. For a more detailed discussion on the original development and use of SLIM-MAUD, see Embry et al. (1984) or Rosa et al. (1985).

4.2 Application of SLIM-MAUD for Integration of Organizational Factors into PRA

4.2.1 Development and Definition of Organizational Factors

Based on the results of the demonstration studies of the NOMAC methodology at the Pittsburg Power Plant (PPP) and the Diablo Canyon Power Plant (DCPP), five broadly defined organizational factors were identified. The five factors are: communications; organizational culture; decision making; management attention, involvement, and oversight; and standardization of work processes. These factors are described below and examples of the types of data that can be collected are also provided. The type of data collected in the Functional Analysis (FA), Behavioral Observation Technique (BOT), and Organizational Cultural Assessment (OCA), are those used to develop a rating matrix of the organizational factors. It should be noted, however, that the characterization of these factors is still preliminary.

For each of the organizational factors, a composite of the data applicable to that factor collected from the NOMAC methods is review by the NOMAC team members implementing this application. Using their expert judgement an linear algorithm of the data for each factor, a number, from 1 to 9, with 1 representing a positive rating and 9 representing a negative rating, is assigned to each factor. Behavioral data from the FA, BOT, and OCA used in the development of the ratings is described in Table II.4.1.

Table II.4.1. Behavioral Data from NOMAC Used in Rating Matrix for SLIM-MAUD

Positive Communication:	High informal vs. formal (BOT) High frequency between units (FA) (BOT) High frequency within units (FA) (BOT) High face-to-face compared to phone (BOT) High communication scales value (OCA)
Positive Decision-Making:	High frequency decision-making (BOT) High collegial between units involved (FA) (BOT) High percentage resolution (BOT) High proactive decision-making (FA) (BOT) High identification of problems (FA) (BOT)
Positive Organizational Culture:	High oppositional scale value (OCA) High avoidance scale value (OCA) High power scale value (OCA) High perfectionistic scale value (OCA) High safety scale value (OCA) High commitment, cohesion, job satisfaction scale values (OCA)
Positive Standardization:	High electronic communication (FA) (BOT) High generation of alternatives High clarification of ambiguity High interaction with technostructure (BOT) High routinization scale value (OCA)
Positive Management Attention:	High delegation of responsibility (FA) (BOT) High monitoring of work (BOT) High conflict resolution (BOT) High informing (FA) (BOT) High strategic apex interactions (BOT)

FA = Functional Analysis
BOT = Behavioral Observation Technique
OCA = Organizational Culture Assessment

As depicted in Table II.4.1, information can be collected from the NOMAC methodology that can be used to make assessments about the organizational factor communication at a particular facility. The formality (or informality) of communication is one aspect that can be assessed from BOT data. Frequencies of communication both within and between organizational units can also be obtained from BOT. Modes of communication, such as face-to-face communication, can also be assessed from BOT. Finally, the Communications Scale scores of the OCA can be included in the rating for this factor, with high values on the four scales indicating positive communication.

The second organizational factor is organizational culture. Culture highly influences behavior within an organization. Culture can be seen in the emphasis the organization places on safety (Safety Scale score from the OCA), the tradeoffs it makes in decision making (frequencies of different types of decision-making from BOT data), and the use of shortcuts in order to meet ends or goals (insights from the FA). The OCA provides the most direct information on this factor with data from several scales. In particular, previous work by researchers at the University of California at Berkeley (Roberts, 1989, personal communication), using the Organizational Culture Inventory (OCI) (Human Synergistics, 1987), suggested that high reliability organizations tend to score high on the Opposition, Avoidance, Power, and Perfectionistic Scales. The results are based on military organizations (e.g., naval aircraft carriers), and should not be regarded as necessarily conclusive for all high reliability organizations. It is also hypothesized that positive organizational culture at a NPP would be reflected in a high Safety Scale value.

The third organizational factor identified is decision-making. Decision-making is a function which reflects the emphasis the organization places on various values, the ability of an organization's management to choose among competing alternatives and its ability to recognize and solve problems (Yukl, 1989). Many of the behaviors collected through the use of the NOMAC methodology, in particular from the FA and BOT, are believed to reflect decision-making in a facility: the frequency of decision-making, the amount of collegial interactions between units involved in a decision, the amount of issues actually resolved, the amount of problem identification, and the amount of proactive decision-making. A high frequency of occurrence for all these behaviors is generally thought to be positive.

The fourth organizational factor is the standardization of work processes. It will be recalled that standardization of work is considered a primary coordinating mechanism of work in a NPP. Utilizing the NOMAC methodology, a number of readily observable behaviors relate to this organizational factor. In particular, it is hypothesized that a high frequency of electronic communication within the facility reflects positive standardization. The generation of alternatives and clarification of ambiguity, behaviors assessed through BOT, are also hypothesized to be related to standardization. Interaction with the technostructure, the designer of standards, is also considered an indicator of standardization. The Routinization Scale of the OCA also indicates the impact of standardization by assessing the perceived repetitiveness of work.

The fifth organizational factor is management attention, involvement, and oversight, referring to management functions which are important to achieving the goal of enhancing organizational awareness and learning. Behaviors observed using BOT relating to this factor include delegation of responsibility, monitoring of work, conflict resolution, informing, and interactions with the strategic apex. For all of these behaviors, a high frequency of occurrence is hypothesized to be positive.

It should be noted that the characterization of these factors is still preliminary and that these five factors do not account for all behaviors observed during the implementation of the NOMAC methodology. However, these factors do represent a large portion of the activities which occur in an NPP and appear to be most central to organizational performance. These factors are by no means independent of each other and sometimes, some factors may be more important for successful plant operations than others. Further research on the factors is needed to better refine and define them.

4.2.2 A Test Case of the SLIM-MAUD Application

4.2.2.1 Methodology

In order to determine the effect that organizational and management factors have on plant core melt frequency (CMF), it was necessary to select a PRA which contained detailed human error modeling. It was also necessary to use a PRA that was readily available on a computer model and that could be easily manipulated to determine changes in CMF. Finally, a PRA was necessary that had human errors that could be categorized in terms of organizational units as well as into pre- and post-accident initiators. The Oconee PRA (NSAC-60, 1984) met all these requirements.

The Oconee human error categorization database, developed by researchers at BNL (Samanta et al., 1989), contains information on all the human errors in the Oconee PRA contributing to core melt frequency (CMF). This database contains information on each human error including the human error probability (HEP), the type of error made (omission or commission), the organizational unit responsible for the error, and the timing of the error (pre or post accident initiator). This database was scanned and all errors that occurred pre-accident initiator were selected. These pre-accident errors were distributed across four organizational units: operations, maintenance, instrumentation and control (I&C), and operations/maintenance (where the error was the result of an activity involving both operations and maintenance).

Using these four organizational units, hypothetical data of the type collected in the demonstration studies, and the five organizational factors, a group of experts from BNL who had been extensively involved in the demonstration studies conducted at the Pittsburg and Diablo Canyon power plants and who had knowledge in the area of organization and management, developed ratings for each of the five factors for each of the four organizational units. Table II.4.2 presents the ratings.

Table II.4.2. Organizational Factors Rating Matrix

SCALE: 1 Excellent ———————————————— 9 Deficient

	Organizational Unit			
Organization & Management Factor	Ops.	Maint.	I&C	Ops./ Maint.
Communications	2	4	6	3
Decision-making	6	8	7	5
Organizational Culture	3	5	4	4
Standardization	1	6	3	5
Management Attention	1	3	8	1

These ratings were primarily developed from hypothetical data, consistent with the organization and management factor definitions discussed earlier in this section. The types of hypothetical data used could be easily obtained through data collection utilizing the NOMAC methodology. It is important to note, however, that if this matrix were based on real data, for each of the organizational units, the ratings would be relative to one another. A rank on the scale toward the negative or positive end could not be interpreted relative to other plants, but rather, the rank would indicate that unit's position relative to the other organizational units within the same facility.

After the ratings for the organizational units were developed, seven expert judges in the area of operations from the Long Island Lighting Company, all of whom had considerable operating experience at various nuclear facilities, were selected to weight the organizational factors, using SLIM. Two hypothetical operational units were presented, one which was high on organizational Factor A but low on Factor B versus a second unit which was low on Factor A but high on Factor B. Using their extensive operational knowledge, the expert judges were asked to decide between the two hypothetical units and determine which unit was more likely to be successful in conducting normal NPP operations. Following this choice, the experts then had to degrade the unit which they had chosen to have the higher success likelihood to a point where they determined that the other hypothetical operational unit would have a higher success likelihood.

For example, consider Figure II.4.1. The expert judge is asked to determine which hypothetical operations unit, A or B, has the greater likelihood of success in operations. In operational unit A, there is fairly deficient management attention, but excellent decision-making while in operational unit B there is excellent management attention, but fairly deficient decision-making. To complete this example, imagine that one of the experts initially chose operations unit A to have a greater likelihood of success. Operations Unit A would then be degraded by the expert by moving the asterisk on the decision-making factor over towards the deficient end of the scale. The expert must decide at which point on the scale they would no longer chose unit A as the better alternative but would now choose B. In the example illustrated in Figure II.4.1, the expert moved the weighting of the decision-making factor about half-way down the scale before determining that Unit B would have a higher success likelihood.

This process was repeated ten times, once for each of the possible pairs of organizational factors. While SLIM-MAUD is a PC-based program, and can be used interactively, this exercise, as well as the exercise involving the ratings, were both completed as paper-and-pencil exercises for logistical reasons. After the weightings were complete, the results from the ratings and weightings were run through the SLIM-MAUD program to obtain success-likelihood indexes (SLIs) for the operations organizational unit. This process was also repeated for the other three organizational units, operations/maintenance, maintenance, and instrumentation and control. For these organizational units, one expert judge in each area was utilized for the weighting process.

4.2.2.2 Results

SLIs were obtained by entering the ratings for each of the four organizational units (refer to Table II.4.2) and the weightings obtained from the judges through the SLIM MAUD PC-computer program. For the operations organizational unit, comparisons could be made between judges since seven separate SLIs were obtained (Table II.4.3). As seen in Table II.4.3, the SLIs were remarkably similar, indicating that the expert judges were relatively consistent in the way they weighted the five organizational factors for the operations unit.

Based on the similarity of the results, the mean of the seven judges was used to obtain the final SLI to be used in the test case application of SLIM-MAUD. Only one expert judge was used for each of the other three organizational units, resulting in a single SLI. The SLIs for each organizational unit as used in the test case are presented in Table II.4.4.

4.3 Implementation of Organizational Factors into PRA

Prior work at BNL using the Oconee PRA (Samanta, et al., 1989) had led to the development of a detailed categorization scheme of the human errors in that PRA. This PRA was set up to run in a PAIRWISE program (Wong, et al., 1989) and was easily manipulatable. Sensitivity analyses on the human errors in the Oconee PRA had been conducted to determine what effect variation of human errors would have on CMF. This entailed the development of factors by which to vary different groups of human errors. These factors were used to increase and decrease the base case of all human errors within a group in order to obtain upper and lower bounds (HIHEP and LOHEP) for each human error.

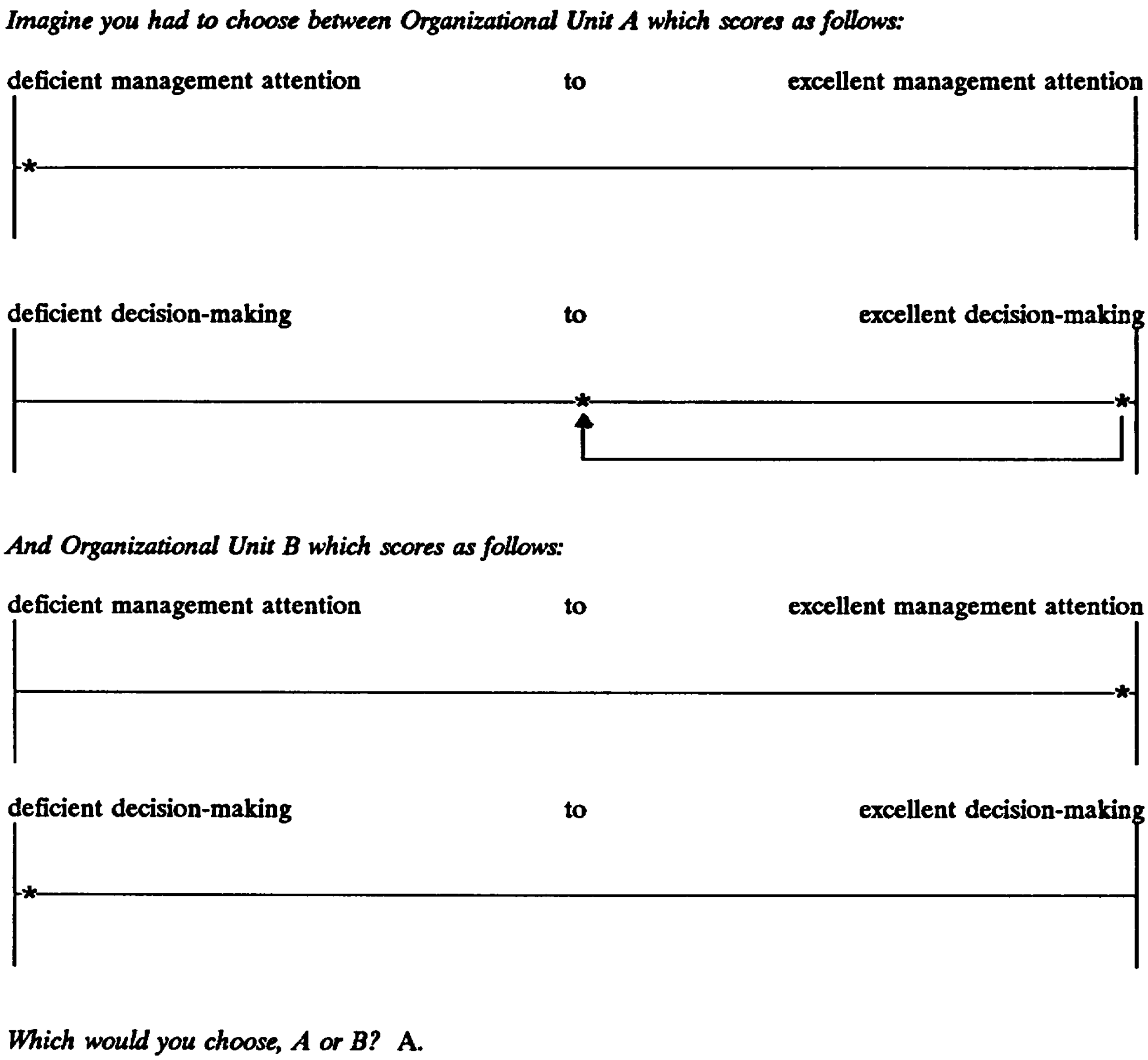


Figure II.4.1. Example of SLIM-MAUD weighting process

Table II.4.3. Operations Unit SLIs

Judge	SLI
1	.92
2	1.00
3	.88
4	.90
5	.91
6	.92
7	.77

Table II.4.4. SLIs for the Organizational Units

Organizational Unit	SLI
Operations	.90
Operations/Maintenance	.77
Instrumentation & Control	.29
Maintenance	.15

These upper and lower bounds were used in this project to derive new base case HEPs for each pre accident initiator human error. A new CMF could then be run, and the hypothetical effect of utilizing organizational and management data in the human error probabilities in PRA could be ascertained.

4.3.1 Algorithm to Incorporate Organizational Factors into PRA

The following algorithm was developed for the purpose of integrating organizational factors into human error probabilities (HEPs):

$$NEWHEP = 10^{[(\log HIHEP - \log LOHEP)(1 - SLI) + \log LOHEP]}$$, which reduces to

$$NEWHEP = (HIHEP/LOHEP)^{(1 - SLI)} * LOHEP,$$

where HIHEP is the upper bound for a specific HEP as determined by Samanta, et al. (1989); LOHEP is the lower bound for a specific HEP also described by Samanta et al.; SLI is the success likelihood index obtained from the SLIM-MAUD program for the HEP-specific organizational unit; and NEWHEP is the new base case value of the HEP. The log of the HIHEP and the LOHEP are used because of the lognormal distribution of human errors. The exponentiation is then used to convert the NEWHEP into the units of the original base case HEP. This algorithm relocated the base case HEP, provided in the PRA, in the interval between the LOHEP and HIHEP using the SLI of the organizational unit to which the human error had been categorized.

4.3.2 Use of Algorithm

This algorithm was first applied to every pre-accident initiator human error, as defined in the Oconee database. The organizational unit of each human error was used to determine the SLI to be applied, and then a new base case HEP was derived. This new base case HEP was then used to obtain a new core melt frequency (CMF) using the PAIRWISE PC program. The new CMF obtained using this process was 7.233E-5. The original CMF for the Oconee PRA is 7.87E-5. An eight percent reduction in CMF is obtained by incorporating the hypothetical data reflecting organizational factors into PRA.

A second demonstration was conducted to determine what the effect of using the same algorithm and SLIs applied to <u>all</u> the human errors in the Oconee PRA would be. The new CMF obtained was 3.579E-6, a 95 percent reduction from the original CMF.

The preliminary nature of the methodology used to obtain these results should be noted again. It is anticipated that future research into the mehtodology detailed here will provide a more refined and credible method for integrating organizational factors into PRA.

4.4 Discussion

Organizational factors had the effect of reducing overall CMF in this test application as a function of the ratings for the organizational units and the weightings of the five organization and management factors. Since the operations unit and the operations/maintenance unit both had very high SLIs (indicating a high likelihood of success), the base case HEP was brought closer to its lower bound. Samanta, et al. (1989) reported that operational errors were the most risk significant errors in the Oconee PRA, and consequently lowering the base case value of these HEPs had a substantial effect on CMF. Conversely, the Instrumentation and Control and Maintenance human errors, which had lower SLIs, did not have a similar impact on overall risk sensitivity, and therefore bringing them closer to their upper bounds did not have a substantial effect on CMF. If different hypothetical data with a low SLI for the operations organizational unit, but the same PRA, had been used, the derived CMF would have been substantially raised instead of lowered.

It is important to note that this test application was simply a demonstration exercise to show how organizational factors might be integrated into a PRA. The data used in this demonstration, however, was hypothetical as this portion of the project was initiated before data collection at the nuclear power plant was completed. However, the ratings were developed in a way so that data from demonstration studies might be used in future applications. No empirical data from the demonstration studies was actually used to derive the ratings for the organizational units. In addition, it was not possible to modify the nuclear power plant demonstration site PRA to make it compatible with the computer system used at BNL in the time allocated to this portion of the project. The data was incorporated into a PRA of a different organization, and it is not known how accurately these data reflect organizational influences at the Oconee power plant. Another issue that needs to be resolved for this application is that a determination to what extent organizational factors might already be reflected in the modeling of the PRA must be made.

This test application demonstration indicates that organizational factors influence might be incorporated into PRA, but it will be necessary to collect the data at a particular plant and then incorporate that data into that plant's PRA. One useful application would be to incorporate this type of plant data into a PRA that is being conducted at the same time as the actual organizational data collection. Another useful application would be to derive possible bounds of CMF variation, due to theoretical variations in organizational factors.

5. REFERENCES

Embry, D.E., Humphreys, P., Rosa, E.A., Kirwan, B., and Rea, K., "SLIM-MAUD: An Approach to Assessing Human Error Probabilities Using Structured Expert Judgement, Volume I: Overview of SLIM-MAUD," NUREG/CR-3518, 1984.

Fenno, R., Home Style: House Members in their Districts, Boston: Little, Brown, pp. 249-295, 1978.

Hays, W.L., Statistics, New York: Holt, Rinehart, and Winston, Inc., 1988.

Human Synergistics, Organizational Culture Inventory, Michigan: Human Synergistics, Inc., 1987.

Komaki, J.L., Zlotnick, S., and Jensen, M., "Development of an operant-based taxonomy and observational index of supervisory behavior," Journal of Applied Psychology, 71, pp. 270-279, 1986.

Miller, L. (ed.), Principles of Everyday Behavior Analysis, Monterey, CA: Brooks/Cole Publishing Company, 1980.

Mowday, R., and Steers, R.M., "The measurement of organizational commitment," Journal of Vocational Behavior, 14, pp. 224-247, 1979.

NSAC-60, "Oconee PRA: A Probabilistic Risk Assessment of Oconee Unit 3," NSAC-EPRI, 1984.

Roberts, K.H., O'Reilly, C.A., Bretton, G.E., and Porter, L.W., "Organizational theory and communication: A communication failure?," Human Relations, 27, pp. 501-525, 1974.

Rosa, E.A., Humphreys, P.C., Spettell, C.M., and Embry, D.E., "Application of SLIM-MAUD: A Test of an Interactive Computer-Based Method for Organizing Expert Assessment of Human Performance and Reliability, Volume I: Main Report," BNL-NUREG-4016, 1985.

Samanta, P., Wong, S., Haber, S., Luckas, W., Higgins, J., and Crouch, D., "Risk Sensitivity to Human Error," NUREG/CR-5319, 1989.

Withey, M., Daft, R.L., and Cooper, W.H., "Measures of Perrow's work unit technology: An empirical assessment and a new scale," Academy of Management Journal, 26, pp. 45-63, 1983.

Wu, J.S., Apostolakis, G.E., and Okrent, D., "On the Inclusion of Organizational and Management Influences in Probabilistic Safety Assessments of Nuclear Power Plants," paper presented at the Meeting of the Society for Risk Analysis, 1989.

Yukl, G., Leadership in Organizations, New Jersey: Prentice-Hall, 1989.

APPENDIX A

DETAILED DESCRIPTION OF ORGANIZATIONAL CONCEPT

Introduction

The organizational literature is replete with models and theories of how organizations are structured. An extensive review of the literature uncovered a lucid and cogent conceptualization of the material in, "The Structuring of Organizations," by Henry Mintzberg (1979). After assimilating the literature, both empirical and theoretical, Mintzberg provides a model to define the basic types of organizational structures and the associated variables that are characteristic of each type. Later work by Mintzberg (1983, 1988) elaborates on the types of organizational structures elucidated in this book, and incorporates new literature into the same basic model.

A description of the variables which are addressed in the literature and the generic types of organizational models that have been identified are presented below. The conceptualizations and definitions below are taken from Mintzberg (1979) so that later discussion will be consistent in terminology and rationale.

Parts of an Organization

The structure of any organization is defined as the sum total of the ways in which it divides its labor into distinct tasks and then achieves coordination among them. Every organization has input and output. The output can be in the form of products or services. There are five basic parts to an organization which comprise its input. The personnel who perform basic work related to the production of products or services are identified as the operating core of the organization. These individuals could be the assemblers in an automobile factory or the professors in an university. The individuals charged with ensuring that the organization serves its mission in an effective way, and also serve the needs of those people who control or otherwise have power over the organization comprise the strategic apex. Examples are the president of a company or the superintendent of a school system. Personnel who are a chain of authority between the strategic apex and the operating core are the middle line of the organization. Senior managers to first-line supervisors would fit into this category. Personnel who are responsible for and effect standardization within an organization are described as the technostructure. Depending upon the type of organization, accountants, trainers, or engineers would fit this description. Finally, the individuals who provide support to the organization outside the operating work flow are the support staff. Included in this group are the cafeteria employees, custodial staff, security, and payroll departments.

Mintzberg's conceptualization of the prototypical structure of an organization is presented in Figure A.1. As the characteristics and parts of each organization become more or less prominent, the shape of the basic structure changes and defines another type. In order to understand the way these types take shape, a discussion of some of the variables associated with an organization follows.

Characteristics of an Organization

Coordinating Mechanisms

Coordinating mechanisms are the fundamental ways in which an organization coordinates its work. There are five basic coordinating mechanisms in Mintzberg, described below. When one individual is in charge of and responsible for the work of others, the mechanism is known as direct supervision. In the standardization of work, the contents of work for an individual are highly specified. Instructions provided to the consumer by a manufacturer to assemble a product is a good example of this mechanism. The standardization of outputs mechanism standardizes the results of an individual's work in the dimensions of a product or the individual's performance in the case of services.

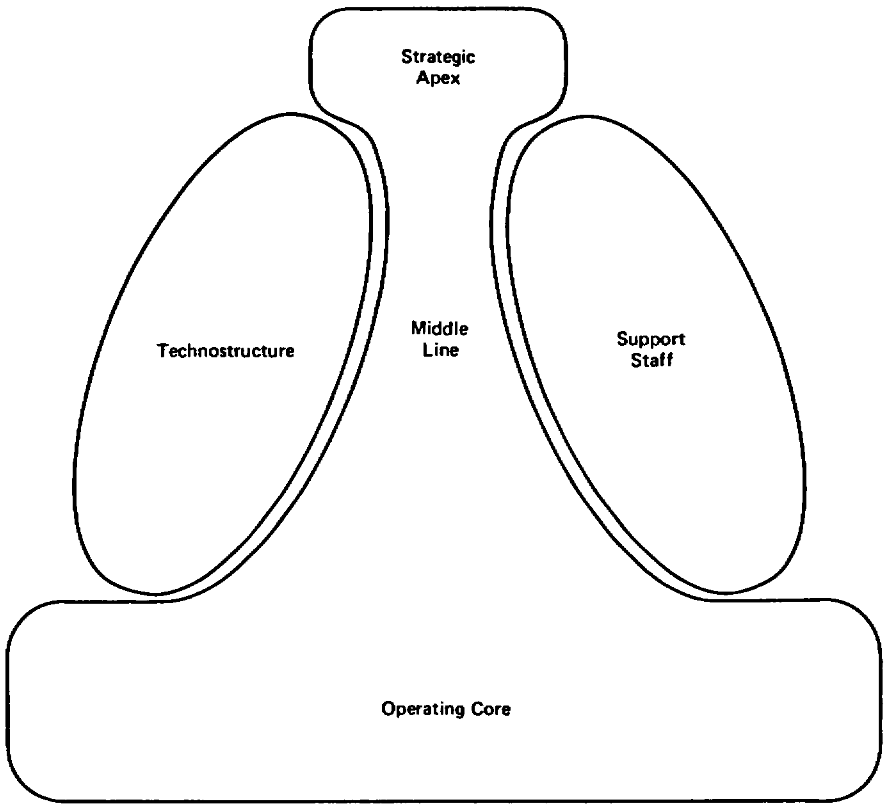


Figure A.1. The five basic parts of organizations*

*Courtesy of Mintzberg, 1979.

A taxi driver has to arrive at a certain destination, but is not necessarily told which route to take to get there. When the type of training required to perform a certain type of work is specified, the mechanism is defined as the standardization of skills. Hospitals hire doctors from reputable medical schools to insure that they are properly trained to perform their job. The last mechanism identified for the coordination of work is mutual adjustment, which is the simple process of informal communication. This process is used in the simplest case and also the most complex organization.

Design Parameters

There are a number of parameters that can be viewed as defining certain characteristics of an organization. Job specialization defines work in terms of breadth and scope (horizontal specialization) and/or depth of job (vertical specialization). Horizontal job specialization refers to the concept of division of labor, while vertical job specialization relates to how much control an individual has over their job. Training is the process by which job-related skills and knowledge are taught, usually outside of the organization. Indoctrination refers to the process by which organizational norms are acquired, or the socialization of the individual for the organization's benefit. Behavior within the organization is usually formalized in one of three ways: by a job description, by the work flow, or by a set of rules or policies within the organization. Grouping coordinates the work within the organization and can be done on the basis of (1) knowledge and skill, (2) work process and function, (3) time (e.g. shiftwork), (4) output, (5) type of client, or (6) geographical location. The two most typical means of grouping are by function and by output (market). The size of each unit within the organization is often related to the type of coordinating mechanism which is used. Generally, the greater the standardization, the larger the size of the unit. Performance control systems and action planning systems allow the organization to plan its future and evaluate its present. The former regulates the results of a unit by setting objectives, budgets, and operating plans, while the latter sets specific actions and decisions for specified points in time. Organizations encourage communication outside formalized channels through liaison devices such as task forces and standing committees. Finally, if all the power in the organization is ultimately in the hands of one individual, the organization is said to be centralized. Centralization can occur both horizontally and vertically.

Contingency Factors

There are certain situations or states that are associated with the use of certain design parameters; these are called contingency factors. The age and size of an organization are two such factors integral to the development of structure. The degree of flexibility of the technical system can dictate a great deal about the structure of an organization. The environment outside of the organization as it relates to the work within the organization is a contingency factor. Power, including the presence of outside control on the organization and/or the personal needs of various members of the organization, is a critical factor in establishing structure.

Structural Configurations

Five "pure" types of structures are identified by Mintzberg and are depicted in Figures A.2 through A.6. The simple structure (Figure A.2) has little or no technostructure and support staff, a loose division of labor, minimal differentiation among its units, and a small managerial hierarchy. A middle-sized retail store would fit this structure. The key part of the machine bureaucracy is the technostructure. There are large-sized units at the operating level, functional basis for grouping, centralized power for decision-making, and a sharp distinction between line organization and staff. A national post office, steel company, or airline are organized in this configuration. A professional bureaucracy relies on the standardization of skills and training and indoctrination for work coordination. It has professionals for its operating core, and gives them considerable control over their work. This structure is common in universities, hospitals, and school systems. The divisionalized form differs from the others in that it is an overall structure superimposed on smaller structures. Each division in this configuration has its own structure held together by a central administrative group. Some of the largest corporations are organized in this configuration. Last, but not least, is the adhocracy which fuses experts drawn from different disciplines into smoothly functioning ad hoc project teams. Little formalization of behavior, high horizontal job specialization and heavy reliance on mutual adjustment characterize this type. The complexity and sophistication of a space agency fits this type of configuration.

Table A.1, from Mintzberg, identifies the five "pure" structural types and the list of variables characteristic of each type. This represents a good summary of the information just discussed and a reference for the next sections.

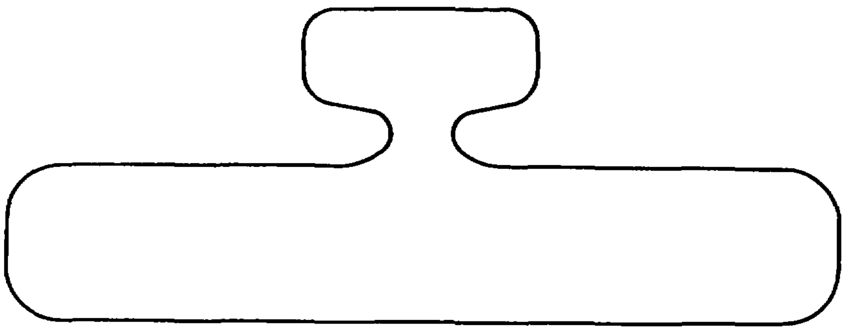


Figure A.2. The simple structure*

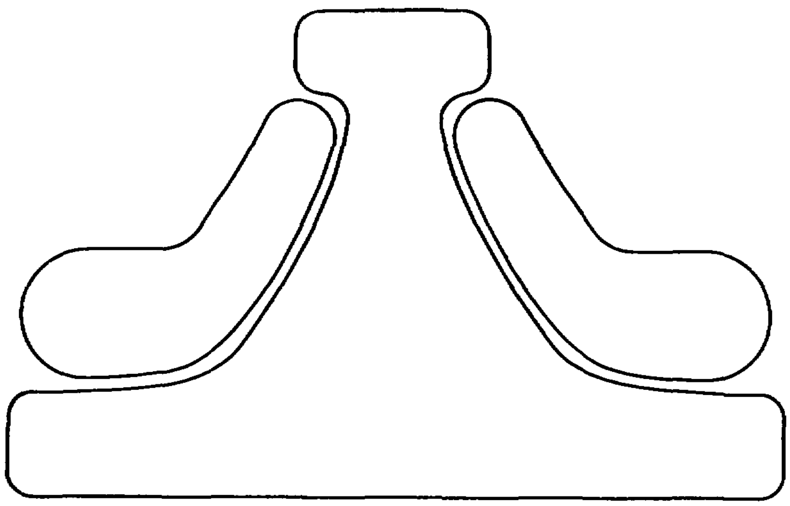


Figure A.3. The machine bureaucracy*

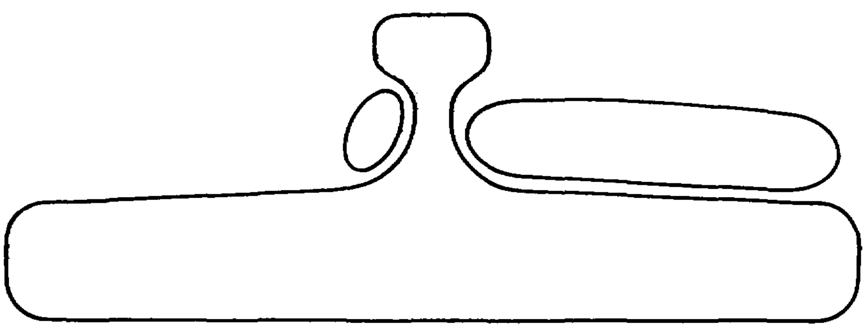


Figure A.4. The professional bureaucracy*

*All figures courtesy of Mintzberg, 1979.

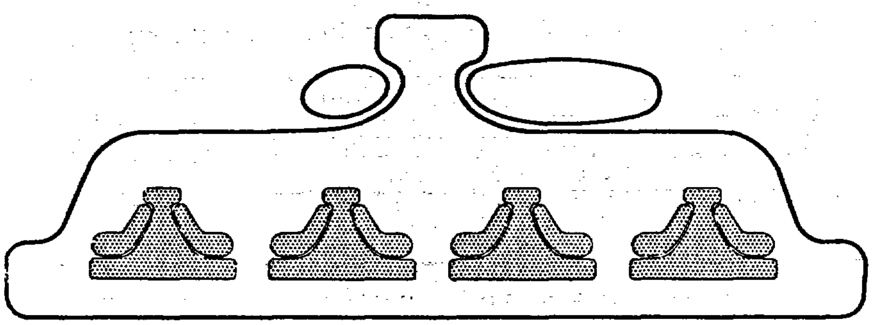


Figure A.5. The divisionalized form*

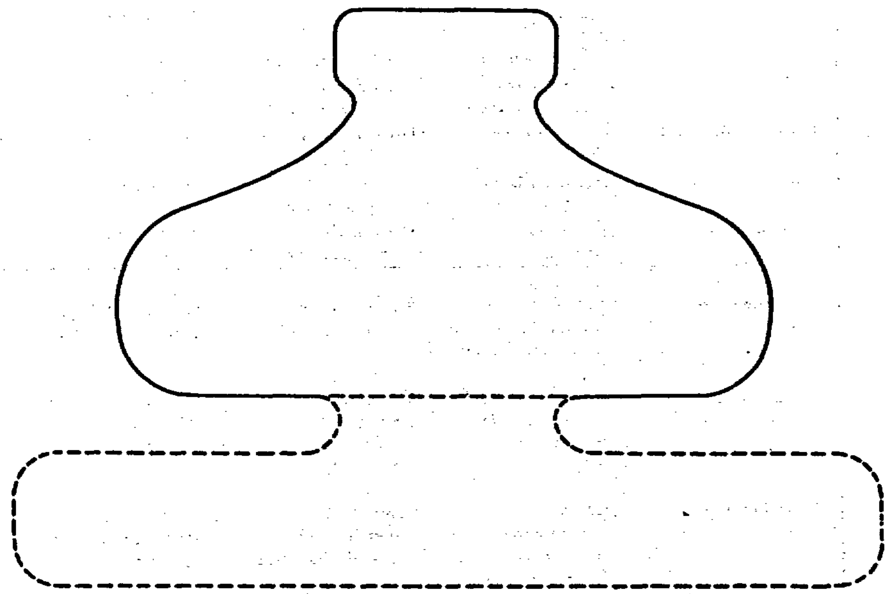


Figure A.6. The adhocracy*

*All figures courtesy of Mintzberg, 1979.

Functional Organization of a NPP

Introduction

The focus will be on an electric generation and distribution utility with a single nuclear power plant unit at one site. In addition, the plant is under operational control by the utility. It should be noted that multiple units at one site and multiple site arrangements do exist within the nuclear industry. The nuclear power division of a utility is a somewhat autonomous division within the corporation's structure and is generally headed by a Vice President for Nuclear Operations. It is extensively supported by its own technical and administrative groups, with some interaction with other parts of the utility.

Table A.1. Dimensions of the Five Structural Configurations*

	Simple Structure	Machine Bureaucracy	Professional Bureaucracy	Divisionalized Form	Adhocracy
Key coordinating mechanism:	Direct Supervision	Standardization of work	Standardization of skills	Standardization of outputs	Mutual adjustment
Key part of organization:	Strategix apex	Technostructure	Operating core	Middle line	Support staff (with operating core in Op. Ad.)
Design parameters:					
Specialization of jobs	Little specialization	*Much horiz. and vert. spec.*	*Much horiz. spec.*	Some horiz. and vert. spec. (between divisions and HQ)	*Much horiz. spec.*
Training and indoctrination	Little tr. and indoc.	Little tr. and indoc.	*Much tr. and indoc.*	Some tr. and indoc. (of div. managers)	Much training
Formalization of behavior, bureaucratic/organic	Little formalization, *organic*	*Much formalization, bureaucratic*	Little formalization, *bureaucratic*	Much formalization (within divisions), bureaucratic	Little formalization, *organic*
Grouping	Usually functional	*Usually functional*	Functional and market	*Market*	*Functional and market*
Unit size	Wide	Wide at bottom, narrow elsewhere	Wide at bottom, narrow elsewhere	Wide (at top)	*Narrow throughout*
Planning and control systems	Little pl. and control	Action planning	Little pl. and control	*Much perf. control*	Limited action pl. (esp. in Adm. Ad.)
Liaison devices	Few liaison devices	Few liaison devices	Liaison devices in administration	Few liaison devices	*Many liaison devices throughout*
Decentralization	*Centralization*	*Limited horizontal decent.*	*Horizontal and vertical decent.*	*Limited vertical decent.*	*Selective decent.*
Functioning:					
Strategic apex	All administrative work	Fine tuning, coordination of functions, conflict resolution	External liaison, conflict resolution	Strategic portfolio, performance control	External liaison, conflict resolution, work balancing, project monitoring
Operating core	Informal work with little discretion	Routine, formalized work with little discretion	Skilled, standardized work with much individual autonomy	Tendency to formalize due to divisionalization	Truncated (in Adm. Ad.) or merged with administration to do informal project work (in Op. Ad.)
Middle line	Insignificant	Elaborated and differentiated; conflict resolution, staff liaison, support of vert. flows	Controlled by professionals; much mutual adjustment	Formulation of div. strategy, managing operations	Extensive but blurred with staff; involved in project work
Technostructure	None	Elaborated to formalize work	Little	Elaborated at HQ for perf. control	Small and blurred within middle in project work
Support staff	Small	Often elaborated to reduce uncertainty	Elaborated to support professionals; Mach. Bur. structure	Split between HQ and divisions	Highly elaborated (esp. in Adm. Ad.) but blurred within middle in project work
Flow of authority	Significant from top	Significant throughout	Insignificant (except in support staff)	Significant throughout	Insignificant
Flow of regulated system	Insignificant	Significant throughout	Insignificant (except in support staff)	Significant throughout	Insignificant
Flow of informal communication	Significant	Discouraged	Significant in administration	Some between HQ and divisions	Significant throughout
Work constellations	None	Insignificant, esp. at lower levels	Some in administration	Insignificant	Significant throughout (esp. in Adm. Ad.)
Flow of decision making	Top down	Top down	Bottom up	Differentiated between HQ and divisions	Mixed, all levels

***Courtesy of Mintzberg, 1979.**

Table A.1. Continued*

	Simple Structure	Machine Bureaucracy	Professional Bureaucracy	Divisionalized Form	Adhocracy
Key coordinating mechanism:	Direct Supervision	Standardization of work	Standardization of skills	Standardization of outputs	Mutual adjustment
Key part of organization:	Strategix apex	Technostructure	Operating core	Middle line	Support staff (with operating core in Op. Ad.)
Contingency factors:					
Age and size	Typically young and small (first stage)	Typically old and large (second stage)	Varies	Typically old and very large (third stage)	Typically young (Op. Ad.)
Technical system	Simple, not regulating	Regulating but not automated, not very sophisticated	Not regulating or sophisticated	Divisible, otherwise typically like Mach. Bur.	Very sophisticated, often automated (in Adm. Ad.); not regulating or sophisticated (in Op. Ad.)
Environment	Simple and dynamic; sometimes hostile	Simple and stable	Complex and stable	Relatively simple and stable; diversified markets (esp. products and services)	Complex and dynamic; sometimes disparate (in Adm. Ad.)
Power	Chief executive control; often owner-managed; not fashionable	Technocratic and external control; not fashionable	Professional operator control; fashionable	Middle-line (control; fashionable (esp. in industry)	Expert control; very fashionable

*Italic type designates key design parameter.

*Courtesy of Mintzberg, 1979.

In general, the entire nuclear power division of a utility is physically located at the plant site. Some utilities do maintain a few groups, such as nuclear engineering, at corporate headquarters. At the site, the Plant Manager (under the V.P. for Nuclear Operations) is directly responsible for all site activities. In general, the two main goals of the nuclear division are the safe operation of the plant and the economical generation of electricity by the NPP. In addition, the United States Nuclear Regulatory Commission (U.S. NRC) oversees the entire operation of each commercial nuclear power plant in the country by many actions which include maintaining an on-site presence, and ensuring enforcement of many rules and regulations for safe operation.

Organizational Units

The functional organization at a nuclear power plant generally contains the following units: Operations, Maintenance, Instrumentation & Control (I&C), Quality Assurance (QA), Health Physics, Chemistry, Independent Safety Engineering Group (ISEG), Administration, Nuclear Licensing, Outage Planning, Reactor Engineering, Design Engineering, Records Management, Spare Parts, Security, and Training. There are also two important standing committees: the Offsite Review Committee and the Plant Operations Review Committee. A typical single unit site employs 300 to 600 people with increased numbers during major outages. The size of each specific unit varies considerably across plants. Each identified unit is described in detail below. Those not familiar with nuclear power plants should read this section before proceeding.

<u>Operations</u>

The Operations Manager has the overall responsibility for this unit. Several engineers along with some administrative help constitute the manager's support staff. The operators, who physically manipulate the equipment and controls necessary to run the plant, are organized into rotating shifts. Typically, there are five or six different shifts, those standing watch on the plant, one on vacation, one in training, and one on relief. Each shift has a Shift Supervisor and at least two licensed control room operators. A few auxiliary operators (non-licensed individuals) are usually stationed outside the control room. The Shift Supervisor is directly responsible for all plant operations during that shift. In the absence of the Plant Manager, for example, on an overnight shift (backshift), the shift supervisor has the responsibility of the Plant Manager. All operations at the plant are covered by very detailed procedures, and are subject to monitoring by different units outside of operations such as quality assurance and the independent safety engineering groups.

Maintenance

This unit is comprised of a Maintenance Manager (with some administrative assistants), engineers, foremen, and mechanics. Maintenance personnel are trained individuals, but non-licensed. This unit is responsible for all mechanical and electrical maintenance in the plant, both preventive and corrective. Almost all the work in maintenance is dictated by procedure and performed during the day shift, with a few individuals available on other shifts.

Instrumentation and Control (I&C)

This unit has a Manager, with administrative help, often an engineer, and several foremen. I&C technicians are highly trained individuals who perform the calibration, maintenance and repair of electronic components used for instrumentation and control purposes. Work in this unit is generally procedurally controlled, but can be more creative when trouble-shooting is required. Most routine calibrations are done on the day shift, but personnel are required on other shifts for repair work.

Quality Assurance (QA)

The Quality Assurance Manager has several engineers and technicians in this unit who perform audits and other quality assurance services. This unit observes the operations, maintenance, and I&C units to ensure that they follow all procedures correctly, and that paperwork is properly completed. Audits of various plant units and activities are conducted regularly to ensure that all rules and regulations are adhered to.

Test and Performance

Generally a small unit, the test (surveillance) and performance group contains several engineers. There is an extensive amount of routine testing required in a nuclear power plant which is generally delineated in the plant's Technical Specifications. This unit writes test procedures, performs and supervises testing, and evaluates testing results performed by themselves and other units for compliance with the specifications.

Health Physics (HP)

A Health Physics Supervisor heads this unit with support from engineers, and health physicists technicians. A nuclear power plant contains radioactive material at all times. This unit controls and monitors all aspects of the radiation control and protection program, including procedures, survey, clean-up, and work control, for both plant employees and visitors on site. This unit is routinely on shift to provide support to the operations and maintenance units as well as where ever needed.

Chemistry

The chemistry unit at a nuclear power plant consists of a Chemistry Supervisor, foremen and technicians responsible for water chemistry control. These individuals perform chemical sampling and analyses, and make chemical additions to the water as necessary.

Independent Safety Engineering Group (ISEG)

This unit is comprised of a Supervisor and several degreed engineers whose function is to evaluate the safety of the plant design, operations and testing.

Nuclear Licensing

This unit usually consists of engineers and a support staff. The primary function of this unit is to interface with the NRC, both on- and off-site. The unit ensures that programs and commitments at the plant are in place to comply with the NRC regulations.

Outage Planning

Generally, a nuclear power plant has to refuel about once every 13-18 months. During a refueling outage, other maintenance and testing activities are required. Due to the large cost associated with a plant not operating, careful planning and scheduling of activities is needed to optimize the use of downtime at the plant. The size of this unit varies, but usually consists of a Supervisor and several outage planners.

Reactor Engineering

The short- and long-term management of reactor fuel utilization and reactor core distribution is the responsibility of this unit. The group is headed by a Reactor Engineer and consists of several engineers and a support staff. Personnel in this unit are highly trained individuals performing complex tasks. Interface with shift personnel is often necessary for short-term recommendations.

Design Engineering

The size of this unit varies across plants, but could be large enough to contain several subgroups for different engineering disciplines. An Engineering Manager heads the unit which is comprised of engineers and draftsmen. This unit's position within a nuclear plant varies considerably between utilities. Its purpose is to provide standard engineering and design services for plant modifications and analyses.

Records Management

A nuclear power plant has very detailed record keeping requirements. This unit handles all documents such as codes, standards, procedures, vendor manuals, drawings, operator logs, and test results. The unit typically consists of a Supervisor and several clerks and technicians.

Spare Parts

Nuclear power plant equipment and parts must be traceable to ensure proper operation. This unit supervises the supply and distribution of parts needed for maintenance and modification of the plant. This unit is sometimes included within the maintenance unit.

Security

A typical security force is about 100 people and includes such high technology items as card reader access, metal detectors, explosive detectors, microwave barriers, remote cameras, and computer monitoring. Security units interface with all activities at the plant site. This unit is organized into shifts similar to the Operations unit, with a Security Manager and Shift Security Supervisor.

Training

A large and varied amount of training is required at a nuclear power plant. The unit generally has a Manager and full-time staff of instructors with courses continually offered during the year. The unit serves many of the other units at the plant.

Offsite Review Committee (ORC)

This is a utility corporate-level committee consisting of approximately 8-10 members. It is tasked with review and audit responsibility for the NPP to help ensure safe operation.

Plant Operations Review Committee (PORC)

This is a very important plant level committee for ensuring safe operation. It is comprised of important middle-line managers such as the Operations Manager, Maintenance Manager, I&C Manager, and the Assistant Plant Manager. Their duties include approval of all plant procedures, design modifications, and tests.

An Organizational Concept of a Nuclear Power Plant

Introduction

Using the model provided by Mintzberg, the NPP can be identified as a particular organizational structure. A fit into a "pure" type for the entire plant is not evident, but a basic structure does take shape, and the inconsistencies within the model are very manageable within Mintzberg's theory.

Utility Structure

Of primary concern is the organizational structure of the NPP itself. Its relationship to the utility structure will be considered when the flow of decision-making and authority within the utility directly impact on the plant. This channel of communication generally occurs through the Vice President of Nuclear Operations, or another individual in the strategic apex of the plant structure.

For most utilities, the divisionalized form best represents the corporate structure. It appears that the Division of Nuclear Operations is identified as one division situated in the operating core of the utility. The Vice President for Nuclear Operations represents the middle line of the corporate structure, but will become the strategic apex of the plant structure. The key coordinating mechanism for the divisionalized form, in this case, the utility, is the standardization of outputs and the various design parameters and contingency factors associated with this structure conform closely to those described by Mintzberg in Table A.1.

Plant Structure

The model of a NPP under consideration is initially best described by the machine bureaucracy structural type and is presented in Figure A.7. The key part of the machine bureaucracy is the technostructure, and many of the nuclear power plant organizational units fit into that technostructure. Units such as licensing, training, quality assurance, health physics, engineering, planning and scheduling, testing and performance, and the independent safety and engineering group, comprise the technostructure of the plant's organization. These are highly developed groups which formalize and standardize the work primarily of the operating core. Much of the work and behavior in a NPP is highly formalized and procedure-based, resulting in the use of standardization of work as a key coordinating mechanism within the organization.

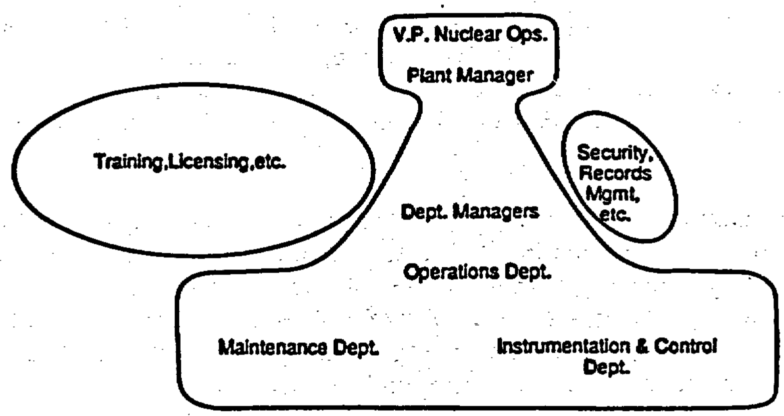


Figure A.7. Organizational structural concept of a nuclear power plant

Support staff in a machine bureaucracy are also organized into well developed units to reduce the ambiguity of their function and position within the organizational structure. Records management, payroll, administration, security, cafeteria and housekeeping personnel are examples of the support staff of a NPP.

The strategic apex of the NPP usually consists of the Vice President for Nuclear Operations, from the utility structure, the Plant Manager and Assistant Plant Manager. These individuals are responsible for the fine tuning of the plant, the coordination of functions, and the resolution of any conflicts occurring among the various units in the plant.

At the heart of the plant is the operating core. The operating core is comprised of three different groups: operations, maintenance, and instrumentation and control (I&C). In the machine bureaucracy described by Mintzberg, the entire operating core would be horizontally centralized. In an NPP, the operations unit has some vertical centralization, both functionally and structurally, over the maintenance and I&C units. Therefore, this unit conceptually resides in a different place in the proposed organizational model than the other two units. We propose that part of the operations unit comprises the middle line structure in the NPP. Specifically, the Operations Manager and Shift Supervisor are part of the middle line, while the auxiliary (non-licensed) and reactor operators remain part of the operating core.(Also, included in the middle line are the managers of other departments in the NPP.) The position of the senior reactor operators is dependent upon their functional role, which is often dependent upon the operating conditions within the plant. The senior reactor operators could, under certain circumstances, reside in the middle line structure of the plant. Under normal operating conditions, they are part of the operating core.

The maintenance unit within the operating core of the NPP appears to be organized and run like a machine bureaucracy. The majority of work is routine and standardized, and authority is vertically centralized. The instrumentation and control unit, however, somewhat resembles the structural type of a professional bureaucracy. The personnel in this unit are skilled professionals with much individual autonomy over their work. Centralization in the I&C unit is both vertical and horizontal. One exception to the professional structural type within I&C is that the work being performed is often standardized, eliminating the creativity and discretion of the "true professional."

Key Supervisory/Management Functions and Processes

The nuclear organization and management analysis concept (NOMAC) was developed as part of the work scope under Task 1 in this project. The concept's basic utility lies in this description of the human organization of a nuclear power plant. NOMAC is a dynamic, interactive, and behavior-oriented characterization of the plant and emphasizes functional relationships between the units in the plant. Consideration is also given to the internal and external forces on the nuclear power plant and how they affect the performance of the organization.

The human organization of a nuclear power plant depends primarily on the standardization of its operating work processes for coordination in meeting its goal of safe operation. For a specific plant, these processes will be empirically validated. The validation will involve identification of the specific managers and supervisors who have key influences on the quality of each process. The nature of these influences will be described as a set of behaviors which each key manager and supervisor exhibits. In addition, management functions and processes will be assessed at the organizational behavior level. The attitudes, policies, and behaviors projected by upper management influence the nuclear power plant's organizational climate. This influence is then permeated to the middle- and first-line management functions. All these influences will be assessed during the data collection phase of this project.

If we assume that the nuclear power plant operates in a machine-like manner, then the key process of the organization is the standardization of work as described earlier. Four subprocesses can be considered under the standardization of work; the design of standards (including procedures for hardware and software components of the plant), the application of standards (the conveyance to personnel performing the work which is involved), the feedback on standards (communication and training of refinements to modify the standards) and the override of standards (modification in the event of abnormal conditions).

The key supervisory and management functions can then be identified in terms of these processes of standardization. The development of the standards occurs largely within the technostructure of the organization. Department heads of the units in this component are critical in developing the policies and procedures included in standardization. The middle line managers are responsible for interpreting the standards that are designed. In turn, the supervisors of the operating core ensure implementation of the standards through their employees. Feedback for modifications to the standards should occur across the components of the organization through these supervisory/management functions as well.

Summary

The NPP is hypothesized to be a machine-like organization with some differences in structure within the operating core. These differences, however, do not significantly effect the overall organization of the plant and how it functions. An important condition that drives this organization to a machine bureaucracy is its special need for safety. Procedures are formalized extensively to ensure that they are carried out and result in safe operation. Key supervisory and managerial functions are best depicted within the machine bureaucracy, and most authority within the plant is vertically centralized.

The proposed organizational structure of a NPP that is described provides one means of conceptualizing the dynamics of a NPP organization. The model as described by Mintzberg is process-oriented and allows for the identification of the key supervisory and managerial influences on plant performance through the evaluation of organizational processes. Examination of the design of standards, both in hardware and software (technostructure), the application of standards through the operating core and the feedback on these standards from the operating core back to the technostructure, are critical in understanding the functional dynamics of an NPP. Evaluation of the design parameters, functional characteristics, and contingency factors associated with the structural type identified will also help to uncover the pathways by which the organization functions. Behavioral factors unique to supervisory and managerial influences can then be identified for further examination.

References

Mintzberg, H. (1979). The Structuring of Organizations, Prentice-Hall.

Mintzberg, H. (1983). Power In and Around Organizations, Prentice-Hall.

Mintzberg, H. (1988). Mintzberg on Management: Inside our Strange World of Organizations, Free Press.

NRC FORM 335 (2-89) NRCM 1102, 3201, 3202

U.S. NUCLEAR REGULATORY COMMISSION

BIBLIOGRAPHIC DATA SHEET

(See instructions on the reverse)

1. REPORT NUMBER (Assigned by NRC. Add Vol., Supp., Rev., and Addendum Numbers, if any.)

NUREG/CR-5538
BNL-NUREG-52301
Vol. 1

2. TITLE AND SUBTITLE

Influence of Organizational Factors on Performance Reliability

Overview and Detailed Methodological Development

3. DATE REPORT PUBLISHED

MONTH	YEAR
December	1991

4. FIN OR GRANT NUMBER

FIN A3956

5. AUTHOR(S)

S. B. Haber, J. N. O'Brien, D. S. Metlay, D. A. Crouch

6. TYPE OF REPORT

Technical

7. PERIOD COVERED *(Inclusive Dates)*

8. PERFORMING ORGANIZATION – NAME AND ADDRESS *(If NRC, provide Division, Office or Region, U.S. Nuclear Regulatory Commission, and mailing address; if contractor, provide name and mailing address.)*

Brookhaven National Laboratory
Upton, NY 11973

9. SPONSORING ORGANIZATION – NAME AND ADDRESS *(If NRC, type "Same as above"; if contractor, provide NRC Division, Office or Region, U.S. Nuclear Regulatory Commission, and mailing address.)*

Division of Systems Research
Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
Washington, DC 20555

10. SUPPLEMENTARY NOTES

11. ABSTRACT *(200 words or less)*

This is the first volume of a two-volume report. Volume II will be published at a later date. This report presents the results of a research project conducted by Brookhaven National Laboratory for the United Stated Nuclear Regulatory Commission, Office of Nuclear Regulatory Research. The purpose of the project was to develop a general methodology to be used in the assessment of the organizational factors which affect performance reliability (safety) in a nuclear power plant.

The research described in this report includes the development of the Nuclear Organization and Management Analysis Concept (NOMAC). This concept characterizes the organizational factors that impact safety performance in a nuclear power plant and identifies some methods for systematically measuring and analyzing the influence of these factors on safety performance.

This report is divided into two parts; Part I presents an overview of the development of the methodology, while Part II provides more details and a technical analysis of the methodological development. Specifically, the results of two demonstration studies, the feasibility of the methodology, and a specific application for which the methodology was developed are presented.

12. KEY WORDS/DESCRIPTORS *(List words or phrases that will assist researchers in locating the report.)*

organizational models; personnel - behavior; personnel - human factors; management; nuclear power plants - organizational models; nuclear power plants - personnel; reactor safety; performance; working conditions; decision making; reliability; risk assessment; performance testing; probability; quality assurance; administrative procedures; U.S. NRC; human factors - research programs; BNL; functional models.

13. AVAILABILITY STATEMENT

Unlimited

14. SECURITY CLASSIFICATION

(This Page) Unclassified

(This Report) Unclassified

15. NUMBER OF PAGES

16. PRICE

NRC FORM 335 (2-89)

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, $300

SPECIAL FOURTH-CLASS RATE
POSTAGE & FEES PAID
USNRC

PERMIT No. G-67