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Organizational Analysis and Safety for Utilities with Nuclear Power Plants

Perspectives for Organizational Assessment

Prepared by R. N. Osborn, J. Olson, P. E. Sommers, S. D. McLaughlin, M. S. Jackson,
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ABSTRACT

A review of the generic organization literature is focused into a model outlining key relationships among organizational factors and nuclear power plant safety. Volume I of the report contains an overview of the literature. Volume II provides a more detailed analysis of those organizational factors which are expected to be associated with measured indicators of plant safety.

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Richard N. Osborn
Seattle

INTRODUCTION

PURPOSE AND SCOPE OF VOLUME II

This two-volume report presents the results of initial research on the feasibility of applying organizational factors in nuclear power plant (NPP) safety assessment. Volume I of this report contains an overview of the literature, a discussion of available safety indicators, and a series of recommendations for more systematically incorporating organizational analysis into investigations of nuclear power plant safety. The six chapters of this volume discuss the major elements in our general approach to safety in the nuclear industry. The integration of these elements was undertaken in Volume I. Here, we go into each element in more detail.

It should also be stated at the outset that the proposed model is not the only legitimate approach to safety. Rather, we see the model (or one like it) as an essential part of a comprehensive treatment. It does not attempt to supplant the hardware and training approaches that are somewhat better developed in the industry. But neither would we agree that the hardware and training concerns are sufficient in themselves. The organizational approach and the specific model advanced here can contribute to improved plant safety over and above hardware and training. Further, we believe that the organizational approach is one of the most cost effective ways to improve plant safety since it requires few capital or staffing changes.

Chapter 1 of this volume focuses on the key link between organizational design and safety. Here the concern is with the logical and empirical relationship between the way the organization is put together and its ability to operate safely. Because very little empirical research has been done on this relationship, the approach taken in this chapter is to focus on other organizational outcomes--quality, efficiency, innovation, and compliance--that are seen as necessary precursors to nuclear power plant safety. The organizational literature provides many insights into how to design organizations to achieve these "intermediate outcomes," and these are reviewed in this chapter.

Central to our model is the notion that organizational design is itself contingent on a number of other factors. One of these factors is organizational governance, or the set of management beliefs and activities concerning appropriate ways of organizing and making decisions. The organizational literature tells us that organizations vary significantly in the nature of their governance systems. Organizations with different governance systems will have different preferred modes of design and orientations toward safety. Chapter 2 reviews the organizational governance literature and applies it to the nuclear power industry setting.

A common fallacy among managers is that there is one best way to organize. The research literature, on the other hand, supports a contingency view. An appropriate organizational design is one that is congruent with the demands placed on it. Since the demands vary from organization to organization, so do appropriate designs. Chapter 3 places the nuclear industry in context

and shows some of the important ways that externally imposed demands vary from utility to utility. The role of these demands in determining organizational design and safety is outlined in this chapter.

Chapter 4 is a review of the regulatory experience of selected federal agencies in the area of management and organizations. The best design model is useless if it is inappropriate within the regulatory framework. This chapter shows how the organizational approach is currently being used by other federal agencies and how this experience is relevant to the regulatory needs of the NRC.

Chapters 5 and 6 are concerned with the empirical investigation of the link between organization and safety. Chapter 5 investigates the nature of the organizational design data available to the NRC. Chapter 5 holds that existing data is not fully adequate to test the propositions suggested by our model. Chapter 6 turns our attention to measures of safety in nuclear power plants. This chapter reviews past attempts at measuring safety and suggests a multiple indicator approach based on existing data as an interim solution to the problem.

This volume reviews the literature from several theoretical perspectives, and then turns to consideration of opportunities for empirical research. For those readers who wish to more closely link theoretical and empirical issues, it may be desirable to turn to Chapter 5, Section 5.1, after reading Chapters 1 and 2, and to follow a perusal of Chapter 3 with Chapter 5, Section 5.2.

Because this is a two volume report, we also want to alert the reader of this volume to the integration of the above elements contained in Volume I. The sections that follow outline this integration and the recommendations that come out of it.

The remaining portions of this introduction repeat selected portions of integration provided in the executive summary.

WHY AN ORGANIZATIONAL ANALYSIS

In an industry dominated by technical concerns, it is logical to ask why one should be concerned with an organizational analysis. There are several reasons.

- Some utility executives, Nuclear Regulatory Commission (NRC) officials, and critics have suggested that organization and management are often root causes for both good and poor performance.
- Experience in other industries suggests that improvements in management and organization have important performance implications.
- Preliminary analyses suggest potentially important associations between organizational factors and selected safety indicators for current nuclear facilities.

- Some accident postmortems have strongly suggested that inadequacies in management and organization were contributing factors to the occurrence and severity of accidents.

AN ORGANIZATIONAL PERSPECTIVE: A PREVIEW

Three broad categories of potentially relevant variables form the basis for this report: organizational contingencies, intermediate outcomes, and safety indicators.

Organizational Contingencies

Early organizational studies searched for universal processes applicable to all firms. Now many in organizational analysis suggest that different types of success are contingent upon different organizational factors. Initial work in contingency theory suggested that the internal anatomy of the firm should be matched to the size and scope of its operations, the character of the work to be performed, and the environmental pressures facing the company. More recent work has stressed the need to incorporate management philosophy (organizational governance). A more complete discussion of specific organizational factors is found below.

Intermediate Outcomes

Recent work also suggests that organizational factors should be adjusted to the types of success desired. Long-term safety appears to be enhanced to the extent a utility promotes quality, compliance, efficiency, innovation, and employee maintenance (e.g., morale, commitment, retention). These desirable conditions are called intermediate outcomes because they are expected to be prerequisites for safe operation of a nuclear power facility. Specifically, we focus on the capability of a utility to:

- (a) emphasize quality with an attention to the unique aspects of the work process
- (b) comply with numerous and sometimes conflicting constraints (including regulatory constraints)
- (c) produce electricity efficiently
- (d) anticipate, identify, and resolve complex problems with innovative solutions
- (e) foster employee maintenance.

Safety Indicators

In the near-term, it is important to isolate specific incidences which appear to reflect the "safeness" of particular plants and facilities. While each available individual indicator appears to be flawed in one way or another, all are not deficient in the same way. By utilizing several measures, it appears possible to compensate for the weakness in one

indicator by incorporating the strength of a second or third indicator. In this report, ten different indicators are evaluated and a method for building upon the strengths of selected indicators is proposed.

THE IMPORTANCE OF SPECIFIC ORGANIZATIONAL FACTORS

The organizational literature suggests that many potentially important organizational factors may be grouped into four categories: the environment, the context, organizational governance, and organizational design. A brief sketch of each follows.

The Utility's Environment

Environmental factors help shape the performance demands placed on the utility, the resources available to utility managers, and the boundaries for action. While all nuclear utilities may be subject to similar general economic trends and NRC requirements, each also faces a unique set of pressures and conflicting demands. Differences in local setting, state regulators, and support offered by vendors appear to alter the capability of a utility to achieve desired intermediate outcomes. Further, most nuclear utilities are not freestanding, independent firms. They are quasi-autonomous units which are embedded in quite complex ownership and power-sharing networks.

Conflicting external demands on utilities for greater efficiency, safety, and regulatory compliance are becoming more difficult to meet as utilities face a more uncertain, contentious, and highly interdependent socio-economic setting. Building and operating a nuclear power plant has become more than a technical challenge. For example, it appears that:

- If greater environmental volatility is coupled with fewer external resources and more dependence upon outside organizations (more complexity), nuclear utilities will find it more difficult to promote quality, innovation, compliance, efficiency, and employee maintenance, thus threatening safety (see Volume I, p. 45).

The Utility's Context (History, Size and Technology)

Utilities are among our largest and oldest institutions. The building of a nuclear facility brings dramatic changes in the size of the organization, its mix of technology, and the sophistication of the process used to generate power. Utilities with a tradition of conservative practices and an attention to sound fiscal management may have difficulty adjusting to a dramatic increase in the number of employees with highly specialized skills. A nuclear facility brings changes in kind, not just in degree, of the demands, constraints, and opportunities facing a utility. For example, it appears that:

- More sophisticated nuclear technology is expected to result in a more diverse organizational design with greater emphasis on quality and administration (see Volume I, p. 47).

- While more sophisticated nuclear technology may yield more emphasis on quality and innovation, it may result in lower efficiency and compliance (see Volume I, p. 47).
- Larger nuclear divisions can take advantage of economies of scale for greater potential efficiency (see Volume I, p. 46).

Organizational Governance (Management Philosophy)

One of the key tasks of top management is to develop, implement, and maintain an overall strategy which allows the utility to recognize and cope with the additional complexity inherent in nuclear operations. The form of organizational governance is a key element underlying the myriad of decisions utility executives must make to successfully operate a nuclear facility. Organizational governance helps define what is important, how issues will be defined, who should (and should not) be involved, plus the range of acceptable alternatives for implementation. A well-designed form of organizational governance permits and facilitates resolution of the competing demands, constraints, and choices facing the nuclear utility.

Three ideal types of organizational governance are useful in analyzing nuclear utilities. A traditional type emphasizes bureaucracy (administrative controls, written policies, elaborate written procedures). A modern type stresses single-set values where individual judgment is to be used to successfully implement policy. A federal type emphasizes negotiation and the integration of several differing views through effective conflict resolution. These various forms of governance suggest several safety relationships. For example:

- The traditional form of governance will be associated with higher efficiency and compliance but lower quality and innovation (see Volume I, p. 48).
- The modern form of governance will be associated with erratic compliance and higher efficiency (see Volume I, p. 48).
- The federal form will be associated with higher quality and innovation, and lower compliance (see Volume I, p. 48).

Organization Design

How the organization is designed (its anatomy) plays an important role in which issues get resolved, which technical skills are developed, what relations with outside technical units will be fostered, and how problems are to be analyzed and prevented. Four aspects of organizational design are emphasized in this report: (a) how work is divided among units and individuals, (b) the nature and types of controls placed on units, managers, and individuals, (c) the mechanisms for coordination, and (d) the developmental mechanisms which foster, reinforce, and direct the actions and decisions of individuals. While each aspect of design appears important, the pattern across these aspects also appears related to intermediate outcomes. Some organizations may select a rigid, machine-like pattern--

a mechanistic design, while some may evolve a more fluid professional pattern--an organic design. Due to environmental, contextual, and governance concerns, it appears that nuclear utilities should consider a mix of mechanistic and organic patterns. Such a mix may be called a diverse design. Several example propositions illustrate the potential importance of organizational design:

- More organic organizational designs promote higher quality, innovation, and employee maintenance (see Volume I, p. 50).
- More mechanistic organizational designs promote higher plant efficiency for plants early in their life cycle (see Volume I, p. 50).
- For routine aspects of the technology, a mechanistic form will be associated with greater compliance; but where measurement is difficult or several alternatives for compliance are available, the more organic design will be associated with higher compliance (see Volume I, p. 50).

Combination Effects and New Issues

There appear to be potentially significant combination effects among factors. While these effects may be most difficult to understand, they could well be the most important. For example:

- With greater environmental complexity (sustained over a lengthy period) there will be a shift toward a federal form of governance and a more diverse organizational design (see Volume I, p. 45).
- The larger the nuclear organization, the more mechanistic it is and the less it tends to emphasize quality (see Volume I, p. 46).
- The dysfunctional effects of size on intermediate outcomes may be partially offset by a change toward a federal form of organizational governance and a more diverse organization design (see Volume I, p. 46).
- Utilities with several types of nuclear plants will experience pressure toward a more diverse organizational design (see Volume I, p. 47).

Combination effects raise a series of new issues. Four issues appear particularly important. First is the question of the interdependence among the factors needed for safety. A simple change in one element of one organizational factor (e.g., the addition of a new headquarters staff unit for safety review) suggests a change in an element of another factor (e.g., a revised view of authority--an element of management philosophy). Are both changes needed? Are both desirable? Could the positive safety effects of one change be more than offset by changes in other factors?

A second issue deals with organizational capability. Assuming that changes are desired, are all factors and all elements within each factor subject to change at the same rate and with similar ease? Probably not. Thus, the burden for change is likely to rest more on some organizational factors than others. Presuming that organizational design is easier to change than other factors in the model, design becomes a major mechanism for meeting new demands. However, it may not always be possible for utilities to develop an organizational design which (a) meets new demands, (b) meshes with its existing environment, context, and form of governance, and (c) continues to provide a viable tool for reaching toward quality, compliance, efficiency, innovation, and employee maintenance.

The third issue also deals with capability. It concerns the role of organizational factors in successfully implementing several changes simultaneously. For instance, could a myriad of mandated technical changes, each of which attempts to improve safety, overload the utility's organizational capacity for successful implementation?

A fourth issue centers on how organizational factors may influence other potential safety determinants. For instance, presume the utility cannot develop an organizational design which helps it meet all the inconsistent demands for change. Part of the burden falls on managers and workers. The implications for safety are clear, even if one presumes that utility executives and employees are unusually competent and vigilant. Just as we do not know which atom will split in a chain reaction, we do not know which mistake, oversight, or failure by a particular manager or worker may threaten health and safety. We can expect, however, that as organizational factors place a greater burden on individual managers and workers, the likelihood and severity of error increases.

OVERALL CONCLUSIONS

Preliminary analysis suggests that important organizational factors are associated with several indicators of safety. However, while considerable information on nuclear utilities exists, comparatively little is now in a form which facilitates systematic analysis. Specifically, our analysis suggests that:

- (1) Potentially important organizational factors can be measured.
- (2) Organizational analyses made by NRC and industry can be made less judgmental by the adoption of a systematic review protocol based on existing organizational knowledge.
- (3) Some, if not much, of the existing industry and NRC attention may not now be focused on those organizational factors that are potentially most important for safe operation of a nuclear power plant.
- (4) Existing safety indicators are flawed, but appear flawed in quite different ways. It appears possible to develop less biased and more meaningful indicators of safety performance with existing data using a "multiple indicator" approach.

LIMITATIONS

The report constitutes only a first step. While it may provide new insight into the question of nuclear power plant safety, it is not a definitive treatment. We did not uncover any empirical analysis linking organizational factors and the safety of nuclear power plants. Further, organizational analysis is a comparatively new field--one where controversy abounds. Finally, the literature review did not attempt to analyze the extent to which the predictors are amenable to different regulatory strategies.

CHAPTER 1

ORGANIZATIONAL DESIGN AND SAFETY

1. INTRODUCTION

1.1 Purpose

The purpose of this review is to summarize the literature linking organizational design characteristics to nuclear power plant safety. In so doing, it presents arguments indicating that (1) organizational design characteristics are relevant to an understanding of nuclear power plant safety, and (2) that certain design approaches are probably more supportive of particular aspects of plant safety than are others. Based on these two arguments the review also takes the position that attention to organizational design is a low cost (minimally intrusive) and potentially high benefit (significantly improved safety) strategy for regulating the nuclear power industry.

The organizational perspective on safety is a new one. Consequently, only a small amount of literature exists which formally links design characteristics to safety. Empirical investigations of this relationship are only now starting within the nuclear industry. In addition, most of the existing studies of safety within other industries focus on the individual worker in terms of the causes and consequences of unsafe behavior. This focus tends to preclude a formal treatment of broader design characteristics. However, a substantial amount of literature exists linking organizational design characteristics to a set of logical precursors to safety--quality, efficiency, innovation, and compliance. By drawing on this literature, it will be possible to make predictive statements concerning the way that variation in organizational design leads to variation in plant safety performance.

1.2 Outline of the Review

There are three major sections to this review. The first section introduces the organizational perspective on safety. In this section the organizational perspective is defined and contrasted with other ways of viewing safety. In addition, this section addresses what we believe to be the advantages and strengths of the organizational approach. The second section provides a brief guide to the important dimensions of organizational design. This guide is intended to help the reader who is not familiar with the organizational literature gain a sufficient understanding of the terminology and perspective so that the literature and arguments presented in the third section will make sense. The third section is the central part of the literature review. In this section we do three things: we introduce and define each of the intermediate outcomes (quality, efficiency, innovation, and compliance); we then show the logical and empirical relationships between the intermediate outcomes and safety; finally, we discuss, from the literature, the relationships between dimensions of organizational design and the intermediate outcomes while making inferences

to safety. Throughout the review, the applications to the nuclear power industry will be stressed. The order of the review is represented graphically in Figure 1.1.

2. THE ORGANIZATIONAL PERSPECTIVE ON SAFETY

2.1 The Organizational Perspective Defined

The organizational perspective is one that emphasizes the influence of the socio-technical context in which work behavior takes place. The socio-technical context, in turn, consists of both the technical (hardware and procedures) and the social factors (administration, communications, group structures, etc.) that characterize the workplace. Rather than focusing on the individual unsafe act and its consequences, the organizational perspective seeks to elaborate a context which promotes safeness across a range of potential acts. In other words, it sees the form of the organization as causative of an organizational level outcome which is safety. The organizational perspective contains several key dimensions.

2.1.1 A Systems Orientation

The first dimension we refer to as a "system orientation" (see Katz and Kahn, 1978). The organizational perspective adopts a view wherein many factors contribute to the creation or frustration of unsafe acts. In fact, the organizational perspective sees any organizational outcome (quality and quantity of product, efficiency, etc.) from this same perspective. Organizations are seen as collections of elements. These elements include people, positions, procedures, hardware, authority systems, communications systems, committees, and the like. Each of these elements contributes to the overall performance (good or bad) of the organization. But the contribution of each element is in terms of its relation to all other elements. The organizational perspective stresses the interconnectedness of the organizational elements. This constitutes the system approach.

2.1.2 Broad Scope

This same orientation is relevant to the issue of causality. Rather than focusing on the immediate cause of an accident, for example operator error, the organizational perspective is more likely to include a wide range of elements in the causal explanation, including supervisory relationships, coordination of operations with other functional areas, training programs, reward systems, and the like. The reason for this orientation is the belief that the effects of no single factor can be understood without taking its relation to the other factors into account. For example, the effectiveness of the supervisor cannot be understood without taking into account the general reward and authority system within which both the supervisor and the employee operate. Another way of describing this orientation is that the organizational perspective adopts a multi-causal view. Some of the implications of this view will be discussed below.

Figure 1.1: Order of Review

2.1.3 Generalizability

Another dimension of the organizational perspective is its emphasis on generalizability. The organizational perspective sees the issue of safety as representing a general class of organizational behavior. Attempts are made to identify the elements and the relationships among the elements that are predictive as well as explanatory of safety (see Sutherland, 1977). The organizational perspective does not attempt to explain individual unsafe acts that are, perhaps, better explained with a reductionist, case history view. Instead, the organizational perspective addresses the general case of safety. For example, the organizational view would be less likely to concern itself with assessing whether or not a specific procedure contributed to safety, than it would be with determining whether or not the organization in question adopts and implements procedures in a way that is congruent with the goal of safety and that is not frustrated by other elements of the organization. In short, the organizational perspective attempts to develop an understanding of safety that can be applied to a wide range of potential problems.

2.1.4 Resolving Common Limitations

The concept of safety has most usually received an individualistic treatment. Themes such as accident proneness and life cycle crisis have dominated the early analyses of why accidents happen in organizations (Heinrich et al., 1978). And, while professionals in the area of accident prevention have come to suspect that organizational variables are the primary, if not the proximate causes of accidents, little systematic research has been done to establish the exact nature of this link (see Shafai-Sahrai, 1973, for an exception). The reasons for this oversight are clear.

First, a number of historical analyses of industrial accidents have pointed out that it has been in the interests of industry to tie the legal responsibility for the accident to the individual (Berman, 1978; Ashford, 1976; Page and O'Brien, 1973). This strategy protects the enterprise from public liability and liability for the worker's injury. Recent years, however, have seen a tremendous increase in the public demand for corporate responsibility for industrial accidents (Stone, 1975), due to the increase in the impact of industrial accidents associated with high energy production systems and man-made chemicals and to the increasing power of workers and public interest groups (Ashford, 1976). One result of this trend is an increasing concern with organizational level causes of industrial accidents in the nuclear power industry.

A second reason that safety has not received organizational level attention is that the organizational literature has been more concerned with outcome measures of efficiency rather than process measures of effectiveness (Scott, 1981). In line with what is frequently the over-riding management concern, budgetary measures of organizational success have been accepted by social scientists as the most relevant measures and other potential measures, such as corporate responsibility and safety, have not been stressed. This bias, too, seems to be changing as the environment of the organization becomes

more active in defining the value orientations of organizations. In addition, the inability of individual level explanations to stand up under scientific scrutiny (Ashford, 1976; Heinrich et al., 1978) has legitimated the shift to the organizational level of analysis.

2.2 Advantages of the Organizational Perspective

The organizational perspective is not the only legitimate way of looking at safety. Both the individual and the hardware orientations are also valuable. However, the organizational view has certain advantages over other perspectives that warrants its inclusion with them in a complete view of safety.

2.2.1 Comprehensive Perspective

First, the organizational view is comprehensive. Its emphasis on systemic mechanisms forces it to include for consideration a wide range of contributing factors. This helps avoid false closure on safety problems. If explanations are based on operator error or equipment failure to the exclusion of the organizational perspective, there is the danger that only the immediate or obvious causes of the safety problem will be addressed. An obvious example is when the individual operator is blamed for a safety problem but the root cause is seen as lying in inadequate training. Such underlying causes are increasingly recognized in the nuclear industry. However, the organizational perspective warns that we should be even more comprehensive in our view of the problem by asking such questions as "What happens to other aspects of plant safety as we start requiring more and more resources and operator time allocated to training activities?" That is, where does the whole training issue fit into the socio-technical context and what are the implications of our actions when we try to use training to solve operator errors? Stated more formally, the organizational perspective asks (1) what is the causal chain leading up to the unsafe behavior, and (2) what are the implications of proposed or alternative solutions for the other elements in the system.

2.2.2 The Stress on Prevention

A second advantage of the organizational perspective is strategic intervention. The organizational perspective addresses the issue of safety a priori, that is, before the accident. The organizational perspective, by seeking general approaches to safety, is not limited to responding to the causes of accidents after they happen. The operator and equipment orientations are both more likely to focus on accident post mortems, that is, to advance safety by tracing backwards from the point of the accident to a point where the causal chain can be effectively severed. This tends to produce an incident by incident orientation. The organizational perspective is inherently preventative since it attempts to understand how the existing work context influences safety. By taking a general perspective, the organizational view attempts to solve a plurality of safety problems at once through the appropriate redesign of the organization (Sutherland, 1977).

A corollary of this theme is that the organizational perspective does not focus nor depend on the individual worker or manager. By defining the context of work, in a way that is conducive to safety, less stress is placed on the individual to be the primary determinant of safety. By designing safety into the organizational system, just as it is designed into the hardware, safety becomes a less conscious act and, consequently, less problematic.

2.2.3 Recognizing the Role of the Regulator

A third advantage of the organizational perspective is that it is consistent with the needs of the NRC as an external regulator. Neither the NRC nor industry wishes the NRC to become involved in the day-to-day management of the nuclear plants. This approach is implied, however, by an emphasis on the management of individual behavior in the context of a case-by-case analysis of safety. This would mean active involvement in supervision and decision-making that would be unhealthy for both parties and the public safety as well since the NRC would be too distant and detached to manage effectively. The organizational perspective, however, suggests a regulatory approach that is both more effective and less obtrusive. By adopting an organizational perspective, the NRC would be concerned with assuring that the organizational design adopted by the utility (its authority, patterns, communications, coordination, procedures, etc.) is consistent with what is thought to promote safety. Within that general design, or range of structures, the utility would be free to manage as it sees fit. (To some extent, the NRC has already adopted such a perspective through such rules as those that assure independence from operating pressures for training and quality assurance as in NUREG-0731.)

2.3 Summary of the Organizational Perspective

The organizational perspective offers advantages to the utility, the NRC, and public safety. By stressing a system orientation it advances a more accurate causal interpretation of the events leading to unsafe acts. This same system orientation leads to a more sophisticated analysis of the probable effects of the application of alternative solutions to safety problems. The approach is comprehensive--not taking a piece-meal incident-by-incident approach to the analysis of safety. Instead, it focuses on general causal patterns. In the next section, we discuss some of the central dimensions of organizational design which appear to be relevant to safety and other organizational outcomes.

3. ORGANIZATIONAL DESIGN

At some point managers must make decisions about how the organization is to be put together--what its rules, standards and patterns of behavior are to be. This is what we mean by organizational design. In designing the organization, leaders normally face a limited number of key issues. A straightforward way of categorizing key design issues is to break them down into the four problems of administration, control, coordination, and development. As defined below, these four issues represent the range of strategic design problems managers face within the organization.

The solution of these problems is imperative if the organization is to attain its system goals. System goals refer to those conditions which give the organization survival capabilities in its environment (Osborn, et al., 1980). That is, system goals pertain to states that promote long term organizational survival. Organizations typically find themselves confronted with a number of system goals such as growth, productivity, stability, and flexibility. As can be easily noted, organizations frequently find themselves pursuing conflicting system goals (Anderson and Duncan, 1977).

Four system goals that appear to be directly related to the issue of safety are quality, efficiency, innovation, and compliance. The ability of the organization to respond to these goals speaks directly to its survival capabilities. Consequently, the organizational design can be seen as promoting these goals to a greater or lesser degree. As will be argued below, the relative emphasis on the strategy of design employed for these goals will help determine the safety of the nuclear plant.

3.1 Dimension of Organizational Design for Nuclear Utilities

3.1.1 Administration

Administration refers to the way work is divided up and carried out in the organization. Another useful term in this context is the division of labor (cf. Osborn et al., 1980). Administration may be understood in terms of the forms used, the use of procedures, the deployment of individuals, and the external resources and constraints that affect operations. The form of administration refers to the division of work into separate units (positions, departments, divisions, etc.), and the position of each of these in the overall vertical and horizontal scheme of the organization. Administrative procedures refer to rules governing the conduct of the work itself. The question of deploying individuals, in this context, refers to the skills and qualifications demanded of incumbents of job positions (e.g., duties, responsibilities, job analysis). Finally, the external resources and constraints refer to the budgetary, staff support, and technical assistance external to the unit being studied. These external resources and constraints help define the conduct of work within the organization but originate from outside or at a higher level of the organization.

3.1.1.1 Dividing Up the Work

Of particular importance in terms of administration are the dimensions of horizontal and vertical differentiation (Blau and Schoenherr, 1971; Hage, 1980; Osborn et al., 1980). Horizontal differentiation refers to the division of tasks into meaningful units. The smallest unit is usually a job position. Job positions are frequently grouped together to become work groups, task forces, departments, or divisions. Through these units, work is defined and administered.

Organizations vary considerably in the nature of their horizontal differentiation. For the same number of people, an organization can have many or few departments. The organization can decide to organize its units according to functional task, or by some other criteria such as market

segment or location (Osborn, et al., 1980). Another important way that organizations vary relative to horizontal differentiation concerns the way in which jobs are defined. Organizations engaged in the same type of work can vary considerably in the number of formal job positions. In general, organizations must decide how narrow or broad job responsibilities are to be (Blau and Schoenherr, 1971). Broad job responsibilities can imply either a lack of formal differentiation of task responsibilities (Blau and Schoenherr, 1971), or a decision to rely on a professionalized workforce (Pugh et al., 1968). The choice of broad or narrowly defined work roles has profound implications for the administration of work and organizational effectiveness (Argyris, 1957). Two important design strategies relevant to horizontal differentiation are standardization and specialization.

3.1.1.1.1 Using Standardization to Define the Work

Standardization refers to another aspect of rules; the extent to which they are unvarying and comprehensive. "Procedures are standardized when there are rules or definitions that cover all circumstances and apply invariably" (Pugh, et al., 1963:303). The establishment of management policy, either written or unwritten, can vary in specificity and scope. Blau (1955) reports on a case where work roles were insufficiently standardized due to management's inability to recognize all work contingencies. Informal norms generated by the work group were required to establish the needed standardization of behavior to get the job done. By making procedures explicit, managers not only provide task relevant information to workers, but they also establish a base-line of behavior to which workers can be held accountable.

Measurement of standardization is difficult, due to the wide range of work activities that can be subjected to standardization. The Aston group empirically located two aspects of standardization; standardization of tasks and standardization of personnel recruitment and advancement (Pugh, et al., 1968). (Their measurement of the standardization of tasks, however, clearly reflects a bias toward manufacturing organizations.) A different approach to measuring standardization is represented by Hall (1963), who measures it as the degree to which organizational members perceive tasks to be regulated by specific rules.

3.1.1.1.2 Using Specialization of Tasks Across the Organization

Specialization is also a multi-faceted concept. The same term has been used to identify a reliance on highly trained experts (Pugh, et al., 1968) and to reflect a tendency for job activities to become so narrowly defined so as to preclude substantial variability (Argyris, 1957). While the double meaning of the concept creates some confusion, both meanings pertain directly to the issue of organizational control, and both refer to the over-riding common feature--the differentiation of tasks into formal occupational roles (Weber, 1947). By specifying the role requirements of each position, management achieves a rational division of effort. As we note later, by matching the responsibility for specific tasks within specific positions, and by assigning the incumbent discretion over only those activities defined in the specialized role, management can use specialization as a basis for control.

There is considerable variation in meaning and measurement of specialization. Blau and Schoenherr (1971), for example, concentrate on the extent to which roles are formally differentiated. Here, specialization is measured by counting the number of people with distinct job titles in the organization. This approach reflects the narrowing of job discretion. For instance, one assembly line worker may be given the title of fork truck driver, and another assembly finisher, and a third quality control specialist. The Aston group, however, measure specialization by the relative presence or absence of a set of professionals or semi-professionals (Pugh, et al., 1968). Here, all assembly line workers would be placed in one group. The presence of such "specialisms" as accounting and engineering would be noted. This definition links the concept of specialization with the concept of professionalization. Again there are implications for control. By relying on the professional commitment and on the high level of skill that professional training establishes, managers implicitly may select a particular type of indirect control--one based on the trust of the professional. This is an important type of control in certain organizations such as hospitals (Perrow, 1961; Etzioni, 1975).

Both usages of the concept of specialization have control implications. The Blau and Schoenherr approach, for example, emphasizes the replacement of individual autonomy with job specifications (e.g., job-task analysis) yielding an increasingly complex division of labor. The Aston group approach, on the other hand, seems to suggest an increase in organizational reliance on highly skilled professionals and an associated increase in individual autonomy. Here a professional definition of how the work should be performed is implied. Such differences must be kept in mind when the concept of specialization is employed.

3.1.1.1.3 Vertical Differentiation; the Question of Rank

Of equal importance to horizontal differentiation is the notion of vertical differentiation. As organizations grow in size they tend also to proliferate ranks (Caplow, 1957). However, organizations have some ability to choose whether to organize work in a way that emphasizes or de-emphasizes vertical (rank) differences (Blau and Shoenherr, 1971; Osborn, et al., 1980). The choice of many versus few ranks has significance for such organizational problems as communication, coordination, and control (Hall, 1977).

The way in which positions and units are vertically differentiated has been discussed under the notions of centralization--decentralization (e.g., Child, 1972). Decentralized organizations allow considerable individual and unit autonomy in deciding how the work is to be conducted. Centralized organizations concentrate discretion in one or a few positions or units. This can be reflected in the pattern of vertical and horizontal differentiation. Organizations with many ranks and few unique positions and units are typically seen as centralized since this configuration implies narrow spans of control, and, therefore, direct supervisory control over the conduct of work (Perrow, 1982). However, there are two necessary refinements to this generalization. First, to the extent that the job can be routinized and standardized, even broad spans can be reflective of

centralization if the organization employs formal procedures (Perrow, 1982). Second, many new high technology, computer-aided surveillance systems have been developed to allow even broad spans to maintain intense supervision (Perrow, 1982).

3.1.2 Control

Control refers to the process whereby the behavior of units and of the organization's members is brought in line with existing standards of conduct. It also can be examined in terms of form, procedures, individuals and external factors. Form of control refers to the structure of the formal hierarchy within which power, authority, and influence are exercised: Where are standards set, what measures of performance are employed and how are rewards/sanctions dispensed? Control procedures refer to rules governing the behavior of members (as opposed to the conduct of work). Individuals, in this context, refers to the rewards and sanctions used to control individuals and questions of who sets standards, measures performance, and dispenses rewards and sanctions. External resources used for control include such factors as regulatory standards and corporate control.

It is not uncommon to equate safety with the process of control (Johnson, 1972). Consequently, we have included a fairly detailed discussion of control strategies in this section. Most of the organizational design literature has focused on organizational strategies of control. The following discussion summarizes this literature.

A number of studies have identified two general ways that managers can establish control. In cases where only routine, foreseeable problems are encountered, managers can rely on formal rules and regulations to establish compliance. In non-routine situations, however, managers must play a more active role, intensifying their direction and making more of the immediate decisions themselves. A variety of labels has been assigned to this general distinction in control strategies including "mechanistic" and "organic" (Burns and Stalker, 1961; Lawrence and Lorsch, 1969), "programmed" and "feedback" (March and Simon, 1958), "structuring of activities" and "centralization" (Child, 1972), and "personal" and "impersonal" (Ouchi and Maguire, 1975; Reeves and Woodward, 1970). A closer look at the formal aspects of control is warranted.

Among the managerial activities that Pugh and his associates cite as relevant to organizational control (and, therefore, compliance) are "...directing, coordinating, stimulating, regulating, appraising, and clarifying all operations (Pugh et al., 1963)". Though this definition is lacking in needed formality, it does serve to illustrate just how varied managerial control activities are. A basic distinction, however, can be made between control as a process of shaping the behavior of others, and control as a process of monitoring the behavior of others. In the latter case the intent is to discover any "...dysfunctional variation in some aspect of the organization's behavior (Haberstroh, 1965:1171)," for purposes of corrective action. Monitoring, as an aspect of control, will be reviewed first. Here the focus is on the use of rewards and sanctions.

3.1.2.1 Control as Monitoring

Social control, according to Parsons (1951), can be achieved either through sanctions (rewards) or socialization. The use of rewards/sanctions is based on monitoring performance. The most direct application of positive and negative sanctions revolves around the pay and promotion system (Blau and Scott, 1962; Etzioni, 1975; Weber, 1947). Many elaborate managerial systems are structured on complex formulas of pay, promotion and bonuses designed to get the highest level of performance, relative to organizational investment, possible. There is no assurance, however, that monetary reward systems alone will generate the needed control as past research has indicated (Behrend, 1959; Mayo, 1945; Roy, 1952, 1953).

To establish the effectiveness of the reward system, most organizations take steps to monitor the activities of their employees. A number of strategies are available for this purpose. One relatively simple technique is the measurement of output against some pre-established quota. The quota system can be directly tied to the reward system through the use of piece-work and commissions. Employees that are not sufficiently productive can be punished and, eventually, released.

Along this same line, managers can also seek to evaluate the quality of the output. Quality control systems, however, can vary considerably as to their formalization (Perrow, 1967). Some organizations may limit themselves to spot-checks at irregular intervals, employing a loose definition of the aspects of quality, while others may test each unit of output against a precise blueprint of quality (Ouchi and Maguire, 1975; Pugh, et al., 1968). Employees subject to the latter form of control are somewhat more closely monitored than in the former type.

Not only do managers evaluate the employee's products, but they evaluate the employee as well. One standard task of a supervisor is to provide occasional evaluations of the employees charged to his or her responsibility to the managers higher up in the organization. These evaluations, too, can vary in formality. Some organizations may depend on a brief oral report at infrequent intervals in order to establish the appropriate rewards and punishments for each employee. Others may develop specific, detailed forms against which each employee's performance is graded at regular intervals. The intensity of monitoring is reflected in the formality of the evaluation system with highly formalized systems indicating a greater managerial emphasis on monitoring (Ouchi and Maguire, 1975; Rushing, 1966; Scott et al., 1967). Some evidence exists to indicate that the accuracy of such evaluations is typically doubtful (Lawler and Porter, 1963). This is important, since in order for compliance to be maximally achieved, control mechanisms must be seen as legitimate by those being controlled (Haas and Drabek, 1973).

3.1.2.1.1 Monitoring and Direct Observation

The ability of managers to evaluate employees, in part, depends upon the amount of contact that they have with them. To some extent, variation in the intensity of supervision is idiosyncratic, reflecting the personality of

the supervisor and the extent to which other activities divide his or her attention. Of more importance to past researchers, however, is the way that managers shape the official structure of the organization to allow for more or less direct supervision. Specifically, managers can alter the official chain of command to allow either direct or mediated relations with subordinates. Two aspects of form are relevant here; the number of ranks in the organization and the number of people reporting to each supervisor at all levels in the organization. The two are functionally related, for as the number of ranks in an organization of a given size increases, the number of persons reporting to the average supervisor must decrease. Span has received more attention in the literature and is more directly relevant to the issue of organizational control (Blau and Scott, 1962; Entwistle and Walton, 1961; Indik, 1964; Ouchi and Dowling, 1974; Udell, 1967; Urwich, 1947).

3.1.2.1.2 Spans and Monitoring

Referred to as the "supervisory ratio" or the "span of control," the number of employees reporting to a given supervisor has direct consequences for that supervisor's ability to monitor the employee's performance. Other things being equal, the fewer the number of subordinates to supervise, the more intense the monitoring can be. Organizations that have many employees reporting to a single supervisor preclude close supervision. Where the supervisory load is light, however, the manager can keep relatively close control over the activities of his or her subordinates and will be in a convenient position to establish proper rewards and punishment. The pioneering work of Graicunas (1937) focused on the discovery of the "ideal" number of subordinates to managers that would result in the proper balance of efficiency and control. Since then, there have been several attempts to establish the "proper" span of control with the fairly common conclusion that it depends on other organizational features such as size and technology. (See Udell, 1967, for a review of this literature.)

The consensus in the management literature, however, is that relatively small spans, somewhere in the neighborhood of six or eight, provide maximum control (Blau and Scott, 1962). As Worthy (1950) has pointed out, however, maintaining small spans in large organizations requires a proliferation of ranks. The result is an increased distance between top management and other levels of the organization and a decrease in the ability of top managers to monitor activity (Blau and Scott, 1962; Simon, 1957). This is a central dilemma of large and growing organizations.

Organizational span has been measured in a variety of ways (Price, 1972). Of common interest, however, are two aspects of span; chief executive's span (Healy, 1956; Pugh, et al., 1968; Blau and Schoenherr, 1971), and the average first-line supervisor span (Pugh, et al., 1968; Blau and Schoenherr, 1971; Udell, 1967). These measures are typically abstracted from company organizational charts or are reported by key informants. Chief executive span, however, has an alternative interpretation, which will be reviewed shortly, that makes it less useful as a measure of intensity of monitoring.

3.1.2.2 Control as Shaping Behavior

Monitoring is only one aspect of control. Managerial control also refers to direct managerial influence over work activities. Among the many ways that managers can exert direct control over the operation of the organization, two basic "administrative strategies of control" have been recognized (Azumi, 1978; Child, 1972; Tracy and Azumi, 1976). The first is for managers to retain as much personal discretion over decision-making as possible. That is, managers attempt to concentrate power and authority in their own hands in order to establish direct, personal control over the vital activities of the organization. The second is to specify techniques for defining and solving problems.

3.1.2.2.1 Retaining Control

One way for managers to retain control is to avoid the formal delegation of decision-making authority to lower levels. This "concentration of authority" has been cited as an important aspect of organizational control by many (Blau and Schoenherr, 1971; Burns and Stalker, 1961; Child, 1972; Pugh, et al., 1968; Rosengren, 1967; Tracy and Azumi, 1976). Centralization in this sense has been measured by the average feeling of participation in decision-making (Aiken and Hage, 1968; Hall, 1963), as the attribution of influence to various levels of the organization (Tannenbaum, 1968; Williams et al., 1959), and as the level at which formal authority rests for making specific decisions (Pugh, et al., 1968).

The retention of direct control by managers is only one of the administrative strategies of control available. Moreover, it is a strategy differentially suited to organizations of varying size, goals, and production techniques (Burns and Stalker, 1961; Child, 1972; Lawrence and Lorsch, 1969; Pugh et al., 1968).

3.1.2.2.2 Formalization

A second strategy of control over the day-to-day operation of the organization is based on the ability of managers to program decision-making (March and Simon, 1958). Where direct control is not possible, managers can employ a number of techniques to insure that subordinate behavior will be in line with organizational goals. Foremost among these is formalization.

"Formalization denotes the extent to which rules, procedures, instructions, and communications are written (Pugh et al., 1968:75)." It constitutes a central dimension of Weber's discussion of rational bureaucracy, because control achieved through the appeal to written rules removes control from arbitrary influences (Weber, 1947). By establishing written rules of employment, on-the-job behavior, work routine, and the like, such areas can be removed from the manager's active concern, in that not only are managers released from constantly having to make decisions in these areas, but they can also relax direct surveillance.

Formalization has been operationalized variously in the literature. The Aston group identified three aspects of formalization; defining work

activities, recording work performance, and information passing (Pugh, et al., 1968). They test for the presence or absence of 38 documents reflecting these three dimensions. Hall (1963) measured formalization by aggregating individual perceptions of the prevalence of written rules. A relatively simple measure of formalization is the number of words in the company rule-book (Blau and Schoenherr, 1971). A final approach to the measurement of formalization is the identification of the proportion of the workforce engaged in the writing and recording of information (Pugh et al., 1968; Blau and Schoenherr, 1971). The higher the proportion in the organization's "bureaucratic component", the more the organization relies on written documents for coordinating and defining work. While this is probably the case in most organizations, this approach to measuring formalization is less direct than simply counting the number and frequency of use of various formal documents.

3.1.3 Coordination

Coordination refers to the need of the organization to mesh or integrate the activities of the different parts of the organization into a cohesive whole. Because the activities of various parts of the organization have input and output affects on each other, coordination is a central concern of organizational design. The form of coordination refers to the formal mechanisms that are established to link activities. Examples are standing committees, linkages through the formal structure, matrix organizations, staff meetings, and the like. Coordinating procedures pertain to rules that purposively link the activities of disparate units in the organization. Individuals are also used to coordinate--here we are concerned with the formal coordinating activities expected of individuals as well as systems designed to assure the participation of individuals in the organization as a whole (e.g., participatory management). External factors relevant to coordination involve the role of corporate units in linking functions within the plant, the role of professional societies, and the role of external, consultive bodies (e.g., INPO) in providing coordination. Much of the discussion concerning the forms or patterns across the dimensions will focus on the centrality of coordination. Thus, we move to the question of development.

3.1.4 Development

Development refers to the strategic problem of planned change. Again, it is useful to examine the forms used to promote change, the procedures employed, the expectations placed on individuals, and the external resources which may be used to facilitate change. Form refers to the existence, nature, and location of organizational units concerned with organizational development (planning units, training, etc.). Procedures refer to the rules that exist to promote development. Incentives and programs designed to encourage individual involvement in development activities are also a concern. External constraints and resources relative to development include the training programs available to the organization and the resources allocated to the units for development purposes.

One may also emphasize the form, procedures, individual and external aspects of organizational design as the primary dimensions for analytical purposes. Here one may make a more direct linkage to the literature in terms of bureaucracy (form), formalization and standardization (procedures), plus participation and centralization/decentralization (role of individuals). Figure 1.2 provides a pictorial representation of the design dimensions we have been discussing.

3.2 Patterns Across the Issues

Organizations vary considerably in the way they address the four strategic problems of administration, control, coordination, and development. It is also clearly the case that this variation is significant for the overall performance of the organization, including safety issues. We will illustrate the importance of these strategic problems by contrasting two generic types of organizations often cited in the literature--the mechanistic and the organic (cf. Burns and Stalker, 1961). (A summary of the dimensions of these two types of organizations can be found in Figure 1.3.) These forms represent significant contrasts on each of the dimensions of administration, control, coordination, and development. The tendency of different parts of an organization toward one or the other alters its ability to operate safely. We also introduce the diverse type since parts of the utility are likely to be organic while others mechanistic. (Many writers discuss the mechanistic versus organic patterns. For one recent example see Hage, 1980.)

3.2.1 The Mechanistic Pattern

In a mechanistic pattern, administration would lean heavily toward extensive vertical specialization (many levels of management) with narrow tasks where each department would be treated as a separate functional area. This would be backed up with extensive use of written rules and procedures for defining individual roles and prescriptions, a de-emphasis of individual discretion, and minimal expectation of external support. Efforts for control would receive considerable attention. Subscription to procedures and written directives would be used more than individual accounts of events. Coordination would be subordinated to control and would be exercised via the line managers. Written protocols may be used to channel coordination (e.g., a schedule and detailed agenda would be used in meetings among subordinates) with little emphasis placed on direct contact between managers in different functional areas. Line managers would be expected to measure performance, define problems areas and dispatch remedies for performance below a pre-set standard. (Average performance would be expected and below average performance would be subject to sanctions according to a prescribed and predetermined written policy.) Development in the mechanistic pattern would follow upon evaluations of technically necessary training. As before, such activities would follow written rules and procedures with minimal discretion given to those whose written job description specified a training function. External support for development would only be used in instances of a clear and present need.

	Form	Procedures	Individuals	External
Administration	1	2	3	4
Control	5	6	7	8
Coordination	9	10	11	12
Development	13	14	15	16

Figure 1.2: Overall Matrix Showing the Design Dimension

	Mechanistic	Organic
Administration	Emphasis on hierarchical structure Narrowly defined jobs Work governed by procedures	Emphasis on network structure Broadly defined jobs Work governed by expertise and advice
Control	Emphasis on vertical control in all areas Emphasis on impersonal mechanisms including procedures and bureaucratic functions	Substantial autonomy Emphasis on internal control through professionalism
Coordination	Coordination through the formal, vertical hierarchy	Coordination through information feedback horizontally
Development	Marginal emphasis on change and innovation	Great emphasis on change and innovation

Figure 1.3: Mechanical and Organic Models of Organizational Design
(Adapted from Burns and Stalker, 1961)

3.2.2 The Organic Pattern

The organic pattern is quite different. Here one expects to find less vertical specialization (e.g., fewer levels) and more emphasis on grouping across the organization. Individuals would be given more discretion as there would be less reliance upon written rules and procedures. It is common for organic organizations to depend heavily on professionalized work roles; there would be more extensive collection of staff groups and perhaps a matrix organization would be developed. Coordination would be stressed over control. The mechanisms used for coordination would most likely emphasize one-on-one contact. Extensive emphasis on individual growth and development would be expected. One would expect more emphasis on individuals and external support than on bureaucratic procedures. A premium is placed on development.

3.2.3 The Diverse Pattern

For nuclear utilities one may expect to find a mix of mechanistically and organically structured units. This can be called a diverse pattern (Hage, 1980). Given the character of the technology, the size range in nuclear utilities, the broad geographical spread of nuclear facilities, and the emphasis on plant level regulation by the NRC, we would expect the following:

- Larger utilities with several nuclear plants/facilities will have more diverse organizational designs than smaller utilities with only one plant/facility.
- Where mechanistic and organic units must interface, there will be conflict and misunderstanding unless precautions are taken to buffer the interface.

These propositions call for some additional explanation. Larger size coupled with more facilities (since each facility is unique) place pressure on organizations to develop more elaborate organizational designs (i.e., more administration, control, coordination, and development) (Blau and Schoenherr, 1971; Hage, 1980). However, NRC regulatory requirements, ANSI/ANS standards and INPO plant assessments place a heavy emphasis on the more mechanistic aspects of plant/facility organization and management. Thus, these pressures reinforce the traditions of the utility industry--traditions developed over decades of managing comparatively simple, highly routine and deterministic operations. It is expected utilities will bow to the mechanistic pressures for individual plants and for specific functional areas (e.g., maintenance, operations, QA, health physics). But they will also recognize the need for quality and innovation. With sufficient resources (as evidenced by larger size) they will add more organic units to the plant (e.g., safety review groups) and reconfigure corporate staff support to cope with exceptions. These arguments are addressed in more detail below.

3.3 Summary of Organizational Design

To reiterate, organizational design refers to the way the organization is put together to achieve its goals. This requires attention to the problems of administration, control, coordination, and development. Within each of these areas the organization must make decisions as to form, procedures, the role of individuals, and the reliance upon outsiders. These decisions tend to cluster into two forms--mechanistic and organic. A third form, diverse, combines both mechanistic and organic tendencies and characterizes some organizations within the nuclear power industry. In evaluating the organizational literature relevant to organizational design, therefore, we will be focusing on both the separate dimensions of design and the more general clusters that tend to emerge in empirical reality.

4. INTERMEDIATE OUTCOMES TO SAFETY

In this section we address four intermediate outcomes to safety--quality, efficiency, innovation and compliance. Each of these factors is an important precursor to safety in nuclear power plants. The importance of each lies in the nature of work (tasks given individuals) and technology in nuclear power plants. These particular organizations contain both standardized and unstandardized tasks, and routine and non-routine technologies.* Tasks range from the relatively routine work of operations and radioactive waste disposal to the non-routine work of maintenance and reactor engineering. Certain elements of the technology are perfectly understood. Other parts of the technology are still in the process of being refined and understood (e.g., the various unresolved safety issues). In order to operate safely, then, nuclear power plant organizations must pursue the goals and behaviors that address both the routine and non-routine dimensions of work and technology. This is something of a paradox since, as we argue below, these goals and behaviors are somewhat in conflict.

The intermediate outcomes we have chosen to look at are reflective of this paradox. On the one hand, there is the goal of quality and the associated behavior of innovation. As we shall see, these are crucial for safety in the context of the non-routine. On the other hand, there is the goal of efficiency and the associated behavior of compliance. These are particularly relevant in the context of routine work and technology. The organizational literature provides many insights into how best to design organizations to maximize a particular goal or behavior. Unfortunately, it is somewhat less helpful in understanding how to maximize apparently conflicting goals and behaviors at the same time.

4.1 Quality and Safety

The first intermediate outcome we will address is quality. As will be argued below, the way in which the organization approaches quality as a goal

*Normally it is assumed that if the technology is routine (predictable, programmable, and repetitive with few exceptions or unknowns arising), the duties assigned to individuals (tasks) will be standardized, and vice versa.

of both the work process and product will also help determine organizational safety.

4.1.1 Definitions of Quality

A popular dictionary definition of quality is "degree of excellence, grade, or superiority in kind." This simple definition has been greatly expanded by scholars interested in the problem of quality in industry and government. Because the definition of quality has received so much attention in the literature, Appendix A contains a more detailed treatment. Utzig (1980) defines quality as "The relative excellence of the composite of all product or service attributes in fulfilling the needs and reasonable expectations of those who receive the product or service, as they perceive such fulfillment from the time of offering through the product life." Hershauer, Ruch, and Adams (1980) propose that "Quality is the degree to which a product or service conforms to a set of predetermined standards related to the characteristics that determine its value in the marketplace and its performance of the function for which it was designed." These latter two definitions have two factors in common; both define quality in terms of the standards set by the consumer and both see quality as pertaining to services as well as products.

It is also possible to define quality by focusing on organizational intentions rather than consumer evaluations. An emphasis on quality is one strategy that an organization has available for satisfying the expectations of the environment (Hage, 1980). Quality, therefore, becomes a dimension of the organization's activities, as well as a characteristic of organizational outputs or products.

4.1.1.1 Quality and Organizational Processes

According to Parsons (1951), quality is an orientation that flows out of a view of the world which focuses on the uniqueness of discrete events. This world view de-emphasizes vague, universalistic criteria and standards. Following from Weber (1947) standardization of market expectations (e.g., one size can fit all) and productive technologies (only one size is manufactured) has been seen as driving out the concern for quality from the western productive process (Ouchi, 1981). This, of course, is a matter of degree as we compare organizations to each other. What accounts, then, for a relative emphasis on quality?

As Perrow (1967, 1970) has argued, organizations vary in the extent to which quality is a central goal. For Perrow, the choice of quality over quantity as the accepted measure of organizational success is a function of the technology available to the organization. Organizations facing a considerable number of exceptions in the productive process are more effective, in Perrow's logic, if they adopt a quality orientation. Organizations that see the work process as containing many exceptions to the routine act irrationally if they impose a standardized solution to problems that would result in the production of products that are inappropriate for the market's expectations.

Since the nuclear power industry appears to be facing a series of unknowns (e.g., unresolved safety issues), the implication of Perrow's logic is that nuclear utilities will be driven in the direction of a concern with quality. Even if Perrow is correct, and a number of studies lend support for his position (Udy, 1959; Stinchcombe, 1959), these organizations can be expected to vary in their responsiveness to this technological imperative. This is true both because of the existence of other factors which appear to foster or impede a quality orientation (such as environmental pressures), and because of the mediating effects of variation in organizational structure.

Probably the most common conception concerning the relationship of quality to other organizational effectiveness criteria is that as quality goes up, quantity goes down. However, there are studies indicating that the relationship may not be all that simple. Conner (1980) suggests that quality and quantity are somewhat independent and that well-designed quality control techniques can improve the quality of textiles and garments without sacrificing quantity. McKinnon (1980) reports that, after a crackdown on safety violations in the United Kingdom, quality went up at no loss of quantity.

Quality has also been related to a number of other criterion measures, most notably organizational or supervisory effectiveness. A number of studies have included measures of quality in estimates of overall effectiveness. Cameron (1982), for example, used ratings of faculty quality, quality of student academic development, student career development, and faculty development as a large portion of his rating of the overall effectiveness of a sample of universities. Staw and Oldham (1978), Petty and Bruning (1980), Wofford (1971), Seashore, Indik, and Georgopoulos (1960), Georgopoulos and Mann (1962), and Turner (1960) have all used some measure of quality in determining overall organizational effectiveness to a greater or lesser extent.

One somewhat disheartening set of results concerns the relationship of subjective ratings of quality to objective quality measures. Turner (1960) reports that foreman ratings of the quality of work produced by subordinates were not significantly correlated with the percentage of materials that went to scrap. The quality ratings were related to other supervisory ratings, but not to any objective quality criteria.

The search for meaningful definitions and measures of quality has been extensive. Appendix A, at the end of this chapter, provides a more in-depth discussion.

4.1.2 Quality and Safety

One of the penalties for lack of quality is reduced safety of a product or process. A poorly made product may break in use, exposing the user to hazards, and a poor quality process may expose workers or the public to industrial hazards. Because of the linkages between quality performance and safety, a review of the literature on quality performance is directly

relevant to the problem of ensuring safety in industrial operations such as a nuclear power plant.

An organizational concern with safety reflects an organizational concern with the process of production itself, since safety refers to the actual work as it is carried out. The importance of this fact lies in the tendency for an organization to be either output oriented or process oriented, but not both. This is an extension of the argument of Perrow (1967) relative to quantity and quality concerns and Etzioni (1975) relative to utilitarian and normative goals.

The link between the concept of safety and the concept of quality, then, reflects the organization's relative concern with the work process. This concern is reflected both in a concern with the product itself (i.e., its uniqueness and complexity [Stinchcombe, 1959; Perrow, 1967]) and with the people involved in the productive process (i.e., their inherent worth and centrality to the organization [Lippitt, 1982]). For the purposes of discussion here, then, the factors affecting quality in organizations will be assumed to be the factors affecting safety. And, in a very real sense, safety can be defined as a dimension of quality.

This set of assumptions is particularly justified for portions of industries, such as nuclear power, where technical unknowns pose potential risks to society. Some technical areas may not be developed to the point where the parameters and problems of the productive process are known. Such technologies appear to require a primary concern with the productive process, and the problematics of production to reduce risk.

A number of studies have shown that quality is positively related to industrial safety. Seashore, Indik, and Georgopoulos (1960) found that the quality of delivery service was inversely related to the number of reported accidents. Bell and Telman (1980) obtained a similar set of results in a sample of workers performing rotating shift work. It is highly likely that the same factors that are conducive to good quality also facilitate safety. Workers striving for quality are less likely to rush to get a product completed, they are less likely to be careless, and more likely to maintain a clean working environment. All of these behaviors should contribute to safety.

4.1.3 Quality and Organizational Design

In general, the literature views the organic model as more consistent with an overall emphasis on quality. The key organizational characteristic to be considered is the degree to which the organization depends upon highly educated and, particularly, professionalized members. A central design question, therefore, is the nature of job positions within the division of labor. There are three themes in this part of the literature: one motivational, another analytical, and a third interactional. The motivational theme is based on the idea that the more highly educated the work force the more concerned it is with quality. Herzberg et al., (1959), for example, has argued that education leads to an interest in the work process in and of itself. Dubin (1956) and Dubin, et al., (1975) have found

empirical support for the contention that better educated workers are more likely to cite work as a "central life interest". Explanations for such findings vary including the relative "enlightenment" of better educated workers (Herzberg, 1959), the oppressiveness of blue-collar working conditions turning the blue-collar worker away from work as a central concern (Chinoy, 1955), and the belief that better educated workers perceive that it is their right to dominate and define the work process (Hage, 1980). For whatever reason, there is support in the literature for the belief that better educated workers are more concerned with the work process and, hence, with work quality.

Another type of argument is based on the analytical properties of professionals. Hage (1980) argues that professionals are unlikely to take superficial views of problems. In fact, because their training tends to emphasize the complexity of issues, they are more likely to adopt a particularistic (quality) orientation. In a similar vein, organizations with many professionals have been found to be more likely to adopt personnel policies based on technical competence (Hall, 1968). And, since the source of the professional's analytic capabilities is typically outside the organization (professional associations, academic disciplines, etc.), organizations that allow their professionals contact with the outside may promote a quality orientation.

It is not simply the existence of professionals that leads to a concern with quality. Rather, the manner of their interaction is also important. Organizations that maintain a number of different kinds of professionals and specialists, are organizations that promote a quality orientation. The logic behind this argument is that the existence of such diversity leads to a situation where there are different perspectives on the same problems (Hage and Dewar, 1973; Lawrence and Lorsch, 1967; Wilson, 1966). This difference can lead to a more systematic analysis of the productive problems and a higher level of quality. The lack of empirical analysis on this issue, however, makes such arguments speculative at this point. One could speculate, however, that organizations with a diversity of specialists, would be more likely to be quality oriented than organizations without such a diversity. One could also speculate that organizations that allow for the free flow of ideas across specialty lines (i.e., organizations that adopt a more organic structure), would be more likely to benefit from this diversity in the area of improved quality.

The organic model provides a context where quality goals can be emphasized. Role definitions are broader and more congruent with professionalization. Rules are subordinated to interaction organized around problem-solving. Power and authority are decentralized to allow individual workers and groups of workers to address work related issues as they emerge. Rewards are oriented toward contributions to change as well as compliance to tradition. In short, a quality orientation tends to emerge and be supported by a somewhat more organic organizational design.

4.2 Efficiency

4.2.1 Definition of Efficiency

Efficiency generally refers to the ratio of output or product to the cost of production (Hage, 1980). Organizations that generate the same amount of output, but at a lower cost are often considered more efficient than other organizations. This type of definition, however, masks the activities that make one organization more cost effective than another. Underlying this output definition of efficiency is a process definition of efficiency which is more appropriate for our purposes. Efficiency can also be defined as the consistent and optimal use of organizational resources in the productive process (see Osborn et al., 1980). This definition focuses our attention on the way in which the organization uses equipment and labor. It does consider variations in wage rates or the "book value" of equipment. For instance, compare utilities A and B which adopt different depreciation schedules. Both purchase new equipment in 1984, and utility A adopts a rapid depreciation schedule. Utility A would be less cost effective in 1984 (higher depreciation costs), but more cost effective in 1990. This difference merely reflects the fact that one organization declares its equipment costs early in the life of the equipment. Organizations that consistently employ the equipment and labor to generate a high level of output are efficient in that they are getting the higher rate of utilization out of their equipment and labor.

4.2.2 Measurement of Efficiency

By far the most common approach to measuring efficiency in organizations is to assign dollar costs to the inputs and outputs of the productive process. Efficiency is then defined as minimizing the dollar costs of inputs relative to outputs (Hage, 1980; Katz and Kahn, 1978). There are some obvious problems to such an approach, however. First, it is not always possible to unambiguously measure all inputs and outputs in terms of dollars (Katz and Kahn, 1978). It has been pointed out that part of any organizational output contains a psychic component such as a sense of satisfaction on the part of the workers (Barnard, 1938; Hrebiniak, 1978). Second, there is the general problem of accurately costing inputs, particularly over the long term. For example, speeding up an assembly line may appear to increase efficiency since labor costs, as measured by wage rates, decline as a proportion of the output unit cost. Such an action, however, may lead to increased turnover and labor problems that only show up in the long run, and that may not, therefore, be reflected in the typical measures of efficiency. Third, as noted above, financial and accounting anomalies may confound direct comparisons.

For the nuclear power industry, it seems appropriate to measure efficiency over the long run in terms of the unit cost of electrical power production, adjusted for demand. This adjustment is necessary since fixed costs (the costs of the plant) constitute such a significant proportion of input costs. (See, also, Chapter 6 of this volume.) If short term estimates of unit costs are used, which may be necessary in a cross-sectional, comparative analysis, the long-term costs, the psychic dimensions, and the

accounting anomalies mentioned above should be taken into account when interpreting the results.

4.2.3 Efficiency and Safety

The relationship between safety and efficiency is complex. On the one hand, organizations that are too efficiency conscious may drive workers and equipment to the point where safety is jeopardized. Such behavior has not been uncommon in our industrial history, particularly prior to the enactment of protective labor laws and the emergence of the federal regulatory bureaucracy (Page and O'Brien, 1973). In general, however, such an extreme approach to efficiency is viewed as false efficiency. As organizations' investments in both labor and equipment have grown, managers have found that it makes little economic sense to push their organizations to the breaking point. U.S. Steel, for example, found early in this century that safety may be cost effective (Ashford, 1976). It is argued today that production without safety is inherently inefficient (Heinrich et al., 1980:90). In the individual case, however, the point at which efficiency demands threaten safety is still difficult to determine.

One reason for this difficulty is that, in some senses, efficiency is positively related to safety--that is, efficiency is a prerequisite to safety. This line of thought reverses the direction of causality in the previous argument. But how can efficiency "cause" safety? Two explanations are offered here; one that focuses on the work routine and the second which focuses on the demands of the plant equipment and design in the nuclear power industry.

4.2.3.1 Efficiency and the Work Process

Efficiency in the work process can be expected to lead to increased safety where tasks involve following set procedures. Properly designed procedures provide a step-by-step pattern for work activities. Within these procedures, energy is expended in known or expected ways for the fulfillment of the task requirements. Unexpected, unplanned, and superfluous (that is, inefficient) behavior is minimized. The existence of this pattern has several positive impacts on safety.

First, the pattern allows consistency in behavior. A common finding in the safety literature is that consistency leads to better safety performance (Riggs, 1981:255-256; Heinrich, et al., 1980). The logic behind this position is that consistency in procedures allows the workers to anticipate successive steps in the work process. Consequently, they are not surprised or endangered by events.

A related finding is that accidents frequently occur at points of decision (Heinrich, et al., 1980). In summarizing the literature Heinrich (Heinrich, et al., 1980:65) argues that safety is threatened particularly during . . .

Unusual, nonroutine work. This is the job that pops up only occasionally, or the one-of-a-kind type situation. These situations may arise in production or in nonproduction

departments. The normal controls that apply to routine work have little effect in the non-routine situation.

Workers in these situations must depend upon their own judgments, which often results in error, rather than tried and true procedures.

4.2.3.2 Efficiency and Plant Design

Within the nuclear industry, the efficient use of the plant is particularly relevant to safety. Nuclear power plants are designed to perform most efficiently at high energy levels. In addition, there are certain critical (more dangerous) operating zones as the plant is brought up to full power.

Consistency in operation is also important. Wide changes in temperature and pressure put strain on the system. (Pressurized thermal shock, the extreme case, can potentially rupture the reactor vessel.) Changes in other operating parameters (e.g., water chemistry) can make the plant more difficult to control. The efficient operation of the plant, therefore, can be expected to establish a range of operating parameters which promote safety.

4.2.4 Some Limiting Conditions

As previously mentioned, the technology of nuclear power plants contains both routine and non-routine dimensions. While the literature suggests that efficient operations improves safety, two limiting conditions exist. First, within the non-routine part of the plant technology, it may be dangerous to stress efficiency. Since efficiency is achieved through procedures, and non-routine technologies are less consistent with a procedures orientation (Perrow, 1967; Hage, 1980), adopting an emphasis on efficiency may actually threaten plant safety. Invoking procedures under conditions of a non-routine technology may give a false feeling of security and, therefore, may frustrate the analytical activities that are necessary to assure safe reactions to operating problems.

The second limit concerns the effects of an extreme efficiency orientation on employee motivation and performance. The procedures orientation that follows from the efficiency orientation can, in the extreme, lead to lower quality work. As Kerr (1957) argues, some autonomy (freedom from procedures) is necessary to provide the rewarding psychological climate necessary to maintain a "level of alertness" which is a prerequisite of high performance. Within these limits, however, the role of efficiency in determining plant safety is probably significant. It is also worth noting that, within the limits, efficiency and safety may be complementary rather than conflicting goals. Finally, it is important to note that alterations in procedures, themselves, and staff additions may be used to broaden the zone of complementarity between safety and efficiency.*

*Explorations into "systems based" procedures controlled experimentation with the independent safety engineering group (ISEG) and the potential requirements for a shift technical advisor position are examples of adjusting procedures and personnel to overcome identified deficiencies.

4.2.5 Design Determinants of Efficiency

The concept of efficiency has a long history in organizational analysis. In fact, the very existence of modern organizations has been linked to a concern with the efficient use of labor and capital (Weber, 1947). By dividing tasks, specializing work, and establishing control, modern organizations attempt to use resources more efficiently than the organizational forms that characterized pre-industrial economies.

Not surprisingly then, the organizational determinants of efficiency are typically seen as those factors that defined early industrial bureaucracy. These are the factors that are characteristic of the mechanistic model outlined earlier. Some of the more important components are:

- The division of labor into its component parts and the strict allocation of responsibility for the parts to positions.
- The organization of the various positions into a clear hierarchy of authority where the rights and responsibilities of each position are clearly defined.
- The centralization of discretion in the hierarchy at the top of the organization.
- The use of written rules and regulations to unambiguously define job requirements and procedures.
- The coordination of activities through the hierarchy and through rules and regulations.

Organizations that emphasize these characteristics are generally seen as performing in a more efficient manner than are organizations that do not (Weber, 1947; Hage, 1980).

Hage (1965, 1980) has provided a more recent treatment of this line of argument. He states the following propositions based on his reading of the organizational literature.

- The higher the centralization (of authority) the higher the efficiency.
- The higher the formalization (use of written rules and regulations) the higher the efficiency.
- The higher the stratification (the more vertical ranks) the higher the efficiency.

In short, Hage agrees with Weber that a heavy emphasis on external controls through centralized authority, vertical ranks, and written rules and regulations leads to an increase in efficiency. Based on these theoretical treatments, therefore, the mechanistic model of organizational design appears

to better address the problem of efficiency in organizations than does the organic model.

4.2.5.1 The Notion of Congruity

However, empirical investigations of organizations have not provided unambiguous support for these theoretical arguments. Instead, the usefulness of the concept of efficiency, itself, has been brought into question. In an early empirical analysis, Burns and Stalker (1961) found that the goal of efficiency is a rational goal for only a subset of organizations. In their analysis they found that organizations operating in stable market environments tended to emphasize efficiency and tended to adopt an organizational structure that is basically mechanistic. Organizations operating in an unstable market environment, however, were pushed in the direction of innovation as a goal capable of assuring survival. For these organizations, organic forms were more adaptive. To argue then, that all successful organizations emphasize efficiency and the mechanistic organizational structures that support it, may not be accurate. Additional support has been provided by other empirical studies (Lawrence and Lorsch, 1967).

4.2.5.2 Organizational Design and Technology

As this line of thought was developing, a very similar line of thought that emphasized the organization's technology also began to emerge. Based on the theoretical and empirical work of a number of scholars (Woodward, 1965; Stinchcombe, 1959; Udy, 1957; Blauner, 1968; Perrow, 1967), most organizational theorists today view the issue of efficiency in organizations as being contingent on the nature of the technology characterizing the organization as well as the unique market environments. Perrow provides a summary of this perspective (Perrow, 1967). In short, he argues that the goal of efficiency is most appropriate in organizations where the productive technology has both unambiguous goals and unambiguous means for achieving those goals. This is characteristic of only some organizations. Figure 1.4, synthesized from the work of Perrow (1967) and Thompson (1967) shows how organizations can differ on these two dimensions. Efficiency is an appropriate goal primarily for organizations falling in the first cell. Other organizations, where either the goal or the means are not well understood, would do better by not stressing efficiency to the same degree. Perrow, however, agrees with Weber (1947) and Hage (1980) that for organizations in the first cell, the mechanistic organizational structure is consistent with their goal of efficiency.

As mentioned earlier, nuclear power plants are complex technologies that contain well defined goals and means in some areas, and less well defined goals and means in others. A basic paradox of the operation of nuclear power plants, therefore, seems to be that both organic and mechanistic structures are required, but for different parts of the organization. Unfortunately, the literature does not explain in detail how an organization best institutes this mixed form. This is certainly an area where additional theory and research is warranted.

Means	Goals	
	Well defined	Not well defined
Well defined	High emphasis on efficiency. Mass production technology.	Moderate emphasis on efficiency. Craft industries.
Not well defined	Low emphasis on efficiency. Medical care.	Very low emphasis on efficiency. Psychological counseling.

Figure 1.4: Relevance of Efficiency as a Goal
Under Varying Technological Conditions

4.3 Innovation and Safety

4.3.1 Definitions of Innovation

A number of definitions of innovation are current in the organizational literature. A fairly standard one is as follows: "Innovation refers to an organization's early use of ideas, processes, programs, services, or products that are new to an industry or class of organization. Innovation represents a purposeful attempt to try something new or different" (Hrebiniak, 1978:271). Other definitions are frequently somewhat more restrictive in one of two ways: either the term innovation is limited to the initial creation rather than subsequent assimilation by other organizations (Daft and Becker, 1978), or the term innovation is limited to major changes in organizational products or processes as opposed to minor or incremental change (Hage, 1980:162). Neither restriction is appropriate for our present purposes. Instead, we see both of these dimensions of innovation as matters of degree. Organizations that create new ideas, processes, programs services, or products are more innovative than those organizations that simply borrow already existing creations. These latter organizations, however, are more innovative than those organizations that do not change at all. The same logic can be applied to the question of the size or impact of the innovation. Organizations that adopt major innovations are more innovative than those who adopt only minor innovations. This latter class, again, is more innovative than the organizations who adopt no innovations.

A common distinction in types of innovation is between technological and administrative innovations (Kimberly and Evanisko, 1981). Technological innovations refer to changes in both the hardware employed and the knowledge and procedures associated with the hardware. Administrative innovation refers to changes in the way in which the organization is structured and managed. Both types of innovation are relevant to the nuclear power industry. The nuclear power industry is faced with considerable pressure to innovate. On the technological side, a number of unresolved safety issues remain in the design and operation of the plants. A significant one is the problem of pressurized thermal shock. On the administrative side are issues of training, appropriate levels of autonomy, and the like.

4.3.2 Innovation and Safety

One key set of relationships linking structure to safety involves the mediating effects of innovation. Many productive technologies are incomplete. That is, current knowledge is insufficient to reach the desired goals in every case. Medical technology is a case in point and so is nuclear power production. There are many unresolved technical problems (water hammer, pressurized thermal shock, etc.) in this technology. Until these problems are resolved, unsafe conditions will remain. The safety of the plants, in the long run, depends upon the solution of such technological problems. It also, however, depends upon the ability of the utility to generate and assimilate administrative innovations supportive of improved safety.

For a given plant, solution to administrative and technological problems can come about either through the creation of new knowledge or from the importation of this knowledge from the environment. Both types of behavior constitute innovation. Not all organizational structures, however, are as capable of supporting innovation. There exists a preponderance of evidence indicating that more bureaucratic or mechanistic organizations are less capable of innovation than organic forms. This relationship exists for a number of reasons.

4.3.3 Design Determinants of Innovation

First, mechanistic organizations (emphasis on authority systems, formalization, job codification and routinization, etc.), are typically associated with technologies and environments that require less innovation. They are, in fact, established to deal with routine situations and are most effective under these conditions (Woodward, 1965; Burns and Stalker, 1961; Lawrence and Lorsch, 1967).

Second, a variety of characteristics of bureaucracy have been found to frustrate the process of innovation. A number of scholars have argued that bureaucracy stifles creativity in organizations (Merton, 1948; Argyris, 1957). Formalization, routinization, and the like are seen as producing conformity at the expense of positive change. The narrowing of job responsibilities that is characteristic of mechanistic organizations has been found to be associated with lower levels of innovation (Pelz and Andrews, 1966; Rosengren, 1967) in a number of settings. Formalization and job codification have likewise been linked negatively to innovation (Thompson, 1967; Hage and Aiken, 1967; Gordon et al., 1972). Hlavacek and Thompson (1973) argue, for example, that the formal process of costing activities in bureaucratic organizations precludes engaging in speculative (innovative) behaviors of untested benefit.

Centralization of authority has also been linked to low innovation rates. Centralized organizations do not allow for individual autonomy in the pursuit of new approaches to problem solving. This is particularly frustrating to professionals in organizations (Kimberly and Evanisko 1981) but some argue that it characterizes a general response to centralization (Tannenbaum, 1968). Another argument made by Cole (1982) is that mechanistic organizations are incapable of absorbing "good ideas" from lower level workers because of the rigid top-down authority patterns (see, also, Brown, 1978). For whatever reason, there exists considerable empirical evidence to support the position that decentralized organizations are more innovative (Kimberly and Evanisko, 1981; Hage and Aiken, 1967, 1970; Aiken and Hage 1971; Corwin, 1972; Gordon, et al., 1972; Burns and Stalker, 1961; Hage, 1980; Blau, 1973; Palumbo, 1969 among others). Price (1968) has offered a limiting condition to this position in arguing, with some empirical support, that only under conditions of task uncertainty and complexity is decentralization crucial for innovation. This evidence would hold, however, that to the extent that innovation is necessary in current nuclear plant technologies, decentralization is positively associated with safety.

Other characteristics of organizations have been found to vary positively with innovation rates. Average leaders' educational attainment has been argued to correlate with a willingness to innovate (Hage, 1980; Becker, 1970; Rogers and Shoemaker, 1971). A related argument with somewhat stronger empirical support is that a relatively high concentration of specialists (professionals) in an organization is associated with innovation and, therefore, quality. Kimberly and Evanisko (1981), for example, take the position that specialists tend to have broad knowledge bases allowing them to engage in innovative behavior. Similar arguments have been made by Hage (1980) and Hage and Aiken (1967). Another explanation is that the existence of a large number of specialists creates a situation where debate on the issues is likely (Lawrence and Lorsch, 1967; Wilson, 1966). This debate is likely to focus the organizations attention on issues of product and process quality (Hage, 1980). A similar argument can be made for the general concept of complexity. Organizations with a large number of distinct occupations (Hage and Aiken, 1967) and with a large number of departments (Hage and Aiken, 1967; Blau, 1973; Heydebrand, 1973), have been found to promote relatively high innovation rates.

Finally, specialists and particularly professionals, are likely to be linked to external sources of information that are crucial for innovation. (Current literature, practices, and associations are examples.) This linkage has been advanced as a basis for the relationship between innovation and the use of professionals (Hage, 1980; Hage and Aiken 1967; 1970). Empirical studies have uniformly affirmed the importance of external links and boundary spanners for successful innovation (Hage and Aiken, 1967; Becker, 1970; Burt, 1973; Kimberly, 1978; Tushman, 1977; Katz, 1982).

To summarize this theme, then, there appears to be substantial support for the general view that organic organizational structures are necessary for innovative behavior. (An important caveat is offered by Pennings and Goodman, 1977, when they argue that conditions of scarcity drive out innovation no matter what the structure.) To the extent that innovation is a determinant of safety, organic structures (ceteris paribus) should be safer structures.

4.4 Compliance and Safety

4.4.1 Definition of Compliance

One of the main problems facing the organization is making sure that its members comply with the behaviors necessary to reach the organization's goals. Compliance, then, is related to safety in so far as the organization adopts safety as one of its goals. Compliance refers to the behavior of organizational members. It is difficult to talk about compliance, however, without also talking about organizational control. Control refers to the process whereby the behavior of the organization's members is brought in line with organizational goals. Control, therefore, is the way the organization achieves compliance.

Few areas have received as much attention in the organizational literature as the control-compliance relationship. If the organization is to avoid

random or dysfunctional behavior and is to be effective, compliance through control much be achieved. It is instructive to look a little more closely at what is meant by compliance.

One useful distinction in terms of types of compliance is that between compliance due the threat of sanction and compliance due to the acceptance of the organization's goals and rules as one's own (Hrebiniak, 1978). Stated another way, compliance can either be imposed on the individual by the organization through its manipulation of rewards and sanctions, or the individual may choose to comply due to the individual's free acceptance of the legitimacy of the organization's expectations for his behavior. On the control side of the equation, then, we can talk about external control mechanisms (forced compliance) and internal control mechanisms (acceptance). It is important to remember, however, that control is not 100 percent efficient in achieving compliance. That is, having a control structure does not automatically mean compliance will be realized.

A related distinction has been advanced by Etzioni (1975). Etzioni argues that organizations vary significantly in their bases for compliance. He has created a typology of organizations which, in its simplest form, differentiates between coercive, utilitarian, and normative compliance. Coercive compliance refers to compliance achieved through the threat of physical violence. Military, penal, and some educational organizations use this form of control to achieve compliance. Utilitarian compliance refers to compliance achieved through the organization's control over (essentially) monetary rewards. Most business organizations stress utilitarian compliance. Normative compliance, on the other hand, refers to compliance achieved through the manipulation of internal normative states. In this case, the individual complies with the organizations perspective because it is believed to be the right thing to do. Religious and voluntary organizations generally fall into this category. It will be noted that Etzioni's typology also assumes an external (coercive, utilitarian) and an internal (normative) source of compliance.

Compliance is usually viewed as a problem relevant to low level workers. We argue here that compliance is not only relevant to low level workers and higher level workers, but that the organization itself can be viewed as compliant or non-compliant. In this case, compliance refers to whether or not the organization complies to externally generated rules for achieving the desired goal of safety. The factors leading to organizational compliance are in some ways the same but in other ways different from the factors leading to individual compliance. It is also worth noting that the tendency to limit the relevance of compliance to the lower level workers is reflective of the distinction between external and internal control. Lower level workers are typically viewed by managers as controllable only through coercive or utilitarian means. This leads to a view of externally induced compliance. Managers, on the other hand, typically see themselves as controlled by internal motivation. This leads to a view of compliance that stresses acceptance. By not realizing that acceptance is also a form of compliance, many organizational theorists have paid too little attention to compliance issues at the higher levels of the organization.

4.4.2 Compliance and Safety

The internal-external distinction is also relevant to the relationship between compliance and safety. There is a strong bias in favor of the perception that compliance is achieved through the strict definition and application of procedures. Several analysts of safety issues in the nuclear power industry have cited non-compliance with procedures as a major, if not the major reason for safety threatening events. The same position has been stated relative to other industries (Heinrich, 1980). The logic behind these assertions is simple and direct. Procedures exist to establish appropriate (safe) work behaviors. Deviations from the procedures indicate deviation from safety. This position is so self-evident that non-compliance with procedures is sometimes used as a measure of safety (see Chapter 6 of this volume). In order to achieve compliance, and hence safety, the organization must establish procedures that emphasize safety and establish the external controls that are necessary to enforce compliance. As will be argued below, the enforcement of procedures tends to be a characteristic of mechanistic organizational structures.

Against this background of logic, there would appear to be very little room for internal determinants of compliance. However, there is a literature that suggests that compliance is most likely if it comes from an internal or normative source (Haas and Drabek, 1973). That is, when workers internalize the goal of safety, compliance is more likely than when the organization depends upon external control to impose safe behavior (see also Heinrich, 1980). To a considerable extent, as argued below, the design determinants of external control are contradictory with the design determinants of internal control. This leaves the organization in the difficult position of emphasizing rules to achieve external compliance, or emphasizing participation and involvement to achieve internal compliance. Despite the substantial research literature indicating that internal compliance is more effective, few organizations or regulators are willing to give up on a reliance on procedures in achieving compliance relative to safety.

It is also important to note that the compliance issue depends upon the nature of the tasks involved. Where the tasks are clear and the safety implications are well known, the organization can specify unambiguous procedures. Exacting compliance with these procedures can be achieved through a number of the external control mechanisms cited below. However, where the nature of the task is unknown, as in areas where some aspects of the technology are still being defined (engineering) or where there are a substantial number of unique events (maintenance), the establishment of rational procedures is more problematic. To impose a procedures orientation toward compliance in these situations is probably dysfunctional. Instead, safety will depend upon the degree to which the workers have internalized the organizational goal of compliance. As in the case of the earlier intermediate outcomes then, technology specifies the relation of compliance to safety.

4.4.3 Design Determinants of Compliance

Organizations rarely leave their operations to chance. Rather, what sets organizations apart from other social units is their tendency to formalize activities and to impose systematic strategies of control. Control structures exist to exact compliance with some standard of behavior. The extent to which compliance is achieved reflects directly on the quality of performance and, hence, safety. While few would argue that compliance is not essential, particularly in the complex systems that comprise the nuclear power industry, the literature offers conflicting information on the best way to achieve compliance. In general, however, the positions resolve into two--a view of the worker as being primarily extrinsically oriented and best controlled by formal mechanisms versus a view of the worker as being primarily intrinsically oriented and best controlled by informal relations (McGregor, 1960; Likert, 1961). A third position, that the relevance of the intrinsic and extrinsic views depends upon the nature of the task involved, will also be discussed.

4.4.4 The Utilitarian-Formal View

In an influential work, Etzioni (1975) points out the basic difference between control systems based on the assumption that workers are motivated by extrinsic (pay, promotion) rewards, versus the perspective that sees the worker as motivated primarily through their commitment to the organization and its goals. This contrast constitutes a central debate in the literature.

Three closely related themes have characterized the utilitarian view of compliance. The first concerns the way in which managers induce the average worker to perform to some minimum standard. For the most part, this has been reduced to the simple problem of providing adequate rewards through pay and promotion so that, in the terminology of March and Simon (1958), the worker's marginal utility of reward over effort is positive, but not excessive. The underlying assumption is that organizational members are motivated purely by the pursuit of instrumental rewards, an assumption that echoes the scientific management point of view (Taylor, 1947).

The second theme follows directly from the first and concerns the formal surveillance systems implemented by managers to determine whether the workers are meeting minimum standards. The relevant activities include quality control, employee evaluations, and intensity of supervision (Ouchi and Maguire, 1975; Rushing, 1966; Thompson, 1967). All of these are attempts to see if the workers are living up to their side of the bargain by producing in proportion to their rewards, and introduces the probability of punishment.

The third theme focuses on managerial control of problem solving. It is this aspect of control that has been of primary concern in the comparative literature. Given that the organizational members have been "properly" motivated by pay and promotion and the threat of dismissal should their contributions fall below acceptable standards, the remaining control problem that managers face is whether workers, when confronted with job related options, are making the correct decisions--a question directly related to

safety. In the utilitarian view, however, the solution to the problem is for the manager to retain as much discretion over problem solving as possible.

The formal control mechanisms outlined earlier are at the heart of the external control approach. Intense monitoring through employee evaluations, narrow spans of control, and quality control, combined with sanction and reward systems closely tied to monitoring constitute the first line of control. Centralized decision making and/or a priori decision making through procedures and written rules and regulations minimize individual discretion.

In combination, these formal control mechanisms just described constitute the heart of the mechanistic model. Starting with the assumption that workers are "out of control," compliance is achieved through the institution of rules, monitoring systems, and utilitarian reward systems, while at the same time retaining power and authority at the top of the organization. An alternative route to compliance is discussed next.

4.4.5 The Normative-Informal View

Just as there is a long history of literature arguing that worker's motives are instrumental (Taylor, 1947; Weber, 1947:333-336; Dubin, 1956), there is also a vast literature arguing that worker motivations include, albeit in varying and uncertain degrees, commitments to the organization, its goals, its leaders, and its members (Blau, 1955; Gouldner, 1954; Hrebiniak, 1978; Mayo, 1945; Roethlisberger and Dickson, 1939). Writers in this tradition have been critical of the limited, instrumental view of motivations. Mayo (1945), has referred to the instrumental view as the "rabble hypothesis" for its inability to recognize social organization at the work-group level. Bennis (1959), has referred to the same phenomenon as "organizations without people" for its neglect of the range of human motivations. Etzioni (1975), has identified commitment as one of the primary ways that organizations can achieve internal compliance. In fact, Weber (1947:324-325), recognized the importance of affective ties binding the individual to the organization and argued that where motivation rested solely on material interests, the corporate group was inherently unstable.

Perhaps the strongest support for the importance of considering worker commitment as relevant to the overall control strategy of the organization has come from cross-cultural research. While commitment has long been recognized as a dominant motivation in voluntary associations (Etzioni, 1975), its relative importance in business organizations has been questioned. For example, Crozier's study of French bureaucracy shows worker identification with and involvement in the organization to be bounded almost entirely by specific work roles and economic motivation (Crozier, 1964:31). In contrast, however, findings from the analysis of Japanese business organizations have indicated that worker commitment plays a vital role in establishing appropriate worker behavior (Abegglen, 1958; Dore, 1973; Rohlen, 1974). The effects of commitment extend beyond the determination of individual levels of productivity to what is mutually accepted by management and labor to be appropriate means of formal control. If as Dore (1973)

argues, western companies are becoming more like Japanese companies in their reliance on commitment, these findings gain in importance. The simple contrast between Crozier's description of French organizations and Abegglen's description of Japanese organizations strongly suggests that variation in worker motivational patterns is an important factor differentiating organizational control systems across, and perhaps within cultures. It further suggests that variation in internal compliance is a major dimension differentiating organizations.

4.4.5.1 Normative Design Characteristics

What are the design characteristics associated with normative or intrinsic motivations? To begin, there is a considerable literature pointing out that formal mechanisms of control are inconsistent with the factors that lead to normative control. For example, since the external mechanisms of control uniformly suggest a loss of individual autonomy, it can be expected that internal compliance will suffer in the face of a dependence on formal mechanisms of control. Considerable evidence exists to support this view. Participation in decision-making, which is frustrated by the formal mechanisms of control, has been found to increase commitment (Likert, 1961; Katz and Kahn, 1966). Argyris (1957) has argued that the use of specialization, intense supervision, and a rigid hierarchy of authority frustrates individual emotional needs. Research on related concepts has found morale, alienation, and job satisfaction to be similarly related to aspects of formal control (Pennings, 1976; Ivancevich and Donnelly, 1975; Udy, 1965; Hage, 1965; Aiken and Hage, 1966). Research by Brown (1969), has found commitment to be negatively related to organizational complexity (specialization), routinization (standardization), and bureaucratization (formalization).

If formal mechanisms are not sufficient to cause compliance based on a normative orientation, what mechanisms exist that are adequate? Ouchi (1981), argues that the main mechanism is managerial trust. Where managers show that they trust workers and perceive them as part of the organization (as evidenced by employment stability and participatory management), Ouchi argues that they will develop a commitment to the organization that will lead to a high level of compliance with the organization's goals and procedures. This argument is at the heart of the Human Relations approach and is present in numerous writings (Likert, 1961; MacGregor, 1960; Lippit, 1982).

The maintenance of this form of compliance hinges on the manner in which hierarchy is managed in the organization. Specifically, if the organization chooses a participatory supervisory pattern, where worker input and autonomy is encouraged, normative compliance has been found to increase (Etzioni, 1975). Also found to increase are related concepts such as job satisfaction (Hall, 1977), and commitment (Brown, 1969). By emphasizing worker participation, the workers come to feel that they have a greater stake in the organization and, therefore, are more concerned with the implications of their behavior for the organization.

4.4.6 Which Approach is Best?

Despite strong opinions on both sides, the literature does not support an unambiguous view of the best way to exact compliance to assure safe performance. To begin, most studies have focused on measures of effectiveness other than safety. Second, studies can be found that support the contention that formal structures are more effective than their informal counterparts and vice versa. For example, Price (1968) argued that centralized organizations are, on the average, more effective. McMurray (1958) has argued that the motivational levels of workers are insufficient, even with participatory structures, to assure compliance and that the organization is better off employing formal structures. Hage (1980), in his review of the literature maintained that there is insufficient evidence to claim that participatory schemes, based on normative orientations and compliance, actually lead to higher levels of productivity. On the other side of the issue, Tannenbaum (1968) and Seashore (1963) offer support for the position that more open structures are more effective. In a major review of the leadership literature, Filley and House (1969) come to the opinion that the participatory leader is able to exact higher satisfaction and greater compliance as indicated by higher productivity.

While ambiguity remains, there is increasing evidence that the usefulness of one or the other approach depends upon the nature of the task and personnel involved. Burns and Stalker (1961) and Lawrence and Lorsch (1969) found that as the degree of uncertainty in the environment increased and, by implication, task uncertainty increased, less emphasis on formal structures was desired if the organization was to be effective. Highly formalized control systems frustrate the ability of organizational members to respond to changing situations. These findings have been replicated in other contexts. Fielder (1972), for example, has found that the need for a participatory structure is less under routine conditions (see also, Hall, 1977). Taylor (1971) has found that participation is a more effective control strategy when technology is sophisticated. Hage (1980) has summarized this literature and comes to much the same point--control systems must be consistent with the tasks confronting the organization. Organizations with routine work may depend on formalized control strategies that tend to frustrate individual and group initiative. However, organizations that depend on such initiative to resolve uncertainty in the production process, can best promote compliance, and, therefore, quality, with participatory control systems.

5. CONCLUSIONS

This review of the organizational literature has argued that organizational design works through a set of intermediate outcomes to influence organizational safety. While such arguments do not take the place of systematic empirical study of the issue, they do serve to legitimate and guide empirical efforts in the future. A number of themes seem to emerge time and again from the literature. Perhaps the most important one concerns the dilemma facing organizations over the conflicting demands of quality, innovation, efficiency, and compliance as goals.

5.1 Organizational Design Dimensions

Design refers to the way that the organization structures its activities to solve a set of universal problems. The problems most relevant to our concern with safety in nuclear power plants are how to divide the work and group activities, how to exact compliance from members, how to link various activities, and how to assure future success. The associated design dimensions of these problems we have called administration, control, coordination, and development, and reflect dimensions of design common in the literature (Osborn et al., 1980). Organizations vary widely on each of these dimensions. However, two "ideal types," the mechanistic and the organic forms, can illustrate the range of variation. In the mechanistic form, administration emphasizes a detailed division of labor and hierarchy, control is via written rules and regulations, coordination depends on the chain of command, and development is limited to such issues as training. In the organic form, administration contains less emphasis on hierarchy, control would allow more discretion, coordination would be emphasized via horizontal communications, and development would be emphasized to the point of major organizational change (Burns and Stalker, 1961).

Our review of the literature suggests several hypotheses about the effects of organization design on the intermediate outcome factors of efficiency, quality, compliance, and innovation. Nuclear operations appear to embody a mix of routine and non-routine operations. Efficient operations are likely to be facilitated by a mixed organizational design, employing a mechanistic or bureaucratic structure for the routine aspects of operations, and a more flexible organic structure for the non-routine and professional aspects of the operation (Hage, 1980; Litterer, 1973). The organization should also pay attention to buffering the expected conflicts between these two somewhat different organizational patterns. A quality orientation is more congruent with an organic rather than mechanistic form (Perrow, 1967). The organic form allows members the autonomy and other resources necessary to go beyond merely adequate levels to improved levels of performance. Innovation is also expected to be facilitated by organizations which employ a more organic structure, particularly when there is a reliance on craft and professional workers. In order for these professional groups to function effectively, the organization must allow for a free flow of information both within and across organizational boundaries (Kimberly and Evanisko, 1967). The linkage between organizational design factors and compliance appears to be mediated by the routine and non-routine aspects of nuclear operations. For the routine aspects, strong external controls may facilitate compliance. On the other hand, in the non-routine areas, the organization may be better off emphasizing internal motivation towards compliance (Hall, 1968).

Significant new insights are likely to be obtained by research in this analysis of utility, nuclear, and plant organizational designs. Such research would necessarily entail primary data collection based on personnel directories and current organization charts of nuclear utilities, plus selected interviews and limited industry-wide surveys. However, NRC could easily make existing information sources more useable by providing common updating specifications.

The NRC has considerable power to push utility organizations in one direction or the other. At the moment, there appears to be a greater and greater tendency to impose mechanistic solutions to perceived safety problems. Perhaps this is due to the fact that rules appear more real or dependable than other ways of promoting safety. The literature reviewed here, however, suggests that the promotion of safety through organizational design requires more serious, systematic attention than it has received to date.

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APPENDIX A

QUALITY: A REVIEW OF THE LITERATURE ON AN ELUSIVE TOPIC*

WHAT IS QUALITY?

Many definitions have been offered for the concept of quality. Below we review some of the conceptual definitions, which get at different aspects of quality, and empirical definitions which attempt to provide operational measures of these aspects.

Conceptual Definitions

Webster defines quality as "degree of excellence, grade, or superiority in kind" (Webster, 1971). This simple definition has been greatly expanded by scholars interested in the problem of quality in industry and government. Utzig (1980) defines quality as "The relative excellence of the composite of all product or service attributes in fulfilling the needs and reasonable expectations of those who receive the product or service, as they perceive such fulfillment from the time of offering through the product life." Hershauer, Ruch, and Adams (1980) propose that "Quality is the degree to which a product or service conforms to a set of predetermined standards related to the characteristics that determine its value in the marketplace and its performance of the function for which it was designed." These latter two definitions have two factors in common; both define quality in terms of the standards set by the consumer and both see quality as pertaining to services as well as products.

A number of terms appear in the literature that seem to be related to quality. Reliability, as applied to products, refers to the frequency with which the product breaks down. In service industries, reliability refers to the extent to which the service is performed or delivered adequately in the absence of supervision. Maintainability, another term that connotes quality, refers to the ease and speed with which a product gets repaired after it has broken down. Product availability is usually defined as some combination of reliability and maintainability. It refers to the proportion of time that the product is actually available to perform its function.

Empirical Definitions

The manner in which quality has been empirically defined depends to a great extent on whether it is a product or service that is being rated. Although there are exceptions, product quality generally is measured by means of some objective criterion while the rating of service quality is somewhat more subjective. For this reason, we will review the empirical definitions of quality separately for product and service industries.

*References may be found in the reference list to the body of this chapter.

Product Quality

It is generally considered that the amount or proportion of items that are defective or fail to meet some predetermined standard is an adequate measure of product quality. For example, Adam (1975) used the number and proportion of diecast shots that were defective as his measure of product quality. Almost identical measures have been employed by Schwinn (1980), automobile engine fastener assemblies; Kozarich and Cornuet (1977), steel tubing; Turner (1960), sheet metal products; and Kimmick (1965), fuses. However, it is quite possible to use other criteria. Other variables that have been used include such measures as mean-time to failure, consumer complaints, customer surveys, or other customer-based measures.

Another aspect of product quality is also related to the consumer. It is possible to break down some overall measure of perceived product quality into a number of component parts and determine which aspects of the product's overall quality are important. Some examples might be: (1) reliability of operations, (2) performance efficiency, (3) durability, (4) ease of installation and maintenance, and (5) product service. Regardless of the specifics, it should be apparent that there is more to determining the quality of a product than merely the number of defective units produced.

Service Quality

Measuring quality becomes somewhat more difficult in the absence of some tangible product that can be weighed, measured, and inspected. However, the quality of services provided by an organization is as important as the quality of some manufacturing product. The social scientists who have examined quality have tended to use relatively subjective measures of quality. Seashore, Indik, and Georgopoulos (1960) had supervisors of a delivery service firm rate quality of the services provided by their subordinates. Georgopoulos and Mann (1962) used the ratings of experts to measure four dimensions of the quality of care provided by a hospital. Wofford (1971) used ratings by subordinates on four 9-point items as a measure of the quality of supervision in 88 companies. Finally, Cameron (1982) used the ratings of faculty and administrators to assess the quality of universities. Among the factors that were included were academic development, student career development, faculty development, and faculty quality.

There have been a number of studies that have attempted to use more objective, quantitative measures in assessing the quality of a service. Petty and Bruning (1980) used error rates as determined by misclassifications, overpayments, and underpayments as a measure of the quality of service in public welfare programs. Adam (1972) also used error rates in assessing the quality of performance on a repetitive clerical task.

Relationship to Other Organizational Effectiveness Criteria

Probably the most common conception concerning the relationship of quality to other organizational effectiveness criteria is that as quality goes up,

quantity goes down. Empirical research seems to bear this fact out. Weiner (1966) reported a case where a 40% loss of efficiency was observed among a group of female inspectors at a factory after the implementation of a quality emphasis program. Buller (1982) has found that ore grade (a measure of quality; ore is comprised of the metal being mined and waste rock) of silver miners is inversely related to the number of tons produced (a measure of quantity). Fitts (1969) conducted an experiment with subjects performing a task under three different reinforcement contingencies: high quality, high quantity, and "do best." He found that the subjects reinforced for high quality had high quality but low quantity, the subjects reinforced for high quantity had high quantity but low quality, and the "do best" group had quality and quantity levels that were intermediate.

However, there are studies indicating that the relationship may not be all that simple. Conner (1980) suggests that quality and quantity are somewhat independent and that well-designed quality control techniques can improve the quality of textiles and garments without sacrificing quantity. McKinnon (1980) reports that, after a crackdown on safety violations in the United Kingdom, quality went up at no loss of quantity.

Quality has also been related to a number of other criterion measures, most notably organizational or supervisory effectiveness. A number of studies have included measures of quality in measures of overall effectiveness. Cameron (1982) in the study described above, used ratings of faculty quality, quality of student academic development, student career development, and faculty development as a large portion of his rating of the overall effectiveness of a sample of universities. Staw and Oldham (1978), Petty and Bruning (1980), Wofford (1971), Seashore, Indik, and Georgopoulos (1960), Georgopoulos and Mann (1962), and Turner (1960) have all used some measure of quality in determining overall organizational effectiveness to a greater or lesser extent.

One somewhat disheartening set of results concerns the relationship of subjective ratings of quality to objective quality measures. Turner (1960) reports that foreman ratings of the quality of work produced by subordinates were not significantly correlated with the percentage of materials that went to scrap. The quality ratings were related to other supervisory ratings, but not to any objective quality criteria.

However, the search for quality ratings goes on. Whitlock, Clouse, and Spencer (1966) attempted to develop and validate a measure of "error behavior" since error rates are not considered to accurately reflect the instances in which an error could have occurred.

One of the penalties for lack of quality is reduced safety of a product or process. A poorly made product may break in use, exposing the user to hazards, and a poor quality process may expose workers or the public to industrial hazards. Because of the linkages between quality performance and safety, a review of the literature on quality performance is directly relevant to the problem of ensuring safety in industrial operations such as nuclear power plant operation.

A number of studies have shown that quality is positively related to safety. Seashore, Indik, and Georgopoulos (1960) found that the quality of delivery service was inversely related to the number of reported accidents. Bell and Telman (1980) obtained a similar set of results in a sample of workers performing rotating shift work. It is highly likely that the same factors that are conducive to good quality also facilitate safety. Workers striving for quality are less likely to rush to get a product completed, they are less likely to be careless, and more likely to maintain a clean working environment. All of these behaviors should contribute to safety.

Finally, there is some literature relating quality to job satisfaction. Walker and Guest (1952) reported that when workers were not able to sustain quality performance, "this was a negative and discouraging feature of the job." Huse (1966) found that 80% of the workers in one plant had a strong desire to do a quality job. One worker was quoted as saying, "I feel rotten if I'm not doing a good job." In light of the prevalent feeling that American workers no longer care about the quality of their work and the inability to find consistent relationships between job satisfaction and performance, more research in the area of the relationship between quality and job satisfaction is in order.

The major factor that does lie with the worker is motivation. Adams (1972) has shown that both monetary and verbal reinforcers worked to motivate workers to higher quality performance; however, it is difficult to improve quality when the reinforcement is suddenly changed from being quantity contingent to being quality contingent. Price (1972) reported a strong, positive relationship between motivation toward quality and actual quality performance. Similarly, Worsley and Fraser (1977) found that constructive feedback from the supervisor concerning quality performance could improve quality in mail sorting. Buller (1982) reports that a goal-setting program improved the quality (oregrade) of miners.

In each of these instances, improvement of quality occurred only after management had made some attempt to motivate employees toward quality. However, Huse (1966) has shown that workers already want to do a good job. Given that that is true, the improvements in quality might be due to the fact that management is indicating that quality is a priority goal. While almost all organizations pay some form of lip service to quality, when it becomes a priority item in an organization some of the barriers to quality that management controls may be removed, without management being aware of it. This allows workers to do what they are already motivated to do: deliver a quality service or product. Motivation becomes, in reality, a form of "Hawthorne Effect": if you pay attention to it, it will get better.

CHAPTER 2

ORGANIZATIONAL GOVERNANCE

1. INTRODUCTION

1.1 Purpose

The purpose of this chapter is to provide a review of the literature on organizational governance and dominant coalitions, in order to hypothesize relationships between these factors and nuclear power plant safety. Specifically, we discuss questions that pertain to:

- (1) organizational governance types and key factors having relevance to the nuclear power industry
- (2) hypothesized dominant coalition values within the industry
- (3) linkages between these values and associated types of governance
- (4) selected logically deduced hypothesized relationships among dominant coalition values, governance types, and nuclear technology that may impact the safety of nuclear power operations.

1.2 Major Subjects Treated

The proposition that organizations are governmental systems, as much as they are technical, administrative, or communication systems, is a fairly recent one in the organization theory and design literature. However, this proposition has gained considerable acceptance, although much research is required to establish more precisely the nature of the relationships among the factors we postulate here. As suggested by the literature review, five dimensions are considered which seem to have fruitful possibilities as they relate to safety. They are:

- (1) types of complex organizational rationale
- (2) models of governance
- (3) dominant coalition cultures and values
- (4) environmental and contextual conditions
- (5) organizational governance and organizational design.

2. TECHNICAL, BUREAUCRATIC AND GOVERNANCE RATIONALES

Complex organizations, such as utilities with nuclear power plants, are likely to employ three distinct but interrelated types of rationale to generate power safely and profitably. The first is a technical rationale based on the peculiarities of nuclear power operations. This rationale

often yields an emphasis on technical functions (e.g., operations, engineering, quality assurance and health physics [INPO, 1981]). A second logic is a bureaucratic one. Here the concern is with the development and successful implementation of an organizational design. Chapter I considered this rationale with the discussion of administration, control, coordination and developments. By employing these two rationales, one would expect to find a high degree of similarity across nuclear utilities with approximately the same type of facilities. Major differences would be expected by type of plant (e.g., PWR versus BWR), the size and age of the facility and by the number of facilities. Given these variations, the emergence of typical organizational designs and comparatively standard management practices might be anticipated. However, such is not the case. One reason is the overriding rationale used to govern the utility as a whole. This third rationale is the basis for this chapter. Here we will examine the rationale of organizational governance and its interplay with technical and bureaucratic rationale.

The distinction between management and organization discussed in Volume I provides a point of departure for an analysis of organizational governance and organizational design. To summarize, management has traditionally focused upon individual action and roles in the organization. This focus may be extended to examine interactions among managers which yield some identifiable differences in management style. Thus, planning, leadership styles, and preferred methods of decision making, motivation, and communications may be charted.

Organizational analysis concerns more the nature and characteristics of the conditions and processes that occur throughout the entire organization. Here, the emphasis is upon the organization's interaction with other organizations (including the government) as well as with the broader environment (Scott et al., 1981; Osborn et al., 1980).

The analysis of large scale organizational dynamics requires the use of fairly abstract concepts. By using these concepts, we hope to further our understanding of (1) how organizations function, (2) their key characteristics, (3) the major determinants of these characteristics, (4) how these characteristics affect other outcomes such as individual, group, or organization-wide behavior, and (5) what might be done to improve these outcomes.

Large organizations are complex phenomena (Etzioni, 1975; Thompson, 1967). One traditional method of analyzing organizations is to look at several aspects of organizational design: administration, coordination, control, and development. They have been widely discussed in the literature (Barnard, 1938; Lawrence and Lorsch, 1967), and in Chapter I of this volume. The analysis of these aspects provides a basis for understanding how an organization works. Yet it falls short of providing insight into improving organizations. Organizations do not just respond automatically to internal or external pressures. Large organizations are governed.

Two concepts have recently entered the literature which seek to provide at least partial answers to why organizations facing similar demands and using

similar technologies may differ considerably. These concepts are called organizational governance and dominant coalitions (Scott et al., 1981; Pfeffer and Salancik, 1978).

3. THE CONCEPT OF ORGANIZATIONAL GOVERNANCE

Organizational governance refers to the pattern of authority, influence, and managerial behavior established by the most influential organizational participants (Scott et al., 1981). The phrase management philosophy is used to identify this phenomenon.

One of the key tasks of top management is to develop, implement, and maintain an overall strategy which allows an organization to recognize and cope with environmental and contextual complexities. The governance system helps define what is important, how issues will be defined, who should (and should not) be involved in key decisions, and the acceptable alternatives for implementation of these decisions. A well-articulated management philosophy facilitates resolution of the competing demands, constraints, and choices facing an organization.

Several analyses suggests that complex organizations are as much political systems as administrative or technical entities (e.g., Cyert and March, 1963; Brown, 1978). They must deal with the authoritative allocation of resources and thus with the basic questions of power: who gets resources, when should they be applied, where should they be deployed, why should power be allocated as it is? It appears that such choices are not made individually, but as part of an overall pattern--the governance system established by the dominant coalition. While such patterns of governance or management philosophy may not be in written form, their influence on the organization is substantial. It will effect, inter alia, the various design dimensions as well as numerous intermediate outcomes.

3.1 Governance Types and Key Factors

Recent work suggests that it is possible to chart a series of key factors or dimensions* for organizational governance and that one can develop consistent ideal or generic types from profiles across these dimensions. Specifically, one can examine (1) the power motives fostered by the dominant coalition, (2) the character of desired behavior by subordinate managers, (3) the character of the constraints placed on individuals, (4) the purpose of the hierarchy, (5) the view or attitude and character of authority and accountability, and (6) the relative emphasis placed on participation (see Scott et al., 1981).

Although a given firm is expected to have its own unique form of organizational governance, these authors suggest that four ideal types can

*Technically, dimension is often used in reference to a conceptual category while factor is often used in the sense of a statistically derived category. For variety, we have used these words interchangeably.

be used to represent basic tendencies. We have called these four types the traditional, modern, federal, and democratic.* Table 1 lists the four types and the governance factors or dimensions, and provides key terms characterizing each dimension. It should be emphasized that the names of these ideal types are suggestive, i.e., conceptual, rather than empirical (see Rogers, 1969).

3.1.1 Power Motives

This factor may be conceptualized as one of the basic goals of the dominant coalition; what do they want to achieve other than economic goals? A traditional system will seek to control the behavior of individuals, whereas the modern system desires to control the values of individuals. In a federal system, while behavior and values are important, there is an emphasis upon influencing individuals through negotiation. A federal system implies a representative situation where a few may negotiate for others. In a democratic model, while influence is predominant, negotiation is carried on primarily by individuals on their own behalf (Gamson, 1968).

3.1.2 Definition of Desired Behavior

While each organization can specify duties and activities for its members, none can comprehensively define all the behaviors desired to achieve success (however defined). The dominant coalition will emphasize underlying types of action and interaction as a guide for subordinate managers and workers.

In a traditional system, the guide will likely stress obedience to the intent of the organization. In some situations this will result in an emphasis on following technical dictates as embodied in rules, policies, and procedures. The basis for such desired action has been labeled coercive, since violation of rules is often met with physical or economic sanctions (Etzioni, 1975). Although obedience is also sought, conformity to and extensions of a well-defined ideology constitute the definition of desired behavior in a modern system. Since the role of values and ideology is paramount, normative prescriptions are utilized (Hart and Scott, 1975). The federal system will likely define desired behavior in terms of organizational development or improvement in order to reinforce and facilitate negotiations based on a utilitarian calculus of costs and benefits. While it may seem contradictory to posit a dominant coalition in an ideal democratic system, it is possible to conceptualize a group in such a system which will define desired behavior not in organizational terms but rather in terms of individual development.

*In Volume I only the traditional, modern, and federal types were discussed because, as argued later, we do not anticipate finding nuclear utilities edging toward the democratic type.

Table 1

Forms and Dimensions of Organizational Governance

Dimension	Ideal Types			
	Traditional	Modern	Federal	Democratic
Power Motives	Behavioral control	Ideological	Influence	Influence
Definition of Desired Behavior	Obedience plus technical competence	Conformity plus proselytizing	Organizational development	Individual development
Constraints Placed on Individuals	Chain of command and bureaucracy	Internalization of single-set values	Professional standards	Self-control by personal norms and values
Purpose of the Hierarchy	Maximizing prescription to preset processes	Maximize prescription to ideology	Maximize interaction and coordination	Maximize representation
View of Authority/Accountability	By position and centralized	By individual and centralized	Multiple and decentralized	Individual and multiple and decentralized
Emphasis on Participation	Low	Low - some staff input	High	High

Source: Adapted from William G. Scott, Terence R. Mitchell, and Newman S. Peery, "Organization Governance," in Paul C. Nystrom and William H. Starbuck (Eds.), Handbook of Organizational Design, Vol. II. Oxford: Oxford University Press, 1981, 144.

3.1.3 Constraints Placed on Individuals

In all organizational settings there is a need to develop constraints or controls upon individuals in order to achieve the organization's various purposes. The methods used in each of the ideal types will typically be consistent with the other factors.

Thus, in the traditional type the constraints will be found in the chain of command and the bureaucracy (Davis, 1951). The constraints will be formally stated and collective in character, as embodied in written policies, rules, and procedures covering a class of workers or managers. In a modern system, while the above methods will also be used, more reliance will be placed on demanding that the single-set values pursued by the dominant coalition be internalized by the members of the organization (Hart and Scott, 1975).

The federal system, however, will rely more upon team-developed constraints which are reinforced by professional norms or standards (Thayer, 1973). The source of these norms may range from recognized professions to a concept of professionalism appropriate for a given type of activity. These constraints will also be found in a democratic organization, but will be furthered by individual self-control relying upon personal norms and values (Bennis, 1966).

3.1.4 Purpose of the Hierarchy

The hierarchy of an organization serves many purposes. In terms of organizational governance, the emphasis is upon the purposes it serves for the dominant coalition. Consistent with the power motive of behavioral control through obedience, technical competence and the chain of command, the traditional governance system will use the hierarchy in order to maximize prescription to preset processes. With its emphasis on ideological conformity, the modern system will use the hierarchy to ensure the maximum prescription possible to the single-set values pursued by the dominant coalition.

In the federal system, with its emphasis upon influence networks, organizational improvement, and semi-autonomous groups constrained by professional standards, the dominant coalition will use the hierarchy to maximize interaction and coordination. The democratic model, grounded in individual influence, development, and self-control, will also use the hierarchy to further interaction and coordination, but in addition will seek to maximize individual representation in decision processes.

3.1.5 View of Authority/Accountability

The classical viewpoint sees authority as moving down the hierarchical chain of command with accountability moving up to a centralized position (Weber, 1947; Davis, 1951). Thus in the traditional system, authority/accountability is seen as being located in positions, i.e., job titles, and centralized at the top of the organization. The modern system follows the same pattern but, with its emphasis upon internalization of the value

system, will focus more upon individual authority/accountability than a particular position within the organization.

In the federal model, characterized by power being distributed by negotiation and supported by professional norms, there is a strong tendency to develop project management or matrix-type organizations. As a result, authority/accountability is often spread among several groups or individuals; it is multiple and decentralized. These dynamics are extended in the democratic system with its emphasis upon the individual. Thus a more elaborate and complex authority/accountability network is found which is both individual and multiple as well as decentralized.

3.1.6 Emphasis on Participation

The concept of subordinate participation in decision making has been long discussed in the management literature (Heller and Rose, 1973; Porter et al., 1975). It has recently become a popular innovation under the guise of team development and quality circles (Lippitt, 1982). From the point of view of governance, the central question is the degree to which the dominant coalition emphasizes and encourages subordinate participation in the decision-making process.

Because a traditional system opts for a formal hierarchical chain of command that seeks to maximize prescription to preset processes, the dominant coalition would elicit information and performance data rather than participation from subordinates. This pattern would then be followed, ideally, throughout the system. Thus there would be a low emphasis on participation in a traditional system. Although the modern system will also de-emphasize participation, it will tend to elicit participation in selected areas, especially from specialized staff units, due to its trust and reliance upon those who have internalized the single-set value system.

In both the federal and democratic system, with their emphasis upon group or individual influence constrained by profession or individual norms and with organizational or individual development as a goal, participation by subordinates will be encouraged. Participation would thus be based on the experience/expertise of both line and staff units.

3.2 Forms of Organizational Governance and Intermediate Outcomes

As the above analysis of the factors implies, the different forms of organizational governance each have their own strengths and weaknesses. Although the history, evolution and character of the nuclear power industry work against finding the democratic form in actual practice, it is expected that variations of the traditional, modern and federal forms will be in evidence. Given the characteristics of each form we would expect the following associations with the intermediate outcomes of quality, efficiency, compliance, and innovation (for an analyses of these outcomes see Volume II, Chapter 1).

With the traditional form, one might expect higher on-line performance early in the operation of the facility. This is attributable to the emphasis on written rules and procedures as an effective training mechanism for normal operations. Later in the operation of the facility, however, such may not be the case. Here the unexpected and the need for coordinated action are inconsistent with the emphasis on written policies and procedures. Innovation, however, is expected to be lower under a traditional form of governance because the bureaucratic logic consistent with this form will screen out the unconventional and the untested ideas. Both quality and employee maintenance are expected to suffer under the traditional form since it emphasizes the repetitive, routine characteristics of work processes, rather than unanticipated events within these processes. Concern is with common characteristics of activities by level in the hierarchy, not on the unique or unexpected events which may arise.

In the modern form, with its emphasis on ideology, we would not predict high on-line performance. The obvious exception would be where the ideology incorporates efficiency as an indication of conformity to the single-set value system. This expectation may be found in some organizations utilizing a financial perspective as a basis for effective management. Where external regulations are consistent with the ideology, one would expect high compliance--particularly where the regulation was legitimized by top management as an embodiment of the ideology. Conversely, where proposed regulations are inconsistent with the ideology, one can expect substantial adverse reaction and systematic attempts to circumvent the intent of such regulatory initiatives. Innovation is bounded by the ideology and changes within the system are not expected to be substantial. There may, however, be substantial innovation if it is imported from an external supporting organization which mirrors the single-set values of the utility. Unless the organization has a unique social function closely associated with dominant societal values and attempts to export its values (e.g., churches), one expects the modern organization to have difficulty with employee maintenance. Participation is moderate and professional concerns are subordinated to the ideology. In essence the single-set values of the organization may conflict with the multiple values and interests of employees.

In the federal system, quality is expected to be emphasized as an expression of professionalism. However, quality for any one component may be comparatively low if the tasks of the component are not considered central to the success of the organization as a whole. In comparison with the other forms, innovation should be higher since the organization is accustomed to dealing with new ideas and is likely to have mechanisms to stimulate participation. For those regulatory initiatives consistent with professional standards, one would expect high compliance. Regulators could expect organizations with a federal form to negotiate for discretionary application of general understandings rather than fighting for autonomy on ideological grounds or resisting regulations because they impose heavy administrative burdens. With its emphasis on participation, employee maintenance will likely be stressed.

These general tendencies of organizations with different forms of organizational governance are quite speculative and based predominately on a deductive analysis of the strengths and weaknesses of the forms themselves. A somewhat clearer picture for the nuclear industry emerges if we incorporate the concept of dominant coalitions with the notion of organizational governance.

4. THE CONCEPT OF DOMINANT COALITIONS

If organizations do have identifiable forms of organizational governance, a next logical question is who establishes the pattern. Here the concept of dominant coalitions is useful for analyzing how four hypothesized group values in the nuclear power industry influences governance and design patterns.

Dominant coalitions are power groups in organizations which are able to muster internal political support for their aims, goals, and values (Pfeffer and Salancik, 1978; Hage, 1980). Dominant coalitions devise organizational strategies and methods of implementation. They specify causal beliefs, assumptions, models, and behaviors to component organizational units. In short, they define reality for the technical core (Pennings, 1982; Norrill, 1982). The culture of the dominant coalition, the "world-view" they hold about the nature of "ideal" organizational structure and accountability, is expected to be reflected in the organizations' form of governance (c.f., Scott, Mitchell, and Birnbaum, 1981).

Dominant coalitions can be found at different levels of an organization. For example, boards of directors, corporate headquarters, a division, and even a plant may each have their own dominant coalition. Although the coalition at corporate headquarters is generally considered to be dominant for the organization as a whole, it is nonetheless important to analyze the coalitions at each level. If these coalitions are incongruent, i.e., if their underlying value premises differ, serious dysfunctional behavior may result (Osborn, Hunt, and Jauch, 1980). Thus, it is important to examine the composition of dominant coalitions which may emerge in the nuclear power industry. Here we focus on "cultural" orientations since the background, experience and prior socialization of managers are expected to have a major influence on their preferred form of organizational governance. Further, by charting the potential types of dominant coalitions, we begin to see the extent to which the interests and orientations of different types of coalitions may be incongruent.

4.1 The Composition of Dominant Coalitions in Utilities with Nuclear Facilities

We may begin looking at the composition of dominant coalitions by stating three premises. First, managements of utilities with nuclear power facilities may manifest one or a combination of four cultural orientations: conventional power (fossil or hydro), commercial nuclear-engineering, U.S. Navy, and regional. The second premise is that the cultural orientation of a dominant coalition will create variability in organizational design, structure, and performance criteria (Kluckhohn et al., 1951; Kohlberg, 1971;

Bobbitt and Ford, 1980). The third premise is that the individuals' backgrounds and career access routes to higher management supply a basis for the dominant coalition's strategy and operation of a nuclear power facility.

4.1.1 Dominant Coalition Managers From a Conventional Power Culture

If the dominant coalition is composed of managers from conventional power utilities, then it is hypothesized that their cultural orientation will tend toward a traditional model of organization governance (Hall, 1962); the criteria of effective utility performance will be cost driven; they will perceive nuclear energy as a power source different in degree, rather than in kind, from conventional energy sources; and controls and safety technology will approximate those in conventional power systems (England, 1978).

We are concerned here with the appropriateness of a transplanted safety philosophy from conventional to nuclear power operations. Systems that may be satisfactory for the former may not be for the latter. Or alternatively, a conventional philosophy might be satisfactory for the safeness of a single small nuclear power facility, but it might not be where there are multiple facilities. Perceptions of this sort have profound implications for safety. If the utility dominant coalition is cost driven and sees nuclear operations as different only in degree, then there is a potential inconsistency with the views of those dominant coalitions running the nuclear facility. Of particular importance may be the utility with extensive hydro or fossil operations and a single nuclear nuclear facility.

Several research questions arise: what is the perception of nuclear power vis-à-vis conventional power by the utility's dominant coalition? Is it a difference in degree or kind? Does the dominant coalition perceive that conventional organizational models used for other non-nuclear plants are appropriate for nuclear power facilities? To what extent has the typical organizational model for non-nuclear plants been modified (informally) in practice to compensate for technological differences between conventional and nuclear power? Do the cost-driven values of conventional power dominant coalitions result in less safe nuclear power facilities? These questions appear more important as one examines a second type--dominant coalition managers from a nuclear-engineering culture.

4.1.2 Dominant Coalition Managers From a Nuclear-Engineering Culture

Given promotional lines, career paths, and a generation of experience, we can expect that some utilities will have dominant coalitions that have come through the commercial nuclear power route almost exclusively. The research question is whether these people differ culturally from managers who gained access to the dominant coalition through conventional power utilities. We might hypothesize that safety awareness is higher among dominant coalition managers with commercial nuclear power experience.

We hypothesize that a nuclear-engineering dominant coalition will show four orientations. (1) It will emphasize technical complexity in plant design. In Perrow's (1981) words, it will favor tightly coupled technical systems to loosely coupled ones. Thus, we might expect that utilities with a nuclear-engineering dominant coalition will exhibit relatively higher degrees of interdependent technical systems. Safety manifestations of this bias will be toward more "bells, lights, and whistles" which report plant conditions. The stress on highly interdependent, impersonal technical design leads (2) to an emphasis on human failure as an explanation of accidents or errors in operations, rather than an emphasis on design failures (Sugarman, 1979).

Two other dimensions of the nuclear-engineering cultural orientation are the potential conflict between (3) professional standards (quality awareness) and (4) cost awareness. The obvious conflict arises between the use of "state-of-the-art" safety technology (a professional consideration) versus economic-driven technological decisions which may compromise professional standards (cost awareness) (Ford, 1981). Ford suggested that when professional standards are in confrontation with economic imperatives, the economic imperatives override "good technical design" for plant safety.

A related issue also is raised by Crowley and Griffith (1982). They point out that through the interaction of NRC and industry staffs, pressure has been exerted for zero defects and zero risks in nuclear power facility design, construction, and operation. The zero defects and risks philosophy has been encouraged by the need for evidence required in the legal proof of perfection. This situation, institutionalized in the industry for over ten years, has produced the norm that the more complex, the more difficult, and the more time-consuming a method (of design, construction, and operation), the safer it must be! In some ways this tradition is consistent with the professional engineering orientation. But in other ways it has taken safety out of the domain of practical field engineering and put it in the domain of academic, analytical technique. The results, according to Crowley and Griffith, have been to shift the engineering concerns from the likely, most probable failures, to the most unlikely, improbable, multiple failure modes. Following Crowley and Griffith (1982), this shift disorients professional engineering judgment, increases cost, and possibly could result in less safe plant conditions.

In summary, a nuclear-engineering orientation in the dominant coalition is likely to favor tightly coupled technical systems of safety that emphasize human failure, rather than design failure, as the cause of errors and accidents. The orientation, however, is likely to be modified by cost awareness and professional standards of engineering practice. Three research questions arise here: To what extent is the nuclear-engineering cultural orientation toward technical complexity and professional standards co-opted by cost-driven managerial imperatives? Is the safeness of a nuclear power facility increased if its dominant coalition has a nuclear-engineering cultural orientation? (The first question suggests a longitudinal study; the second suggests a comparative study.) One suspects the engineering dominant coalition is biased toward quality. The third question centers on the form of organizational governance. Do those from a nuclear-engineering culture lean toward a federal form of governance?

4.1.3 Dominant Coalition Managers from the U.S. Navy Culture

The Navy nuclear program has been a traditional source of staff for nuclear utilities. Navy nuclear operations have several unique features, compared to organizations in the private sector. Cost is not a major factor in Navy reactor operations, whereas safety and reliability are. Navy nuclear operations are conducive to centralization, chain-of-command authority and accountability, and the imposition of single-set (Navy) values on the technical core. Further, it is often presumed that the level of complexity of nuclear technology is compatible with the Navy bureaucratic model of organization and control.

The direct translation of the Navy nuclear experience to commercial installations may be inappropriate for reasons that are exactly the opposite to those above. Commercial reactors are large, installations are complex, and management is cost driven (raising problems of safety and reliability). Furthermore, we think it is highly unlikely that utility management could impose single-set values on such diverse civilian organizations. For example, the hand/mind separation of authority between operators and engineers does not exist in the Navy to the extent it does in commercial nuclear power plants (cf., Egan, 1982).

In sum, the carry-over of Navy tradition and experience into civilian plant organizational designs may not be appropriate to the realities of commercial power generation. The research question is the extent to which the Navy background has influenced safety policies and performance, positively or negatively, in the utilities whose dominant coalitions are composed of ex-Navy people. A collateral question arises when a utility dominated by a conventional power culture (with a traditional form of governance) operates a facility dominated by an ex-Navy coalition (with a modern form of governance). Because of the conflicting value systems, this combination of governance systems could yield, for example, low innovation and problems with employee maintenance (e.g., high turnover).

4.1.4 Dominant Coalition Managers From a Regional Culture

Casual inspection of data showing the percent nuclear of total power generation by states clearly indicates major regional differences (see Table 2). The concentration of nuclear power generating capacity is in the Northeast, Middle-Atlantic, Southeast, and Middle-West. These regions could be broken down further into city or metropolitan service areas. For example, when two new plants come on line in the mid-1980s, Chicago and Northern Illinois will be 52 percent nuclear dependent.

One research question is, what effect does heavy reliance on nuclear power in a region have on the values and perspectives of a dominant coalition?

Table 2
Percent Nuclear of Total Electric Power Production
by State, 1980

Total Production	(MWH)	% Nuclear
Alabama	78.28	30
Alaska	3.1	0
Arizona	36.8	0
Arkansas	19.6	40
California	135.1	4
Colorado	23.6	3
Connecticut	24.7	48
Delaware	6.6	0
Florida	95.8	17
Georgia	63.2	13
Hawaii	6.5	0
Idaho	10.0	0
Illinois	103.3	27
Indiana	70.6	0
Iowa	21.5	12
Kansas	25.9	0
Kentucky	57.0	0
Louisiana	45.7	0
Maine	7.8	56
Maryland	31.2	35
Massachusetts	34.7	9
Michigan	74.6	21
Minnesota	31.4	32
Mississippi	18.4	0
Missouri	48.9	0
Montana	15.4	0
Nebraska	16.2	35
Nevada	14.0	0
New Hampshire	6.0	0
New Jersey	29.6	26
New Mexico	24.6	0
New York	108.4	18
North Carolina	71.9	8
North Dakota	15.8	0
Ohio	122.1	2

Table 2 Continued

	Total Production (MWH)	% Nuclear
Oklahoma	44.6	0
Oregon	36.2	15
Pennsylvania	122.3	9
Rhode Island	1.0	0
South Carolina	41.7	42
South Dakota	8.5	0
Tennessee	60.1	.8
Texas	150.0	0
Utah	12.0	-
Vermont	3.7	78
Virginia	34.1	33
Washington	92.2	2
West Virginia	70.7	0
Wisconsin	37.7	26
Wyoming	22.3	0

Different forces seem to be at work. First, large capital investment and the need for power would require constant operation of plants, with possibly some neglect of safety considerations. Second, a high population density and high level of safety awareness by the people in the areas might create greater pressure for safe operations. It would be interesting to compare population density and safeness of operation. Of course, this assumes that regional cultures do exist and that they place differential and measurable safety demands on the dominant coalitions of local utilities (Gillespie and Mileti, 1979; Warren, 1967).

Another line that might be pursued here is the extent to which dominant coalitions are recruited from the local areas their utilities serve. Are local loyalty, pride, and sense of responsibility important contributors to safe operations?. For example, do locally recruited dominant coalitions run safer plants than "foreign" dominant coalitions? If the dominant coalition running nuclear operations is "foreign" while the bulk of utility management are "local" are incongruent forms of organizational governance developed? Related to the questions of a regional culture is the issue of a "local" versus "cosmopolitan" orientation. Locals are more likely to look within the organization for guidance while cosmopolitans are expected to rely more upon external (often professional) sources. Here a research question is the extent to which regional inbreeding of the dominant coalition yields a narrow view which is centered on prior successful operations. These questions become more important over time as the facilities become older and utilities have the opportunity to train homegrown talent.

4.2 Dominant Coalitions, Organizational Governance, and Intermediate Outcomes

We have reviewed some of the salient cultural/value orientations in four hypothesized dominant coalitions: conventional commercial power, commercial nuclear-engineering power, U.S. Navy, and regional. It is not realistic to expect to find any one of these types in a "pure" form in utility management. Access to the dominant coalition could come through a combination of the above routes. For example, members of a dominant coalition could have an engineering background, spent time in the nuclear program in the navy, and moved into the nuclear branch of a commercial power company. Alternatively, some members could have moved through the operations of a conventional commercial power company serving a city, which subsequently diversified into nuclear power. As we indicated, these access routes, each "loaded" with value orientations and predispositions toward a certain type of organizational governance, may influence organizational structure and networks of accountability. We would expect to find considerable variation in the cultural/value orientations of the dominant coalitions in utilities which have nuclear power facilities.

Relative to the above, if the utility is "mixed" (some combination of fossil, hydro, and nuclear power generating sources), we would anticipate that the dominant coalition would be composed of managers representing the interests of the most important element in the combination. Empirically, we would need to know for a utility what percent of each power source contributed to its total generating capacity; what percent of the total

capital investment each source accounts for; and what percent contribution to revenue each source makes. We believe that such information is critical to understanding the relationship between the dominant coalition of a utility and its influence on the safeness of a nuclear power facility's operation. For example, a utility with a nuclear power facility that makes a small contribution to total capacity, contributes relatively little to revenue, and constitutes a fairly small part of total investment, is likely to have a dominant coalition that is oriented toward its fossil fuel and/or hydro operations. It could also be hypothesized that such a utility would operate a less safe nuclear power facility than if the conditions in the example were reversed. Given such a reversal, would we find a different set of values/culture in the dominant coalition? We may or may not. The interesting problem here is the degree to which the culture/values of the dominant coalition is synchronized with the requirements of the dominant technology of a utility. We hypothesize that the more out of synchronization the dominant coalition is with the nuclear power technology, the less safe the nuclear power facility. A criterion of safeness thus may be a balance between these two factors and others, such as cost awareness and quality awareness.

5. SUMMARY OF HYPOTHESES

The organizational governance model includes six variables that are patterned into four distinct ideal-types: the traditional, the modern, the democratic, and the federal. In addition, we have argued that dominant coalitions for the utilities with nuclear facilities are likely to be composed of individuals with one of four backgrounds. These we labeled conventional commercial power, commercial nuclear-engineering, U.S. Navy nuclear, and regional. The actual governance system and the dominant coalition for any one utility probably is a hybrid of several types. We have suggested that the cultural orientation of a dominant coalition will be reflected in the governance mode of its nuclear subsystem. However, the governance mode is also influenced by the life-cycle phase of a utility's nuclear subsystem, and the size of the utility itself.*

5.1 Dominant Coalitions and Organizational Governance

In Table 3 we have combined the six governance dimensions with the four types of dominant coalitions likely to be found in the nuclear power industry. The following selected hypotheses are derived from this table.

- H₁: Dominant coalition power motives will vary according to each type of socialization pattern, e.g., regional dominant coalitions will emphasize political influence.
- H₂: Desired behavior will vary among dominant coalitions, e.g., regional dominant coalitions will desire conformity plus administrative improvement.

*The life-cycle implications have not been systematically treated in this review. It deserves more attention.

TABLE 3

Governance Variables in Selected Dominant Coalitions

Governance Variables	Dominant Coalition Socialization Patterns			
	Conventional Power	U.S. Navy	Commercial Nuclear Energy	Regional
DC power motives	behavioral control	ideological prescription	professional influence	political influence
DC definition of <u>desired</u> behavior	obedience	conformity plus proselytizing	conformity plus technical improvement	conformity plus administrative improvement
Constraint system on individuals	chain of command	internalization of single-set values	self-control by professional norm	function to be performed
Purpose of hierarchy	prescription of doctrine: written	prescription of doctrine: oral/written	mod. representational: oral/written	mod. representational: oral/written
Authority/Accountability	centralized	centralized	decentralized	decentralized
Participation	low	low	moderate	moderate

- H₃: Constraints on individual behavior will be different in each socialization pattern, e.g., conventional nuclear-engineering dominant coalitions will stress self-control of individuals guided by professional engineering norms.
- H₄: The orientation of hierarchy toward prescriptions will be greater among conventional power and U.S. Navy dominant coalitions than in commercial nuclear-engineering and regional dominant coalitions.
- H₅: Authority will be more centralized in conventional power and U.S. Navy dominant coalition organizations than in commercial nuclear-engineering or regional organizations.
- H₆: Participation in decision making will be greater with regional and commercial nuclear-engineering dominant coalitions than with conventional power or U.S. Navy dominant coalitions.

5.2 Linkages to Intermediate Outcomes

The following selected hypotheses are intended to indicate the possible linkages from dominant coalitions to governance systems to intermediate outcomes.

- H₁: The culture of the dominant coalition, the "world view" it holds about the nature of ideal governance structure, affects safety.

Cor₁: The culture of the dominant coalition in the organization in combination with the governance structure will influence the intermediate outcomes of quality, efficiency, innovation, compliance, and employee maintenance.
- H₂: Conventional commercial power culture dominant coalitions selecting a traditional form of organizational governance will have higher on-line performance early in the life cycle of the plant but will experience more forced shut-downs as the plant/facility matures.
- H₃: Commercial nuclear-engineering dominant coalitions selecting a federal form of organizational governance will have higher rates of innovation and fewer difficulties with employee maintenance.
- H₄: Navy-nuclear dominant coalitions selecting a modern form of organizational governance will experience higher ratings by the Institute of Nuclear Power Operations but lower on-line performance.

- H5: Regional dominant coalitions selecting a traditional form of organizational governance will (a) experience lower on-line performance, (b) face more serious forced outages, and (c) lag behind in the implementation of new systems, components, and techniques.

6. OTHER INFLUENCERS OF ORGANIZATIONAL GOVERNANCE

Up to now we have hypothesized that the cultural orientations of dominant coalitions will result in different organizational governance systems that, in turn, may have an effect on safeness. But other factors are also likely to have an impact upon the governance system found in nuclear power facilities.

6.1 Size and Organizational Governance

With larger organizations, one expects a more complex pattern of organizational governance which permits the interests of a larger number of competing units to be reconciled. In the largest organizations, the organization may subdivide into quasi-autonomous units. Smaller organizations may combine (e.g., holding companies, power pools) where the combined entity operates under what we have called a federal model.

The direct pressures from greater size on the design of the organization are pervasive. They are most clearly seen in the complexity of the design itself. Among organizations with similar environments and technologies, the larger organizations are likely to have more levels of management, more departments, plus more intricate patterns of coordination and control than their smaller counterparts. A greater emphasis on rules, policies, and procedures may also be in evidence and used for general administration, coordination, control, and development. Overall, the larger the organization the more likely it will be traditional. The pressures from greater size on organizational design may be deflected by a federal type of organizational governance. However, the age and historical reliance upon fossil plants of utilities may work against the development of the federal form.

6.2 Ownership and Organizational Governance

We can use ownership change to examine more carefully organizational governance. Earlier we suggested that a switch from an independent utility to a holding company would yield a change in the dominant coalition. Here we examine the expected pattern--the federal form. Power motives would emphasize influence (federal) instead of subscription to an ideology (modern) or an emphasis on the control of individual behavior (traditional). Instead of seeking technical improvement (traditional) or obedience (modern), desired behavior would be framed in terms of improving the organization and its administrative operations. This would be coupled with reliance upon professionalism to control managers as opposed to formal procedures (traditional) or single-set values (modern). The hierarchy would be used to promote interaction and coordination (or communications, in the

words of one utility executive) instead of maximizing prescription (or insuring a "tight ship," in the terms of another utility executive).

Finally, and perhaps most important for external regulators, is the view of authority and accountability. Authority would be seen as a complex issue where power was shared across multiple individuals and units. Authority would be seen as flowing up from operating and staff units, down from the dominant coalition, and across numerous specialized departments and groups. A complex pattern of decentralization would be expected. This compares to the more limited and individual notions of authority found in other forms of organizational governance. Consistent with this view of authority, one would expect to find participation given considerable weight--particularly participation across units which are at or near the same level in the hierarchy.

This aspect of organizational governance is particularly important for the NRC. The NRC often uses a very simple notion of authority and accountability based on the line chain of command (e.g., the plant manager is responsible) or particular technical functions (there should be a particular department which is to perform a particular function such as health physics, QA, or operations). Such a view may run quite contrary to that found in some utilities. If so, one would expect utility managers to complain vehemently that the NRC was over-loading plant managers and functional unit heads.

6.3 Ownership, Boards of Directors, and Organizational Governance

One expects that for private utilities alterations in the form of ownership will be reflected in the composition of the Board of Directors. While analysis of Boards of Directors of a utility with a subsidiary operating a nuclear facility may appear quite remote, such is not necessarily the case. From a legal perspective, the Board of Directors is the primary unit of analysis. By virtue of the incorporating legislation, the Board is charged with the responsibility to oversee corporate operations--a fiduciary standard by which the board can be held civilly and criminally accountable (Jones, 1980; Stone, 1975).

The extent to which boards do, in fact, set policy and oversee its execution will vary. To date, the structure and composition of boards has not been studied relative to safety outcomes. Most studies deal with relationships to economic outcomes (Pfeffer, 1972; Vance, 1964). However, it seems likely that, for example, the degree of interlocks (individuals serving on several boards), the relative amount of inside versus outside directors, the independence of the directors from the dominant coalition, and the nuclear experience of directors will directly or indirectly have significant effects upon the safety of nuclear power facilities. This appears particularly clear where a nuclear utility has extensive ties with non-nuclear utilities.

H₁: There is an inverse relationship between interlocks with non-nuclear utilities and the safety of nuclear plants.

- H₂: There is an inverse relationship between interlocks with financial institutions and quality, innovation, and speed of compliance, but a positive association with efficiency.
- H₃: As the proportion of inside board members increases, operations of nuclear subsystems will be less innovative and efficient.
- H₄: Independent boards produce safer operations than either inside or outside boards.
- H₅: The number of members on the boards with nuclear expertise favorably influences the safeness of nuclear subsystems.

7. INTERFACES AMONG UTILITY AND NUCLEAR ORGANIZATIONAL GOVERNANCE

One of the more interesting but unexplored areas is the interface between nuclear operations and the management of the utility as a whole. The gap between middle management, particularly operations management, and top management has been alluded to several times in NRC postmortems (NUREG-0385). The NRC expects top management support for safe operations of nuclear power plants and has indirectly elevated middle management positions toward the top of utilities. NRC expects to find a Vice President of Nuclear at or near the top of the utility. Further, nuclear utilities are required to have a corporate nuclear safety oversight committee (or its equivalent). Merely elevating a particular post into top management or requiring a committee does not insure an appropriate interface between top management and nuclear operations, however.

Nuclear facilities are at the same time technically similar to fossil plants and yet fundamentally different. Nuclear is comparatively new and yet serves the same functions as other types of plants. It is possible that similarities may be overdrawn. Further, top management has many priorities--the safety of a nuclear facility is only one. The result of these factors is clear. Overall utility policies may be inconsistent with the needs of the nuclear units. If there are also differences in governance, it may be difficult for those in the nuclear units to craft a unique safety program. As the Du Pont experience suggests (see Appendix A), a safety program consistent with the overall governance pattern of the organization is most likely to receive the attention and resources needed.

7.1 Organizational Governance for Nuclear Operations

Commercial nuclear operations are comparatively new and technologically dominated. Many senior nuclear executives most likely received their early management experience outside commercial nuclear operations. Further, by NRC requirements, the background of these executive-engineers is likely to include either extensive work within fossil operations or the Navy nuclear program. These two historical roots for senior nuclear executives and the overriding importance of technical affairs are likely to yield either a

traditional (for those with fossil experience) or a modern (for those with Navy nuclear experience) pattern. It is unlikely that a federal form in most cases, would be seen in nuclear operations.

7.2 Subsidiaries--A Special Case

Huge utilities or licensees which are subsidiaries of holding companies may have much different governance systems than large independent utilities. Specifically, smaller independent licensees may have more traditional and modern forms of governance, while the huge organizations are more likely to have elements of the federal form. While larger organizations can be expected to be more bureaucratic than their smaller counterparts, top officials may select a governance model which promotes the development of quasi-independent units. Holding companies are an example. Further, since nuclear operations are so radically different than other aspects of utility operation, it is likely larger utilities which have a considerable stake in nuclear plants may isolate their nuclear operations. As more utilities have two or more nuclear facilities, we would expect more nuclear divisions to emerge as separate organizational entities. Here, there may be differences between the form of governance employed for nuclear operations and that for the utility as a whole.

In sum, nuclear operations provide technical, administrative, and governance challenges to utilities. While the technical aspects have received considerable attention, the NRC needs to recognize that organizational governance is another important underlying factor for the successful implementation of its regulations and guidelines and, thus, public health and safety.

8. ORGANIZATIONAL GOVERNANCE AND ORGANIZATIONAL DESIGN

Previously we noted that managers make conscious or unconscious decisions about how the organization is designed, and what its rules, standards, and patterns of behavior are to be. In designing the organization, leaders normally face a limited number of key issues. While the literature suggests a potentially vast number (Galbraith, 1977), they may be categorized into areas more familiar to utility managers. Thus, a straightforward way of categorizing key design issues is to break them down into the four problems of administration, control, coordination, and development. As defined below, these four issues represent the range of strategic design problems managers face within the organization. (See also Volume II, Chapter 1.)

In order to gain an understanding of the likely effects the different governance systems will have on the design of an organization, we have attempted to integrate various dimensions of an organization's design at three levels or units of analysis with three different governance systems--the traditional, modern, and federal types outlined above. The democratic type was left out of the analysis since it is unlikely to be found in the nuclear industry.

Table 4 provides a profile of the various governance systems at the three levels or units of analysis. Thus the top of the chart is broken into

Table 4. Organizational Governance and Design Dimensions at Three Levels of Analysis

Design Dimensions	Corporate			Nuclear			Plant		
	Traditional	Modern	Federal	Traditional	Modern	Federal	Traditional	Modern	Federal
Administration									
Forms: Vertical	↑	→	↓	↑	→	↓	↑	↑	↓
Horizontal	↘	→	↑	↓	→	→	↓	→	↑
Procedures	↑	↑	→	↑	→	→	↑	↑	→
Individuals/Staffing	→	↑	→	→	↑	→	↑	↑	↑
External Support/Constraints	↓	→	↑	→	→	↑	↑	→	↑
Control									
Forms: Vertical	↑	→	↓	↑	→	↓	↘	↘	↑
Horizontal	↓	→	↑	↓	→	↑	↗	↗	↑
Procedures	↑	↑	→	↑	↑	→	↑	↑	↘
Individuals/Staffing	↑	↑	→	↑	↓	↑	↑	↑	→
External Support/Constraints	↓	→	↑	↑	↑	↑	↓	→	↑
Coordination									
Forms: Vertical	↑	→	→	↑	↑	↑	↑	→	→
Horizontal	↓	→	↑	↓	→	↑	→	→	↑
Procedures	↑	→	→	↑	→	→	↑	→	→
Individuals/Staffing	↑	→	↑	↓	→	↑	→	→	↑
External Support/Constraints	→	↓	↑	→	↓	↑	→	↓	↑
Development									
Forms: Vertical	↑	↓	↓	→	→	→	↗	→	↓
Horizontal	→	↓	↑	↓	→	↑	↘	→	↑
Procedures	↑	↓	→	→	→	↓	↑	→	→
Individuals/Staffing	↓	↓	↘	→	↓	↗	↓	↓	↘
External Support/Constraints	↘	↓	↑	→	↓	↑	↘	↓	↑

key. ↑ considerable emphasis
 → moderate emphasis
 ↓ low emphasis

(1) Corporate or headquarters; (2) Nuclear division; (3) Plant level. The nuclear category implies a separate organization, i.e., not fully integrated in corporate. Within each level there are three types of governance systems: (1) Traditional, (2) Modern, and (3) Federal.

Along the left-hand column are four key dimensions or characteristics of an organizational design: (1) Administration, (2) Control, (3) Coordination, and (4) Development.

A parallel mode of analysis is followed for each of the four design dimensions. Thus, within administration, control, coordination, and development we have looked at (1) forms of vertical and horizontal specialization of work; (2) the use of procedures; (3) criteria for staffing; and (4) the presence of external support/constraint mechanisms.

Arrows have been used to indicate the hypothesized degree of emphasis each type of governance system will place on the various subcategories of the design dimensions. For example, a traditional system will place high emphasis on vertical forms of administration. The arrow is upward pointing. However, it places a moderate emphasis on external supports/constraints for coordination, and thus the arrow points horizontally. Finally, a low emphasis on individuals in the development function is expected, and the arrow points downward. In this section we will selectively describe how the various governance factors combine to produce dominant design tendencies.

8.1 Corporate

8.1.1 Administration

As stated before, administration refers to the way that work is divided up and carried out in the organization. The form of administration refers to the division of work into separate units (positions, departments, divisions, etc.), and the position of each of these in the overall vertical and horizontal scheme of the organization. Administrative procedures refers to rules governing the conduct of the work itself. Individuals, in this context, refers to the skills and qualifications demanded of incumbents of job positions (e.g., duties, responsibilities, job analysis). Finally, the external resources and constraints refers to the budgetary, staff support, authority, and factors external to the unit being studied. These external resources and constraints help define the conduct of work within the organization but originate from outside or at a higher level of the organization.

In section 3.1.1 we have suggested that in a traditional type organization the driving power motive is to control behavior by using formal mechanisms. Translated into administrative terms, we would expect that such an organization would be characterized by a high degree of vertical specialization, i.e., many levels in the chain of command. The use of horizontal or divisional specialization would be low to moderate. Thus, a tall and narrow structure would emerge.

In a federal system, exercising influence becomes the dominant power motive. Because the emphasis is on individual self-control (influenced by professional and/or team norms) the organizational structure must provide for a high degree of interaction and coordination. Instead of many levels, as in the traditional type, we would expect to find relatively more divisions or, perhaps, vice presidents. Thus, a flat and wide administrative structure would emerge.

The modern type of organization, driven by ideological acceptance, will emphasize neither vertical nor horizontal specialization. Since conformity to an ideology has become dominant, the pool of individuals meeting this criteria will be relatively small. Staffing, however, is relatively more important for a modern organization than for the traditional or federal. Identifying and developing people with the right mind-set becomes critical.

Because a traditional governance system values conformity of behavior, we would anticipate the extensive use of formal, written procedures. As vertical specialization will be emphasized not only in the administrative function but also in the control, coordination, and development functions, so will the use of formal procedures be pervasive within these functions.

A federal system is characterized by the presence of competing groups negotiating over power and influence. This internal dynamic will likely lead to a greater sensitivity and responsiveness to the external environment. Thus, such a system will provide, for example, relatively more boundary spanning positions than either the traditional or modern systems.

A traditional system, dominated by the desire of the top levels of the hierarchy for behavioral control and conformity, will resist impacts from the external environment. Buffering functions will then be emphasized.

8.1.2 Control

As defined in Chapter 1, control refers to the process whereby the behavior of the organization's members is brought in line with existing standards of conduct. It also can be evaluated in terms of form, procedures, individuals, and external factors. Form of control refers to the structure of the formal hierarchy within which power, authority, and influence are exercised. Who sets standards, measures performance, and dispenses rewards/sanctions? Control procedures refers to rules governing the behavior of members (as opposed to the conduct of work). The category individuals, in this context, refers to the rewards and sanctions used to control individuals, and external constraints includes such factors as regulatory standards and corporate control.

The traditional system emphasizes centralized and clear-cut chains of command. As in the other dimensions, vertical forms are dominant, with an emphasis on formal reporting procedures. There is close attention to developing standards and measuring performance. Accountability is focused on individuals with sanctions relatively more emphasized than rewards. A somewhat similar pattern is found in the modern system, but there is likely to be less emphasis on written standards, methods of assessment, and written evaluation.

Because the federal system emphasizes shared authority, there is greater emphasis upon horizontal modes of control. Mechanisms for dissemination of procedures and standards are more highly developed. Accountability is only moderately emphasized. The individual dynamics of shared responsibility are not well understood. Thus, sanctions/rewards are more likely to be group- rather than individual-oriented.

8.1.3 Coordination

Coordination refers to the need of the organization to mesh or integrate the activities of the different parts of the organization into a cohesive whole. Because the activities of various parts of the organization have input and output affects on each other, coordination is a central concern of organizational design. The form of coordination refers to the formal mechanisms that are established to link activities. Examples are standing committees, linkages through the formal structure, matrix organizations, staff meetings, and the like. Coordinating procedures pertain to rules that purposively link the activities of disparate units in the organization. Individuals, in this context, concerns the formal coordinating activities expected of individuals as well as systems designed to assure the participation of individuals in the organization as a whole (e.g., participatory management). External factors relevant to coordination involve the role of corporate units in linking functions within the plant, the role of professional societies, and the role of external, consultive bodies (e.g., INPO) in providing coordination.

A traditional system, driven by the desire to achieve behavioral control and administrative improvement, will stress vertical forms of structures and formal communication procedures. Thus, there will be a need for the coordination function to emphasize these elements. Furthermore, staffing for these activities will be less emphasized since the design of the formal system becomes more important than the individuals performing the coordination activities.

The situation is reversed in the federal system. Horizontal forms, e.g., committees, matrix, or project groups, will be more widely used. Although formal procedures are still moderately employed, the importance of individuals becomes greater in order to deal with the complexities created by these horizontal forms. Moreover, there will be a greater reliance on external supports and responsiveness to external constraints. A more highly developed network with the external environment will likely emerge.

8.1.4 Development

Development refers to the strategic problem of planned change. Form refers to the existence, nature, and location of organizational units concerned with organizational development (planning units, training, etc.). Procedures refers to the rules that exist to promote development. Individuals refers to the incentives and programs designed to encourage individual involvement in development activities. External constraints and resources relative to development include the training programs available to

the organization and the resources allocated to the units for development purposes.

Although all three governance types seek administrative improvement at the corporate level, the traditional organization will emphasize vertical relationships while the federal organization will emphasize horizontal ones. The modern organization, however, due to its acceptance of a single set of values, will be resistant to adaptations or innovations; instead, it will seek to fine-tune the system already in place.

8.2 Nuclear

Envisioned here is a division of a utility that has a fully developed organizational structure or a specialized nuclear facility. In many cases, it appears that the nuclear division, with a relatively small staff, is integrated at the corporate level, and no separate nuclear division will be apparent. However, a separate division may appear with increases in (a) the relative amount of nuclear generating capacity to total capacity for the utility, (b) the number and different types of reactors, and (c) the overall size of the utility.

8.2.1 Administration

In general, the tendencies of the various governance systems found at the corporate level will also be manifested at the nuclear level. Thus, in administration a traditional system will emphasize vertical forms and procedures while a federal system will stress horizontal forms and external supports/constraints. These tendencies may be amplified or attenuated depending on whether the governance system at the corporate level is the same as the system at the nuclear, and on whether the head of the nuclear component is part of the dominant coalition at the corporate level.

8.2.2 Control

One logical difference that might occur with a traditional type governance system at the nuclear level is a greater emphasis on external support/constraint mechanisms in the control function. From the point of view of the nuclear division, corporate would be part of the external environment. Moreover, there is likely to be direct pressure from the NRC. Thus a boundary spanning function will be needed. This, in turn, may lead to a somewhat greater use of external supports/constraints by a traditional nuclear governance system than would be evidenced in a traditional corporate system.

8.2.3 Coordination

This function will likely reflect the same patterns as found in corporate. Thus the traditional system will stress vertical forms while the federal system will stress horizontal. The modern system, however, will likely emphasize vertical forms. Relatively fewer people would be required than at a corporate level, thereby permitting conforming hierarchies to form. The vertical tendency in the nuclear unit will be particularly strong where the

governance system at corporate is traditional and the plant governance system is based on the modern form. This is expected because a primary basis for the modern form is the Navy nuclear program. As but a part of a huge labor-intensive bureaucracy with many vertical levels, the modern form adapted to commercial nuclear operations is expected to reflect its origin. Where the corporate system is federal, vertical forms may still be emphasized where the nuclear operation is dominated by the modern form. Here one expects consolidation of power at the nuclear level so that the dominant coalition for nuclear operations is in a better position to negotiate within the federal corporate system.

8.2.4 Development

Unless the nuclear component is a growing and thus more powerful aspect of a utility, we would not expect to see a substantial effort towards development. A traditional system will only moderately emphasize vertical forms while reducing importance given to horizontal forms of specialization. A modern system, however, committed to its value system, will place moderate emphasis on both vertical and horizontal forms as well as on individuals. A federal system will also likely need to give somewhat more emphasis to vertical forms in order to be more effective in its contacts with corporate.

8.3 Plant

The plant level involves the organizational structures below a plant/facility manager and directly relating to the operation of a nuclear reactor. These structures may vary according to whether there is a single reactor, mirrored reactors (i.e., adjoining reactors), or multiple reactors on a given site. Thus a site or plant manager may be at the top of this level of the organization hierarchy.

In an earlier section we have indicated that most plants are likely to be dominated by a traditional governance system due to operational and technological considerations. However, where there are multiple reactors on a site a federal overlay may emerge. Moreover, other complexities may arise where the governance system at the corporate (or nuclear) level differs from the plant's system.

8.3.1 Administration

As at the corporate (or nuclear) level, a traditional system at the plant level will be characterized by a high degree of vertical specialization and the extensive use of formal procedures. Behavioral control will be even more of a driving force.

Due to the highly technical nature of operations and the need for employee stability, staffing considerations will be given greater emphasis than might otherwise be expected at the plant level in a traditional system.

Further, a plant has available and is subject to a greater array of external supports/constraints. Corporate (and where applicable the nuclear division)

is, from the point of view of the plant, part of the external environment. Organizations such as INPO have been created that manage information primarily directed at the plant level. The NRC, to date, has also primarily focused its attention upon plant activities. As a result, the traditional system, while buffering activities will still be preferred, will nonetheless utilize boundary spanning activities.

8.3.2 Control

Because of the potentially dangerous nature of nuclear plant operation and the plethora of NRC regulations, line control will be emphasized under all three governance systems. Thus, vertical forms of authority will be stressed. Moreover, the use of procedures and the establishment of standards and their levels will be stressed by the three governance systems. However, the traditional and modern systems are likely to rely more on threat of punishment than promise of rewards for control, whereas a federal system is more likely to arrive at a balance between these two methods.

Staff relationships, on the other hand, will likely vary according to the tendencies of the dominant coalition. For example, where there is a federal system due to, perhaps, the presence of multiple reactors, more emphasis will be given to controlling the activities of the various committees, i.e., horizontal forms. Yet even under a traditional system where such horizontal forms are less emphasized, the critical nature of plant operations will still result in stressing control of the horizontal relationships that do exist.

8.3.3 Coordination

A traditional dominant coalition at the plant level will, consistent with its preference for formal vertical forms to achieve behavioral control and conformity, stress mechanisms for vertical coordination, although horizontal relationships will also be closely attended to. Explicit rules and procedures are emphasized. Staffing considerations are given somewhat higher priority than would otherwise be accorded by a traditional system due to the highly critical nature of operations. The modern system will moderately emphasize both vertical and horizontal forms of coordination, as well as procedures and individuals, relying, as it does, on acceptance of its values to achieve overall coordination. As at the other units of analyses, external supports/constraints will be deemphasized unless an external source's value system is harmonious with its own values.

The federal system at this level will reflect the dynamics found at the other levels. Thus horizontal forms will still be stressed, as will be individuals. We would expect to find, also, a greater reliance upon external sources to aid in coordinating activities, especially those of the staff.

8.3.4 Development

It is expected that the various governance systems will likely emphasize development consistent with their overall concept of organization design.

Thus, the federal system will seek to improve horizontal forms relating to negotiation of power and influence and administrative improvement, whereas the traditional system will stress vertical forms to assure obedience and technical improvement. The modern system will also seek technical improvement and behavioral control, but will place an equal emphasis on vertical and horizontal structures.

The traditional and modern systems will still be resistant to external supports/constraints outside of the utility except for limited reliance on the NSSS vendor. The federal system, however, is likely to develop mechanisms to deal with the external environments, with an emphasis on professional groups.

9. CONCLUSION

In this chapter we have argued that large, complex organizations have identifiable governance patterns. Further, we have introduced the concept of dominant coalitions in order to explain potential differences in the governance systems of nuclear utilities.

Four types of organizational governance patterns (or forms) are identified: traditional, modern, federal, and democratic. Our analysis suggests that only the traditional, modern, and federal types will be applicable to the nuclear industry. Although it is expected that these governance systems will not be found in their pure form in a given organization, they nonetheless provide a basis for analyzing expected impacts on various organizational outcomes, especially the intermediate ones of quality, efficiency, innovation, compliance, and employee maintenance. We have also provided a deductive analysis of the expected effects the various governance systems will have upon the design dimensions of administration, control, coordination, and development.

The dominant coalition is a group of individuals who determine key internal policies. Their value orientations are reflected in the governance system of their organizations. While the exact composition of a dominant coalition for a given utility requires empirical verification, we have suggested that there are at least four probable socialization routes: conventional, nuclear-engineering, U.S. Navy, and regional. Each brings to the organization a distinctive value orientation, a world view of how the organization should be run. This orientation is expected to influence the type of governance system found in a utility.

It has also been suggested that environmental and contextual conditions will influence the governance form within an organization. For instance, the composition and characteristics of the board of directors may have significant impacts upon the nature of the dominant coalition and the governance system. Further, as an organization becomes larger, various pressures emerge which will likely require the dominant coalition to adjust its form of governance. Finally, we were also concerned with the degree of consistency in governance patterns for the utility as a whole versus nuclear operations. Will, for instance, one find different governance patterns at different levels (utility, nuclear, and plant)?

In sum, it has been argued that in order to gain an understanding of essential organizational characteristics, their determinants, and how organizations may improve their internal operations, it is necessary to analyze the composition and value orientation of the dominant coalition as reflected in the governance system found in given organizations in the nuclear energy industry.

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APPENDIX A

THE DUPONT EXPERIENCE

Since 1818 occupational safety has been a primary policy and action concern of the DuPont Corporation. This interest grew out of the manufacturing and distribution of a very hazardous product, black powder, and remained a central focus of the company as it expanded into the production of other dangerous and potentially dangerous products.

As a consequence of nearly two hundred years' experience, a safety philosophy has been embedded in DuPont's corporate actions. The payoff has been an enviable safety record--an accident rate that is one-fiftieth the rate for all industry and one-sixteenth the rate in the chemical industry.

Partly this experience is due to a commitment by management from the top down to DuPont's five point safety philosophy:

- All injuries can be prevented. (But it is impossible to make the work environment risk free.)
- Management, which includes all levels through the foreman, has the responsibility of preventing personal injuries.
- It is reasonably possible to safeguard all operating exposures which may result in injuries.
- It is necessary to train all employees to work safely and to understand that it is to their advantage, as well as the company's, to work safely, and that they have a definite responsibility to do so.
- It is good business from the standpoint of both efficiency and economy to prevent personal injuries on the job and off the job (DuPont de Nemours and Co., 1974).

The DuPont organization for implementing this safety philosophy is straightforward. Safety, according to company policy, is a line responsibility, and line managers are directly accountable to their immediate superior for safety performance. The supervisors are on the first level, plant managers the second, and the CEO and other senior company executives the third level of accountability (Willette, 1982). Surrounding the line organization are safety organizations and a safety committee system. The safety staffs are support groups which perform a variety of technical functions. The safety committees include: the central safety committee, departmental safety committee, the supervisor's safety committee, and employee safety meetings. In addition to these basic committees are numerous subcommittees: accident or injury, program or special activities, process hazards, housekeeping, off-the-job, new equipment or process acceptance, and audit.

The line/staff and the committee networks exist to operate the safety program elements, of which there are four:

(1) Plant safety

- a. the establishment of plant safety goals
- c. response to accident and injury/illness
- c. the organization of an on-site safety program.

(2) Specific roles

- a. clear responsibility for safety and health written in management job description
- b. safety performance a factor in job performance evaluation
- c. the maintenance of procedures--where every significant action is covered by a standard, procedure, work-method, or rule
- d. training.

(3) Involvement

- a. individual participation through safety meetings and committee memberships
- b. discipline.

(4) Audits--an ongoing assessment of safety and health conditions.

In addition to its safety program, DuPont established the Haskell Laboratory in 1935. This laboratory does research in toxicology and industrial medicine. Its responsibility is to "screen compounds, conduct laboratory tests, recommend measures necessary to limit exposure to chemicals and advise company plants, research centers, and customers, of possible problems and coorrective measures." This facility reflects DuPont's concern for reducing both acute and chronic job hazards. The company has made great strides in the reduction of acute hazards, but it admits, candidly, that they have a long way to go in the area of chronic hazards.

Discussion

The DuPont case is far from a perfect parallel with the nuclear energy industry, if for no other reason than that its primary concern is with occupational safety and actue job hazards (although they are giving increasing attention to the chronic hazard issue). Our problem is with the implications of nuclear energy for public health and safety and the chronic hazards it creates.

All of this notwithstanding, there are several lessons that may be learned from this example (DuPont de Nemours and Co., 1980).

- (1) Safety is a matter of management commitment to a philosophy, policies, and programs which place it in a priority of job responsibilities and accountability. This is more than rhetoric, although it is difficult to make it seem such. The only measure, therefore, of this commitment is performance.
- (2) DuPont is long on a history of commitment to safety--nearly two hundred years. Utilities, and particularly nuclear power facilities, have had nothing like this length of time to build such a commitment.
- (3) From an organizational standpoint, DuPont's structure of its safety program seems conventional--following a line-safety, committee format. Such a classical system may be appropriate for the level of DuPont manufacturing technology. However, is it appropriate for utilities using a highly sophisticated nuclear technology?
- (4) Superficially it seems that individual utilities may not have gone the lengths that DuPont has to generate and to put into operation a rational program of safety and safety research. Is this due to lack of experience or concern? Or to the cost factors? Or to a regulatory environment that does not emphasize the managerial/organization effects of safety?
- (5) The question of acute versus chronic hazards seems to need attention. Acute hazards--those that cause injury or illness through an accident or one-time exposure--are a major problem, but they seem to be receiving the bulk of study. The chronic hazards question is more elusive and subtle. Just how much low-level radiation in an area is too much? Who makes these decisions? Who bears the risks?

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CHAPTER 3

UTILITY ENVIRONMENT AND SAFETY RELATED OUTCOMES

1. INTRODUCTION

This chapter examines the relationships among the economic and institutional environment of nuclear utilities, utility choices concerning technology and internal organization, and safety related outcomes at nuclear plants. These relationships and choices affect the performance of the utility, in terms of quantity and price of electricity produced, and the safety of generating plant operations. In this chapter we provide a review and synthesis of the economic literature concerning the impacts of the utility's environment on its performance, and of the impacts of the environment itself on the utility and its choices.

Four aspects of the utility and its environment are considered:

- (1) utility characteristics (ownership, pooling, other)
- (2) regulatory influences
- (3) vendors
- (4) associations.

Descriptions of salient institutions and actual empirical characteristics of salient aspects of utility organizations are developed in each of these sections. Literature linking each of these environmental and utility characteristics to utility performance is reviewed in this chapter, and possible linkages to safety performance are noted. Needs for future research are identified in subsections labeled "Research Issues" at the end of each major section of the chapter.

The data presented in this chapter in various tables were compiled from a variety of sources, as shown in the footnotes to the tables. The complete data set is provided in Table 3.8 at the end of the chapter as an aid to readers who may desire to assemble data in different ways.

2. UTILITY AND MARKET CHARACTERISTICS *

2.1 Utility Ownership

There are three basic types of electric utility companies in the United States: investor-owned, government-owned, and cooperative.* The investor-

*To avoid confusion, the term public utility is not used in this paper. Regulated companies owned by investors will always be called investor-owned utilities; utilities owned by municipalities, counties, states, the federal government or other public entities will be called government-owned utilities.

owned utilities comprise about 84% of the nation's generating capacity and annual electrical power production (see Table 3.1). Investor-owned utilities are sometimes referred to as "public utilities" because they are monopolistic companies subject to the regulation of state Public Utility Commissions (PUCs). In this regulated status, they have an obligation to serve the public interest in ways that an ordinary non-regulated company does not. All potential customers within the designated service area must be served, as long as they pay their bills, and restrictions are placed on the regulated utility's ability to initiate or end particular services.

2.1.1 Subsidiaries and Holding Companies

Within the investor-owned subsector, two further distinctions are worth noting. Some utility companies are subsidiaries of other corporations and produce power only for the parent company. Unless the parent is an ordinary utility company selling power to the public, the subsidiary is not itself subject to state PUC regulation. Any corporation that sells power to the public at large may be subject to PUC regulation, even though the corporation is primarily engaged in some other business. For example, a Dow Chemical subsidiary in Louisiana withdrew its proposed participation in a joint venture nuclear power plant when Dow learned that sales of some of the plant's output to regulated utility companies might bring the Dow subsidiary under PUC jurisdiction (Nuclear Regulatory Commission, 1975).

The second point is that there are legal holding company structures in the utility industry. If the subsidiaries of a holding company are located in more than one state, then the holding company must be registered with the Securities and Exchange Commission (SEC) under the Public Utility Holding Company Act passed by Congress in 1935. This Act was passed to give SEC the power to encourage reorganization of the utility industry, to reduce the number of utility companies and to consolidate their service territories. At the time of the Act's passage, many of the utility holding companies had widely separated or checkerboard-type service territories. The numerous subsidiaries of such holding companies could not be operated effectively as a single unit. Proceeding on the authority of the Act, the SEC encouraged mergers and sales that consolidated service territories and reduced the extant number of utility companies. By the time of World War II, the reorganized industry had consolidated service territories and was as a consequence much better able to accommodate large-scale and more efficient generating plants. At present, seventeen utility holding companies are registered with the SEC. Four of these companies are natural gas companies and the remaining thirteen are electric or electric and gas utilities. In addition, there are two single state electric utility holding companies which are not registered with the Securities and Exchange Commission (1975).

The existence of these holding company systems raises a question about the appropriate unit of analysis for operating utilities owned by a holding company. The SEC's explicit intent in reorganizing the industry was to create consolidated systems that could be operated as unitary systems. The holding companies are a result of this policy. Also, the scale of generating plants now being constructed by subsidiaries of holding companies far exceed the plant size that could be justified if the subsidiaries were

Table 3.1. Size of Various Segments of Nuclear Industry in 1980

	Total Generating Capacity (MW)	Nuclear Generating Capacity (MW)	% Capacity Nuclear	Nuclear Capacity Under Construction
OWNERSHIP				
Government Owned	41,879	8,452	.20	17,050
Investor Owned	267,323	47,676	.18	56,779
Cooperative	50	50	1.00	0
Holding Company Systems	52,536	7,494	.14	9,883
COORDINATION				
Power Pool Members	183,368	32,810	.18	39,311
Unaffiliated	122,275	23,319	.19	32,218
INDUSTRY TOTALS (Nuclear + Non-Nuclear Systems)				
Government Owned	77,845*			
Investor Owned	476,288			
Cooperative	17,104			
Total	571,237	56,178		73,829

*Includes Tennessee Valley Authority and 161 public owned utilities reported by DOE in 2 below.

Sources:

1. U.S. Department of Energy, Energy Information Administration. Statistics of Privately Owned Electric Utilities in the United States: 1980 Annual Classes A and B Companies. Washington, D.C., DOE/EIA-0044(80), October 8, 1981.
2. U.S. Department of Energy, Energy Information Administration. Statistics of Publicly Owned Utilities in the United States--1980. Washington, D.C., DOE/EIA-0172(80), December, 1981.
3. U.S. Department of Agriculture, Rural Electrification Administration. 1980 Statistical Report, Rural Electric Borrowers. Washington, D.C., REA Bulletin Number 1-1, June, 1981.
4. Tennessee Valley Authority. Financial Statements for the Year Ended September 30, 1981. Knoxville, Tennessee, TVA/OMS/FIN-82/1.
5. Federal Energy Regulation Commission, Office of Electric Power Regulation. Power Pooling in the United States. Washington, D.C., FERC-0049, December, 1981.
6. "World List of Nuclear Power Plants," Nuclear News, June, 1981.

operated independently. The first nuclear plants built by the subsidiaries of the fifteen holding companies averaged 43% of the subsidiaries' capacity in the years in which the plants were contracted for. These plants averaged only 10% of the holding companies' capacity in the same years (Sommers, 1978, p. 76). No independently operated utility company would build a plant averaging 43% of its current capacity because this would make the utility vulnerable to blackout problems if the plant were to break down. Hughes (1971) cites a utility industry rule of thumb on generating unit size, which is to add generating units not exceeding 10-15% of system capacity. Application of this rule guarantees that the probability of system blackouts will be very low. Holding company behavior indicates that the entire holding company system is considered as a single unit in making expansion decisions. Given both regulatory intent and observed behavior, it seems reasonable to assume that the holding companies, rather than their subsidiary operating companies, are the primary decision-making units with respect to investments in nuclear generating technology.

Holding company systems currently own power plants with over 52,000 MWe of generating capacity, about 9% of total U.S. generating capacity. Of the 52,000 MW, almost 7,500 MW is provided by nuclear plants, and an additional 9,883 of nuclear capacity was under construction in 1980. Holding companies account for 13% of current nuclear capacity and 13% of the nuclear capacity under construction (see Table 3.1). Thus, holding company systems are slightly higher in nuclear capacity than the national average, perhaps due to higher than average system size.

2.1.2 Government-Owned Utilities

Government-owned utility companies comprise 13.6% of U.S. generating capacity (see Table 3.1). There are numerous federal hydroelectric projects, some organized into regional marketing organizations, e.g., the Bonneville Power Administration in the Northwest and the Southeastern Power Administration. The marketing administrations sell federally produced power at wholesale to municipal, cooperative and investor-owned utilities. In addition, one federal utility, the Tennessee Valley Authority, operates fossil and nuclear fueled thermal plants as well as hydroelectric plants. Government-owned utilities provide 15% of current nuclear capacity, and 23% of the nuclear capacity under construction.

Some state governments have created utilities to achieve substantial economies of scale by utilizing large-scale generating plants and selling power at wholesale to municipal or investor-owned utilities in the state. The customers of such state-owned utilities are usually too small to utilize low-cost, large-scale plants independently for the reasons cited above. Among these state-owned utilities are the Nebraska Public Power District, which sells power generated at a nuclear plant to county power districts in Nebraska, and the Power Authority of the State of New York, which sells power generated at a nuclear station to the state's government and investor-owned utilities. The Washington Public Power Supply System was created by publicly owned utilities under authority created by the Washington State legislature, and has participants from several states in the Northwest.

Many municipalities operate their own electric utilities. A few of these municipal systems generate part or all of their supply, but most buy power at wholesale and simply distribute the purchased power to homes and industry. Some 3000 municipal utility systems are listed with the Federal Energy Regulatory Commission. Most of these are so small that they are unable to enjoy the economies of large-scale generating plants except through joint ventures or because wholesale suppliers pass some of the benefits on to them. A few municipal utilities are quite large, e.g., the Los Angeles Department of Water and Power.

Cooperative utilities provide about 3% of the generating capacity in the country. Cooperatives have been organized mainly in rural areas where no investor-owned or municipal utility had been organized. Many cooperatives were created under the auspices of the Rural Electrification Administration which provided very low interest loans to finance capital acquisition. Like the municipal utilities, most cooperative systems are very small and many are primarily distribution systems rather than generators of power. Only one cooperative currently operates a nuclear plant. This plant is a small demonstration plant built in the early years of the Atomic Energy Commission demonstration program. Approximately 40 cooperatives own shares of the Washington Public Power Supply System nuclear projects. Other cooperatives own small shares of investor-owned nuclear projects in Eastern states. Except for the one Wisconsin cooperative with a 50 MW plant, no cooperatives are likely to have any management responsibilities for nuclear plants.

2.2 Power Pools

Utility companies of all three types participate in inter-utility organizations called coordination groups and power pools. Members of coordination groups agree to physically interconnect their transmission systems so that excess generating capacity in one utility's individual system can be used to supplement another utility which cannot meet its load temporarily because of high peak loads or equipment failures. Coordination reduces the amount of capacity each member has to hold in reserve to provide backups for system peaks and equipment failures. One member's peak or plant outage may not occur at the same moment as its neighbors' peaks, thus making it advantageous to consider pooling reserves. The reserve savings often outweigh the necessary investments in transmission lines and switching equipment.

Some more highly integrated inter-utility organizations develop a central dispatching mechanism which allows routine interchanges of power to minimize daily operating costs. This routine interchange of power goes well beyond the emergency, short-term interchanges characteristic of coordination groups. The more highly developed type of inter-utility organization, with central dispatching as a distinguishing feature, is called a power pool by Breyer and MacAvoy (1974).

Power pools are sometimes used to facilitate the construction of low unit cost, large-scale generating plants. Such plants are often too big for individual utilities to install on their own, but the combined capacity of the pool may justify such a plant, and the pool as a whole may be able to

provide sufficient reserve capacity in an economical way. If projected pool load growth warrants a series of large-scale plants, these are sometimes constructed on a "staggered" basis. That is, the burdens of construction and the benefits of an enlarged rate base are rotated among the members of the pool, with interim bulk power sales among pool members to cover load growth of members not currently constructing a plant. Alternatively, joint venture plants can be constructed so as to match more closely each member's load growth, capacity, and rate base.

Coordination groups and power pools now cover much of the country. Approximately thirty such organizations exist (Federal Power Commission, 1970). However, some of these inter-utility organizations are not big enough nor well-integrated enough to take advantage of very large-scale generating technology. Weiss (1975) indicates that members of several groups build plants larger than their individual system size warrants, but smaller than pool size would allow. Other groups build plants of a size which could only be justified on the basis of pool capacity. Weiss concludes that some groups are simply too small to build very large-scale plants, while others are insufficiently integrated to do so. The geographic dispersion of major load centers, especially industrial loads, within a pool area is another factor to keep in mind in judging the capacity of pools to build large-scale plants.

Table 3.2 describes characteristics of major power pools in the U.S. They range in size from under 1,500 MWe of generating capacity to over 44,000 MWe. Nuclear capacity on-line runs from 0 to 6,042 MWe, while nuclear capacity under construction varies from 0 to 6,250 MWe. The three power pools in the Northeast have the highest proportion of capacity currently provided by nuclear plants. Extensive construction programs will maintain the dependence of this region on nuclear power. Substantial nuclear capacity is also seen in the Midwestern and Southeastern regions, although construction programs are less ambitious than in the Northeast. Some nuclear capacity is also on-line or under construction in the South, Southwest and Northwest.

2.3 Impacts of Ownership and Pool Membership on Utility Choices and Performance: Research Issues

The basic decision-making unit in the utility industry is still the individual utility company or holding company, despite the existence of coordination groups and power pools. A major implication of the industrial structure sketched above is that each utility company is a monopolistic supplier of electric power to its customers. Day-to-day price competition of the classic textbook variety has long been thought to be technically infeasible. Recently proposals have surfaced to reorganize the industry, making generation a competitive business with minute-to-minute spot prices (Stelzer, 1980). The feasibility of these proposals has not been thoroughly examined. For the time being, however, power generation remains a monopolistic enterprise. As monopolists, the utilities should still be interested in minimizing production costs at their chosen levels of output. The output level chosen by each company will of course differ from what a hypothetical, purely competitive utility would choose. The point is that

Table 3.2. Power Pool Characteristics, 1980

Pool	Total Generating Capacity (MW)	Nuclear Capacity (MW)	% Capacity Nuclear	Capacity Under Construction
New England Power Pool	21,294	6,042	.28	5,750
New York Power Pool	29,742	4,398	.15	1,900
Pennsylvania-New Jersey-Maryland Interconnection	44,891	7,012	.16	6,250
Southern Co. System	23,909	1,740	.07	1,740
Illinois-Missouri Pool	13,480	0	0	3,250
Mid-Continent Area Power Pool	24,900	3,719	.15	0
Wisconsin Power Pool	3,681	535	.15	0
Allegheny Power System	6,822	0	0	0
American Electric Power System	20,123	2,285	.11	0
Central Area Power Coordinating Group	15,147	1,829	.12	2,243
Cincinnati/Columbus/ Dayton Group	5,788	0	0	810
Michigan Electric Coordinating System	15,791	887	.06	2,435
Middle South Utilities	12,177	902	.07	1,104
Missouri-Kansas Pool	8,879	0	0	1,150
Texas Municipal Power Pool	1,457	0	0	0
Texas Utilities	17,336	0	0	2,300
Lower Colorado River Power Pool	15,109	0	0	3,810
California Power Pool	28,870	1,443	.05	4,390
Pacific Northwest Coordinating Agreement	32,292	2,016	.06	4,990

Sources:

1. U.S. Department of Energy, Energy Information Administration. Statistics of Privately Owned Electric Utilities in the United States: 1980 Annual Classes A and B Companies. Washington, D.C., DOE/EIA-0044(80), October 8, 1981.
2. U.S. Department of Energy, Energy Information Administration. Statistics of Publicly Owned Utilities in the United States--1980. Washington, D.C., DOE/EIA-0172(80), December, 1981.
3. U.S. Department of Agriculture, Rural Electrification Administration. 1980 Statistical Report, Rural Electric Borrowers. Washington, D.C., REA Bulletin Number 1-1, June, 1981.
4. Tennessee Valley Authority. Financial Statements for the Year Ended September 30, 1981. Knoxville, Tennessee, TVA/QMS/FIN-82/1.
5. Federal Energy Regulation Commission, Office of Electric Power Regulation. Power Pooling in the United States. Washington, D.C., FERC-0049, December, 1981.
6. "World List of Nuclear Power Plants," Nuclear News, June, 1981.

utilities should still be sensitive to any cost-reducing opportunities they perceive. Safety improvements which reduce costs are likely to be adopted; safety related changes which are not perceived as cost effective may be resisted.

Limited long-run competition for the business of a utility's present and prospective customers presents a utility with additional incentives for investing in cost-reducing innovations. The long-run elasticity of demand for electricity has been estimated in several econometric studies to range between -1 and -2 (Taylor, 1975). Elasticities of this magnitude indicate that over a period of years both residential-commercial and industrial customers can respond to changing relative prices of electricity and alternative energy sources by modifying their capital stocks to use alternative fuels. Long-run competition between electric utilities also occurs in the market for new industrial customers. New industrial customers imply growth opportunities to the utility due to the demands of the customer and due to the associated workers and service industries that accompany the industrial customer and demand more power. In the long run, an electric utility must avoid pricing itself out of the market for marginal uses of electric power. These long-run competitive issues reinforce the utility's tendency to adopt safety programs only if they are perceived as cost effective.

The distinction between investor- and government-owned utilities is a crucial factor in the inter-utility competition for new industrial customers. Government-owned entities pay no federal corporate income taxes, while investor-owned utilities pay considerable sums to the Federal Treasury every year. If two utilities, one government-owned and the other investor-owned, are competing for new industrial customers, then the government-owned utility may be able to offer a lower rate to the industrial customer than the investor-owned utility. In a period of declining electricity prices, such as the 1960s when many of the nuclear power investment decisions were made, anticipated load growth allowed the utilities to construct new plants with lower costs per KWH of power produced than plants already on-line. Thus the very act of attracting new industrial customers helped the utilities to construct low-cost plants, which in turn allowed the utilities to offer rates for new customers.

This combination of factors yielded competition for new customers between investor-owned and government-owned utilities in the 1960s. The typical situation in the U.S., given the size distributions of investor- and government-owned utilities mentioned above, is that a large investor-owned utility will be in competition with a small government-owned utility. The investor-owned utility may be able to realize more economies of scale in generating power, but these advantages will be offset by the tax advantage of the government-owned utility. Rising real costs of electricity in the 1970s and 1980s have disturbed the status of this competition somewhat. The competitive game now involves raising your own rates more slowly than your competitors in order to keep existing industrial levels, and perhaps to attract new ones.

Power pooling and coordination are probably the most important structural factors in addition to system size (see section on size which follows). Little difference in behavior should result from variation in ownership type--investor-owned, government-owned, or cooperative--apart from the confounding effects of system size. On average, investor-owned systems are larger than cooperative or government-owned utility companies, and for this reason are more likely to invest in large-scale technologies such as nuclear power. The low capital costs of municipal and cooperative utilities may lead some of these utilities to choose nuclear power if other factors place these entities on the borderline between nuclear and fossil fired plant choices. Holding companies exist within the investor-owned subsector. These holding companies appear to be operated as single units with respect to investments in nuclear power. Coordination and pooling agreements affect the utilities by enlarging the effective system size into which a large nuclear plant can be introduced. The degree of integration of the coordination groups and pools is also important to investment and operating decisions. The public-private power debate flares up occasionally in the context of large-scale electric power investment decisions. Inefficient decisions about the construction and operation of large-scale generating plants such as nuclear plants may result from this continuing struggle between government and investor-owned utilities.

Variations in ownership relationships should affect the internal structure of the operating utility responsible for running a nuclear unit to some degree. An operating utility with joint venture partners will allocate some resources to managing that relationship. A utility owned by a holding company may have some decisions made for it by the holding company, but on the other hand it may be able to call in certain staff resources of the holding company. Thus, the amount and kinds of resources (money, skilled people, instruments, software) available to the operating company may vary by type of ownership arrangement. All of these factors may affect a utility's willingness to incur capital or operating costs for the purpose of enhancing the safety of nuclear plant operations.

2.4 Size Characteristics of Nuclear Utilities

The utilities which currently operate nuclear plants vary substantially in the number of plants they currently own and operate. Table 3.3 shows the distribution of number of nuclear plants by utility. Twenty-three utilities own just one nuclear plant, and the number of utilities which own more than one plant falls off radically as the number of plants increase. Ten utilities own two nuclear plants, six own three units, and so on, with only one utility currently owning as many as seven nuclear units. Thus, experience with nuclear power plant operations is spread widely over the nuclear industry, with only a relative handful of utilities having experience in multi-plant nuclear operations. This situation will change greatly in coming years as more and more second, third, and additional nuclear plants are brought on-line by particular utility companies. The organizational capacity to operate not just one but multiple nuclear units will need to be greatly increased by a number of utility organizations.

Nuclear utilities also vary enormously in their total organizational size, as measured by the number of employees. Table 3.4 shows the distribution of

Table 3.3. Number of On-Line Nuclear Plants Per Utility

Number of Plants	Number of Utilities
1	23
2	10
3	6
4	1
5	0
6	0
7	1

Sources:

1. U.S. Department of Energy, Energy Information Administration. Statistics of Privately Owned Electric Utilities in the United States: 1980 Annual Classes A and B Companies. Washington, D.C., DOE/EIA-0044(80), October 8, 1981.
2. U.S. Department of Energy, Energy Information Administration. Statistics of Publicly Owned Utilities in the United States--1980. Washington, D.C., DOE/EIA-0172(80), December, 1981.
3. U.S. Department of Agriculture, Rural Electrification Administration. 1980 Statistical Report, Rural Electric Borrowers. Washington, D.C., REA Bulletin Number 1-1, June, 1981.
4. Tennessee Valley Authority. Financial Statements for the Year Ended September 30, 1981. Knoxville, Tennessee, TVA/OMS/FIN-82/1.
5. Federal Energy Regulation Commission, Office of Electric Power Regulation. Power Pooling in the United States. Washington, D.C., FERC-0049, December, 1981.
6. "World List of Nuclear Power Plants," Nuclear News, June, 1981.

nuclear utilities by number of employees. The majority of nuclear utilities are large organizations with more than 1,000 employees. Ten have more than 10,000 employees, 13 have between 5,000 and 10,000 employees, and 26 have between 1,000 and 5,000 employees. All of these organizations are considered "huge" relative to other business organizations in the United States (Osborn, Hunt, Jauch, 1980). Six of the nuclear utilities are much smaller, with less than 1,000 employees. Two of these are medium-sized utilities, and four are quite small, with under 200 employees each. The four small nuclear utilities are totally nuclear organizations in the Northeast, each of which operates only one nuclear plant.

2.4.1 Research Issues

Size is an important factor in explaining the efficiency and innovativeness of an organization. Because of the variation in overall organizational size in the nuclear industry, very different organizational structures are likely to exist. A 200-employee organization simply cannot be managed in the same manner as an organization with over 10,000 employees. Large organizations may attain economies of scale but may be less likely to innovate than medium-sized firms (Kamien and Schwartz, 1975). These findings from the open economics literature have been examined in the specific case of nuclear power. However, while the size of nuclear plants is often debated (e.g., Komanoff, 1976), much less attention has been given to the size of the utility. The issue of acceptable organizational structures for operation of safe nuclear power plants is likely to be a very complex subject warranting extensive investigations (cf., Osborn et al., 1980).

2.5 Financial Characteristics of Nuclear Utilities

Because nuclear power is so capital intensive, and because interest costs have risen during the 1970s and 1980s, nuclear plant construction programs have tremendous financial impacts on utility companies. In this section, we review literature on efficiency impacts of financial variables, and we explore some of the financial characteristics of nuclear and non-nuclear utilities, disaggregating these data by ownership and other characteristics of the utility industry discussed above.

Patterns of ownership in an industry can affect the financial results obtained in that industry, both in terms of the price of stock offered by particular firms and in terms of the profit rates achieved by those firms. This point has been demonstrated by several authors (Reekie, 1979). If ownership variables can be traced to financial outcomes, it seems likely that safety-related outcomes may play the role of an intervening or mediating variable. That is, ownership variables result in certain choices about organizational structure, which in turn contribute to the pattern of safety-related outcomes. The severity of the safety-related outcomes in turn affects the financial performance of the utility. These hypotheses need to be further developed and empirically tested in future research.

Table 3.4. Size Distribution of Nuclear Utilities

Number of Employees	Number of Utilities
0-199	4
200-499	1
500-999	1
1,000-4,999	26
5,000-9,999	13
10,000 +	10

Sources:

1. U.S. Department of Energy, Energy Information Administration. Statistics of Privately Owned Electric Utilities in the United States: 1980 Annual Classes A and B Companies. Washington, D.C., DOE/EIA-0044(80), October 8, 1981.
2. U.S. Department of Energy, Energy Information Administration. Statistics of Publicly Owned Utilities in the United States--1980. Washington, D.C., DOE/EIA-0172(80), December, 1981.
3. U.S. Department of Agriculture, Rural Electrification Administration. 1980 Statistical Report, Rural Electric Borrowers. Washington, D.C., REA Bulletin Number 1-1, June, 1981.
4. Tennessee Valley Authority. Financial Statements for the Year Ended September 30, 1981. Knoxville, Tennessee, TVA/OMS/FIN-82/1.
5. Federal Energy Regulation Commission, Office of Electric Power Regulation. Power Pooling in the United States. Washington, D.C., FERC-0049, December, 1981.
6. "World List of Nuclear Power Plants," Nuclear News, June, 1981.

Table 3.5 shows four financial ratios which can be used to compare utilities of different types:

- The ratio of construction work in progress (CWIP) to total value of plants. This ratio shows how much of a utility's assets are represented by construction which is not yet completed. Should the plants under construction fail to operate due to licensing or other difficulties, the construction value would have to be written off as losses in future years. Thus, the higher the value of this ratio, the more risky a position the utility is in.
- Value of plant divided by revenue. This ratio shows how many years of revenue are required to pay off the total value of electric plant, assuming that all of the construction costs had been borrowed. This ratio is a measure of the ability of the utility to raise revenues to pay for its investments.
- Long-term debt divided by value of plant. This ratio demonstrates how much of the construction program costs were borrowed. The higher the ratio is, the more "leveraged" the utility company is, that is, the greater the value of debt is in its total assets. A high value of debt to value of plant implies a continuing need for revenues to provide debt service in future years.
- Current assets divided by current liabilities. This "current ratio" is a measure of the short-term financial position of the utility company. The higher is this ratio, the greater is the ability of the company to cover current demands for cash through currently available assets.

Table 3.5 shows these ratios for utilities which have nuclear plants on line, for those which are building plants, and for all Class A and B (large) investor-owned utilities in the U.S. The ratio of construction work in progress to value of plant is higher for both current nuclear utilities and those with plants under construction than it is for the investor-owned industry as a whole. Due to the large size and capital-intensive nature of these plants, a greater proportion of the total value of these companies is represented by the nuclear construction programs. The ratio is highest for those which are currently building nuclear plants, which seems quite reasonable. The value of plant to current revenues is also higher for utilities which now operate or are building nuclear plants than it is for the investor-owned industry as a whole. Thus, for a capital-intensive utility with nuclear plants, more years' worth of revenue are required to equal the value of the plants. Nuclear utilities are simply more capital intensive than the utility industry as a whole. On the other hand, long-term debt as a proportion of total plant value is lower for nuclear utilities than it is for the industry as a whole. The difference is quite substantial. The reason for this difference is that CWIP includes the value of plant even though it does not represent revenue-producing assets until the plants are completed. Thus, the debt to plant ratio is somewhat misleading. There is little variation in the current ratio for nuclear utilities compared to the industry as a whole, although utilities with

Table 3.5. Financial Characteristics of Utilities with Nuclear Plants Compared to Investor Owned Industry Totals*

Utility Subgroup	CWIP/Value of Plant	Value of Plant/Revenue	Long Term Debt/Value of Plant	Current Assets/Current Liabilities
Nuclear Plants On-Line	.23	3.08	.22	.94
Nuclear Plants Under Construction	.26	3.22	.21	1.01
All Class A&B Investor Owned	.21	2.79	.37	.99

Sources:

1. U.S. Department of Energy, Energy Information Administration. Statistics of Privately Owned Electric Utilities in the United States: 1980 Annual Classes A and B Companies. Washington, D.C., DOE/EIA-0044(80), October 8, 1981.
2. U.S. Department of Energy, Energy Information Administration. Statistics of Publicly Owned Utilities in the United States--1980. Washington, D.C., DOE/EIA-0172(80), December, 1981.
3. U.S. Department of Agriculture, Rural Electrification Administration. 1980 Statistical Report, Rural Electric Borrowers. Washington, D.C., REA Bulletin Number 1-1, June, 1981.
4. Tennessee Valley Authority. Financial Statements for the Year Ended September 30, 1981. Knoxville, Tennessee, TVA/OMS/FIN-82/1.
5. Federal Energy Regulation Commission, Office of Electric Power Regulation. Power Pooling in the United States. Washington, D.C., FERC-0049, December, 1981.
6. "World List of Nuclear Power Plants," Nuclear News, June, 1981.

nuclear plants on-line appear to have a lower current ratio than either utilities with plants under construction or the industry as a whole.

2.5.1 Research Issues

While there exist interesting patterns of variation between nuclear utilities and the investor-owned industry as a whole, these data do not indicate acceptable levels of these ratios on which regulatory action could be based. Additional research would be required to establish "safe" levels for these ratios. Such research would involve comparisons with other industries, including other regulated industries such as natural gas companies and telecommunications companies, and unregulated enterprises. The issue for the Nuclear Regulatory Commission is the availability of sufficient financial resources to guarantee safe operation of nuclear plants. Research directed specifically at the issue of financial resources and their linkage to safe operations needs to be conducted. The data above demonstrate that substantial variations exist in the characteristics of nuclear versus non-nuclear utilities. This is an area in which further research should be carried out.

Variations in financial characteristics exist when nuclear utilities are broken down into holding company systems, investor-owned systems, government-owned systems. Variations also exist according to whether the utility is a member of a power pool or an unaffiliated utility company. Data on these aspects of nuclear utilities is shown in Table 3.6. Government-owned utilities stand out in this table as being substantially different from investor-owned utilities on all of these ratios. The unaffiliated utilities appear to be different from power pool members, but this difference may be due to the inclusion of the Tennessee Valley Authority, a government-owned system, in the unaffiliated group. Again, no "safe" or "acceptable" values of these ratios can be established at this point. However, public versus private ownership of a utility is an important characteristics which needs to be kept in mind in interpreting data on the financial characteristics of utilities.

A more detailed look at one of the financial ratios provides additional insights which further research could investigate. Table 3.7 shows the distribution of construction work in progress to value of plant by utility. This frequency distribution reveals that a normal shaped curve could describe the distribution of this ratio across utilities. The most frequent value of this ratio is between .20 and .299. Thirty utilities have ratios of CWIP to plant which is less than .2, representing a relatively low "risk" to the utility due to plants which are now under construction and could conceivably fail to operate as planned. On the other hand, 14 utilities have CWIP to plant ratios in excess of .3, and two utilities have ratios in excess of .5. Should the construction programs of these utilities fail to result in the desired outcome of a safely functioning nuclear plant, these utilities would be in dire financial straits. A financial risk assessment could be constructed by pursuing this avenue of research, establishing a probability distribution for a plant to come on-line and operate

Table 3.6. Financial Characteristics of Nuclear Utility Industry Groups (Plants On-Line or Under Construction)

Utility Subgroup	CWIP/Value of Plant	Value of Plant/Revenue	Long Term Debt/Value of Plant	Current Assets/Current Liabilities
Holding Company Systems	.21	3.14	.40	1.02
Investor Owned	.24	3.01	.37	.99
Government Owned	.09	4.21	.80	2.23
Power Pool Members	.22	2.78	.40	1.04
Unaffiliated	.33	3.97	.44	.72

Sources:

1. U.S. Department of Energy, Energy Information Administration. Statistics of Privately Owned Electric Utilities in the United States: 1980 Annual Classes A and B Companies. Washington, D.C., DOE/EIA-0044(80), October 8, 1981.
2. U.S. Department of Energy, Energy Information Administration. Statistics of Publicly Owned Utilities in the United States--1980. Washington, D.C., DOE/EIA-0172(80), December, 1981.
3. U.S. Department of Agriculture, Rural Electrification Administration. 1980 Statistical Report, Rural Electric Borrowers. Washington, D.C., REA Bulletin Number 1-1, June, 1981.
4. Tennessee Valley Authority. Financial Statements for the Year Ended September 30, 1981. Knoxville, Tennessee, TVA/OMS/FIN-82/1.
5. Federal Energy Regulation Commission, Office of Electric Power Regulation. Power Pooling in the United States. Washington, D.C., FERC-D049, December, 1981.
6. "World List of Nuclear Power Plants," Nuclear News, June, 1981.

Table 3.7. Distribution of Construction Work in Progress (CWIP)
to Value of Plant by Utility

Value of CWIP/Value of Plant	Number of Utilities
.00 to .01	1
.01 to .099	14
.10 to .199	15
.20 to .299	17
.30 to .399	10
.40 to .499	2
.50 to .599	1
.60 to .699	1

Sources:

1. U.S. Department of Energy, Energy Information Administration. Statistics of Privately Owned Electric Utilities in the United States: 1980 Annual Classes A and B Companies. Washington, D.C., DOE/EIA-0044(80), October 8, 1981.
2. U.S. Department of Energy, Energy Information Administration. Statistics of Publicly Owned Utilities in the United States--1980. Washington, D.C., DOE/EIA-0172(80), December, 1981.
3. U.S. Department of Agriculture, Rural Electrification Administration. 1980 Statistical Report, Rural Electric Borrowers. Washington, D.C., REA Bulletin Number 1-1, June, 1981.
4. Tennessee Valley Authority. Financial Statements for the Year Ended September 30, 1981. Knoxville, Tennessee, TVA/OMS/FIN-82/1.
5. Federal Energy Regulation Commission, Office of Electric Power Regulation. Power Pooling in the United States. Washington, D.C., FERC-0049, December, 1981.
6. "World List of Nuclear Power Plants," Nuclear News, June, 1981.

successfully, and associating that probability with acceptable levels of such ratios as CWIP to plant.

2.6 Regulators

The electric utility industry is often characterized as a "regulated industry." This phrase usually refers to rate regulation by state Public Utility Commissions. In fact, the electric utilities are regulated by a variety of agencies--local, state, and federal--some having jurisdiction over only so-called regulated industries and others having impact on a broad range of industries. In this section, the various types of regulation affecting the electric utilities are described and the impacts of the various types of regulation on nuclear utilities assessed.

2.6.1 Public Utility Commission Regulation

Nearly every state has a commission to regulate the electric, gas, and telephone companies operating within state boundaries. This commission may be called a Public Utility Commission, a Public Service Commission, Corporation Commission, or other variants. The acronym PUC is used to refer to all such commissions below. Only three states lack a PUC: Minnesota, Nebraska, and South Dakota. In Texas, a PUC was formed only in 1975; prior to that year, electric rates were set by incorporated cities. In the other non-PUC states, municipalities grant service permits and set rates for electric utility companies that are investor-owned corporations.

In most states the PUCs lack powers over municipal and cooperative utilities comparable to their powers to regulate investor-owned utility companies. Only sixteen state PUCs have powers to regulate municipal utilities comparable to their powers over investor-owned utilities. Twenty-five states regulate cooperative utilities. Municipal level regulation is the only possible substitute with respect to municipal and cooperative utilities and those states lacking PUC authority in these areas (Federal Power Commission, 1973).

Rate regulation has been imposed on electric utilities by most states to prevent monopolistic price and quantity setting. Electric power distribution is a "natural monopoly" in that duplication of distribution networks is thought to be more costly than the benefits achievable by having two or more competitive distribution networks serving the same territory. Generation of power is subject to significant economies of scale, which implies that social benefits accrue to formation of large generating companies which can build very large-scale generating plants. Thus both generation and distribution of power are provided by monopolistic and often vertically integrated power companies. Rate regulation is imposed on these companies if they are investor-owned companies. The intent of rate regulation is to keep rates below the level that would be set by a profit maximizing monopolist and to keep output correspondingly higher. In actual practice, rates are set to allow the monopolistic utility to earn a commission-set fair rate of return on its capital investments or rate base. Empirical evaluations of commission rate controls differ on the efficacy of this form of regulation (Peterson, 1976; Moore, 1975).

PUCs also supervise the financial transactions of the utility companies under their jurisdiction. Purchases or mergers of other utilities, and the issuance and purchase of securities are typically regulated by PUCs. Other matters falling under the jurisdiction of PUCs include the setting of standards for the safety and adequacy of service to customers, and issuance of permits called Certificates of Public Convenience and Necessity (CPCNs) for major additions to physical plant. The standard setting authority applies mainly to the utility's outputs--voltage levels, meter accuracy, and so forth. How the utility company chooses to provide this output, i.e., its choice of generating plant, is not regulated directly by the PUC.

2.6.2 Federal Energy Regulatory Commission and the Securities and Exchange Commission

State regulatory authority stops at the state border, while many utilities operate in more than one state, or buy and sell power across state lines. The Federal Energy Regulatory Commission (FERC) was set up to handle regulation of interstate transactions in the electric utility industry. FERC inherited its powers from the Federal Power Commission in 1977 with the creation of FERC as part of the Department of Energy. Bulk or wholesale rates for interstate transactions are set by the FERC. In setting bulk power rates, the FERC uses the same cost-based, fair rate of return strategy employed by the state PUCs. The FERC also supervises financial operations of utilities falling under its jurisdiction and issues licenses to utilities constructing hydroelectric plants on navigable rivers.

A specialized area of financial regulation of certain utility companies is reserved to the Securities and Exchange Commission (SEC). Under the Public Utility Holding Company Act of 1935, the SEC was empowered to supervise the financial transactions of interstate utility holding companies. A holding company is a corporation that owns all of the stock of two or more subsidiary companies with direct operational responsibilities. The holding company performs financial and managerial functions for all of its subsidiaries. As mentioned above, the utility holding company systems appear to be operated as unitary systems at the holding company level with respect to investments in new generating plants. At present, thirteen electric or electric and gas utility holding companies are registered with the SEC. These companies must secure SEC approval of securities sales or purchases, and of proposed mergers and acquisitions.

2.6.3 Nuclear Regulatory Commission

Regulation of all radioactive materials in civilian hands is the job of the Nuclear Regulatory Commission (NRC). This commission was part of the Atomic Energy Commission (AEC) prior to 1975. AEC's operational and research responsibilities were transferred first to the Energy Research and Development Administration in 1975, and then to the Department of Energy in 1977. The regulatory authority of the AEC was vested in a new agency, the NRC, in 1975 and left untouched in 1977. NRC looks and acts very much like the regulatory part of AEC. The internal structure and process of the AEC were continued by the NRC. The same regulatory rules and precedents are applied. NRC may be somewhat more aggressive in imposing fines on the

utilities for violating safety regulations and in developing new rules, due to the appointment of more aggressive commissioners by recent administrations.

The federal government initially owned and directly controlled all nuclear materials. Almost all research during the 1940s was weapons oriented, whether conducted directly by the AEC or in AEC contractor laboratories. After World War II was over, the possibility of peaceful uses of nuclear materials began to be discussed. A revision of the Atomic Energy Act in 1954 contained provisions for private sector uses of nuclear materials under license from the AEC. Two categories of licenses were created, one category for research purposes and one for commercial purposes. The early nuclear power demonstration plants were licensed under the research category, while since 1970, the commercial category has been used.

In a federal system of government, performance of a function by an upper level of government may preclude any attempt by a lower level to deal with the same issues. This is the case with regulation of nuclear materials in civilian hands. The standards imposed and licenses issued by the AEC, or now NRC, preempt any attempt by state or local governments to set standards for radioactive emissions or to license nuclear power plants. NRC does negotiate agreements with states which allow the states to regulate research uses of nuclear materials under the Agreement States Program. Nuclear power plant licensing authority is not delegated to the states by NRC.

This interpretation of preemption by NRC of nuclear power plant licensing was upheld in a court case originating in the state of Minnesota. The state set up standards for radioactive emissions from power plants which were much stricter than AEC standards. In 1968 the state attempted to enforce the standards on a nuclear plant under construction by Northern States Power Company. Northern States brought suit in federal court, charging that the Atomic Energy Act of 1954 preempted state level regulation of radiological standards and emissions. The District Court ruled in favor of the power company in 1971, and this ruling was upheld by the Supreme Court (Northern States, 1972).

The AEC power plant licensing process, continued in toto by NRC, has two major components: the construction permit and the operating license. When a utility company decides to build a nuclear power plant, it must obtain a construction permit from the NRC. The review of applications for construction permits is delegated by the NRC to an Atomic Safety Licensing Board (ASLB), composed of NRC staff members and professional employees of the nuclear industry and of academic institutions. Most of the members are engineers, but some have legal training as well. The ASLB reviews the applicant's financial ability to carry out a program of constructing and operating a nuclear station in a safe and responsible manner. Then the design of the plant is gone over in great detail to ensure that the plant will meet NRC safety-related emissions and performance standards. Since every plant to date has been largely custom designed to meet each utility's specifications, this part of the review process tends to be quite lengthy.

An Environmental Impact Statement must be prepared by the NRC staff with the use of information provided by the utility. This statement has to be accepted by the Environmental Protection Agency (EPA) before construction can begin. Groups of intervenors opposed to nuclear power have found the EIS process a convenient point at which to attack and delay the construction of nuclear plants. The requirements for an EIS are set forth quite specifically in the law and are quite detailed. This allows intervenors granted legal standing as interested parties in EIS hearings to raise questions on numerous points, to call for new studies or collection of better data on possible impacts of the proposed plant. Several environmental groups have been accused of fighting nuclear power per se by deliberately tying up and delaying specific licensing proceedings.

Finally, since 1970, each applicant for a construction permit is reviewed for possible violations of the federal antitrust laws which construction and operation of the plant may bring about or help to maintain. If possible violations are found, the ASLB may write special antitrust conditions into the construction permit. These conditions may require joint venture participation in the plant by allegedly damaged parties, usually small municipal and cooperative utilities in the neighborhood of an investor-owned applicant, or perhaps the conditions may require provision of wholesale power, transmission services, or wheeling services to the municipals or cooperatives requesting such services (Peen, et al., 1976).

When construction nears completion, the utility must come back to the NRC for an operating license. The ASLB reviews the plant to make sure that the stipulations of the construction permit have been carried out and that the plant is ready to be operated. An interim operating license is usually issued next, allowing operation of the reactor at a small percentage of design capacity for testing purposes. Upon completion of various tests of the plant, a full power operating license is issued for up to forty years of operation. Under the final operating license, NRC retains authority to order partial or complete shutdown of the plant if the operating license conditions are not met or for other reasons such as suspected safety defects in a certain class of components requiring inspection of all reactors containing that component.

2.6.4 Environmental Regulation

The National Environmental Protection Act (NEPA) was passed by Congress in 1967. Early in the Nixon Administration, the Environmental Protection Agency (EPA) was created and the Environmental Impact Statement (EIS) process mandated by NEPA began to affect the electric utilities. EPA's criteria for acceptable emissions from power plant exhaust stacks and from water discharge outlets have become progressively stricter and have made construction of both coal-fired and nuclear plants much more difficult and costly.

An acceptable EIS must be filed with the EPA before construction of a large-scale power plant can begin. The EIS must carefully describe the probable environmental changes that will result from construction and operation of the power plant. Both physical and socio-economic impacts of the plant must be considered. The impacts of alternatives to the proposed

plan for action must also be evaluated. A cost-benefit analysis must be conducted to show that the plant is in the public interest. Once EPA rules that the statement satisfies the requirements of the law, i.e., adequate description of probable impacts of the plant and its alternatives, then construction can begin.

2.6.5 Impacts of Regulation on Utilities: Research Issues

The major effects of regulation on utilities may be lengthened lead times to build plants and uncertainty about the nature of future requirements. It is difficult to find clearcut examples of plant decisions which have been clearly determined by regulatory forces, but it is clear that leadtimes for nuclear units have increased relative to fossil-fired units as a consequence of regulatory programs. Longer leadtimes in and of themselves are not necessarily a problem, but uncertainty about future loads, future inflation, and future regulatory policies are claimed to be a problem for the utilities. An NRC staff member sensitive to the utility companies' claims has said:

The view is sometimes expressed that, insofar as the length of the planning/licensing/construction is concerned, improvements in the predictability and stability of the licensing process are more important than reducing the length of the licensing process. One major aspect of societal penalty from the loss of predictability of the licensing process . . . is delays . . . (author's emphasis) (Spangler, 1978).

Longer leadtimes for plant construction increase construction costs and expose the utility to back-fitting requirements during the construction process. Regulatory impacts are relevant to safety in that they result in requirements for use of certain types of equipment and procedures to enhance safety, which the utility might not have chosen to employ, and by affecting the resources available to the company.

In addition to this affect, state PUCs use financial controls, primarily rate setting powers, to implicitly or explicitly affect utility generation expansion plans and operating decisions, both of which may ultimately affect safety outcomes.

Finally, analyses from the economic and public policy literature suggest that the willingness and ability to follow specific regulatory requirements is altered by size (Marcus, 1983; Cole, 1981), management philosophy (Crow, 1979), and organizational design (Williamson, 1963). The relationships among these factors in the nuclear industry is an area where additional research is needed.

3. NSSS VENDORS

Nuclear Steam Supply Systems (NSSS) include the reactor and other systems required to deliver steam to the generator side of the power plant. Four NSSS vendors have provided all but one of the currently operating nuclear power plants and those under construction. These four NSSS vendors are

Babcock and Wilcox, Combustion Engineering, General Electric, and Westinghouse. General Electric offers boiling water reactors; the other vendors build pressurized water reactors. One plant, Fort St. Vrain, was designed by Gulf Atomic. This plant is a prototype gas-cooled, high-temperature reactor. All of these vendors construct subsystems or some complete systems in factory facilities. However, major structures are site fabricated to a great degree, and the various systems are assembled on the plant site. Thus, building a nuclear plant is an on-site construction process to a very large extent.

Little information is readily available about these companies. Babcock and Wilcox is a subsidiary of another corporation. The parent corporation does not make separate disclosures concerning its subsidiary. The nuclear programs of General Electric and Westinghouse are just one facet of the activities of very large and diverse companies. Some of the vendors provide general descriptions of their nuclear programs, but not in sufficient detail. Financial data are especially scarce or not released at all.

3.1 Research Issues

Given these similarities among the four vendors, there remain important differences among the various plant designs offered, and in the range of services offered by each after construction is complete. These differences, while known in the industry, cannot be precisely specified at this time. However, depending on the services offered by a particular vendor, and on the extent to which a particular utility uses a particular service, differences will be seen in internal organization and utility performance. These differences are likely to take the form of the presence or absence of particular technical capabilities, and in the complexity and size of the utility organization. Depending on the skill of utility management in setting up and operating its organization, differences may be seen in performance across the plants built by each vendor. Some of these performance differences may be traceable to a relatively good or bad configuration of utility versus vendor provision of services, and to the ways in which these choices are integrated into the utility organization.

In sum, the choice of a NSSS vendor may prove to have safety implications. Outcome indicators need to be standardized for vendor differences in some way, or differences in outcomes otherwise traced to the vendor and its particular design choices. Thus, it seems important to learn something about the parameters affecting the utilities' choices of particular vendors. Economic models of plant decisions by economists have focused on such parameters as fuel, operating, and capital costs, and on the size of plant that is available (Joskow and Mishkin, 1974). Just how these parameters sort out among the various NSSS vendors is not clear. The attractiveness of any given vendor's product seems to have varied over time. For example, the Washington Public Power Supply System originally contracted for five nuclear units. Three separate bidding rounds took place for Unit 1, Units 2-3, and Units 4-5. Each time the "best" offer was accepted, where "best" means a whole set of bid variables, and WPPSS ended up picking three separate vendors to build its five units. Other utilities have made similar decisions involving more than one vendor for multiple

nuclear units. In the case of the Tennessee Valley Authority, diversity of vendors in the total TVA nuclear program was an explicit policy. Thus, it would seem that any differences in safety outcomes across NSSS vendors will have to be interpreted as a consequence of a complex decision problem in which a choice was often necessary before any data were available regarding the safety performance, or other performance characteristics of the nuclear units.

4. INDUSTRY ASSOCIATIONS

Four major industry associations exist which may have impacts on choices made by utilities: Atomic Industrial Forum (AIF), Edison Electric Institute (EEI), Electric Power Research Institute (EPRI), and Institute of Nuclear Power Operations (INPO).

AIF is a trade association devoted to advancing the nuclear power industry. It has a long history, dating from the early years of commercial access to the secrets of nuclear technology. It provides information on nuclear technologies and nuclear utilities. It is also a vehicle for industry to influence public policy. EEI is a general trade association of electric utilities. Its purposes and effects on nuclear utilities are similar to those of AIF, although less specific to nuclear power.

EPRI is a utility funded research organization. R&D is conducted to improve existing technologies, to develop new energy supply technologies, and to provide utilities with tools for solving regulatory compliance problems.

INPO is an industry attempt at self-regulation. This quasi-independent institute regularly assesses nuclear utility operations in a number of areas, and makes suggestions to each utility about possible improvements. In addition public reports recommend "good practices" with potential applicability in a number of plants.

4.1 Research Issues

Industry associations may affect the types of information searching, R&D, and internal auditing of operations utilities carry out. By providing these services to the utilities, safety may be enhanced because individual utilities would not otherwise carry out these activities. Alternatively, utilities may reduce the resources devoted individually to these areas, permitting the pre-existing level of safety to be achieved in a more economical fashion. Many of these activities have a "public good" character which implies that an industry association could indeed carry out the activity more efficiently than individual utilities.

5. SUMMARY

In this literature review, we have summarized the patterns of ownership and regulation of the utility industry, described size and financial characteristics of nuclear utilities, and regulatory, vendor, and association characteristics which may affect utility organization choices. We have reviewed theoretical frameworks linking environmental factors to

technology, internal structure, and intermediate safety related outcomes. All of the factors are interrelated and have simultaneous effects on each other. The goal for research in this area is to demonstrate which of these various potential causal paths are potentially important for safety-related outcomes of nuclear utilities, and which of these pathways are amenable to empirical measurement. Much of the theoretical framework sketched in this chapter has not yet been subjected to careful empirical tests. Consequently, while many aspects of the environment and context of utilities may help provide new insight into safety, a good deal of research is required to test hypotheses.

Table 3.8. Data Appendix

Utility Characteristics	Power Pool Member	Holding Company Subsidiary	Publicly Owned Utility	Number of Employees	Generating Capacity 1980	Nuclear Gen. Cap. 1980	Nuclear Cap. Under Construction	Construction Work In Progress (Millions)	Electric Utility Plant (Millions)	Total Utility Plant (Millions)
NEW ENGLAND POWER POOL										
Boston Edison Co.	1	0	0	3799	2760	687		257	1431	2035
Pilgrim 1										
Connecticut Yankee	1	0	0	160	600	600		10	154	1032
Haddam Neck										
Maine Yankee Atomic Power Co.	1	0	0	161	864	864		9	256	457
Maine Yankee										
Northeast Nuclear Energy Co.	1	0	0	7260	6137	3143	1150			
Millstone 1										
Millstone 2										
Vermont Yankee Nuclear Power Corp.	1	0	0	194	563	563		4	228	362
Vermont Yankee										
Yankee Atomic Electric Co.	1	1	0	129	185	185		.6	28	106
Yankee-Rowe										
Public Service Co. of New Hampshire	1	0	0	1863	1092	0	2300	671	1220	1272
NEPOOL TOTAL					21294	6043	5750	953	3320	5267
NEW YORK POWER POOL										
Consolidated Edison Co.	1	0	0	18570	10599	1288		264	6739	7968
Indian Point 2										
Niagara Mohawk Power Corp.	1	0	0	8081	5418	642	1080	633	3829	2924
Nine Mile Point 1										
Power Authority of the St. of NY	1	0	1	1400	6881	1951		84	3095	3443
Indian Point 3										
James A. Fitzpatrick										
Rochester Gas and Electric Corp.	1	0	0	1954	1255	517		220	926	1207
Robert E. Ginna										
Long Island Lighting Co.	1	0	0	5213	2731	0	820	1941	3589	1095
NYPP TOTAL					29742	4398	1900	3144	18180	19718

Table 3.0, Continued

Utility Characteristics	Power Pool Member	Holding Company Subsidiary	Publicly Owned Utility	Number of Employees	Generating Capacity 1900	Nuclear Gen. Cap. 1980	Nuclear Cap. Under Construction	Construction Work In Progress (Millions)	Electric Utility Plant (Millions)	Total Utility Plant (Millions)
PENNSYLVANIA-NEW JERSEY-MARYLAND INTERCONNECTION										
Baltimore Gas and Electric Co.	1	0	0	6072	5249	1828		466	2721	3505
Calvert Cliffs 1										
Calvert Cliffs 2										
Jersey Central Power and Light Co.	1	1	0	3564	3145	550		92	1814	1959
Oyster Creek 1										
Metropolitan Edison Co.	1	1	0	2827	2175	1832		17	1336	1409
Three Mile Island 1										
Three Mile Island 2										
Three Mile Island 3										
Philadelphia Electric Co.	1	0	0	7984	8142	2304	2110	2023	5606	6309
Peach Bottom 2										
Peach Bottom 3										
Public Service Electric and Gas Co.	1	0	0	8228	10078	498	2140	1583	5650	6890
Salem 1										
PJM TOTAL					44891	7013	6250	4183	17128	20074
SOUTHERN CO. SYSTEM										
Alabama Power Co.	1	1	0	9555	7785	888	829	1147	4994	5199
Joseph M. Farley										
Georgia Power Co.	1	1	0	13266	12945	852	2200	810	5505	5612
Edwin Hatch 1										
Edwin Hatch 2										
Mississippi Power and Light	1	1	0	1956	2778	0	2500	17	780	780
SOCO TOTAL					23909	1740	5529	1976	11280	11593

Table 3.8, Continued

Utility Characteristics	Power Pool Member	Holding Company Subsidiary	Publicly Owned Utility	Number of Employees	Generating Capacity 1980	Nuclear Gen. Cap. 1980	Nuclear Cap. Under Construction	Construction Work In Progress (Millions)	Electric Utility Plant (Millions)	Total Utility Plant (Millions)
VIRGINIA-CAROLINAS SUBREGION										
Carolina Power and Light Co.	0	0	0	6784	8126	2502	1800	1616	4490	4720
Robinson 2										
Brunswick 1										
Brunswick 2										
Duke Power Co.	0	0	0	19356	11769	2661	6030	2775	6958	7553
Oconee 1										
Oconee 2										
Oconee 3										
Virginia Electric and Power Co.	0	0	0	10408	10685	2675	907	1446	6445	6836
Surry 1										
Surry 2										
North Anna 1										
North Anna 2										
South Carolina Electric and Gas	0	0	0	2850	2643	0	900	582	1742	1952
VACAR TOTAL					35761	7838	9637	6421	19637	21062
FLORIDA ELECTRIC POWER COOR. GROUP										
Florida Power and Light Co.	0	0	0	11084	13047	2370		1009	5936	6041
Turkey Point 3										
Turkey Point 4										
St. Lucie 1										
Florida Power Corp.	0	0	0	4559	5599	890		245	2325	2419
Crystal River 3										
FCG TOTAL					22626	3260		1254	8262	8460

Table 3.0, Continued

Utility Characteristics	Power Pool Member	Holding Company Subsidiary	Publicly Owned Utility	Number of Employees	Generating Capacity 1980	Nuclear Gen. Cap. 1980	Nuclear Cap. Under Construction	Construction Work In Progress (Millions)	Electric Utility Plant (Millions)	Total Utility Plant (Millions)
WISCONSIN POWER POOL										
Wisconsin Public Service Corp. Kewaunee	1	0	0	1672	1436	535		154	763	9409
WPP TOTAL					3681			154	763	9409
NOT POOL MEMBERS										
Wisconsin Electric power Co. Point Beach 1	0	0	0	5306	4740	1048		215	2242	2307
Point Beach 2										
Commonwealth Edison Co. Dresden 1	0	0	0	15998	18343	5718	6636	4142	11811	12533
Dresden 2										
Dresden 3										
Zion 1										
Zion 2										
Commonwealth Edison Co. with Iowa-Illinois Gas and Electric Quad Cities 1	0	0	0			1657		167	741	958
Quad Cities 2										
Gulf States Utilities	0	0	0	901	6710	0	940	1316	3230	3401
Northern Indiana Public Service Co.	0	0	0	3901	3121	0	645	372	1919	2583
Public Service Co. of Indiana	0	0	0	4868	5802	0	2300	1018	3001	3077
ALLEGHENY POWER SYSTEM INC.								154	3413	3413
APS TOTAL					6822			154	3413	3413

Table 3.8, Continued

Utility Characteristics	Power Pool Member	Holding Company Subsidiary	Publicly Owned Utility	Number of Employees	Generating Capacity 1980	Nuclear Gen. Cap. 1900	Nuclear Cap. Under Construction	Construction Work In Progress (Millions)	Electric Utility Plant (Millions)	Total Utility Plant (Millions)
TENNESSEE VALLEY AUTHORITY Browns Ferry 2 Browns Ferry 3	0	0	1	37469	28428	3456	12060			
TVA TOTAL					28428	3456	12060	7702	4599	12312
ILLINOIS-MISSOURI POOL Illinois Power	1	1	0	3072	3972	0	950	920	2405	2052
Union Electric	1	1	0	5562	6020	0	2300	1094	3623	3694
IL-MO TOTAL					13480	0	3250	2014	6108	6547
MID-CONTINENT AREA POWER POOL Dairyland Power Cooperative	1	0				50				
La Crosse										
Northern States Power Co.	1	0	0	5764	6063	1755		210	2680	3126
Monticello										
Prairie Island 1										
Prairie Island 2										
Iowa Electric Light and Power Co.	1	0	0	1353	926	597		86	688	552
Duane Arnold										
Nebraska Public Power District	1	0	1	2122	2286	836		414	1568	1568
Cooper										
Omaha Public Power District	1	0	1	1640	1960	481		36	1098	1098
Fort Calhoun 1										
MAPP TOTAL					24900	3719		747	6035	6346

Table 3.8, Continued

Utility Characteristics	Power Pool Member	Holding Company Subsidiary	Publicly Owned Utility	Number of Employees	Generating Capacity 1980	Nuclear Gen. Cap. 1980	Nuclear Cap. Under Construction	Construction Work In Progress (Millions)	Electric Utility Plant (Millions)	Total Utility Plant (Millions)
AMERICAN ELECTRIC POWER SYSTEM										
Indiana and Michigan Electric Co.	1	1	0	2945	4106	2285		656	2901	2911
Donald Cook										
Donald Cook 2										
AEP TOTAL					20123					
CENTRAL AREA POWER COOR. GROUP										
Toledo Edison Co.	1	0	0	2317	1835	906		509	1708	1755
Davis-Besse										
Duquesne Light Co.	1	0	0	4382	3622	923	833	454	2575	2580
Beaver Valley 1										
Shippingport										
Cleveland Electric Illuminating Co.	1	0	0	482	5481	0	1410	785	3177	3226
CAPCO TOTAL					15147	1829	2243	1749	7461	7562
CIN. COL. DAYTON GROUP										
Cincinnati Gas and Electric	1	0	0	3651	3898	0	810	741	2124	2366
CCD TOTAL					5788	0	810	741	2124	2366
MICHIGAN ELECTRIC COOR. SYSTEM										
Consumer Power	1	0	0	7986	7242	887	1335	1669	4219	6376
Big Rock										
Palisades										
Detroit Edison Co.	1	0	0	10606	9167	0	1100	1576	6123	6169
MECS TOTAL					15791	887	2435	3246	10342	12545

Table 3.0, Continued

Utility Characteristics	Power Pool Member	Holding Company Subsidiary	Publicly Owned Utility	Number of Employees	Generating Capacity 1980	Nuclear Gen. Cap. 1980	Nuclear Cap. Under Construction	Construction Work In Progress (Millions)	Electric Utility Plant (Millions)	Total Utility Plant (Millions)
MIDDLE SOUTH UTILITIES										
Arkansas Power and Light	1	1	0	3943	4707	920		282	2416	2423
Nuclear One 1										
Nuclear One 2										
Louisiana Power and Light	1	1	0	2376	4719	0	1104	1030	2319	2334
MSU TOTAL					12177	902	1104	1312	4735	4757
MISSOURI-KANSAS POOL										
Kansas Gas & Electric	1	0	0	1561	2145	0	1150	85	1011	1112
MOKAN TOTAL					8879	0	1150	85	1011	1112
TEXAS MUNICIPAL POWER POOL										
TMP TOTAL					1457	0	0			
TEXAS UTILITY CO.							2300	1942	6622	6709
TUCO TOTAL					17336	0	2300	1942	6622	6709

Table 3.8, Continued

Utility Characteristics	Power Pool Member	Holding Company Subsidiary	Publicly Owned Utility	Number of Employees	Generating Capacity 1980	Nuclear Gen. Cap. 1980	Nuclear Cap. Under Construction	Construction Work In Progress (Millions)	Electric Utility Plant (Millions)	Total Utility Plant (Millions)
CALIFORNIA POWER POOL										
Pacific Gas and Electric Co. Humboldt	1	0	0	17524	11648	65	2190	2702	9156	11831
Sacramento Municipal Utility Dist. Rancho Seco	1	0	1		1525	929		87	1084	1004
Southern California Edison with San Diego Gas and Electric Co. San Onofre	1	0	0	14544	649	450	2200	2600 534	8379 1724	8431 2009
CAPP TOTAL					28870	1444	4390	5925	20344	23356
NOT FORMAL POOL										
Public Service Co. of Colorado Fort St. Vrain	0	0	0	4022	3263	343		445	1908	2307
PACIFIC NORTHWEST COOR. AGREEMENT										
Portland General Electric Co. Trojan	1	0	0	3106	2018	1216		377	2014	2134
Washington Public power Supply System Hanford	1	0	1		800	800	4990			
PNCA TOTAL					32292	2016	4990			
LOWER COLORADO RIVER POWER POOL										
Arizona Public Service Co.	1	0	0	4554	2501	0	3810	1081	2958	3199
LCRPP TOTAL					15109	0	3810	1081	2958	3199

Table 3.8, Continued

Utility Characteristics	Current Assets (Millions)	Current Liabilities (Millions)	Long-Term Debt (Millions)	Revenues (Millions)	Const. In Progress/ Util. Plant	Utility Plant/ Revenue	Current Ratio	Long-Term Debt/ Util. Plant	Year Incorporated
NEW ENGLAND POWER POOL									
Boston Edison Co. Pilgrim 1	184	55	337	806	.13	2.30	3.32	.17	1886
Connecticut Yankee Haddam Neck	12	65	820	78	.01	13.15	.19	.79	1962
Maine Yankee Atomic Power Co. Maine Yankee	13	122	279	84	.02	5.43	.11	.61	1966
Northeast Nuclear Energy Co. Millstone 1 Millstone 2									1927
Vermont Yankee Nuclear Power Corp. Vermont Yankee	14	20	81	78	.01	4.63	.72	.22	1966
Yankee Atomic Electric Co. Yankee-Rowe	10	1	2	34	.01	3.06	8.14	.02	1959
Public Service Co. of New Hampshire	112	218	398	351	.53	3.62	.51	.31	1926
NEPOOL TOTAL	347	484	1919	1513	.18	3.48	.72	.36	
NEW YORK POWER POOL									
Consolidated Edison Co. Indian Point 2	946	584	2768	3955	.03	2.01	1.62	.35	
Niagara Mohawk Power Corp. Nine Mile Point 1	373	362	1577	1762	.22	1.66	1.03	.54	1937
Power Authority of the St. of NY Indian Point 3 James A. Fitzpatrick			2596	927	.02	3.71		.75	
Rochester Gas and Electric Corp. Robert E. Ginna	92	85	437	502	.17	2.56	1.08	.34	1904
Long Island Lighting Co.	273	364	1689	1314	.47	3.12	.75	.41	1910
NYPP TOTAL	1686	1397	9069	8462	.16	2.33	1.21	.46	

Table 3.8, Continued

Utility Characteristics	Current Assets (Millions)	Current Liabilities (Millions)	Long-Term Debt (Millions)	Revenues (Millions)	Const. In Progress/ Util. Plant	Utility Plant/ Revenue	Current Ratio	Long-Term Debt/ Util. Plant	Year Incor- porated
PENNSYLVANIA-NEW JERSEY-MARYLAND INTERCONNECTION									
Baltimore Gas and Electric Co.	323	255	1300	1226	.13	2.86	1.27	.37	1906
Calvert Cliffs 1									
Calvert Cliffs 2									
Jersey Central Power and Light Co.	157	238	888	882	.05	2.22	.66	.45	
Oyster Creek 1									
Metropolitan Edison Co.	92	113	542	432	.01	3.26	.82	.38	1922
Three Mile Island 1									
Three Mile Island 2									
Three Mile Island 3									
Philadelphia Electric Co.	443	395	2483	2115	.32	2.98	1.12	.39	1929
Peach Bottom 2									
Peach Bottom 3									
Public Service Electric and Gas Co.	776	999	2352	2994	.23	2.30	.78	.34	1913
Salem 1									
PJM TOTAL	1793	2001	7568	7652	.21	2.62	.90	.38	
SOUTHERN CO. SYSTEM									
Alabama Power Co.	359	375	2207	1426	.22	3.65	.96	.42	1886
Joseph M. Farley									
Georgia Power Co.	837	403	2349	1813	.14	3.10	2.07	.42	1930
Edwin Hatch 1									
Edwin Hatch 2									
Mississippi Power and Light	88	104	264	532	.02	1.46	.85	.34	1927
SOCO TOTAL	1285	884	4820	3772	.17	3.07	1.45	.42	

Table 3.8, Continued

Utility Characteristics	Current Assets (Millions)	Current Liabilities (Millions)	Long-Term Debt (Millions)	Revenues (Millions)	Const. In Progress/ Util. Plant	Utility Plant/ Revenue	Current Ratio	Long-Term Debt/ Util. Plant	Year Incorporated
VIRGINIA-CAROLINAS SUBREGION									
Carolina Power and Light Co.	198	361	1713	1075	.34	4.39	.55	.36	1926
Robinson 2									
Brunswick 1									
Brunswick 2									
Duke Power Co.	348	424	2668	1687	.37	4.48	.82	.35	1917
Oconee 1									
Oconee 2									
Oconee 3									
Virginia Electric and Power Co.	515	411	3009	2119	.21	3.22	1.25	.39	1909
Surry 1									
Surry 2									
North Anna 1									
North Anna 2									
South Carolina Electric and Gas	160	140	784	630	.30	3.10	1.14	.40	1826
VACAR TOTAL	1223	1338	8175	5513	.30	3.82	.91	.44	
FLORIDA ELECTRIC POWER COOR. GROUP									
Florida Power and Light Co.	484	524	2135	2347	.17	2.57	.92	.35	1925
Turkey Point 3									
Turkey Point 4									
St. Lucie 1									
Florida Power Corp.	245	130	920	970	.10	2.49	1.08	.38	1899
Crystal River 3									
FCG TOTAL	730	654	3056	3317	.15	2.55	1.11	.36	

Table 3.8, Continued

Utility Characteristics	Current Assets (Millions)	Current Liabilities (Millions)	Long-Term Debt (Millions)	Revenues (Millions)	Const. In Progress/ Util. Plant	Utility Plant/ Revenue	Current Ratio	Long-Term Debt/ Util. Plant	Year Incorporated
WISCONSIN POWER POOL									
Wisconsin Public Service Corp. Kewaunee	105	107	250	436	.16	2.16	.99	.27	1883
WPP TOTAL	105	107	250	436	.16	2.16	.99	.27	
NOT POOL MEMBERS									
Wisconsin Electric power Co. Point Beach 1 Point Beach 2	280	154	752	769	.09	3.00	1.01	.33	
Commonwealth Edison Co. Dresden 1 Dresden 2 Dresden 3 Zion 1 Zion 2	917	1141	4721	83	.33	150.03	.80	.38	1913
Commonwealth Edison Co. with Iowa-Illinois Gas and Electric Quad Cities 1 Quad Cities 2	84	107	282	374	.17	2.56	.78	.29	1940
Gulf States Utilities	138	203	1330	1045	.39	3.25	.68	.39	
Northern Indiana Public Service Co.	354	216	1029	1366	.14	1.89	1.64	.40	1912
Public Service Co. of Indiana	232	2931	980	6456	.33	4.77	.79	.32	1941
ALLEGHENY POWER SYSTEM INC.	407	256	1289	1177					
APS TOTAL	407	256	1289	1177	.05	2.90	1.59	.38	

Table 3.8, Continued

Utility Characteristics	Current Assets (Millions)	Current Liabilities (Millions)	Long-Term Debt (Millions)	Revenues (Millions)	Const. In Progress/ Util. Plant	Utility Plant/ Revenue	Current Ratio	Long-Term Debt/ Util. Plant	Year Incorporated
TENNESSEE VALLEY AUTHORITY									1933
Browns Ferry 1									
Browns Ferry 2									
Browns Ferry 3									
TVA TOTAL	745	2545	9019	3204	.63	3.84	.29	.73	
ILLINOIS-MISSOURI POOL									
Illinois Power	203	160	991	883	.32	3.23	1.27	.35	1923
Union Electric	330	304	1367	954	.30	3.87	1.08	.37	1881
IL-MO TOTAL	553	465	2358	1838	.31	3.56	1.15	.36	
MID-CONTINENT AREA POWER POOL									
Dairyland Power Cooperative									
La Crosse									
Northern States Power Co.	237	308	833	1098	.07	2.85	.77	.27	1909
Monticello									
Prairie Island 1									
Prairie Island 2									
Iowa Electric Light and Power Co.	76	916	220	313	.16	1.76	.83	.40	1925
Duane Arnold									
Nebraska Public Power District	606	208	1719	373	.26	4.20	2.91	1.10	1939
Cooper									
Omaha Public Power District	133	75	889	227	.03	4.84	1.76	.81	1945
Fort Calhoun 1									
MAPP TOTAL	1053	683	3663	2011	.12	3.15	1.54	.58	

Table 3.0, Continued

Utility Characteristics	Current Assets (Millions)	Current Liabilities (Millions)	Long-Term Debt (Millions)	Revenues (Millions)	Const. In Progress/ Util. Plant	Utility Plant/ Revenue	Current Ratio	Long-Term Debt/ Util. Plant	Year Incorporated
AMERICAN ELECTRIC POWER SYSTEM									
Indiana and Michigan Electric Co.	207	318	1244	748	.23	3.89	.65	.43	1925
Donald Cook									
Donald Cook 2									
AEP TOTAL									
CENTRAL AREA POWER COOR. GROUP									
Toledo Edison Co.	105	210	717	401	.29	4.37	.50	.41	1901
Davis-Besse									
Duquesne Light Co.	197	163	1046	67	.18	3.82	1.21	.41	1912
Beaver Valley 1									
Shippingport									
Cleveland Electric Illuminating Co.	265	402	1221	893	.24	3.61	.66	.38	1892
CAPCO TOTAL	568	775	2985	1970	.23	3.84	.73	.39	
CIN. COL. DAYTON GROUP									
Cincinnati Gas and Electric	258	253	914	879	.31	2.69	1.02	.39	1837
CCD TOTAL	258	253	914	879	.31	2.69	1.02	.39	
MICHIGAN ELECTRIC COOR. SYSTEM									
Consumer Power	874	640	2505	2264	.26	2.82	1.36	.39	1910
Big Rock									
Palisades									
Detroit Edison Co.	551	587	2478	1810	.26	3.41	.94	.40	1903
MECS TOTAL	1425	1228	4984	4074	.26	3.08	1.16	.40	

Table 3.8, Continued

Utility Characteristics	Current Assets (Millions)	Current Liabilities (Millions)	Long-Term Debt (Millions)	Revenues (Millions)	Const. In Progress/ Util. Plant	Utility Plant/ Revenue	Current Ratio	Long-Term Debt/ Util. Plant	Year Incorporated
MIDDLE SOUTH UTILITIES									
Arkansas Power and Light	105	227	924	750	.12	3.23	.46	.38	1926
Nuclear One 1									
Nuclear One 2									
Louisiana Power and Light	97	104	881	853	.44	2.74	.53	.38	1927
MSU TOTAL	203	412	1805	1604	.28	2.97	.49	.38	
MISSOURI-KANSAS POOL									
Kansas Gas & Electric	104	70	459	293	.08	3.79	1.49	.41	1909
MOKAN TOTAL	104	70	459	293	.08	3.79	1.49	.41	
TEXAS MUNICIPAL POWER POOL									
TMPP TOTAL									
TEXAS UTILITY CO.	314	517	2050	2180	.29	3.08	.61	.31	1945
TUCO TOTAL	314	517	2050	2180	.29	3.08	.61	.31	

Table 3.8, Continued

Utility Characteristics	Current Assets (Millions)	Current Liabilities (Millions)	Long-Term Debt (Millions)	Revenues (Millions)	Const. In Progress/ Util. Plant	Utility Plant/ Revenue	Current Ratio	Long-Term Debt/ Util. Plant	Year Incorporated
CALIFORNIA POWER POOL									
Pacific Gas and Electric Co. Humboldt	1672	1553	4036	5887	.23	2.01	1.00	.34	1905
Sacramento Municipal Utility Dist. Rancho Seco	109	95	526	179	.08	6.04	1.14	.49	1923
Southern California Edison	992	930	3089	3661	.31	2.30	1.07	.37	1909
with San Diego Gas and Electric Co. San Onofre	325	391	735	1069	.27	1.88	.83	.37	1905
CAPP TOTAL	3099	2971	8388	10798	.25	2.16	1.04	.36	
NOT FORMAL POOL									
Public Service Co. of Colorado Fort St. Vrain	262	2323	7901	1059	.19	2.18	1.13	.34	1906
PACIFIC NORTHWEST COOR. AGREEMENT									
Portland General Electric Co. Trojan	171	282	1000	490	.18	4.35	.61	.47	1907
Washington Public Power Supply System Hanford									1957
PNCA TOTAL									
LOWER COLORADO RIVER POWER POOL									
Arizona Public Service Co.	160	192	1055	765	.34	4.18	.83	.33	1894
LCRPP TOTAL	160	192	1055	765	.34	4.18	.83	.33	

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CHAPTER 4

ASSESSMENTS BY SELECTED FEDERAL AGENCIES

1. INTROOUCTION

The nature, purpose, and scope of the existing management and organization review by the Nuclear Regulatory Commission do not constitute a common regulatory situation. No other agency has the responsibility of specifying in such detail the organization and procedures of a regulated industry for the purpose of assessing whether an organization is so constituted that it will safely operate an extremely complex technical facility. Nonetheless, after a canvas of regulatory agencies, we chose for brief review three that have a concern with the capability of management and where reviews of management and organization and procedures are basically similar to the responsibilities of the NRC. These agencies are the Comptroller of the Currency and two subunits of the Department of Health and Human Services: the Office of Health Maintenance Organizations and the Food and Drug Administration. The private organizations whose management these public agencies regulate are, respectively, banks, health maintenance organizations, and nonclinical laboratories.

2. METHODOLOGY

In order to select agencies for examination, we first reviewed the mandate of a number of potential agencies that might have management oversight responsibilities. This first cut was based on professional judgment and written sources including the Federal Regulatory Directory and the Unified Agenda of Federal Regulations. These agencies included the Environmental Protection Agency, Federal Communications Commission, Food and Drug Administration, Interstate Commerce Commission, Occupational Safety and Health Administration, Securities and Exchange Commission, Federal Maritime Commission, National Credit Union Administration, Office of Health Maintenance Organizations, Economic Development Administration, and the Federal Aviation Administration. While some agencies such as EPA and FAA were more directly involved with industries of complex technology, the focus on management as a separate subject for review was most evident in the agencies we chose for initial review, as will be discussed below. In each case, we selected agencies that, like the NRC, focus on management and/or organization on the basis that good management and/or organization will lead to sound practices in the regulated activity. The three agencies were chosen for their focus on management and their approach to management reviews. There are other public institutions with an interest in the management of private institutions, but our review indicates the depth and nature of regulation by the selected agencies is most relevant to the NRC situation.

Our review was based on interviews with agency personnel and examination of agency documents. The review focused on the process and content of the management and organization evaluations conducted by the agencies, but we

did not assess the validity, reliability, or effectiveness of those evaluations. Such an assessment must await further research.

3. APPRAISAL BY THE COMPTROLLER OF THE CURRENCY

The Comptroller of the Currency, a regulatory agency in the Department of the Treasury, conducts extensive appraisals of the management of banks whose operations fall within its statutory jurisdiction. The Comptroller of the Currency was created in 1863 and was the first federal agency created to regulate financial institutions. It now shares this general responsibility with other agencies and commissions, but it is still charged with assuring the solvency and operational soundness of nationally chartered banks. Its management appraisals are conducted on a regular basis and are part of larger bank examinations in which the overall performance of financial institutions is reviewed. The purposes of such an examination are to ensure solvency, to verify compliance with governing regulations, and ultimately to guarantee the security of depositors' funds.

Management appraisal is an important part of bank examination. While it may appear secondary to numerous and penetrating audits of financial records which occur during an examination, those interviewed at the Comptroller of the Currency were unanimous in their agreement that when solvency problems are discovered they are usually attributable to management failure.

The centrality of management to the regulatory strategy of the Comptroller of the Currency was reinforced recently when the agency undertook a reappraisal of its functions. It determined that many of its established activities, including audits and credit examinations, could be turned over to the private sector on a contract basis. It decided at the same time, however, that the agency must retain its control over management appraisal. This position reflects the widespread belief among key staff of the Comptroller of the Currency, strengthened by recent bank failures and reports of questionable investment, that poor management is the most frequent and dangerous threat to financial health. The specific jurisdiction of the Comptroller of the Currency is far removed from that of the Nuclear Regulatory Commission and other public agencies; but it does share the general obligation to guarantee the integrity of an industry whose operations have a profound impact on the public. The goals of management appraisal, its methodology, and the guidance available to personnel who conduct it are worth examining by any agency or commission with similar responsibilities.

3.1 Appraisal Objectives

The preamble in Section 502.1 in the Handbook for National Bank Examiners (U.S. Comptroller of the Currency, 1980) states:

Since a direct relationship exists between the overall condition of a bank and the quality of management the first priority in evaluating the condition of the bank is to make an accurate appraisal of the competency of the management team. (Emphasis added.)

The official policy states further that management is to be evaluated on the basis of future performance as well as its past record and current activities. There is an established policy which sets the priorities of the Comptroller of the Currency in its management reviews. The policy is based on two propositions, both of which are still controversial. The first is that bank failure is now accepted as a consequence of the marketplace and the Comptroller of the Currency will no longer prevent such an occurrence at all costs. The second is that small banks will be of little concern to the Comptroller of the Currency in the future. Banks with less than \$300,000,000 in assets, which constitute nearly 90% of the industry, will be examined once every three years if they maintain a good track record. In contrast, banks with assets in excess of \$1 billion will be examined every year, which includes a full management appraisal. The appraisal is a major data collection exercise which draws on available written documents and interviews to obtain a comprehensive profile of management in a given bank. This profile consists of a large number of items that we grouped in the following categories:

- Leadership -- Examiners review a comprehensive listing of bank directors, complete with biographical and financial background data, and of top management officials. Membership in the latter category is determined by federal regulation.
- Management Policies and Reports -- Examiners are to determine whether the bank's board of directors is meeting their management responsibilities. This involves an inventory of all bank operations covered by policies written and published by the board, review of reports to the board by bank officials on compliance with board policies, and an evaluation of omissions or deficiencies in policies or reports from management officials which should be corrected. In the latter activity examiners are guided by a list of the kinds of reports one might expect to be routinely prepared by management for review by directors. Of particular importance is that policies and reports are disseminated to all levels of management whose responsibilities are affected by them.
- Management Structure and Process -- Examiners are to determine the respective roles and powers of the board of directors and stockholders, their method and frequency of meetings, the content of their deliberations, and the means of communicating the decisions of these groups to management officials. Especially important is that a regularized mechanism exists by which the board assigns responsibility to management to correct deficiencies identified by examiners in previous evaluations or by the board itself in its own reviews.
- Management Responsibilities -- There are a number of general responsibilities associated with sound management that examiners are concerned with. These include mechanisms to assure full compliance with all regulations governing bank operations, contingency plans for bank operations in the event of disaster,

procedures to fill key management vacancies, personnel and compensation systems that assure current and future management of high quality, and record systems which adequately support each of these measures.

There is considerable guidance in the Handbook for National Bank Examiners (U.S. Comptroller of the Currency, 1980) on the various elements of each of these management responsibilities.

3.2 Methodology and Development of Appraisal Systems

The methodology for management appraisals places a premium on the skills of bank examiners. Bank examinations, of which management appraisals are a part, are conducted on a regular schedule, which is generally known to the banks. Surprise examinations were common at one time but are used rarely now. Since these examinations constitute comprehensive evaluations of bank conditions each time they are conducted, the Comptroller of the Currency has determined that advance knowledge gives little advantage to those banks wishing to mislead examiners. The schedule itself depends on a variety of factors, including the size of the bank, its current condition, and the historical record of the bank's examinations. It is also important to note that, for those banks with unblemished records and a currently strong solvency position, the presumption in the appraisal is that management is sound. While this may be the result of the evaluation, the management appraisal is still carried out as fully in banks with outstanding histories as in those whose position is less well established.

There is no special communication between the Comptroller and examined banks on expectations regarding management appraisals. When general procedural regulations which govern the management appraisal phase of bank examinations are changed or new regulations are added, the Comptroller consults widely with industry officials and management consultants as to the type of information that will be collected. Once this is determined there is no "continuing dialog" between the Comptroller and the banks. The guidelines for bank examinations are published in the Handbook for National Bank Examiners (U.S. Comptroller of the Currency, 1980), copies of which are available to banks. The Comptroller does not, however, issue additional guidance to banks on how to prepare for management appraisals; they are expected to read the Handbook, which is updated every six months, and plan accordingly. Management appraisal really begins with an "examination planning and control" session at which available documentation is reviewed and the staff involved brief themselves on the general situation in the bank. These documents include profiles of top bank leadership, internal organization and control systems and the various reports issued by the banks to the Comptroller of the Currency. Previous audits of various financial aspects of operations are used as sources of questions regarding management. When all information available offsite is reviewed, the staff involved in the examination develop a general plan to guide them in their work.

The actual management appraisal is conducted by one or more members of a team of bank examiners. Depending on the size of a bank, the team may be as

few as four examiners or as many as several dozen, with as few as one or as many as fifteen assigned to the management appraisal. It is apparent that coordination of the management appraisal crew is a major issue in itself and an effort is made to ensure that the chief of the appraisal crew is a veteran of many other similar evaluation efforts. As will be noted below, the crew chief for management appraisal is a critical element in the onsite coordination of the evaluation effort.

3.3 Training and Guidance

Training of examiners emphasizes management appraisal and is available throughout their careers. Recruitment of bank examiners shifted in the early 1970s from the industry itself to college campuses. Entry level requirements may still be met by work experience in commercial accounting, but it is more common for recent graduates of bachelors programs with course work in business administration, accounting, banking, finance and related areas to be selected. Prior to their appointment as commissioned bank examiners, candidates receive training on the basic elements and process of a bank examination, including management appraisal. As bank examiners move up the ranks and approach a stage at which they might be named crew or team chief, they have access to specialized training on types of problems which arise in appraisals. An attempt is made to anticipate situations, but many key decisions about the information to collect and the way to collect it are made onsite.

While general guidance and training on how to conduct management appraisals is extensive, the crew chief remains the major source of advice on sources of data, including who to interview. Each bank presents a different set of conditions and different management arrangements. Some banks, particularly the large ones, will have extensive written documentation on management policies, internal management structures and procedures, employment and personnel matters, and related concerns. Other, smaller banks may have less written documentation and more of the alive information may have to be collected through interviews or other means. In all banks, face-to-face contact with the board of directors, bank officers, managerial personnel, employees, and, at times, persons outside the bank are needed to determine if written and unwritten policies are actually being carried out.

Once on site it is common practice for the crew chief to assemble the examiners who are members of the team and outline the specific information they must obtain. Based on individual experience, the crew chief will suggest the best sources of this information and will be immediately available for consultation if those conducting the management assessment are unable, for whatever reason, to obtain essential information. On rare occasions, usually when there is reason to believe a bank is evading questions to hide difficulties, the crew chief will consult with the Washington office regarding steps which should be taken. This may include interviews with knowledgeable persons outside the bank. It is apparent in this system that the on-the-job training obtained by those who become crew chief is the critical element in implementation of management appraisal. This individual coordinates the efforts of what may be several examiners,

suggests means to collect needed data, and, in the process, trains other examiners in the finer points of management appraisal.

3.4 Review of Bank Planning

Among the most important recent policy decisions by the Comptroller of the Currency is recent revision of Section 502 of the Handbook for National Bank Examiners (U.S. Comptroller of the Currency, 1980) which outlines an extensive review of bank planning operations. Prior to this revision the Comptroller of the Currency did not require banks to have a planning process, but henceforth it will be mandatory. The Comptroller of the Currency believes that a deregulated industry will make planning all the more essential and states in its guidance on the matter:

"A formal planning process is no longer just a desirable management tool, it is now a necessity in an increasingly competitive banking environment The failure to have a satisfactory planning process is a matter warranting the attention of the directorate In order for the planning process to be effective the operational and strategic plans must be coordinated . . . operational plans must flow logically from the strategic plan."

Official guidance stopped short of requiring a formal written plan for all banks, based on the belief that such a requirement may be inappropriate for smaller institutions. Written or not, plans must be an integral part of bank operations. The revised section of the Handbook (U.S. Comptroller of the Currency, 1980) admonished examiners to be sure that bank leaders have a ". . . common shared perception of future actions" and ". . . the same goals, objectives, and strategies."

Two types of guidance follow these general comments. The first consists of a series of questions which "outline the strategic planning process for affected banks." They are intended as a basic framework for managing the strategic planning process:

What do we want to be?	(statement of mission)
Where are we now?	(evaluation of firm and its operating environment)
Where do we want to go?	(goals and objectives, informed by projections about the operating environment)
How will we get there?	(cost/benefit analysis of options)
Who is going to do what is needed?	(preparation of human resources, operating and capital budgets)
How are we doing?	(analysis of results, revision of plans)

This accessible, simplified outline of strategic planning is meant to apply to all banks and introduce managers to the concept of strategic planning. A second form of guidance follows. It is more detailed, and meant as a guide for both bank management and examiners. It provides specific information on what bank strategic plans are to contain. For example, the revised section states that the answer to "where are we now" should include evaluation of the following factors:

- overall financial condition of the bank
- overall risk position
- management ability and personnel resources
- adequacy of management information systems and effectiveness of bank policies
- adequacy of physical facilities
- existing product lines, customer base and marketing
- organizational structure
- legal and regulatory requirements affecting internal structure of bank.

Most of these factors can be developed from information generated during management appraisals. But evaluation of the operating environment, which is the second half of the answer to the question, entails a different kind of information, including:

- economic conditions on the local, national and/or global levels, as appropriate
- characteristics of the marketplace
- the technological environment
- sociological trends
- legal and regulatory activities.

Obviously, the collection of such data and the projection of such trends requires more than a casual approach to planning. While a written plan may not be required, this may be inconsequential since it is difficult to imagine how these expectations can be met without extensive research.

Examiners are directed in the revised section to determine if specific financial, marketing, operations, human resources, and social responsibility goals and objectives have been established. As important, bank management

will be expected to develop strategies to meet these objectives and performance measures which enable them to know if progress is being made.

Staff of the Comptroller of the Currency recognize that planning requirements of such stringency create a sensitive situation with the banks since they may feel that the agency is attempting to "run the show" or "second guess" management. They countered this potential criticism by developing planning requirements which, in their view, "emphasize a process, not outcomes." Nevertheless, the details of the process have very clear implications for the content of strategic plans. If nothing else, they tend to produce a uniform approach to planning nationwide, assuring that all banks manage their futures according to the same methodology.

Overall, the management appraisal is an essential adjunct to the more technical audits of accounts and investments, and it serves as a form of management consulting as well. Personnel in the Comptroller of the Currency offices in Washington stressed to us that exposure of management deficiencies in some banks allows regulators to advise other institutions on how to avoid the same problems in their own institutions. To this extent, the appraisal conducted by the Comptroller of the Currency helps to advance the science of bank management, as well as to regulate current banking operations.

4. REGULATION OF HEALTH MAINTENANCE ORGANIZATIONS

Analysts might be tempted to assume that the value we place on human life and the vital importance of health care to its preservation would be the primary motivations for any incursion by the government into the operation of private entities that deliver such services. While these may, in fact, be the source of our national policy for health care, the immediate objective of at least one program regarding health care service delivery is economic as well. The Department of Health and Human Services administers legislation to subsidize and otherwise promote health maintenance organizations. HMOs, as they are termed, are combinations of health care professionals who, as a unit, offer comprehensive medical services to those enrolled as members, or clients, of the organizations. As an alternative to "fee for service," with a variety of public and private insurance companies reimbursing individuals for their claims, health maintenance organizations provide members any and all care needed for an annual fixed fee. This approach has been championed by several administrations and while the program is scheduled for large reductions in federal support, there has been an elaborate network of regulations governing the operation of these private "firms."

The primary devices for promoting the concept were financial assistance of various sorts and requirements that employers include HMOs as options in sponsored medical plans for their employees. As experience with the program developed in the 1970s, failures of health maintenance organizations were not uncommon. When an HMO failed there were several implications. The financial commitment which the federal government had made to the organization was either lost or put in jeopardy. Also, there was the real possibility that care for those enrolled as members of the HMO would be

interrupted. Experience showed, as it has with financial institutions, that solvency problems could be traced most often to poor management. Unlike banks which at least had a long tradition of professional and standardized, if not always effective, management practices, health maintenance organizations were new entities with no operational history. The conceptual development of the idea outdistanced by quite a long way actual experience with the wide variety of conditions that might affect the way health care is delivered. As a result, the Office of Health Maintenance Organizations in DHHS undertook to evaluate and, when necessary, regulate the management of HMOs in order to prevent their economic collapse. They carry out these functions in the context of a larger management-oriented program.

4.1 Office of Health Maintenance Organizations (OHMO)

The strategy employed by the Office of Health Maintenance Organizations (OHMO) to assure strong management consisted of three parts: education, self-help, and direct regulation. Education took several forms. A large-scale series of two-day seminars in various aspects of HMO management, including medical practice, finance, marketing, and information systems, was held. The topics covered in these seminars were based on problems common in HMO operations and the intended audience consisted of principal officers and managers of the organizations. A separate series of seminars was developed and provided to members of boards of directors who, under statute and in actual practice, bear significant responsibility for the overall management of the HMO.

The Office of Health Maintenance Organizations has also sponsored a program of a more substantial nature to create what was, in effect, a new type of professional, trained specifically and extensively as a manager of HMO operations. Rather than supplementing the medical skills of HMO officers with organizational tools, this approach seeks to establish a cadre of persons with a common foundation of education, "hands-on" experience, and exclusive interest in management. Participants in this program are selected in a nationwide competition and the curriculum consists of formal course work and an internship in an operating HMO. Obviously, with a curriculum designed under the auspices of OHMO and internship placement in programs with proven performance, this form of training is a method of influencing the management of health maintenance organizations prospectively and for a long period of time.

4.2 OHMO Assistance

As an adjunct to training and education, OHMO has developed a number of handbooks and manuals which provide guidance on management to those working in HMO. Two of these, Guide to Development of Health Maintenance Organizations (DHHS, 1982) and HMO Governing Board Handbook, (DHHS, 1981) are quite detailed in their advice to their respective audiences. The former devotes a full chapter to the development of the organization and to ongoing management. Other chapters, such as those devoted to marketing and finance, also touch on issues and topics that are managerial in nature. In the chapter on the development of organization and management, the Guide (DHHS, 1982) discusses alternative administrative and medical service

models, personnel, management information requirements and systems, community relations, boards of directors, and planning. Related chapters cover marketing analysis and plans, including surveys of competition, setting prices, choosing locations, promotion, budget and actuarial analysis, projecting financial requirements and cash management. The Guide (DHHS, 1982) emphasizes in its introduction that it should not be treated as a "cookbook" for HMO operations since these organizations face a number of different conditions. The Guide has provided what OHMO believes is a comprehensive listing of generic activities which, if properly carried out, will allow an HMO to adopt to the conditions in its own environment.

The HMO Governing Board Handbook (DHHS, 1982) has a similar general purpose but its guidance is directed to a group that OHMO deemed critical but too often ignored in the operations of health maintenance organizations. The Handbook (DHHS, 1982) covers many of the same management issues and principles outlined in the Guide (DHHS, 1981) but it also stresses the legal status and responsibilities of the board as a collectivity and of individual members, considerations in organizing and constituting a board and functions a board performs. It goes so far as to provide alternative position descriptions and listings of preferred qualifications for use in recruiting members of the board.

Training of existing personnel and new managers and self-help manuals are useful, but OHMO has recognized that these are not enough to help health maintenance organizations. To supplement these devices, OHMO organized groups of "consultants" to assist health maintenance organizations in need. In fact, these consultant groups consist of managers of successful HMOs who agreed to provide this service. According to OHMO staff interviewed, HMO officials became involved in this management assistance program for a variety of reasons, not the least of which was a real concern that failure of a significant number of other health maintenance organizations might cause the entire movement to fail. Participation as consultant or client organization was entirely voluntary. If an HMO contacted OHMO for assistance it would act as a clearinghouse to assemble a consultant team from a master list of managers, often matching specific skills to specific problems, but a management consulting team would never be assigned to an HMO without an invitation. When they did work with the HMO they would conduct a site visit for a comprehensive review of the organization. Problems would be identified and analyzed, and recommendations for change would be made in formal report to the board and senior management of the client HMO. The Office of Health Maintenance Organization has sponsored a large number of these exercises during the past decade and considers the program a major element in assuring high quality management in HMOs.

4.3 OHMO Regulatory Program

The activities discussed to this point are not regulatory in nature. Instead, they may be viewed as various forms of technical assistance. But they occur parallel to an established regulatory program which uses mandatory compliance with potential sanctions instead of the volunteerism which characterizes the training, education, and consultant services described above. The Department of Health and Human Services, through its

Office of Health Maintenance Organizations, operates a national reporting system to monitor the financial well-being of all HMOs supported by federal funds. The frequency of reports depends on the current financial status of the HMO (red or black), but financial statements are usually filed on a quarterly basis and audits are conducted once a year. The contents of these reports and audits are reviewed against a number of indicators, which comprise a range of acceptable performance. When an HMO is found to be "out of range," mandatory management assessment is conducted. The assessment, an audit as it is also called, is frequently conducted by private accounting or management consulting firms according to an elaborate protocol developed by the Office of Compliance in OHMO (DHHS, undated).

As with the self-help manuals discussed above, OHMO stresses that the protocols should not be used as "a rigid checklist" or "cookbook," but it outlines in considerable detail those elements of HMO management deemed critical to success. The protocol presents these elements in "modular" form, as separate analytical exercises which site visit teams must complete for a comprehensive management audit. The following is a summary of general protocol items, with explanations of what these entail:

- General management--determination of organizational objectives and operating standards in areas such as leadership, internal communications, policy documents, personnel, and planning.
- Budgeting--determination of methods of preparation, participation and management of the process, revenue estimation, expense estimation, performance analysis.
- Service Delivery Management--determine method of organization of services provided, staffing levels, staff qualifications, utilization review and forecasting, referral procedures, service contracts, and enrollee eligibility.
- Marketing Management--determination of the status of the enrollment program, enrollment projections for the next fiscal year, profiles of marketing activities, organization and operations of the marketing group, method of handling consumer complaints, and involvement of board in marketing decisions.
- Financial Management--determination of organizational capacity for financial management, methods of forecasting and covering cash needs, methods of preparing financial reports, accounting system performance, fee-for-service billing procedures, claims processing, membership management, cash flow management, breakeven analysis methods.
- Board of Directors Management--determine legal and organizational element of board operations, review of information available to board regarding HMO operations, review minutes of board meetings, determine degree of board chairman involvement in HMO operations.

When the data pertinent to these elements of the management audit are collected, the evaluation team analyzes them and reports to OHMO. The Office of Health Maintenance Organization also reviews the data and analysis and decides on the action to be taken. The HMO may be given a clean bill of health, and if so, it is given a period of time to bring its operations back in range. Alternatively, OHMO may conclude that the HMO must file a corrective action plan which details the steps the organization will take to bring its financial performance back in range. The content of the corrective action plan is negotiated directly with the HMO, but it is based on the findings of the management assessment. If the HMO cannot or will not produce an acceptable corrective action plan, a regulatory action is filed which the Office of Compliance develops unilaterally and outlines conditions of continued federal support. Again, these are based on management audits, but may include harsher conditions, such as firing top management, than would have been produced in a corrective action plan. An extreme outcome, possible in regulatory action situations of this sort, is full receivership of the HMO by a group designated by OHMO to bring the organization back to financial health.

4.4 Summary

It is apparent that the Department of Health and Human Services is involved to an extraordinary degree in the management of health maintenance organizations. Motivated by a desire to protect significant public investments in HMOs and convinced that sound management is the key to their survival, the Office of Health Maintenance Organizations has developed an extensive program of assistance. As a last resort, however, the Department can employ regulatory devices and sanctions comparable to those available to any other federal agencies. Like the Comptroller of the Currency, the Department of Health and Human Services does not rely on reporting requirements to monitor the performance of HMOs; instead it conducts comprehensive evaluations of management based on a very detailed assessment methodology. The results of this evaluation lead to corrective plans, voluntarily negotiated with an HMO, or a regulatory action. In each instance, the affected HMO is compelled to act. Health Maintenance Organizations emerge as heavily regulated private enterprises, particularly when their fiscal performance falls outside acceptable ranges.

5. NON-CLINICAL LABORATORY REGULATION

Another part of the Department of Health and Human Services, the Food and Drug Administration, exerts similar regulatory influences over laboratories which conduct nonclinical testing as part of the substance clearance process. The purpose of this regulation is different than that governing HMOs. Here the concern is not with the financial stability of the lab, instead it is the quality and reliability of the results of tests reported by the laboratory to the FDA. Under authority established under several Acts, including the Food, Drug and Cosmetic Act, the Public Health Service Act, the Radiation Control for Health and Safety Act, and the Medical Device Amendments of 1976, industries of various types must submit evidence of the safety and effectiveness of human and animal drugs. Since testing is, in effect, delegated to the very persons interested in marketing a given

product, the FDA is very concerned that the procedures used employ "scientifically sound protocols and detailed attention to quality control." At the same time, the means used to guarantee the reliability of a given manufacturer's research results should not be so burdensome as to establish what is, in effect, a parallel testing program within the FDA. The approach adopted by the FDA is a procedure which is superficially similar to that of the Comptroller of the Currency and the Office of Health Maintenance Organization; teams of evaluators go to the field to examine all phases of a laboratory's operations, including its internal management. This management appraisal is very different in one critical respect, however. Not concerned with the financial status of the laboratories, this regulatory regime is devoted to institutionalizing the scientific method in the management of these nonclinical laboratories. In this instance, profitability is not an appropriate test of the performance of management; on the contrary, it is quite possible that a given laboratory could become quite profitable by producing low quality research. Hence, the examination which is conducted seeks to determine the degree to which management promotes high quality results.

Inspections of nonclinical laboratories occur at least once every two years under a regulatory program known as Good Laboratory Practices (GLP). Individual laboratories are expected to remain in compliance with standards set out in the Compliance Program Guidance Manual (DHHS, 1981). From an organizational perspective, the inspection function is decentralized and supervised by district-level personnel. Current guidelines require that field inspectors chosen for assignment to non-clinical laboratories must be experienced in reviews of non-clinical laboratories. A team leader is assigned, with general responsibilities not unlike the group leader in Comptroller of the Currency appraisals. He is assisted by headquarters (Washington) staff who serve in a scientific advisory capacity. There are occasions when an inspection may be done jointly with other agencies of the government concerned with environmental, workplace safety and health or other aspects of a given laboratory's operations. FDA inspections may impact on these other agency programs without joint activities being involved so interagency cooperation guidelines have been developed. In all such instances, the team leader for the GLP program acts as team leader and FDA concerns assume a top priority. It is the team leader's responsibility to assure all members of the team are familiar with precautions regarding the type of clothing to be worn, the type of equipment which may be used and the state of their physical health at the time of inspection.

Those conducting inspections are generally trained in the hard sciences and a Bachelor of Science degree is considered minimum qualification. Once selected for the position, however, those handling inspections receive extensive training in both the drug manufacturing process and the elements of good laboratory practice. While formal education is expected to assure a background in the development and use of scientific data, it is the training programs sponsored by FDA which are the primary means by which inspection criteria are communicated. New inspectors observe more experienced colleagues conduct onsite inspections before they are given their own assignments.

5.1 Conduct of Inspections

Inspections begin with a decision by the FDA regarding the laboratory to be visited. The laboratory is informed in writing of the intent to inspect by the Commission and a specific study may be selected as the object of the site visit. The critical variable in selecting a specific study is whether it allows FDA personnel to establish whether the laboratory is in full compliance with GLP regulations. The process of selecting the actual examples of laboratory work which will be examined requires the team to obtain a master list of all FDA nonclinical laboratory studies conducted since GLP regulations and all those currently under way. Many laboratory examinations will consist of data and procedure audits of completed studies, as well as evaluations of studies in progress. When the preliminary planning work with involved personnel and affected laboratory is completed, the team goes on site to collect the essential data.

The examination of nonclinical laboratories involves the collection of information on nine interrelated items:

- (1) organization and personnel
- (2) quality assurance
- (3) facilities
- (4) equipment
- (5) testing activities and operations
- (6) animal care
- (7) test and control articles
- (8) study protocol
- (9) record-keeping.

Not all of these items involve questions regarding management, but many do. Organization and personnel matters are reviewed to determine "if the facility have an adequate number of qualified personnel . . . and whether the organizational structure is appropriate to ensure studies are conducted in compliance with GLP Regulations." To achieve this objective, the study team is expected to establish the basic organizational structure of the lab, complete with qualifications of persons in management and those likely to serve as study directors. Of particular importance is a description of how the quality assurance unit is organized and how it fits into the overall organizational structure. Each study is presumed to have an organizational structure of its own and a purpose of the review is to determine how this relates to the overall organization of the lab. Information related to training programs for personnel, supervision of persons offsite, and identification and intervention in health problems which may affect the integrity of a study are part of the examination devoted to organization and personnel. The quality assurance unit in the laboratory is the focal point of the management study since FDA considers this group as the primary mechanism, beyond personnel involved in a study, to assure reliability in results. The examiners are concerned with standard operating procedures used by these units, particularly if they maintain master schedules and full research protocols for individual studies and if they audit regularly. It is considered important to determine who the unit reports to and how records regarding its work are maintained. While the quality assurance unit is

deemed vital to management of a well-run laboratory, FDA personnel will not attempt to review the actual internal reports that the quality assurance units prepare about studies for involved laboratory personnel. In order to guarantee that quality assurance units will issue accurate and meaningful reports internally, the FDA has determined their content must remain confidential and requires only that records show if and when an audit was done.

5.2 Facilities and Equipment

Facilities and equipment have obvious management implications since their continued adequacy for the studies which are conducted is vital to the reliability of work which is produced. The study team examines these elements in the course of a careful review of the adherence of laboratory staff to established research protocols. Equipment, facilities, test animals and test articles and the protocol itself are examined and the study team establishes if and how supervisory personnel were familiar with the research procedure, the methods to ensure personnel were informed of their specific study responsibilities and the methods used by the Study Director to assure all elements of the protocol were implemented. They are also concerned with the capacity of the study group to respond to unforeseen events that might threaten the study. Finally, the study group is concerned with the "reliability, integrity, and utility" of record keeping. This includes not only archival materials which chart the progress and interim results of a study, but actual specimens as well. In addition to these data, FDA personnel should be concerned with methods of access, indexing, and means of storage.

5.3 Reporting

When these elements of a site examination are finished the team leader is required to report on findings. The method of reporting depends on whether the inspection is classified as a "surveillance" or a "directed" inspection. The former are "periodic, routine" actions undertaken to determine a laboratory's compliance with GLP. The latter is undertaken when a surveillance inspection reveals questions regarding the performance of the laboratory or when information from other sources reveals potential problems in operations. Surveillance inspections treat the elements described above in an overall assessment of compliance; a direct inspection is more narrowly concerned with the validity of results of a specific study. Both may entail a facility inspection and both report deviations from the GLP regulations. Onsite personnel are expected to report findings and to refrain, when possible, from interpretation of them. Interpretation is left to the Washington Office, which routinely consults with the program office in FDA which has special expertise in the substantive area of the lab's work. So, there is considerable review and discussion of whether a lab's performance is acceptable.

5.4 FDA Authority

The FDA regulatory authority in the operation of laboratories is considerable. While FDA can compel inspections at only certain types of

nonclinical laboratories (i.e., those performing tests on new drugs, new animal drugs and medical device products), failure to permit inspections causes serious and immediate consequences. It is FDA policy "not to accept studies submitted to the agency in support of any research or marketing permit if those studies were performed or conducted by a facility that has refused . . ." They add that partial refusals are tantamount to complete refusals and are treated accordingly. The FDA can avail themselves of strong sanctions, including sealing of records, when there is reason to suspect fraud or some other type of criminal action. In general, the results of inspections lead to three types of possible action by FDA. "No action indicated (NAI)" means the inspection has revealed substantial compliance with GLP regulations and that deviations which do exist are very minor. Recommendations may be made for improvements in laboratory practices, and a response may be requested, but there is no time limit as to when it is to be received. "Voluntary action indicated" is a conclusion that substantial management problems exist but they are not sufficient to require formal regulatory action by FDA. Instead, the laboratory will be required to submit a response, in a specified period of time, stating how it will correct the identified deficiencies. An adequate response may put the laboratory in the "NAI" category, but FDA might also determine that a reinspection is required. This device is not unlike the "corrective action plan" used by the Office of Compliance in OHMO, and it is clear to the laboratories who receive it more stringent actions will be taken if the voluntary actions are unsatisfactory.

The final option, "Official Action Indicated," is a formal regulatory action representing a decision by FDA that the laboratory is not able or willing to correct perceived problems and must be required to undertake actions specified by the agency. Failure to meet these requirements on a specified timetable will lead to serious sanctions, such as refusal of studies, complete disqualification of the laboratory, injunction, or prosecution. Such action is potentially more severe than actions taken against HMOs and indicates the degree of regulatory authority the FDA enjoys. Its evaluation of management is as penetrating as any conducted by the other agencies discussed here and its approach to evaluating management is fixed and consistent. In this regard, like the Comptroller of the Currency and OHMO, the FDA is a powerful force in private management and the impact of its work can be observed in the substantial uniformity of non-clinical laboratory operations in firms under its jurisdiction.

6. SUMMARY

These three agencies have different ultimate goals propelling their management assessments and, therefore, each of the assessments focuses on different aspects of management and organization. Two of the agencies, the Comptroller and the Office of Health Maintenance Organizations, take a broad approach and review plans and development, organizational design, staffing, leadership, and control. FDA has a less comprehensive review of management per se and has a more functional orientation--based on the functions associated with good laboratory practice. Nonetheless, it is possible to compare them in several respects in order to get a better perspective for the NRC of how other organizations conduct management

appraisals. This summary reviews these appraisals in terms of agency staff, level of analysis, and focal points of their audits.

6.1 Staff

The Comptroller of the Currency utilizes its regular bank examination teams with a designated component of the team doing the appraisal. Typically, the examiners have educational backgrounds in business administration. They receive specialized training in management appraisal, accounting, banking, or a related financial field. The FDA uses agency staff with a formal education background in physical science, and they are trained by FDA specifically in laboratory review and the drug manufacturing process. The HMO office differs in that it uses external auditors (typically from accounting firms) who are guided by a standard protocol and review guide.

6.2 Level of Analysis

In its own management reviews, the NRC looks at top utility management, plant management, and functional area supervisors. Two of the agencies we reviewed, the Comptroller and OHMO, look at the top level only and, in fact, include the boards of directors in their review. The FDA is less concerned with management as a separate entity and so surveys the entire gamut of laboratory personnel.

6.3 Focal Point of Audits

Despite the difference in specific goals of the audits, there are several common areas of emphasis in the audits. The one focal point of review in all three agencies is the staffing and recruitment process - whether there are on hand sufficient staff to handle various key functions and whether management had plans for sufficient recruitment as needed. Two of the agencies (Comptroller and FDA) additionally stressed management attention to personnel qualifications and staff training. Presumably the OHMO did not stress these aspects because the professional staff of HMOs consist of state licensed health professionals.

The planning process was particularly stressed by the Comptroller and OHMO. For the banks, overall strategic planning is now considered essential and is required by regulation. For the HMOs, planning particularly emphasizes marketing and staffing.

The Comptroller and OHMO also shared a concern that responsibility, authority, and accountability be clearly delineated within an organization. This includes lines of authority between units as well as within them. Also, in accord with the need for organizational clarity, both agencies monitor written policy statements used to guide organizations and review how the policies are arrived at and how they are communicated from and to managers.

Finally, control and coordination are emphasized. Both the Comptroller and OHMO are concerned with the dissemination of necessary information to managers both vertically (control) and across organizational units

(coordination). Also, the Comptroller stresses the existence of feedback mechanisms so that managers (and the board of directors) are alerted to problems in a timely fashion. At banks there are extensive reporting requirements (daily liquidity, etc.) designed to assist management to keep problems from occurring.

7. CONCLUSIONS

This research by no means exhausts the available examples of public regulation of private management and organization. It does, however, establish a useable framework for more broadly-based studies of governmental activities of this sort and allows us to draw three basic conclusions. First, other federal agencies do regard management and organization to be sufficiently important to review in pursuit of particular policy goals. Second, other agencies apparently devote more resources and attention to the review of management and organization than does the NRC. Third, other agencies take a "top down" approach that focuses primarily on the highest level within the organization. We have presented information on the content and focus of management and organization evaluations by other agencies, but more needs to be known about the procedural issues raised by such indirect regulation as well as its ultimate impact. Equally important are the relationships which develop between inspection personnel and members of the private organization whose work is being evaluated. This appears particularly pertinent to the Nuclear Regulatory Commission with its current onsite programs. A final set of issues relates to the consequences of the implicit consultation and technical assistance which accompanies all management appraisals. On one level, this activity promotes a degree of uniformity in management practices across the affected industry. In another sense, however, it rivals professional associations and management consultants as a source of information on the state of the art in industry management. There may be interesting questions raised about the competitive effects of such assistance and whether marginal operations rely on such data for their very survival. Finally, there is another side to the technical assistance issue. While the better managed operations develop processes and programs which are "diffused" by the agency to less aggressive organizations, do management innovations confront regulatory obstacles if agency personnel are skeptical of their value and impact on performance government is interested in?

Overall, assessment of management and organization is pervasive and has profound implications for the profitability of firms so regulated. It is clear that the NRC has a large base of similar experiences to compare with its own activities.

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CHAPTER 5

A REVIEW OF DATA SOURCES IN THE NUCLEAR POWER INDUSTRY

1. INTRODUCTION

This chapter describes and evaluates potential sources of data for an investigation of the relationship between organization in the nuclear industry and plant safety performance. In this chapter we address both the measurement of organizational characteristics and the financial and other performance measures essential to a comprehensive analysis. Sources of measurement of dimensions of safety are addressed in Chapter 6. Because the concepts and data sources are significantly different, we have broken this chapter into two fairly self contained sections. The first section concerns measurement of basic organizational design properties. The second section addresses the measurement of financial and volumetric data. Evaluative criteria consistent with the two different types of information are used in the respective sections.

2. AN ANALYSIS OF DATA SOURCES FOR ORGANIZATIONAL DESIGN VARIABLES WITHIN THE NUCLEAR POWER INDUSTRY

2.1 Introduction

The purpose of this section is to assess the nature and adequacy of existing sources of organizational and related data within the nuclear power industry. This assessment reflects a growing concern on the part of the Nuclear Regulatory Commission (NRC) over the relationship between organizational factors and the safe operation of nuclear power plants. Though the NRC has had a long standing interest in the ways utilities shape their nuclear power plant organizations, the accident at Three Mile Island has added some urgency to NRC supported efforts to more systematically investigate how variation in organizational structure and process could be linked to variation in safety outcomes.

An early step in this process is to determine from the relevant literature the aspects of organization that can be seen as causative of plant safety performance. This step is fulfilled in Chapter 1 of this Volume. However, once the relevant dimensions of organization are determined from the literature, attempts must be made to empirically test the promising hypotheses. This section investigates the extent to which existing data can support a systematic investigation of the relationship between organizational factors, on the one hand, and plant safety, on the other.

2.2 Preview of Significant Findings

There are significant problems in finding adequate data to support a systematic comparison of organization and safety outcomes in the nuclear industry. Existing data are rarely by themselves capable of providing a reliable description of all the significant dimensions of organizations held here to be important. This is not surprising given the fact that:

- (1) The data sources were not established for the primary purpose of a strict comparison of organization and safety.
- (2) The data sources tend to have a distinct bias toward management, rather than organizational issues.
- (3) There are understandable pressures not to make certain useful pieces of proprietary information public.

The formal review that follows indicates that no single data source performs strongly on the majority of the evaluation criteria employed. Key problems ranging across the data sources are:

- (1) an incomplete coverage of key dimensions of design
- (2) lack of accessibility for private data sources
- (3) uncertain methods and degrees of "updating" for NRC sources.

Nonetheless, the existing data will allow an initial look at the relationship between organization and safety outcomes. The term "initial" is stressed because only certain dimensions of organization have been reliably measured. These include certain aspects of administrative form or division of labor, qualifications, and procedures related to the nature of work and control. Other aspects, notably organizational coordination, development, and the existence of external resources are consistently ignored in the data sources reviewed.

Based on this review and the developing support for the importance of understanding the relationship between organization and nuclear power plant safety, it is recommended that the NRC commence a program of routinely and systematically updating its information on plant and corporate organization. Several suggestions have been made in this review for this purpose.

In this review we investigate nine potential sources of data. They include both NRC and non-NRC sources. Specifically, we investigate the following:

- (1) Final Safety Analysis Report (FSAR), Chapter 13
- (2) Technical Specifications
- (3) Final Safety Analysis Report, Quality Assurance Program Reviews (Chapter 17)
- (4) Health Physics Appraisal Program
- (5) Edison Electric Institute Nuclear Plant Staffing Survey
- (6) Teknekron Evaluation of Utility Management and Technical Resources
- (7) Institute of Nuclear Power Operations (INPO) Staffing Survey

The EIA inherited these three statistical series from the Federal Power Commission, which existed prior to the formation of the Department of Energy. Hence these series go back for many years, providing a reasonably consistent set of data concerning utilities. For the year 1978 and thereafter, the first two series are available in machine-readable form.¹ The third series is available from 1964 on in machine readable form.² Tapes can be requested for a nominal charge from the EIA. At the present, these series are available in printed form for years up through 1979, and the machine-readable data are available through 1980.

The data covered in Statistics of Privately Owned Utilities are shown in Table 3, and the data from publicly owned utilities is shown in Table 4. These two series provide information on corporate organization, financial position, generating capacity by type of plant, and energy production. These two data series provide only summary data on the aggregate power production of each utility. For detailed information on the output of thermal electric plants, the third EIA series, Thermal Electric Power Plant Construction and Operating Costs, provides information for each plant on capacity, production of energy, and expenses for fuel, maintenance, and other operating costs. Thermal power plant in this context refers to any source of heat energy which is used to drive a turbine. Thus, nuclear, coal, oil, and gas fired turbines are included, as well as the internal combustion engines used to provide power in very small utilities. Note that the only input cost neglected in this data source is capital cost. The historical invested cost per kilowatt of capacity is reported, which allows one to construct a capital cost measure. The data covered by this data series are shown in Table 5.

3.4 Regulatory Data: Securities and Exchange Commission

The Securities and Exchange Commission (SEC) requires annual filings from corporations which fall under its jurisdiction due to the size of securities offerings made by that entity. The filing known as "Form 10-K" provides a basic source of data regarding corporations and their financial aspects in particular. The kinds of data provided in the 10-K submissions are shown in Table 6. While fewer data items are included in comparison with the EIA data, some items which EIA does not report are included in the 10-K submissions. In particular, operating loss or profit is reported for the prior three fiscal years, research investments are reported, and more extensive data is provided in stock issues of the corporation. These data pertain to the utility corporation as a whole. Consequently, no data is provided on individual power plants.

¹Telephone interview with Elsie Bess, Energy Information Administration, U.S. Department of Energy, September 1982.

²Telephone interview with Samuel Brown, Energy Information Administration, U.S. Department of Energy, September 1982.

- (8) INPO Plant Evaluations
- (9) utility annual reports.

A summary of the evaluations can be found in Table 1. A summary of the adequacy of the coverage of key design dimensions across all data sources can be found in Table 2.

The analysis begins by identifying a set of criteria defining adequate data. These criteria include both standards for data quality and the necessary types of organizational variables suggested by the literature. Existing data sources are then compared to these criteria, and the strengths and weaknesses of each are noted. From this comparison, an overall evaluation is drawn of the ability of existing data to support systematic analysis.

2.3 Evaluation Criteria

Each data set is to be evaluated according to seventeen criteria. The criteria employed are of two general classes. The first thirteen address the problem of data quality. The remaining four reflect the extent to which the data support measurement of the concepts identified by the literature as important dimensions of organization relative to safety. It is unrealistic to expect that any data source not specifically collected for the purpose would be likely to provide quality data on each salient organizational variable. In most cases, in fact, the data provides only a partial representation of the theoretical construct in question. So, while measurement may exist on an important dimension of organization, the measurement is rarely of the preferred form. The evaluation criteria to be used are as follows:

- (1) Accessible. Are the data accessible? Do they exist in the public domain or, if proprietary, can an acceptable agreement for use be negotiated? Unless the data can routinely be made available for analysis that can then be shared with the NRC, the data are not useful. The problem pertains not only to the issue of formal authority, but also to the issue of logistics and cost. Some potential data sources are too scattered or costly to assure accessibility.
- (2) Systematic. To facilitate use, the data source should be systematic, presenting the information in the same order and format for each unit or case. The added costs of trying to code data from a data source in which information is entered in random order may be prohibitive and could certainly affect the quality of the coded data.
- (3) Parsimonious. Again, to facilitate ease and reliability in coding, the preferred data source would not contain superfluous information. Rather, it would address only salient organizational issues.
- (4) Recent. The data should not be too old. Particularly since the regulatory environment is constantly changing, the data should reflect, as much as possible, current operating experience. On the other hand,

TABLE 1

RATINGS OF NINE POTENTIAL DATA SOURCES ON 17 CRITERIA

	FSAR	Specifications	Quality Assurance	Health Physics	EEI	Teknekron	INPO Staffing Survey	INPO Evaluations	Utility Annual Reports
1. Accessable	3	2	2	2	5	1	5	5	1
2. Systematic	3	2	3	2	1	1	1	4	4
3. Parsimonious	3	3	4	4	1	1	1	4	4
4. Recent	4	4	3	3	3	4	2	2	1
5. Equivalent	4	4	2	2	2	2	2	3	4
6. Representative	4	3	2	2	2	3	2	3	2
7. On-line	3	3	2	1	1	1	2	2	2
8. Consistent	3	3	3	2	3	3	2	4	5
9. Clear	3	3	3	3	4	3	2	4	4
10. Replicable	2	3		2	4	4	2	4	4
11. Accurate	3	3	2	4	3	3	3	4	2
12. Corporate	4	4	2	4	5	3	3	4	2
13. Plant	2	2	4	3	3	3	2	2	5
<hr/>									
14. Administration									
a. Form	3	3	3	3	2	5	5	4	5
b. Procedures	3	3	3	4	5	4	5	3	5
c. Individuals	3	4	3	3	5	3	3	2	5
d. External	4	5	2	3	5	3	3	5	5
15. Control									
a. Form	3	3	3	4	3	5	5	3	5
b. Procedures	4	3	2	3	5	5	5	3	5
c. Individuals	3	4	3	4	5	5	5	3	5
d. External	3	3	3	3	5	5	5	4	5

TABLE 1 (continued)

Criteria	FSAR	Technical Specifications	Quality Assurance	Health Physics	EEI	Teknekron	INPO Staffing Survey	INPO Evaluations	Utility Annual Reports
16. Coordination									
a. Form	3	3	3	4	3	5	5	5	5
b. Procedures	4	5	4	5	5	5	5	5	5
c. Individuals	3	4	3	5	5	3	5	4	5
d. External	5	5	4	5	5	5	5	5	5
17. Development									
a. Form	2	3	3	4	3	5	3	2	5
b. Procedures	3	3	4	3	5	5	2	2	5
c. Individuals	3	5	5	3	5	4	4	4	5
d. External	2	5	5	3	5	4	3	5	5

1: Completely satisfies the criterion

2: Substantially satisfies the criterion

3: Has both positive and negative characteristics relative to the criterion

4: Only slightly satisfies the criterion

5: Does not at all satisfy the criterion

TABLE 2
OVERALL ASSESSMENT OF DESIGN DIMENSION

	Form	Procedures	Individuals	External
Administration	Fair 1	Fair 2	Fair 3	Fair 4
Control	Fair 5	Fair 6	Fair 7	Poor 8
Coordination	Fair 9	Poor 10	Poor 11	Poor 12
Development	Fair 13	Fair 14	Poor 15	Fair 16

Good = One or more data sources allow measurement on most aspects of the dimension on an organization-wide basis.

Fair = One or more data sources allow measurement on some aspects of the dimension on a significant segment of the organization.

Poor = Measurement is not supported by the data sources.

the data must not be so recent as to preclude matching it to subsequent measures of plant performance.

- (5) Equivalent Timing. If the data is to be used for cross-sectional analysis relative to safety, it is important that the data for each plant/utility be from approximately the same time. This allows for some degree of control over the effects of factors that are spurious but also time-correlated.
- (6) Representative. The data should be from a point in time that is representative of typical operations. Unusual events should be studied separately. The data should not be overly influenced by some unusual event either internal or external to the plant/utility.
- (7) On-line. The data should be from a point in time that is representative of on-line experience. Data reflective of the construction stage or of anticipated on-line status will probably not accurately reflect on-line experiences. Given the unique problems frequently associated with plants first coming on-line, it is probably better if data is collected at a point sometime after the "shake-down" period.
- (8) Consistent. In order to improve reliability, the data should be generated in the same manner for all plants/utilities. For the most part, this means that there should be a standard format and protocol to which all data collectors and respondents adhere in providing the information.
- (9) Clear. The data collection instruments must be clear. They must ask unambiguous questions that minimize individual interpretation. Definitions must be provided where necessary.
- (10) Replicable. The data must be collected in a manner which is replicable by others. It must be capable of being independently verified, that is, measurement instruments and methods must be formally stated to allow others to reconstruct the logic and judge the usefulness of the data.
- (11) Accurate. The information provided by the data source should reflect reality--it should be accurate. It should not contain bias due to self interest or inaccurate perception. The questions that are used to measure a phenomenon should actually be capable of measuring the phenomenon.
- (12) Corporate. The data should be available for that portion of the utility corporate organization that is relevant to nuclear power production. All such utilities should be included.
- (13) Plant/Facility. Data should be available for the entire plant and for all operating plants. The interface with major vendors and contract workers should also be recorded.

While there are a number of different perspectives on which organizational properties are relevant to safety, our reading of the literature and prior work with utility executives suggest that these four dimensions are central--administration, control, coordination, and development. (The basis for the selection of these factors is outlined in Chapter 1.) The vast number of specific management and organizational variables in the literature that are potentially relevant to safety can be fit under these more general dimensions. While each contain a number of important elements, these four constitute an initial point of departure in determining whether the scope of a given data source is adequate. The four dimensions are defined as follows:

- (1) Administration: Administration refers to the manner in which the work of the organization is divided up and organized. It includes such issues as the division of labor, the forms of departmentation, and the requirements of job positions.
- (2) Control: Control refers to the manner in which the behavior of individuals and units is brought in line with management expectations. It refers to the structures, mechanisms, and procedures used in controlling work activities, and how performance standards are to be developed, measured, maintained, and modified.
- (3) Coordination: Coordination concerns the problems of integrating the diverse activities of individuals and units into a cohesive whole. Structures, mechanisms, and procedures that link diverse activities reflect coordination.
- (4) Development: Development refers to the nature and methods of purposive change. Relevant here are the activities undertaken by the organization to improve performance or to better adapt to changing contingencies.

For each of these four general concepts, it is useful to examine the form and nature of organizational resources being used. Specifically, an examination of form, procedures, individuals (people), and external resources and contingencies brings us much closer to actual measurement. These subdimensions may be defined as follows:

- (1) Form: Form refers to the structure used by the organization. The form of administration, for example, would in part refer to the way that work is departmentalized. The form of coordination would, in part, refer to the nature of plant wide committees and formal linkages across departments.
- (2) Procedures: Procedures refer to the rules and plans that the organization employs to guide activities. Control procedures, for example, would refer to rules governing performance.
- (3) Individuals: Individuals refers to the staffing requirements, job responsibilities, and personnel qualifications to be employed.

- (4) External Factors: The specific manifestation of administration, control, coordination, and development will depend upon a set of external factors such as the resources allocated to each dimension or the organizational constraints under which it must operate.

The reader will note that this scheme implies the sixteen cell matrix represented by Table 2. The existing data can be plotted on this matrix to determine whether adequate coverage exists. Further, the data can be evaluated both in terms of the vertical and horizontal axis, i.e., does it allow for complete coverage of organizational administration, on the one hand, and organizational form on the other. This sixteen factor scheme, then, provides substantial flexibility in analyzing data sources where the information was not based on a rigorous review of the organizational literature.

To aid in understanding what each cell requires by way of information from the data sources reviewed, each cell will be defined below and illustrations of specific organization characteristics fitting each cell will be given. A warning is in order, however. This review is oriented toward the types of information that can be reasonably expected in documents not specifically designed for an empirical analysis of the relation between organization and safety. Were it possible to design and implement such a study, substantially different and superior measures of these concepts would be in order.

Cell 1: Administration - Form

This cell refers to the way the organization is structured for purposes of general administration and workflow. A key dimension of this cell is the organization chart describing forms of departmentation, the nature of formal reporting relationships, and the division of work into job positions. Descriptions of the nature of the work and subunits are also included.

Cell 2: Administration - Procedures

This cell refers to the use of rules and plans that the organization uses to govern and guide work activities. Included are standing orders, instructions, manuals, and the like, used to establish how the work is to be done.

Cell 3: Administration - Individuals

This cell refers to the nature of individuals carrying out the work activities. Relevant are issues of selection, credentials, and qualifications. Job descriptions are also pertinent to this cell.

Cell 4: Administration - External

This cell refers to the interface of the organization with resources and constraints outside the organization. Specifically, it is concerned with input and output relationships affecting the nature of the work process (vendors, contract workers, etc.). It is also concerned with the formal

reporting relationships linking the organization to higher organizational units.

Cell 5: Control - Form

This cell refers to such factors as vertical authority relationships, communications channels, spans of control, and formal governing units (boards of directors, etc.), in so far as they concern control activities (e.g., monitoring, rewarding, punishing).

Cell 6: Control - Procedures

This cell refers to any formal instruments or procedures used to measure, evaluate, reward, and sanction performance. Surveillance procedures and employee evaluations are examples.

Cell 7: Control - Individuals

This cell includes information on the performance standards placed on individual workers and roles. Also, relevant here would be responsibilities placed on particular managers and supervisors to control the activities of others.

Cell 8: Control - External

This cell includes any external sources of support or constraint on control capabilities. Relevant here would be the effects of regulators, audit and review procedures imposed by higher-level corporate authorities, union contracts, and the like.

Cell 9: Coordination - Form

This cell pertains to the formal mechanisms employed to integrate the activities of individuals and work units. Included here would be staff meetings, communications systems, committees, and linkages through the formal hierarchy and matrix structures.

Cell 10: Coordination - Procedures

This cell refers to rules and plans used in integrated units within the organization. Pertinent here are rules governing the flow of work from one organizational unit to another, and rules and procedures promoting cross-unit interaction.

Cell 11: Coordination - Individuals

This cell concerns mechanisms (e.g., rewards, programs) for integrating the individual into the organization. This includes provisions for nurturing the "informal" organization, and each position's expectations for interface with other positions.

Cell 12: Coordination - External

This cell refers to coordinating activities carried out by higher organizational units and outside influences. Examples include regulatory requirements for coordination and information on the linkage of functions outside the organization through professional associations, vendors, and corporate management.

Cell 13: Development - Form

This cell refers to the identification of units and structures designed to promote positive organizational change. Data that allows for the description and location (as in an organizational chart) of training departments, strategic planning units, mechanisms for employee participation, suggestions, and the like, would be included here.

Cell 14: Development - Procedures

This cell includes technical aids and formal procedures established within the unit to facilitate successive improvements in the quality or sophistication of the unit's knowledge base. Examples would be rules and procedures for training and staff development.

Cell 15: Development - Individuals

This cell refers to the organization's plans for members to obtain training, retraining, continuing education, or upgrading of skills, and the incentives or rewards available as inducements to employee efforts to improve performance and ability.

Cell 16: Development - External

This cell refers to outside development resources such as training conducted by vendors, information provided by the industry concerning problems and solutions, and so forth. Also included would be relationships with universities, professional associations, and higher level organizational units promoting innovation.

Each data source will be analyzed to determine if measurement is possible on each of the subdimensions of administration, control, coordination, and development. The review of the literature in Chapter 1 of this volume (and, to a lesser extent, Chapters 2 and 3), suggests that measurement on these 16 subdimensions will allow a reasonably comprehensive, first look at the relationship between organizational design and safety. The rating system used is based on our judgment of the adequacy of each data source on each criteria. Data sources that completely satisfy a specific criterion have been scored as "1" on that criterion. Data sources that do not at all satisfy the criterion (or that do not provide any measurement on a concept) have been scored as "5". The complete scoring system is as follows:

- 1: completely satisfies the criterion
- 2: substantially satisfies the criterion
- 3: has both positive and negative characteristics relative to the criterion
- 4: only slightly satisfies the criterion
- 5: does not at all satisfy the criterion.

It should be pointed out that the criteria are interrelated. Therefore, a positive score on the measurement of a particular organizational dimension does not mean that the data source is a good source for that variable; the data source may fail on some other prerequisite of quality. It should also be pointed out that some of our ratings are speculative. A more thorough investigation of certain data sources, particularly those of a proprietary nature (such as INPO corporate criteria) could not be completed under existing schedules. Further, a revision of PAT assessment checklists was completed just as this report was being finalized, and could not be included in this analysis.

2.3.1 Final Safety Analysis Report

One requirement for the application for an operating license is the preparation of the Final Safety Analysis Report (FSAR). As outlined in section 34 of 10 CFR 50, the purpose of the FSAR is to provide information ". . . that describes the facility, presents the design bases and the limits on its operation, and presents a safety analysis of the structures, systems and components and of the facility as a whole . . .". While this section provides general guidelines for the content of the FSAR, more detail for the compilation of the report can be found in the Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants, Office of Standards Development, U.S. Nuclear Regulatory Commission. These guidelines include separate chapters for the following topics:

- (1) Introduction and General Description of Plant
- (2) Site Characteristics
- (3) Design of Structures, Components, Equipment, and Systems
- (4) Reactor Design
- (5) Reactor Coolant System and Connected Systems
- (6) Engineered Safety Features
- (7) Instrumentation and Controls
- (8) Electric Power System

- (9) Auxiliary Systems
- (10) Steam and Power Conversion System
- (11) Radioactive Waste Management
- (12) Radiation Protection
- (13) Conduct of Operations
- (14) Initial Test Program
- (15) Accident Analyses
- (16) Technical Specifications
- (17) Quality Assurance.

The Standard Format is used by utilities to guide in the compilation of both the Preliminary Safety Analysis Report and the FSAR. A parallel document, U.S. Nuclear Regulatory Commission Standard Review Plan, is used by the Office of Nuclear Reactor Regulation for review of the FSAR. While many of these chapters contain management and organization variables, particularly in the area of procedures (Chapters 12 and 17, for example), the chapter primarily concerned with management and organization is Chapter 13. For this analysis 10 industry submissions of Chapter 13 of the FSAR were reviewed along with the Standard Format and Standard Review Plan documents.

- (1) Accessible. In general, the FSARs are accessible. They are available for public review. As will be discussed below, however, some material submitted to "update" the FSARs may not be as conveniently procured.
- (2) Systematic. The Standard Format provides a systematic format for industry response. Within Chapter 13, six sections are required: (1) organizational structure of applicant, (2) training, (3) emergency planning, (4) review and audit, (5) plant procedures, and (6) industrial security. While the data is usually presented in this order, the flexibility of the FSAR requirements allows for some variation to exist.
- (3) Parsimonious. There is a tendency, perhaps, for the utility to provide excessive information in some areas. This is particularly true in the areas of qualifications where long, detailed biographies are submitted. Nonetheless, Chapter 13 is sufficiently parsimonious to allow its use.
- (4) Recent. The FSARs are written at the license application stage. This means that the basic document is somewhat older than the plant itself. Regulations require that the FSARs be updated annually to reflect significant changes. In addition, certain classes of changes require a priori NRC investigation of recent editions of the FSARs, however, suggest that in the management and organization area, the

update procedure may not be working according to plan. For example, a number of the organization charts provided suggest no authority or staffing changes over the course of 10-15 years (since last amended)--a somewhat unlikely event. Also staffing qualifications sections included resumes that were somewhat dated. This makes the recency of the FSARs suspect. Substantial cross-checking would be necessary, perhaps by the resident inspectors, to assure that the current FSARs actually are being updated in the management and organization areas.

- (5) Equivalent Timing. To the extent that the FSARs actually are updated, they satisfy this criterion. However, as mentioned above, serious questions can be raised about the update process. It should also be mentioned that since the FSARs reflect the regulatory requirements at the time of application, except for those regulations that are backfitted, the FSAR is always somewhat defined by the time it was first written.
- (6) Representative. The FSAR represents a plan for operations. Only through the updates does it begin to reflect a reality that is representative of operating reality. Again, the usefulness of the FSAR depends upon the accuracy of the updates.
- (7) On-line. Since the FSAR is submitted prior to licensing, the base document does not reflect on-line status. Updates would allow for the document to be more representative of on-line conditions--though in a piece-meal, one-change-at-a-time manner.
- (8) Consistent. For the most part, the data collection protocol is consistent within a specific regulatory period. However, the NRC allows a certain amount of discretion in the submissions. This is particularly true of the management and organization areas. In addition, the NRC reserves the right to require additional information for the FSAR other than that required in the Standard Format and the Standard Review Plan. In essence, while the Standard Format and the Standard Review Plan provide the basis for consistent data collection in the management and organization area, there is also somewhat of a tendency to tailor the process to each specific applicant. This detracts from the consistency of the FSAR as a data source for organizational design.
- (9) Clear. The instructions for compiling the FSARs are of moderate clarity. One problem that exists is the lack of specificity in instructions and definitions for presenting organizational charts and job responsibilities as reflected in the wide variation in form and detail within the FSAR sample reviewed.
- (10) Replicable. The data collection protocol is sufficiently clear that replicability does not appear to pose a major problem.
- (11) Accurate. The accuracy of the information is in some ways an unknown quantity. The FSAR submissions come initially from the applicant and

reflect responses to regulatory guidelines. It would be logical to assume that the applicant would want to provide the most positive view of its management and organization possible. Whether this results in inaccuracies is uncertain. The NRC does have the authority and opportunity to check on the accuracy of the FSAR data, perhaps improving the accuracy of the utility submissions. In comparing FSAR submissions with other sources of data (Battelle site visits, Edison Electric Institute Survey), however, there is not always perfect agreement. In part, this could be due to the problem of updating the FSAR. However, some confidence can be placed in this information if for no other reason than inaccuracies, if discovered, could lead to NRC levied fines.

- (12) Corporate. The FSARs are not primarily concerned with the management and organization of the utility (applicant) as a whole. Consequently, very little information beyond the plant level is included in the FSAR submissions. Exceptions to this are that utility organizational charts are provided, as are the qualifications of key corporate staff. (Chapter 17 [QA] reviewed separately contains significantly more corporate information.)
- (13) Plant/Facility. The bulk of the information provided in the FSARs pertains to the plant level. Information is available for every licensed plant. In general, information is not included on vendors and contract workers.
- (14) Administration.
 - a. Form. Organizational charts are included in the FSARs allowing for the partial assessment of the form of administration. In general, these charts are helpful. Three caveats are in order, however. First, at the plant level, lower level positions are sometimes not included. Second, at the corporate level there is a general lack of detail in many submissions (number of staff in a given department, for example). Finally, many of the charts show no changes in the past 5-10 years. This raises doubts about their accuracy.
 - b. Procedures. Some information is provided describing areas of responsibility and administrative procedures under the discussion of operating organization. The level of detail varies considerably by plant.
 - c. Individuals. Key managers are identified in the FSARs. In addition, minimum qualifications and summary background information for key personnel are also provided.
 - d. External. In general, budgetary information is not available. Some information is available on resources provided by vendors that aid in the administration of the work. Administrative links between the corporate level and the plant level are also given.

(15) Control.

- a. Form. The form of control can be inferred, in part, from the organizational charts and from formal statements of authority. Such factors, as spans of control and vertical authority patterns, are relevant. However, lower level spans cannot be derived because of lack of detail in the organization charts. Information is also provided on the existence of committees with review and audit functions.
- b. Procedures. Some information is provided on control procedures for specific functions (security, radiation protection). For the most part, however, the FSAR does not include information on procedures related to the measurement, reward, and sanction of behavior.
- c. Individuals. The FSAR contains some information on the control responsibilities of individual managers and personnel. This information is more detailed for certain types of activities (QA, Radiation Protection) than for others.
- d. External Factors. Limited information is available on sources of control external to the plant. Control relationships linking the corporate and plant levels are referenced for line management, QA, and safety audit activities. Other relevant factors, such as corporate personnel and budgeting policies, are not referenced. Compliance with NRC accepted standards is listed.

(16) Coordination.

- a. Form. Inadequate information is provided on the form of coordination. Formal linkages of activities are available from the organization charts. Standing review committees pertaining to safety are also outlined. Missing are mentions of other common integrative mechanisms such as project oriented committees, monthly/weekly staff meetings, etc.
- b. Procedures. With the exception of QA and radiation protection, the procedures outlined in the FSAR generally do not address the integration of different job functions.
- c. Individuals. For the committees described, the individual members and their organizational responsibilities are listed. This allows for some indication of the way in which individuals are used to integrate disparate activities. Little information is provided concerning the interface of task activities.
- d. External. Very little information is provided as to external mechanisms for coordination. While the use of outside consultants (INPO, vendors, etc.) is common in the industry, this type of information is not included in the FSARs.

(17) Development.

- a. Form. The organizational charts allow for the identification of organizational units (training, staff development) primarily concerned with organizational improvement.
- b. Procedures. Considerable information is available in the FSAR on policies and practices relative to training. Other forms of development (hiring, problem solving, quality circles, etc.) are not addressed.
- c. Individuals. The individuals providing and receiving training are identified. Incentives and rewards are not mentioned relative to development activities.
- d. External. The external resources (schools, programs, vendors) used in training are identified. Resources for other types of development (budget allocations for in-house research, for example) are not mentioned.

2.3.2 Overall Assessment

The major problems with using the FSARs as a data source are (1) the problems of assuring that all information is up to date, and (2) the fact that many key dimensions are not adequately covered. In general, measurement is possible on some aspects of the form of administration, control, coordination, and, to some extent, development, although lack of specificity in some organizational charts creates problems. Procedures, individuals, and external factors are somewhat less well covered. Nonetheless, a certain amount of useful management and organization data can be gleaned from the FSARs.

2.4 Technical Specifications

Each applicant for an operating license is required by 10 CFR 50.36 to submit technical specifications. After being reviewed and changed as needed by the NRC, the technical specifications become a condition of the license. The major sections of the technical specifications are:

- (1) safety limits, limiting safety system settings, and limiting control settings
- (2) limiting conditions for operations
- (3) surveillance requirements
- (4) design features
- (5) administrative controls.

The section on administrative controls (Chapter 6 in the Technical Specifications) is particularly relevant, in that it contains the bulk of

the information concerning management and organization. Among the themes contained in this section are the following:

- (1) on-site and off-site organizational charts
- (2) shift crew composition
- (3) minimum staff qualifications
- (4) training
- (5) plant and corporate safety review committees
- (6) mandated procedures
- (7) reporting (to NRC) procedures.

Because the technical specifications are part of the license, there are relatively clear, rigorous rules for keeping the technical specifications up-to-date. In general, changes that affect safety related systems and procedures must be cleared, in advance, by the NRC. This means that a permanent record is kept of changes in the technical specifications. However, the changes may not be incorporated into the technical specifications document, itself. Rather, in order to establish a truly updated technical specification, the existing document may have to be augmented by plant specific information contained in the NRC's Public Document Room data base. Chapter 6 of approximately 35 plants' technical specifications have been reviewed for this analysis.

- (1) Accessible. The Technical Specifications are accessible, though it may be somewhat more difficult to acquire Technical Specifications that contain all of the updated information.
- (2) Systematic. The Technical Specifications are organized in a fairly systematic format.
- (3) Parsimonious. The Technical Specifications do not contain a substantial amount of superfluous information.
- (4) Recent. While the Technical Specifications are to be updated to keep them current, there is some indication that the technical specifications reviewed do not totally reflect the current operating experience. For example, many of the documents reviewed showed no amendments to the management and organization parts of the technical specifications in over five years. Given significant changes in the industry during this time, such facts raise doubts about how current the base document is.
- (5) Equivalent Timing. Because of the problem of getting updated information, the Technical Specifications only partially satisfy this criterion. As in the case of the FSAR, the requirements for content are somewhat different for recently licensed plants than for older

plants. Therefore, there are significant questions about the equivalence of the Technical Specifications.

- (6) Representative. The Technical Specifications represent an operational plan, not actual operating experience. To the extent that they have been updated, a condition that varies from plant to plant, they are more reflective of the typical conditions.
- (7) On-line. The base document is created prior to the plant going on-line. Management and organizational factors (staffing levels, authority patterns, procedures) may be expected to change as the plant gains operating experience. Again, these changes should be reported to the NRC. There is no assurance, however, that a specific change will be recorded as an amendment to the base document, reflecting the difficulty in record keeping.
- (8) Consistent. The NRC provides a format for the Technical Specifications. However, because each Technical Specification is tailored to the conditions of the specific applicant, the final documents may not be consistent. While the NRC generally has the same concerns from plant to plant, certain concerns may be stressed more in one plant as compared to another, leading to some inconsistency in application. Then again, the requirements for the Technical Specifications change over time, also threatening consistency.
- (9) Clear. While the instructions for the Technical Specifications seem straightforward, it was noted in the review of various submittals that substantially different levels of detail were being provided. For example, organization charts varied from simply identifying department heads to charts where all levels of personnel were represented. This may reflect a lack of clarity in instructions.
- (10) Replicable. Most of the basic document conforms to a protocol that allows replication. Through the somewhat complex task of tracing all correspondence on a particular plant, the current information could probably be replicated.
- (11) Accurate. The same general comments can be made about the accuracy of the Technical Specifications as were made concerning the FSARs. Of particular concern is the issue of updating management and organization variables. Nonetheless, the Technical Specifications are probably reasonably accurate.
- (12) Corporate. Some information is included for the corporate level. Specifically, organizational charts (of varying specificity) and safety review information is required in the Technical Specifications. Few other areas are addressed.
- (13) Plant/Facility. The Technical Specifications are primarily concerned with the plant level. Technical Specifications exist for all plants. Little information on vendors or contract workers is provided, but a plant wide perspective is taken.

(14) Administration.

- a. Form. Organization charts allow for partial coverage of this concept. One problem is that the charts rarely depict the number of lower level workers making it difficult to compare departments as to size, estimate the supervisory responsibilities of first-line supervisors, and the like. The corporate organization charts tend to lack detail as well. Forms of departmentation and plant management are usually clearly represented.
- b. Procedures. With the exception of reporting of safety threatening events, the technical specifications do not address administrative procedures.
- c. Individuals. Information is available on the minimum qualifications of staff. These minimum criteria, however, tend to be invariant across plants.
- d. External Factors. No information is provided for administrative resources (budgets/constraints) or input and output relationships, except for the administrative link to the corporate headquarters.

(15) Control.

- a. Form. The form of control can be inferred, in part, from the organizational charts and from formal statements of authority. Such factors as spans of control and vertical authority patterns are relevant.
- b. Procedures. The technical specifications contain some information on the use of procedures to attain control over work related behavior. Specifically areas for which procedures have been adopted are typically listed. The exact nature of the procedures, however, may not be included. In addition, the audit and review functions of the Plant Operations Review Committee (PORC) are typically given.
- c. Individuals. Not much detail is provided concerning job descriptions and responsibilities in the technical specifications.
- d. External Factors. The technical specifications do not address in any detail external (corporate) determinants of control.

(16) Coordination.

- a. Form. The Technical Specifications identify the PORC. Although the main function of this committee concerns control, it can be argued that any committee representing a plurality of task functions serves a coordinating, integrating role. Other standing and project specific committees that may exist are not mentioned.

- b. Procedures. No information is available concerning procedures related to coordination during normal operation.
- c. Individuals. Information in this regard is limited to the identification of the individual members of the plant operations review committee.
- d. External. No information is provided concerning external coordination resources.

(17) Development.

- a. Form. The organization charts allow for the identification of organization units devoted to training and some other development activities.
- b. Procedures. Very brief information is provided concerning training policies.
- c. Individuals. No information is provided concerning the individual responsibility for development activities, nor inducement aimed at individuals.
- d. External. Information is not routinely included concerning external development programs.

2.4.1 Overall Evaluation

The technical specifications provide, in a more condensed form, some of the information contained in the FSARs. The Technical Specifications support measurement of some of the form variables, but little else. Like the FSARs, the issue of "updates" is also significant.

2.5 Quality Assurance Programs

As required by Appendix B of 10 CFR 50, each applicant is required to submit as part of the Safety Analysis Report a plan for dealing with Quality Assurance (QA) issues. This chapter becomes part of the FSAR. While QA is a single function within the organization, the information provided in the submittals includes some of organization-wide importance and scope. The major areas addressed by the QA documents are:

- (1) organization (responsibility) of the QA function
- (2) description of the QA program
- (3) design control plans
- (4) procurement document control
- (5) instructions, procedures, and drawings

- (6) document control
- (7) control of purchased material, equipment, and services
- (8) identification and control of materials, parts, and components
- (9) control of special processes (welding, testing, heat treating, etc.)
- (10) inspection
- (11) test control
- (12) control of measuring and test equipment
- (13) handling, storage, and shipping
- (14) inspection, test, and operating status
- (15) non-conforming materials, parts, or components
- (16) corrective action
- (17) quality assurance records
- (18) audits.

A review of three submittals indicates overall conformance with the above outline.

- (1) Accessible. The QA assessments are accessible. It may be somewhat more difficult to conveniently add updated information resulting from NRC audits of the QA programs.
- (2) Systematic. The three programs reviewed seem to conform to the order outlined in Appendix B. Within each section, however, some variation in order was noted.
- (3) Parsimonious. Since the purpose of the QA document is to provide information on a specific function rather than management and organization as a whole, the ratio of useful to less useful information is not as large as would be desired for present purposes.
- (4) Recent. The QA programs are kept up-to-date through periodic audits. One problem in this regard is that the operational document is patched together with amendments, giving it something less than a cohesive appearance.
- (5) Equivalent Timing. Because the QA programs are periodically audited, their up-to-date status may be less uncertain than the Technical Specifications and FSARs. However, there can be a lag between audits so that the recency of information available can vary significantly from plant to plant.

- (6) Representative. As amended, the QA documents appear to be representative.
- (7) On-line. As amended, the QA documents appear to reflect on-line status as well as retaining information concerning the construction stage.
- (8) Consistent. A systematic format has been provided by the NRC for industry submittals. This seems to have led to substantial consistency in responses, though variation in detail has been noted. It is not possible to determine if NRC audits of the QA programs have been consistent.
- (9) Clear. The general requirements for submittals appear to be clear. Variation in the level of detail provided, however, suggests that more specific instructions might add clarity.
- (10) Replicable. The data collection process appears to be replicable, although subsequent audits and changes in the QA programs may be more difficult to trace.
- (11) Accurate. Given that the QA documents have been kept up-to-date, there is little reason to doubt the accuracy of the information.
- (12) Corporate. Documents exist for all license holders. Most of the information is at the corporate level. Relations with major vendors are described. The documents vary as to the amount of the corporate organization included for discussion.
- (13) Plant. The documents focus on the QA function and, therefore, provide limited plant-wide information.
- (14) Administration.
 - a. Form. The QA reports provide a certain amount of information on administrative form. Specifically, the reports provide corporate organization charts and plant charts of somewhat less detail. The supporting narrative describes the job activities of top management, technical, and QA personnel. Somewhat less attention has been directed toward other functions.
 - b. Procedures. The QA reports provide a considerable amount of information on procedures relevant to QA activities. Procedures concerning the nature of the work for other functional areas are addressed in less detail.
 - c. Individuals. The QA reports identify the individuals responsible for administering the work in the QA, construction, design, maintenance, operations, and other areas. The qualifications of non-managers are not addressed. Plant level personnel are not accorded the same level of attention as corporate level personnel.

- d. External. The QA reports provide information on outside vendors and the off-site support for functions audited by QA. This results in a considerable amount of information.

(15) Control

- a. Form. The organizational charts allow a partial picture of the form of control. In addition, the responsibilities of specific positions affecting plant and operations quality are described. Spans of control are not available for all units nor are communications systems routinely described.
- b. Procedures. Considerable information is provided concerning the procedures to be used in monitoring the quality of work in a number of functional areas at both the corporate and plant levels. This is a good source of information concerning this dimension of control procedures. Control of personnel, rewards, and sanctions are not addressed.
- c. Individuals. The reports identify individual responsibility for controlling and monitoring the quality of work and product.
- d. External. The relationship between the QA function at the plant level and its control by the QA function at the corporate level is addressed. The authority resources of on-site QA personnel are outlined. Regulatory constraints are mentioned. External resources for other functions are not addressed.

(16) Coordination

- a. Form. The organization charts show the positions linking functional areas. In addition the on-site and off-site safety review committees are identified. Other committees and coordinating mechanisms were not mentioned in the documents reviewed.
- b. Procedures. Some mention is made of coordination procedures relative to QA. Specifically, procedures governing the interface of the QA function with other functions are outlined. Similar procedures for the interface of non-QA functions are not mentioned.
- c. Individuals. The responsibilities for the coordination of activities within broad functional areas are typically referenced in the job descriptions of management. The coordination responsibilities are presented in relatively more detail at the corporate than at the plant level. Mechanisms for integrating the individual are not mentioned.
- d. External. Some mention is made at the corporate level of the interface of the various QA related functions.

(17) Development

- a. Form. While the training function is identified on the organization charts, discussions of training and other development activities are not well developed.
- b. Procedures. Mention is made of the necessity of a QA audit of training procedures. The procedures, themselves, are not reviewed.
- c. Individuals. Little information is provided concerning the individuals responsible for development activities.
- d. External. Little information is provided concerning external support for development activities.

2.5.1 Overall Assessment

The QA documents provide a wealth of information on control issues. The information on administration and coordination is largely limited to the QA function. Development receives very little attention. The reports tend to emphasize corporate rather than plant level data. Still, the QA documents are a useful source of information for organizational data.

2.6 Health Physics Appraisal Program

The Health Physics Appraisal Program was an outgrowth of breakdowns in health physics procedures at TMI. The NRC (Inspection and Enforcement) targeted health physics programs for a fairly massive study. Teams comprised of NRC and Battelle staff spent an average of about 6 weeks studying the health physics programs at each of 48 reactor sites. The study was conducted in the last half of 1980 and the first three quarters of 1981. The purpose of the research was to use health physics professionals to evaluate the adequacy of the health physics programs relative to the following areas:

- (1) radiation-protection organization and management
- (2) personnel selection, qualification, and training
- (3) exposure control, external and internal
- (4) surveillance
- (5) radioactive-waste management
- (6) ALARA program
- (7) facilities and equipment.

The research team developed a comparative system comprised of "analytical trees" for each of the above areas. The trees represented the step-by-step prerequisites for arriving at desired goals for each of the seven areas. In

general, the analytical trees appear logical. In the area of management and organization, however, the goals and means reflect a wholesale adoption of classical management approaches. (See pages A-61 to A-70 of NUREG-0855: Health Physics Appraisal Program.) As such, the evaluation of organization and management may contain inaccuracies and oversimplifications. In other areas, goals and means were derived primarily from NRC rules, ANSI standards, and ICRP/ICRU recommendations. Each site was compared to the analytical trees. The report contains a listing of the areas in which the site deviates from the analytical trees. The list is divided into significant (major) and informational (minor) deviations. Plants are expected to submit a report to the NRC concerning their solutions to the significant deviations. The bulk of each report is comprised of an area by area summary of deviations and compliance. Each report gives a summary ranking of the program on a three point scale.

- (1) Accessible. The Health Physics Appraisal reports are available for 48 sites. There is no significant problem in getting them.
- (2) Systematic. The reports follow a standard outline. They are systematic.
- (3) Parsimonious. The reports contain a majority of information not related to management and organizations. In addition, they are quite long with the useful information imbedded in the text. The reports, therefore, cannot be considered parsimonious from the perspective of management and organization data.
- (4) Recent. The reports are fairly recent (1980-1981) and probably do not deviate significantly from current reality. However, the Health Physics Appraisal Program is not conducted periodically nor are there update mechanisms. Therefore, the usefulness of this data source relative to this criterion will diminish with time.
- (5) Equivalent Timing. Data for all plants was collected within the span of eighteen months. This is not judged excessive, particularly in comparison with Technical Specifications and FSARs.
- (6) Representative. As far as can be determined, the reports seem to satisfy this criterion.
- (7) On-line. All participating plants were on-line when surveyed.
- (8) Consistent. The method applied (a set of analytical trees) probably assures consistency in application. Because different teams of researchers were used, however, the evaluative component may not be as consistent. Consistency is not judged to be a major problem of the Health Physics Appraisal Program.
- (9) Clear. It is not possible to judge the clarity in that this is contingent upon the training received by the research team. The appraisals seem to consist of a large number of fairly precise

questions. Therefore, lacking additional information, this criterion is not seen as problematic.

- (10) Replicable. The documents contain sufficient information (questions asked, documents reviewed, staff interviewed) to allow replication. In fact, the Health Physics Appraisal Program does an exceptional job of reporting its research protocol.
- (11) Accurate. The data are probably accurate, given the questions asked and the expertise of the researchers in Health Physics. In the organizational areas, however, the questions asked follow a bias toward classical management concepts leading to a somewhat incomplete view. To illustrate, the questions generally have an evaluative component so that the interviewers are frequently asking questions of the general form "Is it done right?" rather than "How is it done?" The two approaches generate substantially different but not equally usable forms of information.
- (12) Corporate. The Health Physics Appraisal Program is not substantially concerned with the corporate organization. Skeleton corporate organization charts are available as are off-site resources for the health physics function. Information is not available for other functions.
- (13) Plant. The documents provide a substantial amount of information on the health physics function and its interface with other functions. Skeleton organizational charts are provided. Very little information, however, is provided on the other functions.
- (14) Administration.
 - a. Form. The organizational charts provided lack detail at the lower levels. However, they can be used to identify forms of departmentation if not always job titles. Job descriptions within the radiation control function are given. Other functions are generally not addressed.
 - b. Procedures. Although the review of procedures is evaluative, some descriptive information of work procedures within the radiation control function is provided. Other functions are generally not addressed.
 - c. Individuals. A considerable amount of information is provided on the selection and qualifications of staff within the radiation protection function. Other functions are generally not addressed.
 - d. External. A brief description of off-site support for health physics is generally included in the report. This is primarily in the form of technical expertise. Information on other types of resources is not provided. Other functions are generally not addressed.

(15) Control.

- a. Form. The organization charts depict formal authority relationships. They are not provided in sufficient detail to discern spans of control.
- b. Procedures. Within the radiation control function, information is provided concerning the measurement of work activity and the procedures used in exacting compliance. Information on reward and sanctions is not provided. Other functions are not considered.
- c. Individuals. Within the radiation control function, the authority and control responsibilities of individuals are identified. Other functional areas are not mentioned.
- d. External. The control responsibilities of the corporate health physics unit over the plant health physics unit are described in these reports. The role of corporate QA audits is also described.

(16) Coordination

- a. Form. Other than the formal linkage of departments depicted on the organizational charts, no information is provided on the form of coordination.
- b. Procedures. No information is provided on the procedures for the interface of the radiation control function with other functions.
- c. Individuals. Job descriptions for radiation control personnel do not include information concerning the coordination of radiation control activities with other departments.
- d. External. No mention is made concerning external mechanisms for coordination.

(17) Development.

- a. Form. The organization charts identify the staff units relevant to development. Descriptions of the units are not provided.
- b. Procedures. Considerable detail is provided concerning training and other development activities within the radiation control area. Other functional areas are not considered.
- c. Individuals. The individuals conducting and involved in training are identified by position. Some mention is made of inducements oriented toward the development of individuals.
- d. External. External training and development resources are mentioned. It is not possible to determine if those mentioned constitute an exhaustive list. The information is limited to the radiation control function.

2.6.1 Overall Assessment

In general, the Health Physics Appraisal Program appears to provide high quality data on a limited part of the plant organization. Though the evaluative nature of the reports may introduce some bias, they have the advantage of being conducted by outside reviewers with a standard, systematic protocol. Rather than representing a general data source, this program can stand as a partial model for other data collection programs to emulate.

2.7 Non-NRC Sources

In this next section we will review five potential data sources that are not primarily NRC generated. Three of them (EEI, Teknekron, and INPO staffing survey) are primarily staffing surveys and are, therefore, less comprehensive in their coverage of design dimensions. In addition, with the exception of the utility annual reports, this information is not in the public domain. Before these documents can be of any use to the NRC or outside evaluators, approval for their use must be obtained. Further, some of the information necessary to evaluate the adequacy of the data sources has not been available to us. Consequently, we must infer the adequacy of the data collection protocol from the published results. The inferences made, therefore, may contain some error.

2.7.1 Edison Electric Institute Nuclear Plant Staffing Survey

In the Spring of 1980, the Edison Electric Institute (EEI) conducted a staffing survey of 60 reactor units operating at 41 sites. The purpose of the survey was to (1) identify staffing levels within a comprehensive set of job categories, and (2) record the lines of authority linking the various job titles to each other.

- (1) Accessible. The survey is not in the public domain. Approval for use would have to be negotiated with the EEI on a case by case basis.
- (2) Systematic. The data is presented in a systematic format.
- (3) Parsimonious. The data is very parsimonious. No extraneous information is present.
- (4) Recent. The data, collected in 1980, is becoming somewhat dated. However, it probably continues to reflect the rank order of the plants on staffing levels with some degree of accuracy. To the extent that plants have added new job titles subsequent to 1980, these data are not sufficiently recent.
- (5) Equivalent Timing. The data was collected within a three month period for all participating plants. The data source satisfies this criterion.
- (6) Representative. The data was collected at a time which should, on the average, be representative of the plants' experience.

- (7) On-line. The participating plants were on-line.
- (8) Consistent. It was not possible to review the data collection protocol. Consequently, it is not possible to directly assess whether or not the data was collected in a consistent manner across plants. The results, however, tend to support a positive evaluation.
- (9) Clear. The instructions for compiling the information were not available for review. There is some reason to doubt the adequacy of their clarity. First, contract workers were reported in different ways across plants. Second, lines of authority were not always given.
- (10) Replicable. Since the data collection protocol was not part of the document reviewed, the replicability of the data collection process is unknown.
- (11) Accurate. The data is probably accurate. Substantial agreement was noted with other data sources (Technical Specifications).
- (12) Corporate. No information is provided for the corporate level.
- (13) Plant. Not all plants are represented in the survey. Vendors and some contract workers are not included. All other workers seem to be included.
- (14) Administration.
 - a. Form. Organizational charts can be derived from the survey showing forms of departmentation and division of labor. Job activities are not described.
 - b. Procedures. No information is provided on administrative procedures.
 - c. Individuals. No information is provided on the qualifications of individuals.
 - d. External. No information is provided on external resources or constraints.
- (15) Control.
 - a. Form. Derived organizational charts show formal lines of authority and spans of control within the plant.
 - b. Procedures. No information is provided on control procedures.
 - c. Individuals. No information is provided on the control responsibilities of individuals.
 - d. External. No information is provided on external sources of control.

(16) Coordination

- a. Form. The derived organizational charts show the formal linkages among functions. Committee structures are not provided.
- b. Procedures. No information is provided on procedures establishing coordination.
- c. Individuals. No information is provided on the coordinating activities and responsibilities of individuals.
- d. External. No information is provided on external sources of coordination.

(17) Development

- a. Form. Units devoted to development can be located from the organizational charts.
- b. Procedures. No information is provided on development procedures.
- c. Individuals. No information is provided on the individuals engaged in development activities.
- d. External. No information is provided on external support for development.

2.7.1.1 Overall Assessment

The EEI survey provides useful, though somewhat dated information on organizational form at the plant level. The other dimensions of procedures, individuals, and external resources and constraints are not included. While the EEI survey could be useful, its proprietary status makes its use problematic.

2.7.2 Teknekron Evaluation of Utility Management
and Technical Resources

The report was written by Teknekron for Nuclear Reactor Regulation (NRR) as part of the TMI response. Its purpose is to assess the ability of utilities to respond to TMI-like accidents. It identifies three tasks:

- Task 1: Analysis of licensee submittals in response to an NRC request to identify management and technical short-term and long-term resources for reacting to TMI-type accidents.
- Task 2: Development of acceptance criteria that specify the minimum management and technical (offsite and onsite) resource needs of the licensee for both the short-term and long-term accident phases.

Task 3: Evaluation of the adequacy of licensee management and technical resources (offsite and onsite) to cope with nuclear power plant operational events similar to the TMI-2 type accident.

The report is based on letter responses to inquiries from H. Denton to each utility concerning each of its operating plants. The responses were written during the summer months of 1979. Unfortunately, the report does not include information on the nature of Denton's request, making it difficult to judge the reliability of the responses. The bulk of the report consists of a plant by plant listing of technical and management personnel, associated background information, and offsite resources. A smaller section of the report deals with emergency management issues which are outside the scope of this report, and will not be reviewed.

- (1) Accessible. The information exists in published form and is, therefore, accessible.
- (2) Systematic. The data are presented in tabular form in a very systematic format.
- (3) Parsimonious. The report presents the data in a parsimonious manner.
- (4) Recent. The data were collected in 1979 and is becoming dated; particularly as an indication of staff qualifications which tend to change with time.
- (5) Equivalent Timing. The data were collected at nearly the same point in time for each plant.
- (6) Representative. The proximity to the Three Mile Island event may be an issue--although the type of information requested should be insensitive to short term fluctuations.
- (7) On-line. The data represent plants in the on-line status.
- (8) Consistent. The exact nature of the data collection protocol is not apparent from the report. Consequently, it is not possible to judge the consistency of data collection. Each plants' submission seems to contain the same types of information, however, suggesting a fairly consistent application.
- (9) Clear. It is not possible to evaluate the clarity of the instructions for providing information. Several respondents seemed to provide considerably more and less information than the norm, suggesting some problems with clarity.
- (10) Replicable. It is not possible to evaluate the replicability of the data collection process, since the report did not provide an adequate description.

- (11) Accurate. Since the data requested are fairly straightforward and non-threatening, the data are probably accurate. The main question concerns whether or not all respondents provided the same amount of detail and comprehensiveness in reporting staff positions and qualifications. That is, the question remains as to whether observed differences are differences in staffing practices or simply differences in attention to detail.
- (12) Corporate. Although the data are collected at the plant level, information is also provided for corporate staffing in the technical area.
- (13) Plant. The information provided does not include all plant personnel. Rather the data is limited to technical areas and top management in other functional areas. Expertise available from contract workers and vendors is not mentioned. Only seven of the plants on-line at the time of the survey are not included in the report.
- (14) Administration.
- a. Form. No information is available on administrative form.
 - b. Procedures. No information is available on administrative procedures except under emergency conditions.
 - c. Individuals. The job titles and qualifications of plant technical and management personnel and corporate technical personnel are provided. Brief job descriptions are sometimes provided.
 - d. External. Technical resources available to the plant from the corporate level are cited.
- (15) Control.
- a. Form. No information is available on the form of control.
 - b. Procedures. No information is available on control procedures.
 - c. Individuals. No information is available on control as applied to by individuals.
 - d. External. No information is available on external bases of control except during emergency situations.
- (16) Coordination.
- a. Form. No information is available on the form of coordination.
 - b. Procedures. No information is available on procedures for coordination.

- c. Individuals. The members of the Plant Operations Review Committee are typically identified.
- d. External. No information is provided on external bases of coordination.

(17) Development.

- a. Form. No information is available on units devoted to development.
- b. Procedures. No information is available on development procedures.
- c. Individuals. Background information is sometimes provided on the Training Supervisor.
- d. External. The report specifies whether or not a simulator is available for training.

2.7.2.1 Overall Assessment

The Teknekron Report is of limited use for most organizational concerns. It does provide a systematic and parsimonious accounting of technical staff and plant management qualifications.

2.7.3 INPO Staffing Survey

The Institute of Nuclear Power Operations (INPO), Training and Education Division periodically conducts surveys of staffing and training practices and problems for onsite and offsite personnel. These surveys provide a comprehensive view of manpower issues. Although the data are publically reported at the aggregate level, the raw data underlying the reports could be of considerable use in certain organization-safety comparisons. The initial surveys were conducted in 1981, with results and implications reported in A Survey of Occupational Employment and Training in the Nuclear Power Industry. This review is based on that report and the reproductions of the survey instruments contained in its Appendices. Questionnaires were constructed and implemented concerning (1) onsite staffing, (2) offsite staffing, (3) turnover, and (4) training.

- (1) Accessible. The raw data is proprietary. INPO, and perhaps the participating utilities would have to allow its use.
- (2) Systematic. The surveys follow a very standard format. They are systematic.
- (3) Parsimonious. The surveys do not contain a lot of superfluous information.
- (4) Recent. Because the surveys are conducted periodically, the data are recent.

- (5) Equivalent Timing. All plants and utilities were surveyed at roughly the same time.
- (6) Representative. The data appear to be representative of normal operating experience.
- (7) On-line. The data are from on-line plants and associated utilities.
- (8) Consistent. The surveys provide a consistent format for data collection.
- (9) Clear. The instructions appear to be clear. Definitions are provided for key terms.
- (10) Replicable. Adequate information is provided so that the surveys could be independently replicated.
- (11) Accurate. The data are probably accurate, given the research protocol used. One potential problem concerns the employee categories used. By necessity, the large number of possible positions have been collapsed into more general categories. This raises the possibility that useful data has been lost through the categorization process. According to the report, the categories have been assessed for "face validity" by a number of knowledgeable individuals.
- (12) Corporate. Information is available for the nuclear component of most utilities operating nuclear power plants.
- (13) Plant. Information is available for almost all plants and for personnel on a plantwide basis. Contract workers are included. Vendors and construction workers are not.
- (14) Administration.
 - a. Form. No information is available on administrative form.
 - b. Procedures. No information is available on administrative procedures.
 - c. Individuals. Staffing levels with general job titles are reported.
 - d. External. By reporting utility staffing patterns and contract workers, some measure of external staffing support is available.
- (15) Control
 - a. Form. No information is available on form of control.
 - b. Procedures. No information is available on control procedures.
 - c. Individuals. No information is available on control behaviors of individuals.

- d. External. No information is available concerning external bases of control.

(16) Coordination

- a. Form. No information is available.
- b. Procedures. No information is available.
- c. Individuals. No information is available.
- d. External. No information is available.

(17) Development

- a. Form. Information is available concerning the location within the organization of training activities.
- b. Procedures. Information is available on the methods and content of training for various classes of employees.
- c. Individuals. Some information is available on the nature of the trainers employed, but not on individual development inducements.
- d. External. Some information is provided concerning training activities at the corporate level and by contract organizations.

2.7.3.1 Overall Assessment

The INPO Staffing Surveys address a very limited segment of the organizational variables central to an analysis of safety. However, those issues addressed have been treated in a manner that appears valid and reliable. A major problem with the data, however, is their proprietary status.

2.7.4 INPO Plant Evaluations

INPO has conducted its first round of plant evaluations aimed at assessing the nature, problems, and strengths of plant management and organization in the nuclear industry. (A similar program at the corporate level is just now getting underway.) The INPO Evaluations are based on a number of assumptions concerning the management practices and organizational structures leading to safe and efficient operations. These assumptions have been codified in a set of performance criteria addressing the following areas:

- (1) station organization and administration
- (2) mission, goals, and objectives
- (3) management assessment and quality programs

- (4) personnel planning and qualification
- (5) industrial safety
- (6) document control.

In addition, the functional areas of operations, maintenance, technical support, training, radiological protection, chemistry, and emergency preparedness are evaluated separately. It should be stressed that the INPO reports are not primarily descriptive in nature. Instead, they are evaluative, comparing plant characteristics to a set of standards and making judgments as to the adequacy of the characteristics. The criteria can be found in Performance Objectives and Criteria for Plant Evaluations (INPO, 1982). The application of the criteria can be found in plant specific reports. Both the criteria document and the evaluation reports suggest a considerable amount of useful information has been collected. However, neither the precise instruments for operationalizing the criteria nor the raw data evaluated are available at this time for review. These facts severely limit our ability to fairly and accurately evaluate the INPO evaluations as a data source.

- (1) Accessible. The data and procedures underlying the INPO plant evaluations are not currently available to the public. This, more than any other factor, limits their usefulness.
- (2) Systematic. While the evaluation reports progress in a systematic manner, nothing is known about the organization of the data underlying the reports.
- (3) Parsimonious. Because the reports are primarily evaluative, the descriptive data contained in them is not presented in a parsimonious fashion.
- (4) Recent. The evaluations are fairly recent.
- (5) Equivalent Timing. Because each evaluation is a substantial undertaking, there is a considerable gap between the first and last plants evaluated.
- (6) Representative. The data underlying the reports probably reflects normal operations.
- (7) On-line. The plants evaluated were in on-line status.
- (8) Consistent. It is not possible to tell whether the criteria were applied in a consistent manner.
- (9) Clear. It is not possible to tell if instructions and methods for data collection are clear and unambiguous.
- (10) Replicable. Published information is not sufficient to allow replication of the INPO techniques.

- (11) Accurate. Because the actual protocol was not presented in the documents reviewed, we are not able to assess the accuracy of the data. It is important to point out that the purpose of the INPO evaluation was to evaluate not to describe. Consequently, it is doubtful whether the raw data underlying the evaluations is capable of supporting valid and reliable descriptions of characteristics identified here as important to an assessment of safety. This, after all, was not the intended purpose of INPO's activities.
- (12) Corporate. The evaluation does not focus in a substantial way on the corporate organization.
- (13) Plant. Essentially all operating plants have been surveyed. Within the limits cited above, the entire plant has been surveyed.
- (14) Administration.
- a. Form. It is not at all clear that data has been collected on administrative form or structure. The criteria used seem to suggest that forms of departmentation and the like are not a primary concern.
 - b. Procedures. A considerable number of the evaluatory criteria address the perceived adequacy of procedures. Consequently, we assume that some information (quality unknown) has been collected on administrative procedures.
 - c. Individuals. The criteria seem to address issues of individual authority and responsibility. Also included in the criteria are evaluations of qualifications standards.
 - d. External. The criteria do not seem to include assessments of external resources and constraints.
- (15) Control.
- a. Form. Little information appears to have been collected concerning form of control, though some mention is made of managerial spans of control.
 - b. Procedures. A number of the criteria suggest that information was collected concerning monitoring and reward/sanction procedures.
 - c. Individuals. Some mention is made of criteria assessing the controlling activities of individuals, particularly in the assessments of functional areas.
 - d. External. No mention is made of external factors except in regard to the context of each functional area within the plant as a whole.

(16) Coordination

- a. Form. Little information appears to have been collected concerning the form of coordination.
- b. Procedures. Little information appears to have been collected concerning the procedures for coordinating activities.
- c. Individuals. Some information is apparently generated concerning the knowledge of individuals concerning activities outside their own jobs.
- d. External. No information appears to have been collected concerning external bases of coordination.

(17) Development

- a. Form. Information appears to have been collected concerning the location and organization of training activities.
- b. Procedures. Information appears to have been collected on procedures for conducting training. Other forms of development are not addressed.
- c. Individuals. It is not clear what information of this kind has been collected.
- d. External. No information is provided.

2.7.4.1 Overall Assessment

The INPO Evaluations are a potentially valuable source of information. However, their usefulness is currently impeded by (1) lack of access, (2) unknown data collection procedures, and (3) an evaluative bias. It is also fair to say that the evaluations stress the individual manager and worker rather than issues of organizational design that we believe to be of paramount importance.

2.7.5 Utility Annual Reports

Utility annual reports (SEC requirement) have been investigated as a possible source of utility wide data. They appear to have very limited use. No detailed organizational data is available for nuclear operations or plants. One possibility that has yet to be explored is that measures of management values can be extracted from the statement of organizational goals contained in these reports. Some budgetary information is available, though not at the nuclear or plant levels. Because so little usable information was found to be contained in these reports, a formal evaluation will not be reported here.

2.8 Conclusions

Table 1 provides a criterion by criterion summary of the performance of each of the data sources. What should be clear from this table is that existing sources of data are severely limited in their ability to address the range of organizational issues while at the same time satisfying problems of accessibility, timing, reliability and the like. Data sources that are most successful in concept coverage tend to have other significant problems. More narrowly focused data sources perform somewhat better on issues of accessibility and reliability.

Table 2 attempts to further summarize this information by addressing the degree of concept coverage across all data sources that at least marginally satisfy the first thirteen criteria. The table indicates that good measurement does not exist in the data sources reviewed. What does exist are parts of most concepts weakened by other inadequacies in the data. It should be clear that in order to support the scope and quality of data needed for an empirical analysis of the relation between organization and safety, significant improvements will have to be made in the data currently available to the NRC.

3. OTHER NON-NRC DATA SOURCES FOR ANALYSIS OF UTILITY ORGANIZATION AND PERFORMANCE OF COMMERCIAL NUCLEAR POWER PLANTS

3.1 Introduction

This section discusses various non-NRC sources of data on utilities, and on the capabilities and performance of their generating plants. Such financial and performance data are widely available, and have been extensively used by economists and others in the research community. In part due to extensive federal and state regulation of this industry, much more detailed data are available on both the organizations and on the plants they run than is the case for other industries. Despite this relative wealth of information, little careful research has been done on the reliability, validity, and completeness of various sources of data which are used by researchers. Glueck and Willis (1979) is one of the few research notes in the literature which addresses the methodological issue of using a particular documentary data source, the Securities and Exchange Commission 10-K submissions, for research purposes. Here data sources describing utility operations are compared. By comparing the methods by which the data are obtained and published, by conducting limited comparisons of the data themselves from different sources to check on their agreement, an overall profile can be developed.

3.2 Sources of Utility Data

Three types of publicly available data bases concerning utilities have been identified. These three sources are regulatory agencies, especially at the federal level, the utilities themselves through regular annual reports, and corporations which sell information in the form of industry manuals or machine-readable data files. The last category will be referred to as commercial data bases hereafter. The types of variables concerning utilities, and/or their power plants, frequency of reporting, and methods of data collection are discussed for examples of each of these types of data sources below.

3.3 Regulatory Data: Energy Information Administration

The Energy Information Administration (EIA) publishes three statistical series on electric utilities:

- statistics of Public Owned Utilities
- statistics of Private Owned Utilities
- thermal Electric Power Plant Construction and Operating Costs.

These statistical series are published annually using data submitted by the utilities. To the extent that cross-checking against other utility submissions is possible, the EIA does conduct attempts to assess the reliability of the information. For example, the plant capacity information reported in the third series is checked against monthly capacity reports submitted by utilities on another form.

The EIA inherited these three statistical series from the Federal Power Commission, which existed prior to the formation of the Department of Energy. Hence these series go back for many years, providing a reasonably consistent set of data concerning utilities. For the year 1978 and thereafter, the first two series are available in machine-readable form.¹ The third series is available from 1964 on in machine readable form.² Tapes can be requested for a nominal charge from the EIA. At the present, these series are available in printed form for years up through 1979, and the machine-readable data are available through 1980.

The data covered in Statistics of Privately Owned Utilities are shown in Table 3, and the data from publicly owned utilities is shown in Table 4. These two series provide information on corporate organization, financial position, generating capacity by type of plant, and energy production. These two data series provide only summary data on the aggregate power production of each utility. For detailed information on the output of thermal electric plants, the third EIA series, Thermal Electric Power Plant Construction and Operating Costs, provides information for each plant on capacity, production of energy, and expenses for fuel, maintenance, and other operating costs. Thermal power plant in this context refers to any source of heat energy which is used to drive a turbine. Thus, nuclear, coal, oil, and gas fired turbines are included, as well as the internal combustion engines used to provide power in very small utilities. Note that the only input cost neglected in this data source is capital cost. The historical invested cost per kilowatt of capacity is reported, which allows one to construct a capital cost measure. The data covered by this data series are shown in Table 5.

3.4 Regulatory Data: Securities and Exchange Commission

The Securities and Exchange Commission (SEC) requires annual filings from corporations which fall under its jurisdiction due to the size of securities offerings made by that entity. The filing known as "Form 10-K" provides a basic source of data regarding corporations and their financial aspects in particular. The kinds of data provided in the 10-K submissions are shown in Table 6. While fewer data items are included in comparison with the EIA data, some items which EIA does not report are included in the 10-K submissions. In particular, operating loss or profit is reported for the prior three fiscal years, research investments are reported, and more extensive data is provided in stock issues of the corporation. These data pertain to the utility corporation as a whole. Consequently, no data is provided on individual power plants.

¹Telephone interview with Elsie Bess, Energy Information Administration, U.S. Department of Energy, September 1982.

²Telephone interview with Samuel Brown, Energy Information Administration, U.S. Department of Energy, September 1982.

TABLE 3

Federal Energy Regulatory Commission
Investor Owned Utility Data

General Corporate Information and Financial Statements

General Information

Control over Respondent

Corporations Controlled by Respondent

Officers

Directors

Security Holders and Voting Powers

Important Changes During the Year

Comparative Balance Sheet

Statement of Income for the Year

Statement of Retained Earnings for the Year

Statement of Changes in Financial Position

Notes to Financial Statements

Balance Sheet Supporting Schedules

Summary of Utility Plant and Accumulated Provisions for Depreciation,
Amortization, and Depletion

Nuclear Fuel Materials

Electric Plant in Service

Electric Plant Leased to Others

Electric Plant Held for Future Use

Construction Work in Progress-Electric

Construction Overheads--Electric

General Description of Construction Overhead Procedure

Accumulated Provision for Depreciation of Electric Utility Plant

Nonutility Property

Investments in Subsidiary Companies

Extraordinary Property Losses

Material and Supplies

Miscellaneous Deferred Debits

Accumulated Deferred Income Taxes (Account 190)

TABLE 3 (Continued)

Balance Sheet Supporting Schedules (Liabilities and Other Credits)

Capital Stock

Capital Stock Subscribed, Capital Stock Liability for Conversion,
Premium on Capital Stock, and Installments Received on Capital Stock

Other Paid-In Capital

Discount on Capital Stock

Capital Stock Expense

Long-Term Debt

Taxes Accrued, Prepaid and Charged During year

Reconciliation of Reported Net Income with Taxable Income for Federal
Income Taxes

Accumulated Deferred Investment Tax Credits

Other Deferred Credits

Accumulated Deferred Income Taxes--Accelerated Amortization Property

Accumulated Deferred Income Taxes--Other Property

Accumulated Deferred Income Taxes--Other

Income Account Supporting Schedules

Electric Operating Revenues

Sales of Electricity by Rate Schedules

Sales for Resale

Electric Operation and Maintenance Expenses

Number of Electric Department Employees

Purchased Power

Interchange Power

Transmission of Electricity for or by Others

Depreciation and Amortization of Electric Plant

Particulars Concerning Certain Income Deduction and Interest Charges
Accounts

Common Section

Regulatory Commission Expenses

Research, Development and Demonstration Activities

Distribution of Salaries and Wages

Common Utility Plant and Expenses

TABLE 3 (Continued)

Electric Plant Statistical Data

Electric Energy Account

Monthly Peaks and Output

Steam-Electric Generating Plant Statistics (Large Plants)

Steam-Electric Generating Plant Statistics (Large Plants) Average Annual Heat Rates and Corresponding Net Kwh Output for Most Efficient Generating Units

Hydroelectric Generating Plant Statistics (Large Plants)

Pumped Storage Generating Plant Statistics (Large Plants)

Generating Plant Statistics (Small Plants)

Changes Made or Scheduled to be Made in Generating Plant Capacities

Steam-Electric Generating Plants

Hydroelectric Generating Plants

Pumped Storage Generating Plants

Internal-Combustion Engine and Gas-Turbine Generating Plants

Transmission Line Statistics

Transmission Lines Added During Year

Substations

Electric Distribution Meters and Line Transformers

Environmental Protection Facilities

Environmental Protection Expenses

Footnote Data

Stockholders' Reports

Source: U.S. Federal Energy Regulatory Commission. FERC Form No. 1: Annual Report of Electric Utilities, Licensees and Others (Class A and Class B) OMB No. 1902-0021. Washington, December 1981. (These data are published in U.S. Department of Energy, Energy Information Administration, Statistics of Privately Owned Electric Utilities, Washington, D.C., annual.)

TABLE 4

Annual Reports from Publicly Owned Utilities Required by
the Federal Energy Regulatory Commission

Balance Sheet--End of Year
Condensed Income Statement for the Year
Electric Sales Data for the Year
Expenditures for Certain Political, Promotional, and Related Activities
Sales of Electricity for Resale
Operation and Maintenance Expenses
Purchased Power
Utility Plant
Accumulated Provisions for Depreciation of Utility Plant
Long-Term Debt
Taxes, Tax Equivalents, Contributions, and Services During Year
Large-Electric Generating Plants Using Fuel
Hydroelectric Generating Plant Statistics (Large Plants)
Large Electric Generating Plants Using Fuel
Generating Plant Statistics (Small Plants)
Steam-Electric Generating Plants
Hydroelectric Generating Plants
Internal-Combustion Engine and Gas-Turbine Generating Plants
Changes Made or Scheduled to be Made in Generating Plant Capacities
Transmission Line Statistics
Electric Energy Account
Footnote Data

Source: U.S. Department of Energy. Annual Report of Public Electric Utilities OMB No. 1905-0136. Washington, D.C., June 1982.

TABLE 5

Annual Reports on Thermal-Electric Power Plants

General Operating Characteristics

Installed maximum generator nameplate rating--MW

Generation--million kWh

Plant factor, based on nameplate rating--percent

Net peak demand on plant--MW (60 minutes)

When not limited by condenser water

When limited by condenser water

Cost of Plant

Land and land rights

Structures and improvements

Equipment

Total cost

Cost per kW of installed capacity

Production Expenses

Operating expenses

Operating supervision and engineering

Coolants and water

Steam expenses

Steam from other sources

Steam transferred (CR)

Electric expenses

Miscellaneous steam power expenses

Rents

Maintenance expenses

Maintenance supervision and engineering

Maintenance of structures

Maintenance of boiler plant

Maintenance of electric plant

Maintenance of miscellaneous steam plant

Total (exclusive of fuel)

Fuel

TOTAL PRODUCTION EXPENSES

TABLE 5 (Continued)

Fuel Used

Coal burned--1,000 short tons; cost per ton--\$
 Btu per pound; cost per million Btu--cents
 Cost per ton, as delivered F.O.B. plant--\$
 Oil burned--1,000 bbls of 42 gals; cost per bbl-\$
 Btu per gallon; cost per million Btu--cents
 Cost per barrel, as delivered F.O.B. plant--\$
 Gas burned--million cu. ft.; cost per 1,000 cu. ft.--\$
 Btu per cubic foot; cost per million Btu--cents
 Other fuel--1,000 units; cost per unit--\$
 Thousand Btu per unit; cost per million Btu--cents
 Cost per unit, as delivered F.O.B. plant--\$

Plant Characteristics

Average Btu per kWh net generation
 Plant hours connected to load
 Total number of units (exclusive of auxiliary units)
 Number of reheat units
 Reheat units--total MW
 Condensing water supply
 Average number of employees
 Type of plant construction (Conv., Semi-O.D., O.D.)
 Initial year of plant operation

Source: Energy Information Administration, U.S. Department of Energy,
Thermal-Electric Plant Construction Cost and Annual Production
Expenses--1979. Washington, D.C., DOE/EIA-0323(79), May, 1982.

TABLE 6

Securities and Exchange Commission Form 10-K Data*

	Time Period Covered
General	
Sales	Prior 3 fiscal years
Operating loss or profit	Prior 3 fiscal years
Assets for each industry segment	Prior 3 fiscal years
Narrative Description of Business	Current
Principal products and services	Current
Methods of distribution	Current
Percent of revenue attributable to any class of similar production services	Last 3 fiscal years
Company sponsored R&D	Last 3 fiscal years
Customer sponsored research	Last 3 fiscal years
Foreign and domestic operations and export sales	
Revenues	Last 3 fiscal years
Profits	Last 3 fiscal years
Assets	Last 3 fiscal years
Subsidiaries	
State or jurisdiction of incorporation	Current
Stocks	
Markets in which traded	Current
Number of holders	Current
Frequency and \$ of dividends	Current
Financial Statement	Current
Management's Discussion of Financial Condition and Results of Operations	
Liquidity	Current
Capital Resources	Current
Results of Operations	Current

Source: Federal Register, Vol. 45, pg. 63631, 1980.

The SEC also publishes guidelines or requirements for annual reports of corporations which are required to submit the 10-K filing. This requirement assures a certain uniformity in the contents of company annual reports as discussed in the next section. Table 6 shows selected information from the SEC's 10-K filing.

3.5 Annual Reports from Business Entities

Annual reports are published by both investor-owned and publicly owned utilities in this country. For investor-owned utilities which meet the requirements of the SEC for filing of data with the SEC, the SEC regulations prescribe certain items to be included in annual reports. These requirements include:

- certified financial statements
- a summary of operations
- management analysis
- description of the entity's business
- lines of business breakdown
- identification of the issuers, directors, and executive officers
- identification of the principal market in which securities are traded. (Federal Register, 1980:63631)

Annual reports are issued after the end of the company's fiscal year, which of course varies from one company to another. Thus, an advantage of the annual reports is that they are available quite soon after the end of the fiscal year, in contrast to the EIA data which is only available one to two years later. Also, more detail is provided about corporate structure at the very top level, and about lines of business and markets, than is available from other sources. On the other hand, fiscal years vary, which limits the comparability of the information looking across utilities, and little data is provided on individual power plants. Rather, the data are at the corporate level of analysis.

3.6 Commercial Data Bases

Several companies publish financial and other data on major corporations as a line of business. These publications may be in the form of manuals describing companies within a specific business sector, or in the form of machine-readable tapes. Some of these data sources include:

- Moody's manuals on utilities and on public sector entities
- Dun and Bradstreet data files on businesses
- the COMPUSTAT tapes and manuals describing large corporations published by Standard and Poor.

Other corporations may publish similar data bases; our attempt is not to be exhaustive of such data sources, but to indicate a sample of some of the well-known sources. In addition, trade journals such as Nuclear News often publish data pertaining to their particular industry. Battelle has assembled information from the Moody's data bases regarding utilities (both the utility manual and the government manuals) and from Nuclear News describing nuclear power plants. The information selected from these data bases is summarized in Tables 7 and 8. The Moody's data describes utilities. These data are compiled from a number of sources including the EIA reports, annual reports of utilities, submissions from the companies to Moodys, in addition to proxy statements and prospectuses associated with the issue of securities by these utility organizations. The Moody's manuals provide a handy reference source for investors who are seeking information about the entities issuing securities for investment purposes. They are not designed particularly for research purposes. Consequently, little attempt is made to assure the accuracy or consistency of the information compiled from different sources. Off-setting this possible lack of reliability is the timeliness of the information provided by Moody's and the other information companies. These manuals are published on a very timely basis, necessitating the use of information from a variety of sources including annual reports of corporations. Timeliness must be traded against reliability and accuracy, unfortunately, making this type of data source somewhat less accurate for research purposes. Comparisons are offered of data in the Moody's and EIA data bases for selected utilities in the next section of this paper.

Nuclear News publishes data pertaining to individual nuclear power plants. These data are quite detailed, showing the type of plant, the reactor/supplier, the generator/supplier, the architect, engineer and construction firms, and data regarding original and actual construction schedules. These detailed data regarding nuclear plants are not readily available from any other single source, although the various items of data can be found in a variety of sources including Nuclear Regulatory Commission reports and private sources such as the Atomic Industrial Forum. Hence, the Nuclear News is a handy reference for all of this information collected together in one source. However, no check has been made by Battelle HARC at this point of the accuracy and reliability of this information.

3.7 Comparison of Selected Data Items for Selected Utilities

To access the various sources of data a limited comparison of data in the Moody's and EIA data bases concerning utility companies was conducted. Three utilities were selected at random, one investor-owned utility and two publicly owned utilities. For every data item we had selected from the Moody's/Nuclear News data bases, we looked for a comparable item in the EIA data for the same year. Tables 9 through 11 summarize these comparisons. Many data items turned out to be missing in the Moody's data base, even though they were contained in the EIA data. This may be due to the need for timely publication of the Moody's manuals, as opposed to the EIA emphasis on complete data with a substantial time lag. For those variables where we had data from both sources, there were discrepancies ranging from the very small

TABLE 7

Variables in Moody's Data Base Pertaining to Utilities

Utility Identification Code
 Ownership
 Area Covered
 Population Served
 Hydroelectric Capacity
 Steam Fossil Fueled Capacity
 Internal Combustion Capacity
 Nuclear Capacity
 Gas Turbine Capacity
 Other Capacity
 Non-Nuclear Net Generation
 Nuclear Net Generation
 Residential Customers 1980
 Residential Customers 1975
 Commercial and Industrial Customers 1980
 Commercial and Industrial Customers 1975
 Residential Sales 1980
 Residential Sales 1975
 Commercial and Industrial Sales 1980
 Commercial and Industrial Sales 1975
 Sales-Other Utilities 1980
 Sales-Other Utilities 1975
 Residential Revenues 1980
 Residential Revenues 1975
 Commercial and Industrial Revenues 1980
 Commercial and Industrial Revenues 1975
 Revenues--Other Utilities 1980
 Revenues--Other Utilities 1975
 Steam--Fossil-Generated 1980
 Steam--Fossil-Generated 1975
 Hydroelectric Generated 1980
 Hydroelectric Generated 1975
 Other Generated 1980

TABLE 7 (Continued)

Other Generated 1975
 Nuclear Generated 1980
 Nuclear Generated 1975
 Electric Operations Revenue 1980
 Electric Operations Revenue 1975
 Operation and Maintenance Expenses 1980
 Operation and Maintenance Expenses 1975
 Gross Income 1980
 Gross Income 1975
 Net Income 1980
 Net Income 1975
 Total Assets 1980
 Total Assets 1975
 Residential Average Rate Per Kwh 1980
 Residential Average Rate Per Kwh 1975
 Commercial-Industrial Average Rate Per Kwh 1980
 Commercial-Industrial Average Rate Per Kwh 1975
 Operating Ratio 1980
 Operating Ratio 1975
 Percent All Debt to Depreciated Plant 1980
 Percent All Debt to Depreciated Plant 1975
 Percent Depreciation Reserve to Gross Plant 1980
 Percent Depreciation Reserve to Gross Plant 1975
 Labor Cost as Percent of Electricity Revenue 1980
 Labor Cost as Percent of Electricity Revenue 1975

Source: Moody's Public Utility Manual, Moody's Municipal and Government Manual, 1980.

TABLE 8

Nuclear News Data on Nuclear Power Plants

Plant ID Code
 First Utility ID
 Second Utility ID
 Third Utility ID
 Operational Status
 Yes
 No
 Geographical Region
 Northeast
 Midwest
 South
 Southwest
 West and Northwest
 Net Megawattage
 Type of Plant
 PWR
 BWR
 LMFBR
 LWBR
 HTGR
 LGR
 Reactor Supplier
 Combustion Engineering
 General Electric
 Westinghouse
 Babcock and Wilcox
 Allis
 Gulf Atomic

TABLE 8 (Continued)

Generator Supplier

General Electric

Westinghouse

English Electric

Allis

Brown, Boveri, et Cie

General Electroc (UK)

Architect Engineer

Bechtel

Stone and Webster

United Engineers & Constructors

Burns & Roe

Utility

Ebasco

American Electric Power Service Corp.

Fluor Power Services

Gibbs & Hill

Brown & Root

Gilbert

Sargent & Lundy

Black & Veatch

Burns & Roe-General Electric

Bechtel-Sargent & Lundy

Southern Company Services, Inc.-Bechtel

Utility-Bechtel

Southern Services-Bechtel

Constructor

Bechtel

Stone & Webster

United Engineers & Constructors

Brown & Root

TABLE 8 (Continued)

Utility
 Ebasco
 American Electric Power Service
 Fluor Power Services
 Gibbs & Hill
 Brown & Root
 WEDCO (a subsidiary of Westinghouse)
 Kaiser
 Maxon
 Daniel
 Baldwin
 Braun
 Jones
 General Atomic
 Independent
 Duquesne Light Co.-Stone & Webster
 Construction Stage
 Original Schedule Month Complete
 Original Schedule Year Complete
 Actual or Expected Month Complete
 Actual or Expected Year Complete

TABLE 9
Baltimore Gas and Electric

Variable		Source of Data		Discrepancy	
		EIA ¹	Moody's ²	Absolute ³	Percentage ⁴
Ownership	1980	Private	Private		
Area, sq. mi.	1980		2,000		
Population	1980		2,271,000		
Hydroelectric Capacity, Kw	1980				
Steam Capacity, Kw	1980	2,663,920	2,506,000	157,920	6%
Internal Combustion Capacity, Kw	1980	3,460	3,000	460	13%-15%
Nuclear Capacity, Kw	1980	1,828,000	1,635,000	193,000	11%-12%
Gas Turbine Capacity, Kw	1980	753,500	717,000	36,500	5%
Other Capacity, Kw	1980				
Non-nuclear Net-Generation, Kwh	1980	8,537,994,000	8,537,994,000		
Nuclear Net-Generation, Kwh	1980	10,946,911,000	10,946,911,000		
Number Residential Customers	1980 1975	754,812	755,000 692,000	-188	.02%
Number Commercial and Industrial Customers	1980 1975	76,289	76,000 72,000	289	.38%

TABLE 9 (Continued)
Baltimore Gas and Electric

Variable		Source of Data		Discrepancy	
		EIA ¹	Moody's ²	Absolute ³	Percentage ⁴
Residential					
Sales	1980	6,005,110	6,005,000	110	.002%
Thousand Kwh	1975		4,664,000		
Commercial and Industrial					
Sales	1980	10,895,534	10,896,000	-466	.004%
Thousand Kwh	1975		8,881,000		
Other Sales					
Utilities	1980				
Thousand Kwh	1975				
Residential	1980	342,795,972	342,796,000	-28	0%
Revenues \$	1975		198,303,000		
Commercial and Industrial	1980	487,816,844	487,817,000	-156	0%
Revenues \$	1975		299,957,000		
Other					
Utilities	1980				
Revenues \$	1975				
Steam-Fossil					
Generation	1980	8,164,510			
Thousand Kwh	1975				
Hydro					
Generation	1980				
Thousand Kwh	1975				
Other					
Generation	1980	373,484			
Thousand Kwh	1975				
Nuclear					
Generation	1980	10,946,911	10,947,000	-89	0%
Thousand Kwh	1975				
Electric					
Operation	1980	857,263,985	857,000,000	263,985	.03%
Revenue \$	1975		516,000,000		

TABLE 9 (Continued)

Baltimore Gas and Electric

Variable	Source of Data		Discrepancy	
		EIA ¹	Moody's ²	Absolute ³ Percentage ⁴
Operating and Maintenance Expenses \$	1980 1975	465,310,108	465,000,000 179,000,000	310,108 .07%
Gross Income \$	1980 1975	225,223,032	221,000,000 153,000,000	4,223,032 1.9%
Net Income \$	1980 1975	139,399,371	139,000,000 93,000,000	399,371 .29%
Total Assets \$	1980 1975	3,091,646,584	3,073,000,000 2,187,000,000	18,646,584 .60%
Resid-Avg. Rate Cents per Kwh	1980 1975		6 4	
Commercial-Industrial Average Rate Cents per Hwh	1980 1975		5 4	
Operating Ratio	1980 1975		77 82	
% Debt to Depreciated Plant	1980 1975	49		
% Depreciated Reserve to Gross Plant	1980 1975		15 14	
Labor Cost % of Elec. Revenue	1980 1975		14 12	
Total Kw Generating Capacity	1980	5,248,880	4,858,000	390,880 7%-8%
Nuclear Kwh Generating Capacity	1980	1,828,000	1,635,000	193,000 10.5%-12%

TABLE 9 (Continued)

Baltimore Gas and Electric

Variable	Source of Data		Discrepancy	
	EIA ¹	Moody's ²	Absolute ³	Percentage ⁴
Nonnuclear Kw Generating Capacity	1980 3,420,880	3,223,000	197,880	6%

¹Compiled from U.S. Federal Energy Regulatory Commission. FERC Form No. 1: Annual Report of Electric Utilities, Licensees and Others (Class A and Class B) OMB No. 1902-0021. Washington, December 1981; U.S. Department of Energy. Annual Report of Public Electric Utilities OMB No. 1905-0136. Washington, D.C., June 1982; and Energy Information Administration, U.S. Department of Energy, Thermal-Electric Plant Construction Cost and Annual Production Expenses--1979. Washington, D.C., DOE/EIA-0323(79), May, 1982.

²Moody's Public Utility Manual, Moody's Municipal and Government Manual, 1980.

³EIA value minus Moody's Value.

⁴(EIA value - Moody's value)/EIA value.

TABLE 10
Nebraska Public Power District

Variable	Source of Data		Discrepancy	
	EIA ¹	Moody's ²	Absolute ³	Percentage ⁴
Ownership	1980	Public		
Area, sq. mi.	1980			
Population	1980			
Hydroelectric Capacity, Kw	1980	32,868		
Steam Capacity, Kw	1980	392,725		
Internal Combustion Capacity, Kw	1980	122,933		
Nuclear Capacity, Kw	1980	801,000		
Gas Turbine Capacity, Kw	1980			
Other Capacity, Kw	1980			
Non-nuclear Net-Generation, Kwh	1980	716,772,000		
Nuclear Net-Generation, Kwh	1980	3,853,630,000		
Number Residential Customers	1980 1975	84,163 77,767	79,000	5,163 6%
Number Commercial and Industrial Customers	1980 1975	20,127 18,330	18,000	2,217 11%-12%

TABLE 10 (Continued)

Nebraska Public Power District

Variable	Source of Data		Discrepancy	
	EIA ¹	Moodys ²	Absolute ³	Percentage ⁴
Residential				
Sales Thousand 1980	748,916	678,000		
Kwh 1975	639,741			
Commercial and Industrial				
Sales Thousand 1980	1,291,967	1,195,000		
Kwh 1975	924,564			
Other Sales				
Utilities 1980	-12,241,475			
Thousand Kwh 1975	8,652,412			
Residential 1980	36,548,225	28,649,000	7,899,225	22%-28%
Revenues \$ 1975	17,757,641			
Commercial and Industrial 1980	44,896,648	38,634,000	6,262,648	14%-16%
Revenues \$ 1975	19,828,743			
Other				
Utilities 1980	286,300,898			
Revenues \$ 1975	109,014,612			
Steam-Fossil				
Generation 1980	4,116,389			
Thousand Kwh 1975	1,564,060			
Hydro				
Generation 1980	144,316			
Thousand Kwh 1975	109,956			
Other				
Generation 1980	1,937			
Thousand Kwh 1975	42,756			
Nuclear				
Generation 1980	3,788,053			
Thousand Kwh 1975	3,853,630			
Electric				
Operation 1980	377,128,779			
Revenue \$ 1975	151,668,701			

TABLE 10 (Continued)

Nebraska Public Power District

Variable	Source of Data		Discrepancy	
	EIA ¹	Moody's ²	Absolute ³	Percentage ⁴
Operating and Maintenance Expenses \$	1980 295,107,872 1975 107,674,272			
Gross Income \$	1980 75,591,739 1975 32,586,827			
Net Income \$	1980 -10,155,620 1975 2,459,645			
Total Assets \$	1980 2,124,772,870 1975 1,081,693,446			
Residential Average Rate Cents per Kwh	1980 1975			
Commercial-Industrial Average Rate Cents per Hwh	1980 1975			
Operating Ratio	1980 1975			
% Debt to Depreciated Plant	1980 125 1975 113			
% Depreciated Reserve to Gross Plant	1980 12.5 1975 15.8			
Labor Cost % of Elec. Revenue	1980 1975			
Total Kw Generating* Capacity	1,349,526			

TABLE 10 (Continued)

Nebraska Public Power District

Variable	Source of Data		Discrepancy	
	EIA ¹	Moody's ²	Absolute ³	Percentage ⁴
Nuclear Kwh Generating* Capacity 1980	801,000	400,000	401,000	50%-100%
Nonnuclear Kw* Generating Capacity 1980	548,526			

*These figures are different for 1980; utility sold some hydro plants and bought some steam plants.

¹Compiled from U.S. Federal Energy Regulatory Commission. FERC Form No. 1: Annual Report of Electric Utilities, Licensees and Others (Class A and Class B) OMB No. 1902-0021. Washington, December 1981; U.S. Department of Energy. Annual Report of Public Electric Utilities OMB No. 1905-0136. Washington, D.C., June 1982; and Energy Information Administration, U.S. Department of Energy, Thermal-Electric Plant Construction Cost and Annual Production Expenses--1979. Washington, D.C., DOE/EIA-0323(79), May, 1982.

²Moody's Public Utility Manual, Moody's Municipal and Government Manual, 1980.

³EIA name minus Moody's Value.

⁴(EIA value - Moody's value)/EIA value.

TABLE 11

Power Authority of the State of New York

Variable	Source of Data		Discrepancy	
	EIA ¹	Moodys ²	Absolute ³	Percentage ⁴
Ownership	1980	Public	Public	
Area, sq. mi.	1980			
Population	1980			
Hydroelectric Capacity, Kw	1980	4,102,000		
Steam Capacity, Kw	1980			
Internal Combustion Capacity, Kw	1980			
Nuclear Capacity, Kw	1980	821,000		
Gas Turbine Capacity, Kw	1980			
Other Capacity, Kw	1980			
Non-nuclear Net-Generation	1980	24,433,232,000		
Kwh	1975	2,116,576,000		
Nuclear Net-Generation, Kwh	1980			
1980 Number Residential Customers	1980			
	1975			
1980 Number Commercial and Industrial Customers	1980	12		
	1975	14		

TABLE 11 (Continued)

Power Authority of the State of New York

Variable	Source of Data		Discrepancy	
	EIA ¹	Moodys ²	Absolute ³	Percentage ⁴
1980 Residential Sales Thousand Kwh	1980 1975			
1980 Commercial and Industrial Sales Thousand Kwh	1980 1975	9,827,748 4,618,703		
1980 Other Sales Utilities Thousand Kwh	1980 1975	29,359,629 21,705,728		
1980 Residential Revenues \$	1980 1975			
1980 Commercial and Industrial Revenues \$	1980 1975	68,347,520 18,080,902		
1980 Other Utilities Revenues \$	1980 1975	422,871,736 116,698,924		
1980 Steam-Fossil Generation Thousand Kwh	1980 1975	2,932,128		
1980 Hydro Generation Thousand Kwh	1980 1975	23,029,223 24,433,232		
1980 Other Generation Thousand Kwh	1980 1975			
1980 Nuclear Generation Thousand Kwh	1980 1975	7,412,020 2,116,576		

TABLE 11 (Continued)

Power Authority of the State of New York

Variable		Source of Data		Discrepancy	
		EIA ¹	Moody's ²	Absolute ³	Percentage ⁴
1980 Electric Operation Revenue \$	1980 1975	927,189,724 143,363,169			
1980 Operating and Maintenance Expenses \$	1980 1975	635,849,000 38,910,348	102,864,000 29,250,000	532,985,000 9,660,000	84% 25%-33%
1980 Gross Income \$	1980 1975	347,788,724 116,820,815			
1980 Net Income \$	1980 1975	0 a 0 a			
1980 Total Assets \$	1980 1975	2,755,160,121 2,755,160,121	4,072,566,000 2,755,159,000	191,317,000 1,121	4%-5% 0%
1980 Residential-Average Rate Cents per Kwh	1980 1975				
1980 Commercial-Industrial Average Rate Cents per Hwh	1980 1975				
1980 Operating Ratio	1980 1975				
1980 % Debt to Depreciated Plant	1980 1975	75 142			
1980 % Depreciated Reserve to Gross Plant	1980 1975	0 b 0 b			
1980 Labor Cost % of Elec. Revenue	1980 1975				

TABLE 11 (Continued)
Power Authority of the State of New York

Variable	Source of Data		Discrepancy	
	EIA ¹	Moody's ²	Absolute ³	Percentage ⁴
Total Kw Generating* Capacity 1980	4,923,000 c			
Nuclear Kwh Generating* Capacity 1980	821,000 c	400,000	401,000	50%-100%
Nonnuclear Kw* Generating Capacity 1980	4,102,000 c			

¹Compiled from U.S. Federal Energy Regulatory Commission. FERC Form No. 1: Annual Report of Electric Utilities, Licensees and Others (Class A and Class B) OMB No. 1902-0021. Washington, December 1981; U.S. Department of Energy. Annual Report of Public Electric Utilities OMB No. 1905-0136. Washington, D.C., June 1982; and Energy Information Administration, U.S. Department of Energy, Thermal-Electric Plant Construction Cost and Annual Production Expenses--1979. Washington, D.C., DOE/EIA-0323(79), May, 1982.

²Moody's Public Utility Manual, Moody's Municipal and Government Manual, 1980.

³EIA name minus Moody's Value.

⁴(EIA value - Moody's value)/EIA value.

^aNo profit or surplus has resulted from operations that power authority act limits authority revenues to those amounts required for operation and maintenance, debt amortization and necessary reserves.

^bGeneral revenue bond resolution provides that no provision shall be made for depreciation, amortization or similar changes.

^c1975.

to the very large. No pattern is apparent for these discrepancies if one looks across the different data items for a particular utility, or across utilities shown in the four tables. It would appear that the requirement of timeliness in the Moody's manuals results in a substantial price in terms of accuracy. The other possible conclusion is that both data sources are subject to random error, and neither should be believed. The project was terminated before data from other sources could be analyzed.

The nature of the EIA data collection process suggests it is more reliable than Moody's. The EIA data result from legal requirements for data submission. Any deliberate distortions or incompleteness could result in imposition of sanctions. Furthermore, EIA makes an attempt where possible to cross check these data submission against other submissions. A good procedure would be to compare Moody's data against annual reports from the utilities themselves if data from a very recent time period is required. EIA data should also be compared to annual reports when possible and any discrepancies resolved through discussions with the utility.

3.8 Conclusions

Glueck and Willis (1979) conclude that the use of documentary evidence for research purposes has three dangers: bias due to the design of the information system which generated the data, clerical error due to many transformations of the data, and deliberate distortion by an individual or organization to further its own ends. They also note that commercial data bases have serious reliability problems,⁴ whereas regulatory data may be more accurate due to the legal circumstances surrounding their collection.

To that list of conclusions, we can add the following. Reliability is a serious question in the specific case of the utility industry, and here as elsewhere the regulatory data are most likely to provide completeness and reliability. On the other hand, timeliness is a problem with regulatory data. Automation of EIA databases is providing a substantial improvement on this score.

For research purposes, the EIA files backed up, and cross-checked against SEC 10-K submissions and annual reports from the utilities, are all likely to be required to develop an accurate and complete data base regarding utility management and organization.

⁴Glueck and Willis reference problems with COMPUSTAT which sound similar to the problems we experienced with Moody's and Dun & Bradstreet data. Thus the problem is generic and relates to the data collection procedures and goals of these commercial services. These comments are in no way meant as indictments of these services. These machine readable data bases serve business purposes, and within certain limits, research purposes.

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CHAPTER 6

EXISTING SAFETY INDICATORS: A CRITICAL ANALYSIS

1. INTRODUCTION

The objective evaluation of the safety implications of utility and plant organization requires a set of criterion indicators of plant safety. These criterion indicators are necessary to analyze the safety performance of plants with differing organizational characteristics. Such an analysis would identify those aspects of a utility's organization which are or are not associated with plant safety. Without these criterion indicators, any NRC evaluation of the organizational factor of licensees will be based on subjective criteria such as professional judgment, operating experience, or a passive acceptance of current practice. A successful development of criterion indicators will make it possible to identify those organizational characteristics which are associated with safety (and, therefore, demand further attention) as well as those organization characteristics which are not related to safety.

However, a finding of "no relationship" cannot, by itself, be taken as justification for the NRC to ignore a particular factor. The true relationship may be obscured by other unobserved factors not included in the analysis. Consequently, this empirical approach, like all statistical analyses, cannot be based solely on the examination of associations. In order to correctly pose the right questions and interpret both the presence and absence of empirical association, the analysis must be embedded in organization theory.

This chapter describes the results of an evaluation of existing plant safety indicators to determine their utility as criterion measures in the assessment of the safety implication of current organizational conditions. As a first step in this effort, attention is focused on existing data in order to determine if adequate indicators of one or more dimensions of plant safety can be developed from existing (primarily public) data. Each of the potential indicators is evaluated on the basis of the following five factors:

- (1) the extent to which the indicator is reliable (e.g. repeated measurements would produce the same results)
- (2) the extent to which the indicator is readily available in a form suitable for analysis
- (3) the extent to which the indicator is valid (i.e., a specific dimension of plant safety is actually measured by the indicator)
- (4) the extent to which the indicator is objective (i.e., not affected by bias from differential interpretation and/or perception)

- (5) the extent to which the indicator is conceptually distinct from the predictor variables (indicators of safety that are influenced by measured aspects of organization will lead to tautological arguments and, therefore, must be avoided).

Before considering each of the evaluated indicators in detail, Table 1 provides a brief overview of the entire set of indicators along with a summary of the conclusions regarding the indicator's standing on each of these five factors. It is important to note that these evaluations concern the use of the indicator as a source of plant safety information in a statistical analysis. None of the indicators were specifically developed for that purpose. Consequently, the following evaluation says little about the indicator's ability to perform the function for which it was originally designed.

A five point scale was used to reflect the judgments regarding each indicator's standing on the five factors. A 1 in Table 1 means that the indicator is judged to be completely acceptable in its current form on the relevant factor. A 5 represents the conclusion that the indicator is unacceptable on the factor even after all feasible and realistic adjustments. Values 2 through 4 represent intermediate levels of acceptability. A 2 means that the indicator is acceptable with minor modifications, a 3 means the indicator has significant weaknesses but may be adequate with adjustments, and a 4 means the indicator is only marginally acceptable with major modifications.

The judgments summarized in Table 1 will be discussed in detail in the following sections. However, several preliminary comments can be made at this point. First, the summary column indicates that no single measure is considered adequate by itself. This should not be interpreted to mean that no empirical indicators of plant safety can be developed. As will be demonstrated in subsequent sections, the weaknesses of some indicators are strengths of other indicators which raises the possibility of a multiple indicator approach.

Three indicators were assigned an "unacceptable" summary evaluation: operator exam scores, liability insurance data, and Institute of Nuclear Power Operations (INPO) plant evaluations. The rationale for this assessment is provided in subsequent sections, but because of this assessment they are not discussed in as much detail as the other indicators. In addition, the personnel exposure and effluent release data are not given lengthy treatment because non-trivial variations in either exposure or release data are recorded in Licensee Event Reports (LERs), or in Inspection and Enforcement Reports.

The indicators receiving major attention in this report are LERs, Inspection and Enforcement Reports, Operating Reports, SALP reports and a potential survey of I & E staff. Each of these are discussed in the subsequent sections. Following the evaluation of each of the indicators, a procedure for combining several indicators to create an index of plant safety is described.

TABLE 1
SUMMARY OF THE EVALUATIONS OF PLANT SAFETY INDICATORS

<u>Indicators</u>	<u>Reliability</u>	<u>Availability</u>	<u>Validity</u>	<u>Objectivity</u>	<u>Conceptual Distinctness</u>	<u>Summary Evaluation</u>
Licensee Event Reports	2	2	3	4	3	3
Inspection & Enforcement Data	1	1	3	3	2	2
Operating & Outage Data	1	1	3	2	3	2
Systematic Assessment of Licensee Performance (SALP)	3	2	3	3	3	3
I&E Staff	3	5	3	4	2	3
Personnel Exposure Data	1	1	3	3	3	3
Effluent Release Data	2	2	2	2	2	2
Operator Exam Scores	3	3	4	3	5	5
Liability Insurance Risk Assessments	3	5	3	3	3	5
INPO Plant Evaluations	4	3	4	4	5	5

The values in Table 1 represent evaluations of the indicator on each factor and an overall summary evaluation. A "1" represents the best evaluation and a "5" represents the worst. See text for definitions.

1.1 Licensee Event Reports (LERs)

The most commonly used source of information regarding plant performance is the Licensee Event Report (LER). LERs are filed by utilities to the NRC in compliance with the plant's Technical Specifications and in compliance with NRC regulations. Approximately 5,000 LERs are currently reported each year by power plant licensees. Most LERs are based on violations of technical specifications, but others reflect an event that may have potential public interest. The primary reference concerning LER requirements is "Regulatory Guide 1.16, Reporting and Operating Information -- Appendix A Technical Specifications."

The Office of Management and Program Analysis is responsible for the entry of LERs to a computer file. The Nuclear Safety Information Center (NSIC) at Oak Ridge also maintains a computer file. The files contain data on the date of event, the system and components involved, and the cause of the event. There is also a brief written description (504 characters) of the event. This text is entered into the LER computer file verbatim. When an event can not be fully described in 504 characters, additional text is added to the LER form and filed with the NRC. However, only the 504 character text is recorded in machine readable form. Efforts at Oak Ridge to standardize the words used in this 504 character field have made it somewhat easier to search this field for key words. However, current access via data sets such as the Oak Ridge RECON system is still difficult when the objective is to create a coded data file for statistical analyses.

Some effort is made to check the computer version of the LER file against the written versions. These efforts include a mechanized audit check and a second manual check by NRC personnel of the coded LER form against the written description that accompanies practically all LERs. This check insures that all data are on the LER form and that there is a reasonable match between the attached description and the 504 character description in the LER file.

There are two separate categories of LERs: those requiring 24 hour notice and 14 day follow-up (two week LERs), and those requiring a 30 day written report only. These two LER types are meant to distinguish between those events with major safety significance versus those with lesser significance. About 20% of all LERs are the more significant two week type.

The following are summaries of reportable occurrences which require prompt notification and submittal of a report within two weeks:

- (1) Failure of reactor protection system.
- (2) Operation of unit when any parameter exceeds the least conservative limit established in the technical specifications.
- (3) Abnormal degradation in fuel cladding, reactor coolant boundary, or primary containment.

- (4) Reactivity anomalies such as reactivity imbalance.
- (5) Failure or malfunction of a component that adversely affects a system used to cope with accidents analyzed in the FSAR.
- (6) Personnel error that adversely affects a system used to cope with accidents.
- (7) Conditions arising from natural or man-made events that require plant shutdown.
- (8) Errors in the transient or accident analyses.
- (9) Performance of structures, systems or components that require immediate action to conform to technical specifications or safety analysis report.

The less significant reportable occurrences listed below require submittal of a report within 30 days:

- (1) Reactor protection system or engineered safety feature instrument settings less conservative than technical specifications but not preventing functional requirements of affected systems.
- (2) Conditions leading to operation in a degraded mode (redundant system or conditions ok).
- (3) Inadequate administrative or procedural controls that threaten to cause reduction in redundancy.
- (4) Abnormal degradation of systems designed to contain radioactive material except those mentioned in (3) above.

An apparent distinction between the two LER types is that the events requiring more immediate reporting are those involving a safety-related system becoming nonoperational or a condition requiring plant shutdown. Events requiring a report within 30 days appear to be those in which the event causes less than optimal operation of a system for which a redundant system could substitute.

Events of potential public interest also require nonroutine reporting. The following list of events, while not classified as reportable occurrences, require telephone notification to the NRC Regional Office as soon as possible:

- (1) Event that causes damage to property or equipment and thus affects the power production capability of the facility.
- (2) Radiation exposure to licensee personnel or public in excess of limits set forth in 10 CFR Part 20.
- (3) Natural or man-made conditions that may require action but are not otherwise reported.

- (4) Unscheduled shutdowns expected to last for more than one week.
- (6) Unusual release of radioactive material from site boundary not reported under other requirements.
- (7) Failure or damage to safety-related equipment not otherwise reported and if time for repair exceeds time allowed by Tech Specs.

Instructions for completing the LER form were revised in 1977 to add cause sub-codes and sub-codes for some components. Codes were also added to describe actions to be taken in the future, effect on the plant, the method (if any) used to shut down the plant, and the length of time the plant was shut down.

A sample LER form is displayed in Figure 1. Item 12 of the LER form provides a space for the utility to enter a cause code. Item 13 provides cause subcodes. There are six cause codes covering the following:

- (1) personnel error
- (2) design manufacturing construction/installation
- (3) external causes
- (4) defective procedures
- (5) component failure
- (6) other causes.

The cause subcode defines the cause more specifically when the approximate cause of the event is personnel error, design, manufacturing, construction/installation or component failure. Most licensees began using the new codes at the beginning of 1978.

The NRC's Office for Analysis and Evaluation of Operational Data is currently developing a new computer file for LER data called the Sequence Coding and Search System. Their system provides coded technical information drawn from the LER making it possible to examine trends, patterns, and statistical associations far more effectively than is possible with existing computer files. The system is described in a paper by Hebdon (1982) but is not yet completed.

LERs have been heavily analyzed for a wide range of purposes. For example, the Institute of Nuclear Power Operations (INPO) screens LERs for safety significance and then alerts member utilities of the event. INPO also initiates an investigation of particularly significant events which include LER trend analyses and searches for patterns of LER recurrence. The Advisory Committee on Reactor Safeguards (ACRS) advocates the use of LERs by the NRC to share event experience among utilities (as INPO does) and to subject LERs to "lessons learned" analyses.

LERs have also served as one of the major sources of information in evaluations of plant safety performance. The use of LERs in this capacity is the subject of much debate, not only because of the political implications of any plant evaluation or "rating," but also because of many legitimate concerns regarding the validity of LERs as an indicator of safe

LER Form

JNC FORM 34
 (7-71)

U. S. NUCLEAR REGULATORY COMMISSION

LICENSEE EVENT REPORT

CONTROL BLOCK: _____ (1)

PLEASE PRINT OR TYPE ALL REQUIRED INFORMATION

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99

LICENSEE CODE (1) LICENSE NUMBER (3) LICENSE TYPE (4) CAT (5)

COMT

REPORT SOURCE (6) DOCKET NUMBER (7) EVENT DATE (8) REPORT DATE (9)

EVENT DESCRIPTION AND PROBABLE CONSEQUENCES (10)

(0 3) _____

(0 3) _____

(0 4) _____

(0 5) _____

(0 6) _____

(0 7) _____

(0 8) _____

SYSTEM CODE (11) CAUSE CODE (12) CAUSE SUBCODE (13) COMPONENT CODE (14) COMP. SUBCODE (15) VALVE SUBCODE (16)

EVENT YEAR (17) SEQUENTIAL REPORT NO. (18) OCCURRENCE CODE (19) REPORT TYPE (20) REVISION NO. (21)

LEAK REPORT NUMBER (22) ACTION TAKEN (23) FUTURE ACTION (24) EFFECT ON PLANT (25) SHUT DOWN METHOD (26) HOURS (27) ATTACHMENT SUBMITTED (28) NRC-1 FORM SUB. (29) PRIME COMP. SUPPLIER (30) COMPONENT MANUFACTURER (31)

CAUSE DESCRIPTION AND CORRECTIVE ACTIONS (32)

(1 0) _____

(1 1) _____

(1 7) _____

(1 2) _____

(1 8) _____

FACILITY STATUS (33) S. POWER (34) OTHER STATUS (35) METHOD OF DISCOVERY (36) DISCOVERY DESCRIPTION (37)

ACTIVITY CONTENT RELEASED OR RELEASE (38) AMOUNT OF ACTIVITY (39) LOCATION OF RELEASE (40)

PERSONNEL EXPOSURES NUMBER (41) TYPE (42) DESCRIPTION (43)

PERSONNEL PLUMES NUMBER (44) DESCRIPTION (45)

LOSS OF OR DAMAGE TO FACILITY TYPE (46) DESCRIPTION (47)

PUBLICITY ISSUED (48) DESCRIPTION (49)

NRC USE ONLY

NAME OF PREPARER _____ PHONE: _____

operation. These issues are of central concern to this effort. Consequently, the following section considers the major findings of studies evaluating the analysis of LERs to assess plant safety.

ACRS undertook an analysis of LERs which occurred between 1976 and 1978 with the objective of evaluating their ability to serve as a safety indicator. The major focus of the study was a component specific analysis to determine if problematic components could be identified. ACRS divided the LERs into the following components:

- (1) Instrumentation and Controls
- (2) Reactor Cooling System
- (3) Electric Power Systems
- (4) Engineered Safety Features
- (5) Steam and Power Conversion Systems
- (6) Diesel Generators
- (7) Boron Control Systems
- (8) Valves, Pumps and Seals
- (9) AC Power Supplies
- (10) DC Power Supplies
- (11) Containment Systems
- (12) Radioactive Waste Management Systems.

The majority of the report involves the findings of an in-depth study of a select number of LERs divided into these twelve components. An important finding of the study was that there were deficiencies in the reporting system as well as in the procedures under which the data were recorded in the computer files. The ACRS report also points out that the nuclear industry is not using the experience available in the LER data. Consequently, failures that occur in a single plant are repeated elsewhere as well as at the same plant.

The ACRS report emphasized that the NRC should spend some time developing a more uniformly positive attitude among utilities towards submitting LERs. Such a positive attitude would, in the opinion of the ACRS staff, result in increased safety and the ability to use LERs for "lessons learned" approaches. This may well be one of the reasons that the NRC is reluctant to encourage the use of LERs to evaluate plant performance. If utilities know that they are being rated on the basis of number of LERs, this will clearly influence the probability of their submission.

In addition to the component specific analysis, the ACRS study also contains a "statistical analysis" of the 8,700 LERs which were submitted between 1976 and 1978. This analysis involved a simple counting of LERs to determine whether or not the number of LERs exceeded that which one would have expected by chance. LERs from 67 nuclear power plants were reviewed. These were divided into PWRs (42) and BWRs (25), and each of these groups were further subdivided into "older" and "newer" plants. Older plants were defined as those that went into operation prior to 1976. The LERs themselves were divided into those which were required to have been reported within two weeks and those for which there was a 30 day reporting period.

Finally, the LERs were divided according to the system to which they pertained.

The findings indicated that during the three year period, five units among the 29 old PWRs had significantly different numbers of two week LERs than most old PWRs. Calvert Cliffs I, Palisades, Rancho Seco, and Three Mile Island I were high. Maine Yankee was low. The remaining 24 PWRs were "average" in the number of two week LERs. For the same 29 old PWRs considered year by year, the data indicated a gradual decrease in each year of the total number of two week LERs. The averages were 10 per unit in 1976, six per unit in 1977 and four per unit in 1978. Significant deviations occurred at Calvert Cliffs I in 1977, Palisades in 1977 and 1978, Point Beach in 1978, Rancho Seco in 1977, and Three Mile Island I in 1978. Maine Yankee had a rate in 1976 significantly lower than normal. Thus, the high three year totals for the units analyzed over the three year period were basically due to high rates in just one of the three years.

Further analysis showed that the high number of two week LERs among the four older PWRs was attributable to abnormally high numbers of LERs concerning specific systems. Calvert Cliffs had problems in the electric power systems and reactor systems. Palisades had high totals for the same two systems and, in addition, engineered safety features were a problem. Rancho Seco reported a high total for electric power systems. Three Mile Island I had high totals for radiation protection systems and for events classed as "systems not applicable." Many of the electrical power systems LERs were related to off-site power systems and to emergency diesel generators.

Among the older PWRs with normal yearly totals for the two week LERs, some had significantly higher LERs for specific systems. For example, the reactor system when analyzed by itself showed higher than normal level LERs at Arkansas Nuclear I, Oconee II and III, and Robinson II. Zion I was higher than normal for radiation and protection systems. There are other examples such as these.

ACRS staff found it possible to group PWRs into three groups on the basis of how many 30 day LERs they reported but there were not statistically significant differences among them. Units that were in a high or low reporting subgroup for the three year period generally tended to remain in the same subgroup when the analysis was conducted by single year. The exceptions were Yankee Rowe which was in a higher reporting group in 1977 but in a lower reporting group in the other two years, and Surrey I and II which were in the lower reporting subgroup during the first two years but in the higher subgroup in 1978. Units tended to remain in the lowest reporting subgroups but to increase their reporting rates for 30 day LERs from year to year. The sum of their 30 day and two week LERs, however, remain essentially constant in time since the two week LER total steadily decreased during the same three year period. Large units of 1,000 megawatts or more reported higher numbers of 30 day LERs except when the plant operating capacity for the year was low, i.e., less than one-third.

Among the 22 older BWRs, eight units deviated from the normal range of two week LERs. Two had lower rates than normal, and six had higher rates than

normal. Hatch I reported two week LERs at a high rate for each of the three years.

Another study of LERs as a potential source of plant safety information was conducted by L. M. Potash. His research involved an analysis of LERs occurring between November 1, 1977 and October 30, 1978. (Note that this period overlaps the major changes that took place in the LER form.) Potash analyzed data from 52 power plants, all of which were operating at least 50% during the time period. He also analyzed BWRs and PWRs separately and made a distinction between two week and 30 day LERs. He also selected LERs with "human error" cause codes for separate analyses.

About 20% of all LERs are Human Error LERs (HELERS), and most HELERS are due to errors committed by licensed operators, senior operators, or maintenance/repair personnel. Most HELERS were events that took place when the reactor was in a normal steady state of operation. Plants were rated consistently from one year to the next when the rating criteria was number of HELERS.

The correlation between the number of HELERS in year one with a number of HELERS in year two was .76 for both BWRs and PWRs. Potash found that the underlying cause for about 65% of the HELERS remains unknown. BWRs produced more HELERS than PWRs and newer, larger plants produced more HELERS and LERs than smaller, older plants. The percentage of the more serious HELERS (two week HELERS) was lower for the newer plants than for the older plants. About 30% of LERs filed from PWR plants are the two week reports. About 20% of the BWR plant LERs are of the two week variety. (This percentage refers to the proportion of all HELERS which are serious HELERS.) Vendor does have an effect on the percentage of two week HELER reports.

Another report prepared by Teknekron (NUREG/CR-0110), dated October 1978, involves an analysis of LERs from the perspective of Teknekron's FPM model. The FPM model refers to the conceptualization of the utility as an interaction among Facility (F), Personnel (P), and Management (M). This FPM model was applied to three licensees: Zion Unit I, Point Beach Unit I, and Prairie Island Unit I. These three case studies were selected in order to eliminate regional bias and to prevent the possible bias of vendor comparisons. All three of these facilities have been operating for more than two years and, thus, were not subject to a learning curve effect. Finally, it was decided to study facilities perceived by the NRC as both below and above average.

The Teknekron report reinforces the point that the most problematic concern regarding the quality of LER data involves differences in how licensees report events. The primary problem in utilizing LERs to assist plant performance is the fact that LERs are generated by the utility. Consequently, whether or not an LER is submitted, the completeness of the report and the attributed cause of the report are subject to wide variation from one utility to another. According to Teknekron, NRC personnel generally feel that licensee reporting of events is not uniform. For example, some individuals feel that personnel errors are reported as component failures because component failure looks better than human error.

Another frequently cited problem is the relationship between technical specifications and the number of LERs. Teknekron indicates that conversations with licensees lead them to characterize some as following a policy of "if in doubt, file an LER", while others report only events that clearly must be reported. Those with a good corporate attitude who cooperated with the NRC and who have a systematic approach to detecting and identifying occurrences, probably do file more LERs. But those same conversations with Licensees lead Teknekron to believe that all Licensees report to the baseline of clearly reportable events. This category is sufficient to form a base on which to compare licensees. The content of LERs in a grey area often shows that immediate steps are taken to correct a problem or that a number of the events are unrelated.

1.2 Conclusions

While variations in the number of LERs may be indicative of actual differences in safety, there are also other possible explanations. It is important to understand these other sources of variation in the number of LERs so they can be statistically controlled. These other sources include the following:

- (1) Technical specifications and license provisions vary among nuclear power plant facilities. These variations cause differences in the reporting requirements.
- (2) There may be a tendency at some facilities to report events more readily than others. This tendency can also change with time.
- (3) The occurrence of an event may affect the probability of a future event. The repair of a component may decrease the likelihood of an associated event. On the other hand, an ineffective action following an event may result in repeated occurrence.
- (4) The mode of operation (e.g. on-line or in a shut-down) influences the susceptibility of the systems to LER events. The amount of downtime may affect the frequency of LERs.
- (5) When doing comparisons between units at the same facility, LERs which involve generic plant systems or components common to all units are reported by the NRC under the docket number of the first unit.

A recurring issue in studies of LERs is whether or not to adjust LER data for age and size. The issue is that adjusting raw LER data for age and size may mask the actual "unsafety" of newer, larger plants. In other words, new or larger plants may indeed be less safe and, consequently, the number of LERs should be larger. Potash argues that this conclusion is not warranted at this time because unless one controls for size, the opportunity for occurrence is not controlled. If it were possible to calculate a rate or to normalize the results for opportunity, it would still be difficult to know whether rates represent differences in safety significance.

More analysis could be done with the LER data. In particular, an indepth study of the full written account of the event could be performed to identify causally linked events. This approach, suggested by Teknekron, attempts to find events that occurred because the cause of a previous event was not adequately resolved. Counts of these events and the amount of time between them have been used to assess management effectiveness in recent SALP reports (e.g. Rancho Seco SALP Report 6/80-6/81 dated April 13, 1982). This intensive study of LERs may well be the optional approach but it would require substantial resources for a study of the entire industry.

In spite of the wide range of problems confronting the use of LER data as an indicator of performance, there is a great deal of potential for properly adjusted LER data to make a valuable contribution to an indicator of performance. The required adjustments/modifications to the LER file include the following:

- (1) Safety significance ratings: LERs must be distinguished according to the severity of the events' safety significance. This could be accomplished in the following ways:
 - a. Utilize the NRC's existing file of rated "abnormal events." This is a file of events reported verbally by utilities between December 13, 1980 and October 7, 1981. These "events" were significant occurrences selected for discussion and ratings for safety significance during weekly meetings of the Operating Reactors Measurement Branch of NRR. Most, but not all, of these events became LERs, but not all LERs reported during this period are in this file. Each of over 100 events was rated on a four point scale ranging from 0 for "no" safety significance to 3 for "high" safety significance." Those making the rankings were experienced NRC staff but the ranking process was not formalized and may not be replicable. Nevertheless, it does represent an existing, rated LER file for a relatively recent period of time. This file should be obtained and subjected to further statistical analysis.
 - b. Use NRC's on-going evaluation of the safety significance of LERs. Once again, the rating procedure is not formalized but is performed by experienced and knowledgeable individuals. The major disadvantage is that the ratings are not in machine readable form and would require coding from NRC paper files.
 - c. Assemble a team of experts to rate the safety significance of a specific set of LERs. This is an expensive approach but has the advantage of permitting formalization of the process and a flexible time frame.
 - d. Utilize the two week versus 30 day LER distinction to identify the most significant LERs. This is an easy and inexpensive approach. The major weakness is its lack of precision since all two week LERs would have to be assumed to be of equal safety significance.

The recommended procedure is a combination of the above in which two week LERs with specific cause codes and specific systems are selected for analysis and then rated for severity by experts. This would generate a cause-specific and systems-specific file of generally "important" events for which severity distinctions are made.

- (2) LERs should be statistically adjusted for the following factors known to influence the number of LERs:
 - a. age of the plant
 - b. type (PWR vs. BWR)
 - c. size (megawatts)
 - d. region
 - e. vendor
 - f. mode of operation during relevant time period.

As indicated in the summary evaluations in Table 1, the LER data is judged to be an acceptable indicator of plant safety only after the statistical adjustments described above. LERs are reliable in that any statistical analysis would yield consistent and replicable results. The data is widely available but, at the present, they are in a format which is not conducive to numerical analyses. The on-going efforts of NRC's office for Analysis and Evaluation of Operational Data will make LER data readily available in a coded format. The validity of LERs as safety indicators is somewhat suspect, largely because of the fact that they are generated by the utilities themselves and represent a form of "self reporting" of events to a regulatory agency. Utility policy and practices regarding when and how to report will affect the extent to which LER variation is a function of safety. The evaluation of LERs concerning the danger of a tautological analysis is closely related to the validity issue. Variation in LERs may be a function of management and organization practice, not because of variation in plant performance but because of management orientations toward LER reporting. There is some reason for optimism regarding future use of LERs as safety indicators since the presence of a resident inspector probably will influence the filing of LERs. The plant will be provided with immediate NRC feedback on whether or not an event should be reported. This may be bad for the purpose of evaluating performance because the LERs will reflect differences in inspector interpretation rather than licensee interpretation. On the other hand, the use of resident inspectors may result in LER reporting becoming more uniform, particularly if inspectors are given uniform criteria.

In general, LERs should be considered a reliable source of information regarding plant performance but not alone. In conjunction with other indicators and with appropriate adjustments, the LER data can make an important contribution to plant safety indicators.

1.3 Inspection and Enforcement Data

The second major source of plant performance data is the file of information regarding the findings of NRC's office of Inspection and Enforcement (I & E) concerning the regulatory compliance of each plant. This file, known as the

766 File, is an NRC management tool to maintain and report statistical data concerning inspection, investigation, inquiry, and enforcement actions conducted by I & E. The input for this file is the NRC forms 766 and 766A. Instructions for completing these forms, instructions for entry of the data into this computer system, and codes for the data are detailed in the NRC's Inspection and Enforcement Manual, Chapters 0500 and 0535.

The office of Inspection and Enforcement conducts a quality assurance program for the 766 computer system. This program is conducted at the regional level before releasing the data for entry into the master computer file. Each regional office performs an independent audit of the data on the computer input form against the data in the inspection or investigation report. Then an audit of the data on the computer printout is performed to insure that no errors have been made in the typing of the data into the computer file. Then the internal structure of the computer file is analyzed to identify the machine recognizable errors. The headquarters quality assurance program involves a statistical sampling audit at the end of each quarter and a 100% audit each month of headquarters enforcement actions to insure that these are accurately reflected in the 766 master file.

On the average, there will be between two and five thousand entries for any given year (the number of entries has increased dramatically during recent years). The data are recorded according to fairly well-defined rules with a certain amount of consistency over time. The computerized 766 file has existed in its present form since July of 1975. Instructions for completing the form were revised in February, 1978 and have subsequently been revised again, primarily to make the entry of the data into the computer file more reliable and to reduce the redundancy of previous forms.

There are several major classifications of (I & E) activities which utilize the 766 Form and, thereby, are entered into the 766 computer file. The following outline briefly describes those activities:

1.3.1 Inspections

Inspections are the first source of 766 data and fall into several different classifications.

- A. Safety Inspections -- These inspections concern the safety of construction, quality assurance, operational safety, radiological health and safety, environmental protection, and emergency planning which are performed at prescribed frequencies and in accordance with the procedures and instructions covering routine inspections. Sometimes, during a routine inspection, a review will be made of the status of a previously identified enforcement matter, LERs or abnormal occurrences which were identified for follow-up.
- B. Incident Inspections -- These are unscheduled inspections performed as a consequence of an incident reported by the utility or by others.
- C. Enforcement Inspections -- These are non-routine inspections performed for the exclusive purpose of reviewing a licensee's corrective action

or response to a significant violation identified during a previous inspection.

- D. Management Audit Inspections -- These are inspections conducted by teams of inspectors scheduled as a result of a programmatic requirement, or as a result of inspection findings which focus on the management aspects of the facility.
- E. Management Visit Inspections -- These are periodic visits to the facility performed as routine visits in order to inform the licensee management of I & E inspection practices and methods. These are usually conducted during major milestones in a construction and start-up of a facility. They do not involve fact-gathering activities.
- F. Special Inspections -- These are non-routine inspections performed when it appears that significant requirements are not being complied with.
- G. Vendor Inspections -- These are inspections performed of companies which plan, engineer and build nuclear steam system components.
- H. Material Control and Accounting Inspections -- These inspections involve material control and accounting and licensee measurement programs covering all components used for material control and accounting.
- I. Plant Security Inspections -- These are inspections performed for the physical protection of Significant Nuclear Material (SNM) against acts of industrial sabotage and thefts of SNM.
- J. Inventory Verification Inspection -- These are inspections performed to evaluate the utilities accounting of SNM and for conducting physical inventories in order to provide independent assurance that there are no losses of SNM.
- K. Shipments/Export Inspections -- These are inspections regarding the shipment and export of SNM.

1.3.2 Inquiries

Inquiries are activities in which a minimum amount of investigation is used to determine if an investigation or a routine or special inspection or no action at all is required as a result of an allegation, a complaint, or a report related to a licensed facility, or the result of inaction by a recipient to an order issued by the NRC.

1.3.3 Investigations

An investigation is an activity conducted in response to a complaint, an incident or an allegation with the objective of gathering, correlating and evaluating material in depth for the purpose of establishing the cause, the nature, the extent, and the particulars of a condition or an occurrence. An investigation for matters other than a complaint or an allegation may be requested by I & E.

These three general activities, along with related enforcement actions (i.e., civil penalties), are the major sources of information for the 766 file. A sample of the 766 Form and the 766S Form (used for data entry) are shown in Figures 2 through 4.

Whenever items of violation or deviation have been identified, a 766A form must be completed. The 766A is the back of the 766 form which contains the severity code of the violation and a blank sheet in which the inspector provides a narrative description of the violation or the deviation up to 2,400 characters for each item. Beyond the identifying information, the 766A form contains the following information:

- (1) Violation Severity or Deviation. The inspector enters the severity level assigned to the violation item for those violations identified in the enforcement letter. Appendix B provides detailed definitions of each severity code (1-5) for each of seven activities (reactor operations, facility instruction, safeguards, health-physics, transportation, fuel cycle and materials operation, miscellaneous matters).

When a licensee does not conform to commitments to the NRC or to provisions of guide codes and standards and these provisions were made available to the licensee, and when the non-conformity does not constitute a violation, then it is referred to as a deviation and a "D" is entered into the 766A form.

- (2) Each violation or deviation narrative description begins with the statement "contrary to", and the specific guide or standard which was violated is then cited. These narrative descriptions are entered verbatim into the computer file.
- (3) The Principal Inspector also records the following data:
 1. the period of inspection/investigation (date)
 2. members of the inspection team
 3. region, division, and branch of the I & E office
 4. the type of activity conducted
 5. the findings of the inspection which are coded into the following categories: clear violation, deviation, or violation and deviation
 6. the total number of violations and deviations discovered
 7. an indication of whether or not an enforcement conference is to be held
 8. the date at which the report was transmitted to the utility

The Front Side of the 766 Form

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Figure 3

The Back of the 766 Form

FORM 766, Rev. 1-84

USNRC - INSPECTION & ENFORCEMENT STATISTICAL DATA

(NOTE: % COMPLETE AND STATUS:
LEAVE BLANK FOR MC 92, 93 & 94
PROCEDURES AND 30-702, 30-703 &
30-800)

(NOTE: STATUS CODING:
BLANK - TO REMAIN OPEN
C - CLOSED
L - REOPEN & LEAVE OPEN
P - REOPEN THIS TRANSACTION
ONLY)

(NOTE: MODULE REQUIRING
FOLLOWUP:
USE ONLY WHEN MODULE
INSPECTED IS 92-7018.)

MODULE TRACKING INFORMATION																	NONCOMPLIANCE									
MODULE NO. INSP.					DIRECT INSP EFFORT MAN HAS EXPENDED THIS INSP.	% COM- PLETE TO DATE	STATUS	MODULE REQ. FOLLOWUP					N/C		N/C		N/C		N/C		N/C					
PHASE	MANUAL	CHAP.	PROC.	NO.				LEVEL	PHASE	MANUAL	CHAP.	PROC.	NO.	LEVEL	CODE	SEV	CODE	SEV	CODE	SEV	CODE	SEV	CODE	SEV		
1	0																									
1	1																									
1	2																									
1	3																									
1	4																									
1	5																									
1	6																									
1	7																									
1	8																									
1	9																									

LIKE COLUMN NUMBER SHOWN IN BOTTOM LINE

CONTINUES ON REVERSE OF SHEET

40 AM NAC 756-8
 XCTD 89A 1077
 PAC 0624J

GENERAL INSTRUCTIONS: BLOCK A MUST BE CHECKED TO SHOW TYPE OF INFORMATION CONTAINED ON THE FORM. ONE FORM IS TO BE COMPLETED FOR EACH.

- (A) ITEM OF NONCOMPLIANCE CITED.
- (B) ITEM OF NONCOMPLIANCE NOT CITED, AND,
- (C) DEVIATION CITED IN ENFORCEMENT CORRESPONDENCE.

6-19

9. direct inspection effort in staff hours expended during this inspection
10. the status of the inspection (codes referring to whether the issue is open, closed, reopened or reopened for this transaction only).

There have been three studies evaluating the 766 file as a source of plant safety data. The first was the previously discussed analysis by Potash which described and compared both the 766 and LER data. A second project was the NRC Region Four "Howard" statistical analysis project. His analysis indicated that most entries have minor or no safety significance. Less than 5% of the 766 reports had safety significance during the time period of his study but, with four or five thousand entries per year, this is a respectable number from the perspective of statistical analysis.

Potash found that the 766 file data varied from plant to plant in systematic ways. BWRs produced more noncompliance data than PWRs, and the newer, larger plants produced more noncompliances than the smaller, older plants. There was also evidence of designer differences in the number of noncompliances. Finally, there were regional differences in the number and severity of noncompliances. Potash's analysis did not include deviations (however, these comprise only 4% of the 766 file). When he correlated the number of noncompliances during the year prior to the study with the number of noncompliances during the year of the study, he found low positive correlations which were not significantly different from zero. These findings have implications for regulatory performance measurement since they are not stable over a two year period. Potash also reports that almost all noncompliances are due to human error.

Potash argues that the 766 file is a direct measure of "how well the plant is being run" since it is not dependent on licensee reporting initiative. When Potash examined noncompliance data, there were three sub-categories of severity. These categories were:

- (1) violation
- (2) infraction
- (3) deficiency.

This differs from the current practice of violations, each with a five point severity level, and another classification of deviation which is not given any severity ranking at all. Potash also found that not only do the number of noncompliances vary by region but also the severity of noncompliance varies by region. Although these differences suggest that there may be differences in NRC inspector practices, it is not necessarily the case that different NRC regions should produce the same rate of noncompliances. It has not yet been determined whether or not region would still demonstrate an effect after one controlled for plant age, size and type. Since regions are not homogenous with respect to these three plant characteristics, controlling for them may eliminate the apparent region affect. In other words, the uniformity of NRC inspectors has not yet been given a fair test.

In comparing the 766 file with LERs as a source of safety data, Potash found that LERs, including those caused by human error, were oriented toward safety related operation of the plant while noncompliance data concerned plant management. He also found no significant correlation between the number of human error LERs (HELERS) and the number of noncompliances.

Potash also examined differences between the LER file and the 766 file. The LER data base has two human error cause categories while the 766 file has 14. Almost all 766 data are human error where 20% of the LERs are HELERS. Potash reports a relatively low correlation between the number of 766 entries and HELERS.

Potash concludes that when the factors of size, age, and reactor type are controlled, either statistically or through the use of specific comparisons, when the report frequencies are weighted by significance and the number of repetitive concurrences, then large differences in the number of LERs can be interpreted as an indicator of a problem. If regulatory performance is defined as the degree of compliance with NRC requirements, below average regulatory performance can be measured with 766 data and used to indicate that the licensee needs more investigation. Regulatory performance, according to Potash, means the degree of compliance of reactor operations with NRC requirements. In contrast to the LER data, Potash asserts that the 766 file is a direct measure of "how well the plant is being run", particularly since it is not dependent on self-report.

A second study of the 766 file was performed by Teknekron and reported in NUREG/CR-0110. This report provides a number of reasons for caution in using the 766 file. The severity codes are also broken down into "cause", meaning that the one to five severity levels are assigned on the basis of the activity within which the noncompliance occurred. Teknekron reports that discussions with NRC personnel revealed that most inspectors have "favorite" codes and that each inspector does not use the code in the same way. Given Potash's finding that 766 file data does evidence regional bias, it is reasonable to suggest that inspectors do have varying interpretations of severity codes and varying interpretations of how those codes ought to be used. Teknekron conducted a "mini-audit" by reading every inspection report that was associated with a noncompliance and some reports that document inspector follow-up of LERs. This audit led Teknekron to conclude that the correspondence between the 766 file and the inspection report is quite good, but the match between the elements of the 766 data themselves is much poorer. Teknekron concluded that the problem was caused by the noncompliance codes and their use by inspectors. Teknekron also felt that the narrative description in the 766 file was too brief and did not permit an independent evaluation of the cause and severity codes. Another problem with 766 file discussed by Teknekron is the issue of timing. Inspection reports are filed within a month of the inspection, but the noncompliance as cited in those reports were often events from sometime ago.

The Teknekron report makes a number of other important points regarding the analysis of the 766 file. Noncompliances are either random lapses from good performance or systematic lapses due to a performance defect. Since the NRC conducts its inspection program in modules, a part of the pattern in 766

file data is due to NRC scheduling and the time dependency of inspection modules. In Teknekron's terms, the inspection module becomes the "point of origin" for the detection of licensee performance patterns, a point well removed from the actual event that created the occurrence. Teknekron found that counting repeat noncompliances was a far more valid indicator of plant performance than simply counting noncompliances. The utility is obligated to operate the facility in such a way that it violates the original license conditions to the least possible extent, and also institute adequate remedial measures in the least possible time when such violations occur. The key factor here is whether the utility is willing and able to respond effectively to the identified noncompliance situation. It does not necessarily follow that the number of noncompliances are reliable indicators of performance. If Facility A has twice as many noncompliances as Facility B over a similar time period, one cannot conclude that Facility A is only half as safe as Facility B. Noncompliance recurrence is far more sensitive an indicator of licensee performance, particularly managerial performance.

Teknekron proposed the following 766 indicators:

- (1) licensee action on identified noncompliance items
- (2) repeat non-compliance items
- (3) a profile of Licensee performance based on the noncompliances attributed to human causes.

A third study involving the 766 data was plant evaluation prepared by Morris Howard (1977). At the time his report was prepared, the 766 file utilized a three point severity ranking system. Counts of each of the three levels of noncompliances for each of six operating areas were used as the basic "noncompliance" indicator. The six operating areas were:

- (1) administrative control
- (2) operations
- (3) emergency planning
- (4) radiological protection
- (5) safeguards
- (6) quality assurance.

The Howard report notes that the number of noncompliances is a partial function of the number of hours of inspection effort ("the more you look, the more you find."). This was treated as a source of error and removed by residualizing the number of noncompliances for hours of inspection effort. Thus, it was found that, on the average, 1.27 noncompliances were reported for every hour of inspection effort. Plant scores were based on the extent to which the number of noncompliances they experienced was less than the number they would have at the rate of 1.27 per hour of inspection. After the adjustment, the distribution of noncompliances was normal.

1.4 Conclusions

The 766 System can provide an important source of information for the creation of plant safety performance indicators. The machine readable file is subjected to a reasonable quality assurance program and is, therefore, a

reliable indicator. Moreover, the noncompliance entries are rated for severity according to well defined rules, making it possible to replicate the ratings.

The 766 file could be used as a complementary data set to an LER file in which both files have the following characteristics:

- (1) severity ratings
- (2) equivalent systems
- (3) statistical adjustments for:
 - a. age
 - b. size
 - c. vendor
 - d. operation mode
 - e. region
 - f. type
 - g. hours of inspection.

As with all other indicators, there is an arguable relationship between inspection and enforcement data and actual safety, but it is probably safe to conclude that there is a relationship between the noncompliance data and "conformity of the utility to NRC regulations." There is some evidence, however, that 766 data is subject to regional bias which is due to the fact that 766 files are provided by regional offices and entered by regional inspectors, each with varying standards and perceptions of compliance. Because of the role of inspector bias and the fact that all plants are intentionally subjected to differential "risk" of receiving a noncompliance, the validity and objectivity of the file was given a "3" evaluation in Table 1. Similarly, the overall evaluation of the 766 file is that it is not adequate by itself without the adjustment discussed above. However, the parallel employment of the two files with similar statistical adjustments, similar severity ratings, and within the same systems could permit a "triangulation" of the problem area from two sources: one self-reported (LERs) and one collected by NRC inspectors (766). Furthermore, the two files can be synchronized by time, permitting LER-766 links where they occur and identifying recurrences either within a file or between files. In other words, a noncompliance may be followed by a related or identical noncompliance (within file), or a noncompliance may be linked to a related subsequent LER (between files). This intersecting of two independent files will add much to the validity of any effort to create performance indicators.

1.5 Operating and Outage Data

The NRC requires that utilities provide a monthly operating report to the Office of Management and Program Analysis and the NRC regional office no later than two weeks after the end of each month. These monthly operating reports contain information on power generated each day of the month, power generated up to that month during the current year, and total cumulative power generated. It also contains information on the capacity of the plant and a number of proportions (i.e., monthly proportion of capacity generated). Each day's generation is plotted so that shutdowns can be isolated by day.

All of this information is provided on a monthly basis by the Nuclear Regulatory Commission in NUREG-0020. This document, known as the Graybook, contains LER and inspection information as well as data from the monthly operating reports. There does not appear to be any fixed procedure for the selection of what additional information will be included but, in general, major inspection events are reported from the noncompliance 766 file, an enforcement summary is provided, and reports from the licensee are listed. Most, but not all, of these reports are LERs.

Coded data from the monthly operating reports include whether or not a shutdown was forced or scheduled, eight different reasons for the shutdown, and six different methods by which the shutdown was accomplished. Coded reasons for each shutdown are:

- (1) equipment failure
- (2) maintenance or test
- (3) refueling
- (4) regulatory restriction
- (5) operator training and license examination
- (6) administrative
- (7) operator error
- (8) other.

Coded methods by which the shutdown was accomplished are:

- (1) manual
- (2) manual scram
- (3) auto scram
- (4) continued
- (5) reduced load
- (6) other.

The following summarizes, from December, 1981 data, the nature of the information contained in these reports. During this month there were 70 operating commercial plants. Two plants, Sequoyah 2 and McGuire 1 were in power ascension. Three plants, Dresden 1, Humboldt Bay and TMI 2 were shutdown indefinitely. Among the 70 operating plants, electricity was produced at about 66% of capacity. Over 8% of capacity was lost due to forced outages and 26% was lost due to scheduled or other non-forced outages. There were 67 forced outages and 28 scheduled outages during the month. Equipment failure was the reason given for 57% of all shutdowns. Operator error is the cause of about 10% of all forced shutdowns.

The Monthly Operating Report data is maintained in machine-readable form by the NRC on a file called, Statistical Information System for Operating Reactor (SISOR). This data file is divided up into a number of subfiles. The ordering of these files follows the organization of the Graybook itself. The first file is titled, "Operating Status". It contains 23 variables which include information on the docket number, the name of the unit, the reporting period, the capacity, hours the reactor was critical, number of shutdown hours, hours the generator was on-line, and the amount of electricity generated.

A second file contains information on the facility which provides information on the contractor and the vendor.

Another file is titled "Unit Shutdowns and Power Reductions." This file contains 14 variables which provide information regarding the outages, the date of the outage, the type of the outage, and the duration of the outage. In addition, there are codes for the reasons the outage occurred, the method by which the outage was accomplished, LER report numbers, if an LER was filed, and the cause and corrective action in a narrative field.

Another file is titled, "Average Daily Unit Power Level." This file contains the daily output for each plant and contains only six variables. These variables identify the utility and the plant, the date and the average daily power level, as well as a plant summary, which summarizes the plant output for that month.

1.6 Conclusions

Graybook data has only rarely been utilized in a safety evaluation effort. Even though it is possible to distinguish between scheduled and unscheduled shutdowns, as well as the reason for the shutdown (operator error being one of the reasons), a number of individuals have expressed reservations regarding the use of this data. For example, reductions in electricity generated may be due to variations in demand. If a utility is 100% nuclear or only a very small fraction non-nuclear, then they may be forced to reduce their generation of nuclear energy in response to consumer demand. However, this can be adjusted with a variable that identifies load dependent shutdowns. Low quality fuel is another potential cause of frequent unscheduled shutdowns. However, we are not convinced that the use of bad fuel and the shutdowns that result from that usage are entirely unrelated to safety.

In spite of these problems, the data on forced shutdown due to equipment failure or operator error can be used to quantify the ability of the plant to efficiently and consistently generate power and to avoid the adverse consequences of frequent, unscheduled scrams. The premise in examining unscheduled shutdowns is that a continuously operating, reliable plant that has relatively few incidents of forced shutdown is more safe than a plant with frequent forced shutdowns.

A straightforward interpretation of shutdown counts as an indicator of safety, however, is not satisfactory. There are a number of reasons for forced scrams which may be unrelated to safe operation, but the data can, and should be, adjusted for these factors. Since there is no existing performance evaluation research using operating data, a first step is to obtain it and examine patterns of forced shutdowns by cause, duration, vendor, size, age, and type, in order to determine which statistical adjustments will be required.

As indicated in Table 1, the operating and shutdown data is not regarded as adequate without some adjustment. Although reliable and readily accessible, the validity of the data as a safety indicator is the major issue. Like the

previous assessments of LER and 766 file data, the operating and shutdown data may serve as part of a multiple indicator approach to developing safety indicators. When coupled with other data, adjusted forced shutdowns may capture some portion of safety missed by the other data sets.

1.7 Systematic Assessment of Licensee Performance (SALP)

The NRC conducts annual reviews of the performance of all commercial nuclear power plants that are either operating or under construction. These reviews are conducted under the Systematic Assessment of Licensee Performance program (SALP). The objectives of this program are to improve licensee performance and assist the NRC in allocating resources for regulatory efforts.

Each plant is evaluated annually on the basis of performance during a 12 month period. Each of the following functional areas is considered for operating reactors:

- (1) plant operations
- (2) radiological controls
 - a. radiation protection
 - b. radioactive waste management
 - c. transportation
 - d. effluent control and monitoring
- (3) maintenance
- (4) surveillance - includes inservice and pre-operational testing
- (5) fire protection
- (6) emergency preparedness
- (7) security and safeguards
- (8) refueling - includes initial fuel loading
- (9) licensing activities
- (10) others (as needed).

Each area is evaluated by the following criteria:

- (1) management involvement in assuring quality
- (2) approach to resolution of technical issues from safety standpoint
- (3) responsiveness to NRC initiatives
- (4) enforcement history
- (5) reporting and analysis of reportable events
- (6) staffing (including management)
- (7) training effectiveness and qualification.

These criteria are then used to assign each area into one of three categories indicating that: (1) reduced NRC attention may be appropriate, (2) NRC attention should be maintained at normal levels, or (3) NRC and licensee attention should be increased.

In making these evaluations, the SALP teams utilize inspection and enforcement data, LERs, and forced outages during the relevant time period. The manner in which these indicators are analyzed and used in the evaluation vary from plant to plant. Unfortunately, there is no standard procedure for incorporating this data into the evaluation. Inspection of several sample

SALP reports revealed wide variation in the use of data to either derive an evaluation or support an opinion.

This characteristic makes it difficult to utilize the results of SALP investigations for statistical analyses. This, of course, is not the purpose of SALP, but since they are not replicable and the data are treated differently from plant to plant, they must be used with extreme caution.

Another problem with SALP for analysis purposes is the long time span during which the evaluation takes place. Utilities are likely to respond to identified problems before the end of the evaluation period so comparisons of SALP ratings among plants may be based on conditions which no longer hold. A related problem is the fact that plants are evaluated at different times during the year. It generally takes 24 months or longer to complete SALP reports on all plants. This creates problems for causal inference when SALP scores are associated with management and organization characteristics which are generally collected at a single point in time.

1.8 Conclusion

SALP reports are unreliable because of the fact that each plant is evaluated with different procedures during different 12 month time periods. They are readily available, however, and may serve as an indicator of "plant reputation" or a summary of NRC opinion regarding the plant's recent performance. The validity of the previous data is untestable, but given the expertise of the SALP team and the intense effort involved in each evaluation, there is reason to believe that differences in SALP scores do reflect plant differences in safety. Like the other measures, however, they cannot stand alone.

The dimension of safety tapped by opinion data is important as it encompasses those aspects of plant performance not directly measurable with objective indicators. The environment created by management and the overall orientation toward safety and the NRC are critical precursors of safety which should not go unmeasured. The next indicator to be discussed, an I & E staff survey, would be specifically designed to measure plant reputation and, if the data were collected, could replace SALP ratings in a multiple indicator measurement model.

1.9 I & E Staff Evaluations

Staff members of the NRC's Office of Inspection and Enforcement provide another potential source of data regarding plant performance. I & E staff evaluation of utilities or plants are not directly available in public documents, but staff could be surveyed regarding specific dimensions of plant performance for those plants about which they are knowledgeable. This approach was actually tested by I & E in the Fall of 1977 and the results appear in an unpublished 1978 report by Stephen K. Conner.

I & E staff had been critical of previous "in-house" statistically oriented efforts to measure plant performance because those efforts did not utilize the qualitative judgments of the I & E staff most familiar with each plant.

Recognizing the value of this internal information, a survey was prepared to quantify each I & E inspector's evaluation of the sites in his or her region. A total of 45 sites were evaluated by all those familiar with the plants. The questionnaires were not signed and were mailed directly to a contractor for analysis.

In general, the procedures described in the report seem sound and the questionnaire is reasonably well constructed. Each respondent graded the plant on the following dimensions:

- (1) overall safety
- (2) attitude toward safety
- (3) attitude toward cooperation with NRC
- (4) technical competence
- (5) quality of design
- (6) administrative control
- (7) operations
- (8) emergency planning
- (9) radiation control
- (10) safeguards
- (11) quality assurance.

The scale used for each of these dimensions ranged from "acceptable" to "exceptional." Safety was defined as:

The degree to which the licensee protects the public against exposure to radiation resulting from the licensee's use of nuclear materials.

"Acceptable" was defined as "barely enough to be permitted to continue operating", and "Exceptional" was defined as "having a virtual absence of risk."

Each respondent also indicated how well they knew the plant, how long ago they had last inspected the site, and how demanding they felt the NRC requirements were for the site relative to other sites.

In order to make individual I & E staff member's evaluations comparable, each respondent was asked to rank "the typical plant" on each of the eleven dimensions. Then these scores were used as a standard for each respondent's evaluation of specific sites. This permitted an internal control for individual variations in perceptions of the scale or tendencies to rank plants either positively or negatively.

The results of this typical plant rating are shown on the survey instruments itself in Figure 5.

Since this data is now over five years old, it is not useful to the current effort. However, a replication survey could be utilized to collect I & E opinion data on these or other dimensions of plant safety. The results could be used to replace SALP data and would have the advantage of currency, a single time point, and a standardized methodology.

Figure 5

Survey Instrument and Average Generic Plant Ratings
From Conver (1978)

SITE Typical Site in U.S.

DOCKET NUMBER 50-999

NUMBER OF PEOPLE RATING SITE = 94

FAMILIARITY OF RATERS WITH SITE (ON 7 POINT SCALE) = N/A
(1 = HARDLY AT ALL, 7 = EXTREMELY WELL)

AVERAGE NUMBER OF MONTHS SINCE RATERS' LAST INSPECTION = N/A

STRINGENCY OF REQUIREMENTS FOR SITE (ON 7 POINT SCALE) = N/A
(1 = MUCH LESS DEMANDING THAN THOSE OF OTHER SITES,
7 = MUCH MORE DEMANDING THAN THOSE OF OTHER SITES)

INDICATIONS OF CHANGE IN SITE SAFETY SINCE JANUARY 1977

1 = NO CHANGE IN SAFETY.....	<u>28</u>
2 = SAFETY SLIGHTLY IMPROVED.....	<u>39</u>
3 = SAFETY SUBSTANTIALLY IMPROVED.....	<u>4</u>
4 = SAFETY SLIGHTLY WORSE.....	<u>1</u>
5 = SAFETY SUBSTANTIALLY WORSE.....	<u>0</u>

NARRATIVE STATEMENTS OF CHANGES IN SAFETY AND OTHER SAFETY
CONSIDERATIONS

1.10 Conclusion

In general, the approach taken in the Conner report was sound and a replication has potential as a source of information for an indicator of NRC opinion that would be superior to the use of SALP ratings. A replication could be tailored to consider specific safety dimensions of interest and to a specific time period. This would make the results compatible with the use of LERs, inspection data, and operating data.

Table 1 indicates that the proposed I & E survey would be only moderately reliable like all self-report opinion data of this sort. It is expected to be a valid measure of NRC opinion and would not be tautological because the specific safety dimension being assessed would be designed to be distinct from management and organization characteristics.

As a primary data collection effort, the survey would require both time and resources, including additional funding. Therefore, a long term recommendation is to collect this data and integrate it with the other sources of information on plant performance to create plant safety indicators. A short term recommendation is to utilize SALP ratings as the preliminary indicator of plant reputation, recognizing the weaknesses discussed above.

1.11 Personnel Exposure Data

Utilities make regular reports to the NRC regarding the results of their monitoring of radiological exposure of plant personnel. This data was considered a potential safety indicator under the premise that high levels of personnel exposure would be negatively associated with safe plant operation. Unfortunately, there are a number of serious problems with this indicator.

The risk of exposure is greatest during a refueling. Even with a control for whether or not a refueling outage occurred between two exposure reports, it would be extremely difficult to make comparisons among technologically diverse plants, some of which had refueled during the relevant time period. Staff turnover and the use of contractors and/or temporary employees during refueling outages introduces even more error into a plant by plant comparison of exposure data. Inspection of a sample of these reports indicate some variation in plant exposure levels, but rarely does the variation approach the specified maximum. When a worker is exposed to radiation levels deemed unsafe by the NRC, the event is reportable and, therefore, would be recorded in the LER file. Thus, when the exposure data suggests employee risk, the event would be included in the LER analysis.

1.12 Annual Summaries of Environmental Monitoring and Semi-Annual Effluent Release Reports

These reports to the NRC contain information regarding the local environmental effects of the plant. Included are measurable release of tritium, noble gases, total alpha activity, radionuclides released and

levels of liquid and solid waste generated. Problems with utilizing this data set include:

- (a) Wide variation from utility to utility in the type and format of the information provided in the reports.
- (b) Data would have to be prepared for analysis (e.g. no machine readable format exists).
- (c) The unique physical and environmental setting of each plant alters the safety implications of release practices and the boundaries of acceptable utility practice. Consequently, plant comparisons would be difficult and error prone.
- (d) Environmental testing is frequently influenced by external factors such as weather and other local conditions such as industrial facilities sharing water sources. These unique conditions invalidate most straightforward comparisons of these data.

Like the exposure data, significant events reported involving effluent release will be contained in the LER analysis.

1.13 Operator Exam Scores

Although it is possible to obtain scores for all operators, the use of this data to measure plant safety in an organization and management study was judged to be tautological. Variation in plant scores would be more likely to reflect plant management differences (the predictor variables) than safe operations (the dependent variable). For this reason, exam scores were rejected as a plant safety indicator.

1.14 Liability Insurance Risk Assessments

The NRC requires all licensees of nuclear power plants with a rated capacity of 100,000 KW or more to have liability insurance protection equal to \$160 million per incident. Licensees may either buy a policy from American Nuclear Insurers (ANI)*, buy a bond for that amount, or put \$160 million aside. At this time, all commercial plants choose to buy an ANI policy. In determining premiums, ANI attempts to measure risk to the general public. For new plants, ANI determines premiums based on their nuclear engineers' evaluations of plant characteristics: size (MGW), location (population and property values within a 25-50 mile radius, hydrology, meteorology), reactor type (PWR or BWR), use of plant (commercial or research), and how well the nuclear hazard is contained (fuel cladding, pressure vessel, containment vessel, etc.). The engineers' evaluation is both a subjective judgment of how location conditions might affect the risk and an application of a formula for determining how other plant characteristics alter the risk.

*ANI is the underwriter for both the Nuclear Energy Liability Insurance Association (NELIA) and the Mutual Atomic Energy Underwriters (MAEU).

After a plant has been in operation for three years, ANI modifies the premium based on operating history as documented by the NRC. This experience is evaluated on the basis of indicators such as man-rem exposure, containment incidents, number of two week LERs, waste-handling techniques, etc. Because few claims have been filed in the 25 year history of the nuclear insurance business, the assessment of nuclear power plant liability, unlike conventional liability assessment, is not based upon claims experience. For this reason, 75% of the premiums are held in reserve for 10 years, and based on actual loss experience, portions are returned to the licensees. The risk is shared among all licensees in that any loss suffered by one licensee lowers the refund to all policy holders by the same percent.

In addition to the ANI policy, each plant pledges \$5 million per incident in case the \$160 million is exhausted. The Price-Anderson guideline currently requires that \$560 million be available in case the ANI insurance is exhausted. The U.S. government supplies the difference between the \$5 million x the number of operating plants and the required \$560 million. Finally, as a third level of protection, and at the request of the state where an incident has occurred, Congress can increase the amount of federal money supplied.

There are several problems with using the ANI insurance premiums as a safety indicator. First, the actual premiums charged each plant are proprietary. Secondly, many of the ANI measures, such as reactor type and size, are already being considered as control variables, and containment incidents, number of two week LERs, as well as man-rem exposure violations are part of the LER data being considered as criterion variables. Thirdly, the population and property values within a 25-50 mile radius, as well as size (MGW) of plant if considered a criterion variable, measure the potential severity of an incident rather than the likelihood of an incident. For these reasons, the insurance data is not regarded as a potential source of safety data.

1.15 Institute of Nuclear Power Operations Evaluations

The Institute of Nuclear Power Operations (INPO), a utility sponsored organization, conducts evaluations of member nuclear power plants. These evaluations are organized around seven functional areas:

- (1) organization and administration
- (2) maintenance
- (3) technical support
- (4) training and qualification
- (5) radiological protection
- (6) chemistry
- (7) emergency preparedness.

Each of these broad functional areas are further divided and each sub-area is evaluated according to specified criteria. However, the criteria published by INPO are not specific, observable factors that would permit unambiguous evaluation. They are statements of "good practice" developed from INPO staff's knowledge and experience in the operation of nuclear power plants. Example criterion are:

- (1) Management quality assessment and improvement efforts are conducted in such a way as to reinforce and enhance the line functions of managers and supervisors.
- (2) The staff size is sufficient to accomplish assigned tasks.
- (3) Good operating practices are followed in conducting plant operations.

These statements may provide guidance for utility management in the form of a checklist for self evaluation but they are difficult to use in a reliable, empirical assessment of plant performance. A conclusion that Plant A follows "good operating practices" while Plant B does not is not a quantifiable statement without an operational definition of "good practice" and some evidence that "good practice", however defined, is linked to safety. The INPO evaluation, like the SALP, contains largely opinion data from knowledgeable evaluators. Like SALP, they are performed serially so that evaluations cannot be tied to a specific time period. These characteristics, coupled with the link between INPO and the utility being evaluated, leads to the conclusion that the data source should not be included as a safety indicator.

1.16 Conclusions and Recommendations for Future Work

Among the available indicators discussed in this report, four were judged to have some potential as a contributing element in a multiple indicator approach to measuring safety. No one source was adequate alone but the same weaknesses are not shared by all. Consequently, by combining the indicators it may be possible to capitalize on their strengths.

This conclusion leads the problem of measuring safety directly into a long standing tradition of measurement theory and techniques developed within the social sciences. The need to measure elusive and unobservable phenomenon is common in the social sciences. In response to this need, a number of multiple measurement techniques have been built around the statistical technique of factor analysis and the more recent developments surrounding confirmatory factor analysis. Without describing the technical details of these procedures, the methodology requires that the investigator identify one or more factors underlying the associations among a set of observed indicators. These factors, or unmeasured variables, are hypothesized to cause all or part of the association among the indicators. In other words, the associations among a set of observed variables are thought to be due to the fact that they serve as indicators of the same underlying concepts or factors. These factors can be dimensions of safety or unmeasured sources of error such as self report bias. The confirmatory factor analyses approach permits the hypothesized model of factors and indicators to be statistically tested to determine if it is consistent with the data. If it is not, the model can be modified to improve the fit.

The construction of such a multiple indicator model for measuring plant safety requires access to the data set described above which, at this point, has not yet been accomplished. The number of indicators involved will, in part, depend on their distribution. For example, decisions regarding time

frame, division of indicators by system or cause codes, statistical adjustments, etc, all require a careful examination of the data.

It is possible, however, to illustrate the proposed technique under a number of simplifying assumptions. First, let the LER, inspection data, operating data, and an I & E staff survey serve as the four major sources of information. Second, assume for purposes of this illustration, that these four sources are not further differentiated by time, system, cause or any other factor. Third, assume that each indicator has been statistically adjusted for all of the technical factors described above. Finally, assume that there are four underlying safety related factors measured by these indicators: regulatory compliance, quality, efficiency, and innovation. Again, these are intended to serve as initial hypotheses that could be confirmed or rejected only after the data are analyzed.

One model for stating the relationships among these hypothetical factors and the four indicators is portrayed in Figure 6. The four unmeasured safety related factors are illustrated by the circles. The first, regulatory compliance, is a factor thought to influence variance in three of the four indicators: LERs, inspection data, and the I & E survey. This represents the hypothesis that the extent to which a plant conforms to the NRC regulations will be reflected in the number of LERs, the number of inspection findings, and the opinion of I & E staff regarding the plant.

Similarly, the occurrence of safety significant errors is a plant safety characteristic hypothesized to influence variance in the LER data, and the I & E staff survey. The other two factors are seen to be reflected in the observed variance in operating data (forced shutdowns) and the I & E staff survey, respectively.

It should be noted that these hypothetical relationships between factor and indicator are subject to modification with support from the data. Furthermore, the actual analysis may suggest the need for fewer, more, or different safety factors to explain the underlying associations among the indicators.

In Figure 6, the four indicators are shown to be affected by two "bias" factors, illustrated by the two boxes labelled "Self Report Effects" and "Regulator (NRC) Effects." These two unmeasured factors are intended to serve as examples of non-safety related causes of variation in the indicators. For purposes of illustration, the self report bias is expected to account for variation in LER and operating data because they are data sets provided to the NRC by the utilities themselves. Utility practice regarding the filing of LERs and recording outage cause codes may have an effect on the variance of two indicators. Likewise, the two indicators with the NRC as the source (inspection data and the I & E staff survey) may share some association due to the fact that both involve interpretations of NRC inspectors.

Once a model such as this is defined, the next step is to estimate the parameters and assign a value to each plant on each of the underlying dimensions of safety. The solution to a measurement model such as described

Figure 6. Hypothetical Model for Multiple Indicator Approaches to the Measurement of Plant Safety

in Figure 6 will provide four equations (one for each factor) that can be used to assign each plant scores on safety factors. The final step is to utilize these dimensions of safety in models that incorporate management and organization characteristics of the plant as predictors or determinants of safety.

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