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IMPLEMENTING EXTERNALLY INDUCED INNOVATIONS: A COMPARISON OF RULE-BOUND AND AUTONOMOUS APPROACHES

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This research analyzed how nuclear power plants implemented safety review innovations introduced by the Nuclear Regulatory Commission after the Three Mile Island accident. The findings suggested that nuclear power plants with relatively poor safety records tended to respond in a rule-bound manner that perpetuated their poor safety performance and that nuclear power plants whose safety records were relatively strong tended to retain their autonomy, a response that reinforced their strong safety performance.

Innovations are ideas, formulas, or programs that the individuals involved perceive as new (Beyer & Trice, 1978; Hill & Utterback, 1979; Rogers, 1982; Zaltman, Duncan, & Holbeck, 1973). The stages in their development have been the subject of much scholarly discussion and debate (Rothwell & Zegveld, 1985; Strebel, 1987). A common view is that implementation follows conception, proposal generation, and initiation, and that the factors that facilitate the former inhibit the latter (Duncan, 1976: 172; Wilson, 1963: 200). Rule-bound approaches, which involve central direction and highly programmed tasks, are supposed to promote implementation; that is, the number of routine tasks prescribed from above should increase as an organization moves toward implementation (Wilson, 1963: 198). Conception, proposal generation, and initiation, on the other hand, require fewer controls and more autonomy, because diversity, openness, informality, and the ability to bring a variety of bases of information to bear on a problem need to be encouraged (Duncan, 1976: 174). Duncan suggested that making the transition from conception, proposal generation, and initiation to implementation

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can be difficult and that the "ambidextrous" organization, adept at moving from stage to stage, is likely to be rare (1976: 167).

Several authors (Burgelman, 1984; Kanter, 1985, 1986; Lawrence & Dyer, 1982; Strebel, 1987) have dealt with the problem of a dominant corporate culture in established firms that is centered around rules that tend to stifle innovation. They suggest that for innovation to occur, spin-offs, independent task forces, and autonomous teams that simulate entrepreneurship are necessary. Their analysis primarily applies to internally generated, opportunity-driven innovation (Andrews, 1971; Bourgeois, 1984; Child, 1972). However, many innovations arise when an unanticipated external threat or challenge occurs.

The insight that crises, dissatisfaction, tension, and significant external stresses play an important role in bringing about innovations is a common one (Bateson, 1979; Crozier, 1964; Cyert & March, 1963; Downs, 1967; Kelly & Kranzberg, 1975; Meyer, 1982; Schon, 1971; Zaltman & Duncan, 1977). Because people are programmed to "focus on, harvest, and protect existing practices" (Van de Ven, 1986: 591), they are likely to resist new practices and programs (Gricar, 1983; Leonard-Barton & Kraus, 1985; Rogers, 1982; Rothman, 1974; Schultz & Slevin, 1975; Sturdivant, Ginter, & Sawyer, 1985; Zaltman & Duncan, 1977; Zander, 1977). To stimulate the introduction of the new practices, disruptive events, which threaten a social system, may be needed. In fact, Terreberry (1971: 69) maintained that innovations are largely a matter of external inducement.

The problems that surface during the implementation of externally induced innovations, however, can thwart technological improvement and distort the innovation process both directly and indirectly (Ettlie & Rubinstein, 1981; Rothwell, 1981; Schwietzer, 1977). Little attention has been devoted to those problems. This study compared the effects of using rule-bound and autonomous approaches to deal with the implementation of externally induced innovations.

THE LITERATURE ON IMPLEMENTATION

A large body of research deals with the problems of implementation. Early case studies (Bardach, 1977; Marcus, 1980; Pressman & Wildavsky, 1974) supported the view that excessive decision-making autonomy during implementation is counterproductive. When numerous decisions have to be made and many participants are involved, the probability of success decreases, and the possibility of unexpected problems arising increases. Critics (Berman, 1980; Elmore, 1979; Lipsky, 1978; Palumbo, Maynard-Moody, & Wright, 1983; Thomas, 1979) of that literature, however, have contended that implementors have a greater knowledge than their superiors of multiple and contradictory demands and of conflicting legal, political, professional, and bureaucratic imperatives at the point of delivery (Rein & Rabinowitz, 1978), that denial of adequate autonomy is likely to affect the disposition of implementors negatively, and that their dispositions are often critical to

Only Nutt (1986, 1987) appeared to find mixed support for autonomy. In the innovations he analyzed, upper managers had the highest success rates in installing planned changes in organizations when they justified the need for change and played a critical role in formulating a plan, illustrating how performance could be improved, and showing how the plan would improve performance.

INNOVATIONS IN THE NUCLEAR POWER INDUSTRY

In *Normal Accidents: Living with High-Risk Technologies*, Perrow suggested that a major dilemma in the organization and management of nuclear power plants is how to balance rule-bound and autonomous approaches:

> High risk systems have a double penalty; because normal accidents stem from the mysterious interaction of failures, those closest to the system, the operators, have to be able to take independent and sometimes quite creative action. But because these systems are so tightly coupled, control of operators must be centralized because there is little time to check everything out and be aware of what another part of the system is doing. An operator can't just do her own thing; tight coupling means tightly prescribed steps and invariant sequences that cannot be changed. But systems cannot be both decentralized and centralized at the same time (1983a: 10).

In a paper published the same year as *Normal Accidents*, Perrow (1983b) developed some of the arguments for operator autonomy. He maintained that efforts to centralize authority and to control the actions of operators—reducing their role to passive monitoring so that they no longer have significant decisions to make—end up deskilling the operators and increasing the chances of error. Such efforts encourage low system comprehension, low morale, and an inability to cope with anything but the most routine conditions. Autonomy is needed to encourage a high level of commitment and knowledge. Similarly, Weick (1987: 122–123) highlighted the importance of autonomy but suggested that a balance between autonomy and rules is necessary to achieve reliability in high-risk technologies.

Hypotheses

On the basis of the empirical literature, it appears that the more that managers exercise choice within a situation of constraints (cf. Hrebiniak & Joyce, 1985), the better the outcomes will be.

> *Hypothesis 1: When managers retain autonomy, externally induced innovations will be positively related to the safety of nuclear power plants.*

The concept of self-perpetuating organizational cycles (Masuch, 1985) is relevant here. Masuch maintained that in trying to avoid undesired outcomes, organizations actually can contribute to them. If the prior safety record of a plant is poor, managers will feel that they have little latitude: they have to carry out rules precisely as they have been written. The tendency of nuclear power plant managers and regulators to become more rule-conscious when a plant has had a number of unsafe events may explain rule-bound behavior. On the other hand, if the prior safety record of a nuclear power plant is good, its managers are likely to enjoy increased discretion. Regulators are less likely to intervene in day-to-day decision making, which may partially explain autonomy.

Two cycles are likely to exist in implementing externally induced innovations.

> *Hypothesis 2: Organizations with poor safety records respond with rule-bound behavior, a response that perpetuates poor safety outcomes.*
>
> *Hypothesis 3: Organizations with good safety records retain their autonomy, a response that reinforces their strong safety records.*

Evidence for the existence of a vicious (Hypothesis 2) and a beneficent (Hypothesis 3) cycle comes from an examination of safety review innovations introduced by the Nuclear Regulatory Commission (NRC) at nuclear power plants after the accident at Three Mile Island.

Background on the Three Mile Island Study

The NRC, industry, public interest lobbyists, and academics thoroughly studied the incident at Three Mile Island, one of the worst industrial accidents in history. Some of that work was quite pessimistic about the prospects for safety in the nuclear power industry. Ford (1981), for example, found inertia and unwillingness to change. Perrow (1983a) suggested that accidents were inevitable and that little could be done to prevent them. Many analysts (Perrow, 1983b) attributed what went wrong to human error (Egan, 1982). Apparently, as a result of repeated assurances that the technology was safe, there was a mindset that the equipment was infallible and a preoccupation with the technical aspects of nuclear power, rather than with the human dimensions (Sills, Wolf, & Shelanski, 1982). Institutional and organizational inadequacies were said to have contributed as much to the accident as mechanical breakdowns.

According to investigations of the accident, one of the reasons it took place was that lessons had not been learned from similar events that had occurred at other nuclear power plants (Rogovin, 1979). Even before the Three Mile Island accident, there was concern about an increase in the number of unsafe events at nuclear power plants. The occurrence of such events had outpaced the growth in the number of new nuclear power plants, escalating from about 90 a year in 1970 to more than 3,000 a year in the late 1970s (Del Sesto, 1982).

The NRC introduced independent safety engineering groups after the Three Mile Island accident (Office of Nuclear Reactor Regulation, 1980) to deal with this problem. It proposed that all newly licensed power plants should have such groups in order to learn appropriate lessons and to implement prevention strategies. Neither the nuclear power industry nor the utilities within it sought the introduction of safety review groups; such groups had been thrust upon them by the NRC because of the unfortunate Three Mile Island accident.

This structural innovation, which the NRC developed in revised standard technical specifications, was unique in at least three ways. First, there was a focus on safety incidents and their prevention, that is, on examining safety incidents at the plant involved and at other, similar plants, to discover ways to improve safety. Second, the NRC for the first time proposed that newly licensed nuclear power plants have a full-time safety review staff—the independent safety engineering group—which was to be composed of five engineers (it was unclear why the NRC chose that number). Third, the NRC proposed that the five engineers be independent of nuclear power production; they were to be on-site reporting to someone off-site who was not in the chain of command for power production.

Four dimensions proposed by Beyer and Trice (1978) can be used for assessing the extent of the change in practice that the innovation represented. The new resources required were evidence of the *magnitude* of the task. The safety groups were expensive additions, as the five full-time engineers could cost a nuclear power plant more than half a million dollars annually. The independent safety groups also had a *pervasive* character because, as developed in the standard technical specifications, a group's full-time engineers were supposed to devote exclusive attention to examining safety incidents and to suggesting ways to prevent them. The presence and functioning of a safety group was supposed to make all employees at a plant become more safety conscious. The *novelty* was that safety engineers outside the chain of command for nuclear power production were interacting with operators and production workers and trying to influence their behavior. Clearly, the innovation was extensive.

The only aspect of the safety group's innovativeness that was not evident was its *duration*: how long would the NRC be committed to the innovation in the form in which it was proposed? Soon after requiring that newly licensed plants implement an independent safety engineering group, the NRC initiated a study to review the groups and other safety review procedures at nuclear power plants to determine if safety review groups should be extended to all power plants or if safety review systems at nuclear power plants should be revised in some other way.

METHODS

In analyzing the approaches nuclear power plants took toward implementing independent safety engineering groups, this study used both qualitative and quantitative methods. The NRC establishes standard technical specifications when it regulates nuclear power; individual plants then are allowed to customize those requirements in individual technical specifications that the NRC must approve. The technical specifications of individual power plants and interviews held at some of those plants were used to classify the implementation approaches, which were then related to safety outcomes and other measures of nuclear power plant performance.

The data were collected at the end of 1981, when the United States had 72 licensed nuclear power plants. The accident at Three Mile Island took place in April 1979. After numerous reports about the accident had appeared, the NRC established the safety review group requirement in September 1980 (Office of Nuclear Reactor Regulation, 1980). To add the five full-time engineers the requirement mandated necessitated a long lead time because of shortages of skilled people in the nuclear power industry. Moreover, the adjustment of nuclear power plants to the post-Three Mile Island situation was long and complex because of the many other changes that the NRC required: the Three Mile Island Action Plan had over 100 items. This research took place between September 1981 and September 1982 and reflected the state of implementation at that time.

In carrying out the research, a team of analysts and I compared the administrative sections of the technical specifications of 24 nuclear power plants with the administrative section in the NRC's standard technical specifications. The six plants that had been licensed after Three Mile Island were chosen for close scrutiny, as were 18 other randomly selected plants. Through the mediation of the NRC, we conducted interviews at 13 of the 24 plants whose technical specifications we had examined. The interviews confirmed the impression of rather slow adjustment by plants in the post-Three Mile Island period. They also showed that in many cases the technical specifications were incomplete or inaccurate. Thus, the interviews provided a check on the technical documents, and the analyses reported here are confined to the 13 plants for which interview data were available. Six of those plants were licensed after the accident and seven were licensed before it.

The plants were located in the eastern, midwestern, and southern United States. They had different reactor types (pressurized water or boiling water), reactor suppliers (Westinghouse, Babcock and Wilcox, or General Electric), architectural engineers, dates of initial commercial operation, and electrical power generating capabilities. The utility systems to which they belonged differed in their structure, size, and profitability.

Three days were spent at most of these facilities, with visits to both the corporate office and the plant site. To assure objectivity, interviews were conducted by a team that included me and at least one person with a disciplinary background different from mine. Usually that person was an engineer with some nuclear power training. In most cases the members of the team did separate interviews. We carried out 80 open-ended interviews with safety review staff members at 13 plants between February and September 1982.

Questions were posed about why a particular method of safety review was chosen and how that method of safety review operated (see the Appendix). The questions covered the pre-Three Mile Island requirement that plants have plant and corporate safety review groups as well as the post-Three Mile Island requirement that newly licensed plants have an independent safety engineering group. As the interviews were designed as a check on the document analysis, they followed the format of the technical specifications, with questions about the rationale, mission, composition, major tasks, processes, output, and workflow relations of the safety review groups at a nuclear power plant. Although the questions were standardized, with their precise sequence and wording determined in advance, interviewers were encouraged to probe for additional responses and to obtain other types of feedback when appropriate.

Variables and Measures

On the basis of the document analysis, the interviews, and the other information that was available, I developed the following measures.

Implementation approaches. I relied on the documentary record and the interviews to construct a typology of implementation approaches. The primary distinction I made was between *rule-bound* behavior, operationally defined as compliance with the standard technical specifications, and *autonomy*, defined as customizing those guidelines through the adoption of unique, plant-specific characteristics.

To ensure coding reliability, I had at least three members of the research team play a role in the analysis. They independently classified the safety review systems of the plants they had visited on the basis of the documents examined and the interviews conducted. The documents were primarily the technical specifications, but during the site visits safety review staff often volunteered additional documents.

As a further check on this analysis, two steps were taken. First, I shared our classification of the plants with the NRC officials responsible for the independent safety group program. Second, I showed copies of the classification to the safety review staff members who had been interviewed. As Patton (1980) remarked, analysts can learn a great deal about the accuracy of their findings from their subjects' comments. Those checks indicated that there was a consensus among the nuclear power plant staff members, the analysts, and the NRC about the classifications made.

Safety outcomes. Reports of unsafe events, which the NRC receives in the form of "license event reports," are one of the main methods that nuclear power plants and the regulatory agency have for assessing safety.[1] Events attributable to human error, such as failure to follow a procedure, constitute anywhere from a third to a quarter of the total number of reports. Significant events involve serious deficiencies in major safety-related systems because of which the NRC may require that a nuclear power reactor be shut down. The main safety outcome that I used was the number of unsafe events attributable to human error that occurred in 1982. I assumed that events occurring in 1981 came before the implementation of the new safety review systems and that events occurring in 1982 came after implementation. Comparable records for the total number of human factor and the total number of signifi-

[1] See Osborn and Jackson (1987) and Olson, McClaughlin, Osborn, and Jackson (1984) for a discussion of license event reports and other methods of assessing nuclear power safety.

cant events in 1981 and 1982 were not available, because in the interval the NRC changed the way it defined those categories.

Other performance measures. There are drawbacks to using license event reports as a measure of safety. Some plants tend to report events more readily than others, and differences in amounts of on-line time and other operational features can affect a nuclear power plant's susceptibility to events. Because of those limitations, I examined other performance measures as well. The NRC has selectively assessed the management capabilities of nuclear power plants on the basis of various criteria. According to those assessments, if a plant is given a rating of 1, it means that management attention and involvement are "aggressive"; a rating of 2 means that management attention and involvement are "adequate"; and a rating of 3, that "weaknesses are evident." Those criteria, which do not depend on self-reporting by the plants, may be less prone to manipulation by plant managers than are license event reports. However, they are highly subjective inasmuch as they depend on the impressions formed by NRC staff members during fairly brief site visits. The NRC is aware of that limitation and, largely for that reason, has discontinued the management assessments. I, therefore, relied primarily on the license event reports and used the management ratings only in a supplementary fashion.

To correct for different amounts of on-line time and other operational features that can affect the number of events a plant has, I examined 1982 plant capacity ratings. Capacity ratings show the percentage of electric power that a nuclear power plant has generated in a particular period in comparison with the amount that it could generate given its overall capacity. This indicator is very important to nuclear power plant managers, and some even have instruments on their desks that provide them with up-to-the-minute reports of their progress.

Capacity ratings have significance for two reasons. First, a plant can have few events because it has been shut down for a significant period of time; that can occur because of technical problems, or it can be the result of a reduced demand for power. If a plant has been shut down for a long time, it will show up in low capacity ratings. The second reason for examining capacity ratings is that variations in the number of events can occur because of trade-offs that nuclear power managers make among different measures of performance. Conflict among competing performance goals has been noted by many scholars (Cyert & March, 1963; Dill, 1965; Miles & Cameron, 1982; Sonnenfeld, 1982). Safety can be jeopardized to increase productive efficiency, or productive efficiency can be sacrificed for the sake of safety. If a plant has sacrificed safety, a higher capacity factor combined with a lower safety rating may result.

Controls. Other factors besides the implementation approaches may have caused the variations in outcomes that occurred. I therefore introduced the following control variables into the analysis.

Age. Plants that were newer in terms of years of commercial operation in 1982 may have had more safety events because of start-up problems. Also newer plants may have had more violations because the NRC ten pose additional rules over time. However, older plants may have had ties because of equipment obsolescence and maintenance failures.

Profitability. Utilities that were profitable in terms of return on 1981–82 may have had the resources to be able to pay for increased the other hand, less profitable utilities may have had to make sacrif maintain plant safety.

Size. A large commitment to nuclear power, measured by net megaw of operational nuclear capacity in 1982, may have meant possession overall technical resources necessary to run fairly safe plants; but a commitment may have meant less bureaucracy and more flexibility therefore an ability to manage nuclear power plants more safely.

Long-term debt. High debt measured as long-term debt in 1981–82 have meant high spending on staff and other items related to safety, or have meant that a utility had little slack to pay for safety.

Analysis strategy. To determine if there were significant correlat between the two approaches to implementation and the other variables intercorrelation analysis of all the variables in the study was carried out. Hypothesis 1, I compared the safety and performance outcomes of having rule-bound and autonomous approaches. To test for the signific of the differences between means, *t*-statistics were computed.

For Hypotheses 2 and 3, two determinations were necessary. (1) D plant's prior (i.e., 1981) safety record influence its implementation appro (2) Did the implementation approach then affect the number of safety e attributable to human error in 1982? A probit analysis was necessary to whether a plant's prior record affected its implementation approach beca the dependent variable is dichotomous, with the approach either rule-bou or autonomous. To test whether the implementation approach affected su quent safety outcomes with age, profitability, size, and long-term debt c trolled for, I conducted a series of regression analyses including prior perf mance and, because of the small number of degrees of freedom availa various combinations of the other control variables.

RESULTS

Implementation Approaches

I classified five plants as rule-bound and nine as autonomous. Because some plants were required to have an independent safety engineering group and others were not, the types of responses classified as rule-bound were: (1) Two plants had engineering groups exactly like those the NRC proposed. The NRC's standard technical specifications matched precisely what these nuclear power plants had adopted. This response was called obedience. (2) Plants licensed before the Three Mile Island accident did not have to have an independent safety group or equivalent. For those plants, rule-bound behav ior meant doing what the NRC expected and little more; with very minor exceptions, their technical specifications precisely matched the applicable

RC standards. To the extent that they modified their behavior after the Three Mile Island accident, they created subcommittees as appendages to their part-time safety groups (two plants) or added a single full-time safety review position (one plant). This response was called incremental adjustment (cf. Lindblom, 1959; Quinn, 1980).

These responses were classified as autonomous: (1) Some plants licensed after the Three Mile Island accident were in the process of creating a corporate nuclear safety review department with responsibility for both off-site review and on-site safety engineering. The head of this department had vice-presidential status and reported directly to a top utility executive. Because the purpose of this new safety review component was to build an entirely different type of organizational structure to achieve the intent of the NRC's guidelines, we labeled this response (found at two plants) modification.

(2) At two other plants the existing quality assurance function was combined with safety engineering. Managers at these plants decided on their own to add the five full-time safety engineers to their existing quality assurance staff. Doing so altered the nature of what the NRC intended. The distinction the NRC was trying to make was between the "policeman" role that quality assurance traditionally performed and the ability to challenge existing procedures that the independent group was supposed to carry out. This response, therefore, was called combination.

(3) Significant planned and actual alterations of safety review systems at plants licensed before the Three Mile Island accident were not required. When such plants made these changes, they were acting on their own initiative, in response to what they believed to be the lessons of the incident. Some of the plants planned for adoption of a safety review system, taking comprehensive steps to consider what they might do. Two plants, for example, did detailed studies that would have created an entirely different type of system. The proposed technical support group that they intended to create would have aided existing review groups as well as having responsibilities of its own. Partial staffing had started, even though implementation was not obligatory, with full staffing taking place only if an independent safety engineering group or equivalent were mandated. This response was called planning.

(4) A different response was to create a group like an independent safety engineering group that was the equivalent of what the NRC proposed, not because the NRC required it, but because management believed that such a group was necessary. To the extent that these plants complied with the NRC's proposal, they did so voluntarily, taking the initiative, and did not act because of NRC pressure or fear of NRC disapproval. The response of these two plants was called anticipation.

Obedience and anticipation. Although it is not possible to take full advantage of the qualitative analysis because there was so much material (cf. Marcus & Osborn, 1984), a revealing comparison summarizing some of the major differences between obeying and anticipating plants can be made. At the two plants that obeyed, the offices of the independent safety engineering group were located in a temporary structure in the parking lot, and group members had to obtain visitors' badges before entering the plants. The plants' staff maintained that the safety group's role had not been well defined, that it did not fit in with existing practices, and that it was not likely to have a major impact. The safety group was making many recommendations, but the plants were not adopting those recommendations. The plant manager pointed to a huge stack of papers in the corner of his office and said, "Do you know how many of these [recommendations] we have acted on?" Showing a space of about a quarter of an inch between his thumb and forefinger, he continued, "that much."

In contrast, at the plants that anticipated, safety review managers maintained that the group resembling an independent safety group had technical potential, was compatible with existing practices, and could have an important impact. Interviewees at such plants said that the group's members had "years of operating experience," were capable of understanding the plant's personnel, had an appreciation for "what was possible," and could "put in perspective" whether something was "significant." Their recommendations, both formal and informal, were accepted and were "promptly carried out."

The structures of the safety groups at these plants were similar. Both at the obeying and anticipating plants, there were five engineers on-site who reported off-site to someone in the corporate office. The primary emphasis of the independent safety group was on events at a plant and at other plants that might indicate ways to improve safety. The major difference between the two types of plants concerned their approach to implementation. Relinquishing freedom and control to an external agent (the NRC) when preferred states had been disturbed by an unwelcome surprise (the Three Mile Island Accident) created resistance, but independently tailoring a response to conditions at a plant resulted in acceptance and understanding.

Safety Outcomes

Table 1 presents the intercorrelations of all the variables in the study. As can be seen, autonomy is significantly correlated ($p < .05$) with a low occurrence of events in 1981 and 1982 and very significantly correlated ($p < .001$) with a low occurrence of human error events. These findings support Hypothesis 1.

There are also significant correlations between autonomy and high profitability, between low profitability and the number of events in 1982, and between low profitability and a high number of human error events. The overall number of events is significantly correlated with the overall number of human error events but not with the number of significant events; the reason may be that significant events represent a situation that has dramatically deteriorated, but human error events and general events represent precursor circumstances.

Significant correlations also exist between age and the number of events in 1981 and between long-term debt and the number of events in 1981. There are a number of ways to interpret these findings. Experience may be a factor in reducing the number of events, older technologies may be safer, or the correlation may simply represent increased reporting requirements that the NRC has imposed on newer plants. Plants belonging to utilities with high debt also had fewer events and in 1982 had fewer significant events. That finding could reflect a spillover effect on safety of a utility's long-term capital commitments.

Table 2 shows that the plants classified as autonomous outperformed the plants classified as rule-bound on nearly every performance indicator, with long-term debt the only exception. The smallest differences in outcomes are in the capacity ratings. Thus, it appears that productive efficiency was not sacrificed for the sake of safety, nor was safety jeopardized for the sake of productive efficiency.

The largest differences between the rule-bound and autonomous plants are in the number of human error events. Rule-bound plants had more than three times the number of human error events than the autonomous plants. Significant differences also exist with respect to events in 1981 and 1982 and with respect to profitability. Autonomous plants had fewer events and were generally more profitable. These findings support the hypothesis that autonomous implementation approaches do better than rule-bound approaches with regard to safety and other indicators.

To test for the existence of the hypothesized vicious and beneficent cycles (Hypotheses 2 and 3), I first made a determination about the effects of past events on implementation approaches. The probit analysis showed that the number of 1981 events correctly identified 85 percent of the implementation approaches (see Table 3). The adjusted R^2 value, .91, supports the hypothesis that a poor safety record leads to rule-bound behavior.

Table 4 shows the results of four regression analyses assessing the effect of the implementation approaches on 1982 performance. Different combinations were analyzed because the N is so small. The relationship between implementation approaches and human error events is strong, even after the introduction of the control variables. Implementation approach is the only variable with a significant value in each regression equation.

Thus, the probit analysis and regression results support Hypotheses 2 and 3. Plants with a poor 1981 safety record tend to respond in a rule-bound manner, a response that only perpetuates their poor safety performance, and plants with a strong 1981 safety record tend to respond in an autonomous way, a response that reinforces their strong safety record.

DISCUSSION AND IMPLICATIONS

After the Three Mile Island accident, nuclear power plants became pervious to outside forces; the NRC introduced new organizational arrangements for safety review management. Some power plants followed the guidelines the NRC established; others customized those guidelines to fit their individual circumstances. I called the former approach rule-bound and the latter approach autonomous and related those approaches to safety outcomes and

TABLE 1
Descriptive Statistics and Correlations Between Variables[a]

Variables	Means	Standard Deviations	1	2	3	4	5	6	7	8	9	10
1. Implementation approach[b]	0.62	0.51										
2. Events, 1981	66.00	29.33	−.75									
3. Events, 1982	69.85	38.84	−.83	.80								
4. Human error events	19.92	11.85	−.98	.69	.80							
5. Significant events	3.85	2.76	−.16	.52	.26	.03						
6. Management rating	1.73	0.42	−.41	.05	.25	.35	−.04					
7. Capacity rating	60.68	12.85	.10	.02	.32	−.05	.03	−.46				
8. Profitability[c]	12.59	1.57	.58	−.30	−.59	−.59	.18	−.54	−.02			
9. Age	6.92	4.86	.43	−.61	−.53	−.46	−.38	.29	−.40	−.13		
10. Size	1,948.30	994.89	.02	−.00	.03	−.11	.16	.35	.03	.26	−.21	
11. Long-term debt[d]	45.46	3.89	.35	−.57	−.39	−.19	−.59	−.47	.27	.30	−.10	−.23

[a] $N = 13$. Correlation coefficients above .49 are significant at $p < .10$; those above .57, at $p < .05$; those above .71, at $p < .01$; and those above .82, at $p < .001$.

[b] Rule-bound = 0, autonomous = 1.

[c] Profitability was measured as a percentage of return on average common equity.

[d] Long-term debt was measured as a percentage of year-end capitalization ratios.

TABLE 2
A Comparison of Rule-bound and Autonomous Implementation Approaches[a]

Variables	Rule-bound Means	Rule-bound Standard Deviations	Autonomous Means	Autonomous Standard Deviations	t	p
Events, 1981	92.6	26.4	49.4	16.0	−3.71	.003
Events, 1982	109.2	33.1	45.3	12.7	−5.01	.000
Human error events	34.0	3.2	11.1	2.3	−15.08	.000
Significant events	4.4	3.8	3.5	2.1	−0.55	.590
Management rating	1.9	0.3	1.6	0.5	−1.50	.161
Capacity rating	59.1	17.9	61.7	9.8	0.35	.736
Profit[b]	11.5	1.6	13.3	1.2	2.35	.039
Age	4.4	2.2	8.5	5.5	1.57	.145
Size	1,922.4	568.9	1,964.5	1,229.3	0.07	.944
Long-term debt[c]	43.8	4.4	46.5	3.4	1.25	.238

[a] For the rule-bound plants, $N = 5$; for the autonomous plants, $N = 8$.
[b] Profitability was measured as a percentage of return on average common equity.
[c] Long-term debt was measured as a percentage of year-end capitalization ratios.

TABLE 3
Results of Probit Analysis of Effects of Past Safety Record on Rule-bound and Autonomous Implementation Approaches[a]

Independent Variables	Maximum Likelihood Estimates	Standard Errors	Maximum Likelihood Estimate/ Standard Error
Constant[b]	8.14	5.34	1.52
Past safety record[c]	−0.12	0.08	−1.52
Adjusted $R^2 = .91$			

[a] Percent predicted correctly = .85.
[b] Rule-bound = 0; autonomous = 1.
[c] The past safety record was measured as the total number of safety-related events in 1981.

various other measures of the performance of nuclear power plants and found that prior safety outcomes affected implementation approaches. Poor safety performance restricted choice. It yielded rule-bound approaches that perpetuated poor safety outcomes. A good record, on the other hand, opened a zone of discretion. It preserved autonomy, which resulted in continued strong safety performance.

Autonomy is the outcome of a good safety record and contributes to a good safety record. That is the essence of a self-perpetuating cycle—it is hard to break. If poor performers are given more autonomy, this analysis suggests, their safety record is likely to improve; but this analysis also suggests that they are not likely to be given more autonomy precisely because they are

TABLE 4
Results of Regression of Human Error Events on Implementation Approach and Other Variables[a]

Independent Variables	Controlling Prior Events	Controlling Age and Profits	Controlling Size and Long-term Debt	All Six Variables
Constant	37.60	43.83	14.93	28.65
	(3.83)	(8.78)	(6.84)	(22.60)
Implementation	24.54*	−20.48*	−24.09*	−22.71*
approach[b]	(2.28)	(2.42)	(1.10)	(1.10)
Events, 1981	−0.39			−0.18
	(0.39)			(0.65)
Age		−0.24		−0.21
		(0.21)		0.28
Profitability		−0.76		−0.57
		(0.71)		(0.54)
Size			−0.74	−0.82
			(0.54)	(0.81)
Long-term debt			0.47*	0.36
			(0.15)	(0.34)
Error term	2.66	2.70	1.80	1.98
	(0.52)	(0.53)	(0.35)	(0.39)
Adjusted R^2 ($N = 13$)	.95	.95	.98	.97
F (entire equation)	114.07*	74.01*	170.29*	70.73*

[a] Ordinary least squares regression used; unstandardized coefficients reported. Standard errors are in parentheses.

[b] Rule-bound = 0; autonomous = 1.

* $p < .01$

poor performers. That is the essence of a vicious cycle. Thus, I have presented evidence for the existence of a vicious cycle in which poorly performing nuclear power plants have their choices narrowed, which leads to continued poor performance, and evidence for the existence of a beneficent cycle in which nuclear power plants with stronger performance retain their autonomy, which perpetuates their strong safety performance. The findings suggest that the potentially most dangerous plants are the least likely to benefit from the innovations introduced by the NRC after the Three Mile Island accident and that the least dangerous plants are the most likely to benefit. Thus, in the short run, the performance gap between the strong and weak plants increases.

As was shown in the literature section, many studies of the implementation process have been carried out. Most of them have focused on social policies. Although an older tradition (Duncan, 1976; Pressman & Wildavsky, 1974; Wilson, 1963) suggests that rule-bound behavior is necessary during implementation, most recent studies (Bourgeois & Brodwin, 1984; Guth & Macmillan, 1986; Lipsky, 1978) have put greater emphasis on autonomy.

This study addressed how an externally induced innovation affects the organization and management of a high-risk technology and showed that autonomy is needed. The more managers exercise choice within a situation of constraints, the better the outcomes are.

Thus, this study's results are consistent with the results obtained in research examining implementation of social programs (Beyer & Trice, 1978; Maynard-Moody et al., 1987). Implementation is likely to be more effective when policy implementators are free to design and determine the specifics. The reasons include the following: (1) Policy formulators may not possess sufficient information at the level at which policy is carried out. Implementors are likely to have greater knowledge at the point of delivery, where there are multiple and contradictory demands. (2) Efforts to centralize authority and control the actions of implementors may deskill those who carry out policy and increase chances of error. Such efforts may encourage low system comprehension, low morale, and an inability to cope with anything but the most routine conditions. Autonomy is needed to encourage high levels of commitment and knowledge. (3) In particular, the disposition of implementors is likely to be negatively affected if they are not granted a sufficient level of autonomy, and it is their dispositions that are often critical to assuring a program's success.

Autonomy is needed for organizations to go beyond mere formal compliance to identification and internalization (cf. Kelman, 1961). In this respect, it resembles market-driven processes, which rely on individual initiative and competence to achieve objectives that cannot be accomplished by central direction. The peculiar advantage of market-like processes is their dependence on search, trial and error, and experimentation at the point of delivery, where specialized knowledge and skills are needed (Schultze, 1983). If implementors have flexibility to customize external demands, implementation is likely to be with the spirit, not the letter, of the law, and particular outcomes are likely to be enhanced.

Managers therefore should be aware of the possible consequences of blind acceptance of external dictates, and regulators should take heed of companies that strictly obey the law. These companies may not achieve the results the regulators intend.

Of course, there are important limitations to our findings. The small number of plants studied, the use of judgment in coding the implementation approaches, and the possibility that reports of events were inaccurate all limit the generalizability and validity of the findings. Additional research on the implementation of externally induced innovations after crises like the accident at Three Mile Island and on the organization and management of high-risk technologies like nuclear power needs to be done.

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APPENDIX

The outline of the major questions used in the interview guide follows. The actual guide also included one or more probes after most questions. Further details can be obtained by contacting the author.

1. Safety review structure. The standard technical specifications say that the methods of independent review and audit may take many forms: the license may utilize a standing committee or it may assign the function to a separate organizational unit. At your plant, the decision has been made (a) to utilize standing committees, or (b) to assign the function to a separate unit.

a. Rationale. Why was this method of review chosen?

b. Advantages and disadvantages. In your opinion, what are the advantages and disadvantages of this method?

2. Plant review group. Let's turn to the plant safety review group. Can you tell us a little about its history?

a. Rationale. Why was it formed?

b. Mission. What is its mission? Is it achieving its mission?

c. Composition. What is its composition? How are individuals selected?

d. Major tasks. What are the major tasks it carries out? What other tasks should it undertake?

e. Process. Describe how the safety review group performs its task.

f. Output. What are the products of the committee's work? List items like reviews, reports, rules, and meeting minutes that the committee issues. (Try to obtain selected copies of these items.)

g. Workflow relations. Who does the committee report to, that is, to whom does it submit its output? Who else should receive its output?

h. Impact of plant safety. Assess the impact of the group on plant safety. Describe its impact.

i. Possible changes. What are the most important changes in mission, composition, tasks, procedures, or powers that would improve the performance of the committee? Discuss.

3. Utility review group. Let's turn to the utility review group. Can you tell us a little about its history?

a. Rationale. Why was it formed?

b. Mission. What is its mission? Is it achieving its mission?

c. Composition. What is its composition? How are individuals selected?

d. Major tasks. What are the major tasks it carries out? What other tasks should it undertake?

e. Process. Describe how the utility review group performs its tasks.

4. ISEG. (This section only applied if a plant had an independent safety engineering group or the equivalent.) Let's discuss ISEG (or the ISEG-equivalent). Can you tell us a little about its history? Has it performed useful functions?

a. Rationale. Why was it formed?

b. Mission. What is its mission? Is it achieving its mission?

c. Composition. What is its composition? How are individuals selected?

d. Major tasks. What are the major tasks it carries out? What other tasks should it undertake?

e. Process. Describe how ISEG performs its tasks.

f. Output. What are the products of ISEG's work? List items like reviews, reports, rules and meeting minutes that ISEG issues. (Try to obtain selected copies of these items.)

g. Workflow relations. Who does ISEG report to, that is, to whom does it submit its output? Who else should receive its output?

h. Impact on plant safety. Assess the impact of ISEG on plant safety. Describe its impact.

i. Possible changes. What are the most important changes in mission, composition, task, procedures, or powers that would improve the performance of ISEG? Discuss.

5. Possible ISEG. (This section only applied if a plant did not have to have an independent safety group or the equivalent.) Discuss the possible functions that could be performed by an ISEG. Would an ISEG perform useful functions?

a. Formation. How would an ISEG be formed?
b. Mission. What would be its mission?
c. Composition. How would it be composed?
d. Major tasks. What major tasks would it perform? What other tasks should it undertake?
e. Agenda. How would issues get on its agenda?
f. Analysis. What kind of analysis would it do?
g. Powers. What powers would it have?
h. Output. What would be its outputs?
i. Workflow relations. To whom would it report?
j. Impact on plant safety. What impact would it have on plant safety?
k. Impact on current practices. How would it affect current safety review practices?

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IN SEARCH OF EXCELLENCE

Lessons from America's Best-Run Companies

by Thomas J. Peters
and Robert H. Waterman, Jr.

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rant. Sometime later a letter was sent to these establishments asking whether they would accept Chinese as guests. [There was a strong anti-Chinese bias in the United States at the time.] Ninety-two percent said they would not. LaPiere, and many after him, interpreted these findings as reflecting a major inconsistency between behavior and attitudes. Almost all the proprietors *behaved* in a tolerant fashion, but they expressed an intolerant *attitude* when questioned by letter.

Analogously, what's called "foot-in-the-door research" demonstrates the importance of incrementally acting our way into major commitment. For instance, in one experiment, in Palo Alto, California, most subjects who initially agreed to put a *tiny* sign in their front window supporting a cause (traffic safety) subsequently agreed to display a billboard in their front yard, which required letting outsiders dig sizable holes in the lawn. On the other hand, those not asked to take the first small step turned down the larger one in ninety-five cases out of a hundred.

The implications of this line of reasoning are clear: only if you get people *acting,* even in small ways, the way you want them to, will they come to believe in what they're doing. Moreover, the process of enlistment is enhanced by explicit *management* of the after-the-act labeling process—in other words, publicly and ceaselessly lauding the small wins along the way. "Doing things" (lots of experiments, tries) leads to rapid and effective learning, adaptation, diffusion, and commitment; it is the hallmark of the well-run company.

Moreover, our excellent companies appear to do their way into strategies, not vice versa. A leading researcher of the strategic process, James Brian Quinn, talks about the role of leadership in strategy building. It doesn't sound much like a by-the-numbers, analysis-first process. He lists major leadership tasks, and the litany includes amplifying understanding, building awareness, changing symbols, legitimizing new viewpoints, making tactical shifts and testing partial solutions, broadening political support, overcoming opposition, inducing and structuring flexibility, launching trial balloons and engaging in systematic waiting, creating pockets of commitment, crystallizing focus, managing coalitions, and formalizing

commitment (e.g., empowering "champions"). The role of the leader, then, is one of orchestrator and labeler: taking what can be gotten in the way of action and shaping it—generally after the fact—into lasting commitment to a new strategic direction. In short, he makes meanings.

The leading mathematician Roger Penrose says, "The world is an illusion created by a conspiracy of our senses." Yet we poor mortals try valiantly, at times desperately, to inscribe meaning on the *tabula rasa* given to us at birth. As Bruno Bettelheim has observed in *On the Uses of Enchantment,* "If we hope to live not just from moment to moment, but in true consciousness of our existence, then our greatest need and most difficult achievement is to find meaning in our lives." Bettelheim emphasizes the historically powerful role of fairy tales and myths in shaping meaning in our lives.

As we worked on research of our excellent companies, we were struck by the dominant use of story, slogan, and legend as people tried to explain the characteristics of their own great institutions. All the companies we interviewed, from Boeing to McDonald's, were quite simply rich tapestries of anecdote, myth, and fairy tale. And we do mean fairy tale. The vast majority of people who tell stories today about T. J. Watson of IBM have never met the man or had direct experience of the original more mundane reality. Two HP engineers in their mid-twenties recently regaled us with an hour's worth of "Bill and Dave" (Hewlett and Packard) stories. We were subsequently astonished to find that neither had seen, let alone talked to, the founders. These days, people like Watson and A. P. Giannini at Bank of America take on roles of mythic proportions that the real persons would have been hard-pressed to fill. Nevertheless, in an organizational sense, these stories, myths, and legends appear to be very important, because they convey the organization's shared values, or culture.

Without exception, the dominance and coherence of culture proved to be an essential quality of the excellent companies. Moreover, the stronger the culture and the more it was directed toward the marketplace, the less need was there for policy manuals, organization charts, or detailed procedures and rules. In these companies, people way down the line know what they are supposed to do in most situations because the handful of guiding values is crystal clear. One of our colleagues is working with a big company recently thrown together out of a series of mergers. He says: "You know, the problem is *every* decision is being made for the first time. The top people are inundated with trivia because there are no cultural norms."

By contrast, the shared values in the excellent companies are clear, in large measure, because the mythology is rich. Everyone at Hewlett-Packard knows that he or she is supposed to be innovative. Everyone at Procter & Gamble knows that product quality is the sine qua non. In his book on P&G, *Eyes on Tomorrow,* Oscar Schisgall observes: "They speak of things that have very little to do with price of product. . . . They speak of business integrity, of fair treatment of employees. 'Right from the start,' said the late Richard R. Deupree when he was chief executive officer, 'William Procter and James Gamble realized that the interests of the organization and its employees were inseparable. That has never been forgotten.'"

Poorer-performing companies often have strong cultures, too, but dysfunctional ones. They are usually focused on internal politics rather than on the customer, or they focus on "the numbers" rather than on the product and the people who make and sell it. The top companies, on the other hand, always seem to recognize what the companies that set only financial targets don't know or don't deem important. The excellent companies seem to understand that *every* man seeks meaning (not just the top fifty who are "in the bonus pool").

Perhaps transcendence is too grand a term for the business world, but the love of product at Cat, Bechtel, and J&J comes very close to meriting it. Whatever the case, we find it compelling that so many thinkers from so many fields agree on the dominating need of human beings to find meaning and transcend mundane things. Nietzsche believed that "he who has a *why* to live for can bear almost any *how.*" John Gardner observes in *Morale,* "Man is a stubborn seeker of meaning."

Some of the riskiest work we do is concerned with altering organization structures. Emotions run wild and almost everyone feels threatened. Why should that be? The answer is that if companies do not have strong notions of themselves, as reflected in their values, stories, myths, and legends, people's only security comes from where they live on the organization chart. Threaten that, and in the absence of some grander corporate purpose, you have threatened the closest thing they have to meaning in their business lives.*

So strong is the need for meaning, in fact, that most people will yield a fair degree of latitude or freedom to institutions that give it to them. The excellent companies are marked by very strong cultures, so strong that you either buy into their norms or get out. There's no halfway house for most people in the excellent companies. One very able consumer marketing executive told us, "You know, I deeply admire Procter & Gamble. They are the best in the business. But I don't think I could ever work there." She was making the same point that Adam Myerson at *The Wall Street Journal* had in mind when he urged us to write an editorial around the theme: "Why we wouldn't want to work for one of our excellent companies." The cultures that make meanings for so many repel others.

Some who have commented on our research wonder if there is not a trap or two in the very strength of the structures and cultures of the well-run companies. There probably is. First, the conventions are so strong that the companies might be blindsided by dramatic environmental change. This is a fair point. But we would argue that in general the excellent company values almost always stress being close to the customer or are otherwise externally focused. Intense

* The converse, apparently, is also true. When we were working for our first client in Japan on a problem that had nothing to do with organization, we happened to witness a major reorganization in process at the same time as our study. We were startled by the dramatic nature of the change and the speed with which it took place. Within a week, nearly all the top 500 executives had changed jobs, many had moved from Tokyo to Osaka or vice versa, the dust had settled, and business was proceeding as usual. We concluded that the Japanese were able to reorganize as seemingly ruthlessly as they did because security was always present; not security of position, for many were demoted or transfered to subsidiary companies, but security that had its roots in solid cultural ground and shared meanings.

customer focus leads the prototypical excellent company to be unusually sensitive to the environment and thus *more* able to adapt than its competitors.

For us, the more worrisome part of a strong culture is the ever present possibility of abuse. One of the needs filled by the strong excellent company cultures is the need most of us have for security. We will surrender a great deal to institutions that give us a sense of meaning and, through it, a sense of security. Unfortunately, in seeking security, most people seem all too willing to yield to authority, and in providing meaning through rigidly held beliefs, others are all too willing to exert power. Two frightening experiments, those of Stanley Milgram at Yale and Philip Zimbardo at Stanford, warn us of the danger that lurks in the darker side of our nature.

The first, familiar to many, are Stanley Milgram's experiments on obedience. Milgram brought adult subjects off the street into a Yale lab and asked them to participate in experiments in which they were to administer electric shocks to victims. (In fact, they were not doing so. The victims were Milgram conspirators and the electric shock devices were bogus. Moreover, the experimental protocol made it appear that the choice of both the victim and the shocker was random.) Initially, Milgram had the victims placed in one room and the shock givers in another. Following instructions given to them by a white-coated experimenter (the authority figure), the shock givers turned the dial, which went from "mild" to "extremely dangerous." On instruction, they administered the electricity, and to Milgram's surprise and disappointment, the experiment "failed." All went "all the way" in administering shock. One hundred percent followed orders, although in earlier written tests over 90 percent predicted they would not administer any shock whatsoever.

Milgram added embellishments. He connected the rooms with a window, so the shock givers could see the "victims" writhe in pain. He added victim "screams." Still, 80 percent went to "intense" on the dial, and 65 percent went to "extremely dangerous." Next he made the victims appear to be "homely, 40-year-old female accountants." He took the experiments out of the university and conducted

them in a dreary downtown loft. He had the shock giver hold the victim's hand on the electric charge plate. All these steps were aimed at breaking down the subject's acceptance of the white-coated experimenter's authority. None worked very well. People still by and large accepted authority.

Milgram postulated numerous reasons for the outcome. Was it genetic? That is, is there species-survival value in hierarchy and authority that leads us all to submit? Are people simply sadistic? He concluded, most generally, that our culture "has failed almost entirely in inculcating internal controls on actions that have their origin in authority."

In the other case, Zimbardo advertised in a newspaper in Palo Alto, California (a prototypical upper-class community), soliciting volunteers for a "prison" experiment. At dawn one Saturday morning he went out, picked the volunteers up, booked them, and took them to a wallboard "prison" in the basement of the Stanford University psychology building. Within hours of their arrival, the randomly assigned "guards" started acting like guards and the randomly assigned "prisoners" started acting like prisoners. Well within the first twenty-four hours, the guards were behaving brutally—both physically and psychologically. By the end of the second day, a couple of the prisoners were on the verge of psychotic breakdown and had to be released from the experiment. "Warden" Zimbardo, afraid of his own behavior as well as that of the others, stopped the experiment four days into a ten-day protocol.

The lessons are applicable to the cultures of the excellent companies, but the apparent saving grace of the latter is that theirs are not inwardly focused. The world of the excellent company is especially open to customers, who in turn inject a sense of balance and proportion into an otherwise possibly claustrophobic environment.*

On the whole, we stand in awe of the cultures that the excellent

* Another worrisome aspect of the strong corporate culture is how well those who have spent most of their lives in it will fare on the outside should they ever leave, which some do. Our observation, though not backed by research, is that they do less well than might be expected, given their often stellar records in the top companies. It's a bit like a baseball pitcher traded away from the Yankees. These people often are totally unaware of the enormous support system they had going for them in the excellent company, and are at the very least initially lost and bewildered without it.

then. Maybe March would contend that his book *Ambiguity and Choice in Organizations,* co-written with Johan Olsen in 1976, is a full-blown theory, but we think not. Certainly Karl Weick does not contend that his marvelous *Social Psychology of Organizing* is a fully developed theory. In fact, he says simply, "This book is about organizational appreciation."

The point is that the efforts by today's leading theorists add up to an important set of vignettes about managing. In crucial ways, these vignettes accurately contravene much of the conventional wisdom that existed previously. What is more, they counter old shibboleths in ways that are entirely congenial with our observations about excellent companies. But that is not to say that there is no need for new theory. The need is desperate if today's managers, their advisers, and the teachers of tomorrow's managers in the business schools are to be up to the challenges we posed in Chapter 2.

Certainly we are not proposing a complete theory of organizing here. But we do think that via the excellent companies findings we see a few dimensions of theory that have not been given attention by scholars or practicing managers. Moreover, we think that these findings provide us with a simple and direct way to express some concepts hitherto obscured in today's state-of-the-art theories. Meanwhile, there are a few underlying ideas that ought to be brought out as a basis, at least, for understanding the eight attributes we will be discussing in the next eight chapters.

The clear starting point is acceptance of the limits of rationality, the central theme of the last two chapters. Building on that, four prime elements of new theory would include our observations on basic human needs in organizations: (1) people's need for meaning; (2) people's need for a modicum of control; (3) people's need for positive reinforcement, to think of themselves as winners in some sense; and (4) the degrees to which actions and behaviors shape attitudes and beliefs rather than vice versa.

There are some very important ideas from past and current management theory that need to be woven into the fabric of new theory. Two that we particularly want to stress, because we don't think they have received the attention they deserve, are (1) the notion of companies, especially the excellent ones, as distinctive cultures; and (2) the emergence of the successful company through purposeful, but specifically unpredictable, evolution.

THE IMPORTANCE OF CULTURE

Some colleagues who have heard us expound on the importance of values and distinctive cultures have said in effect, "That's swell, but isn't it a luxury? Doesn't the business have to make money first?" The answer is that, of course, a business has to be fiscally sound. And the excellent companies are among the most fiscally sound of all. But their value set *integrates* the notions of economic health, serving customers, and making meanings down the line. As one executive said to us, "Profit is like health. You need it, and the more the better. But it's not why you exist." Moreover, in a piece of research that preceded this work, we found that companies whose only articulated goals were financial did not do nearly as well financially as companies that had broader sets of values.

Yet it's surprising how little is said about the shaping of values in current management theories—particularly how little is said about companies as cultures. The estimate of 3M quoted in Chapter 1—"The brainwashed members of an extremist political sect are no more conformist in their central beliefs"—remember, is the same 3M that's known not for its rigidity but for its unbridled entrepreneurship. Delta Airlines lives its "Family Feeling," and, notes chairman Tom Beebe, "What Delta has going for it is the very close relationship we all feel for one another." Some people leave Texas Instruments because it is "too rigid"; on the other hand, it has been tremendously innovative, and chairman Mark Shepherd says of its Objectives, Strategies, and Tactics planning system,"OST would be sterile were it not for the culture of innovation that permeates the institution." A *Fortune* analyst makes the following observation about Maytag: "The reliability of Maytag washers owes a lot to the Iowa work ethic." Columbia University's Stanley Davis claims, "Firms operating out of Rochester, New York [e.g., Kodak], or Midland, Michigan [e.g., Dow], often have very strong corporate cultures. Much stronger than firms that operate out of New York City or Los Angeles."

A few audible murmurings about values and culture have been made by the academics since Barnard and Selznick raised the issue. Richard Normann, in *Management and Statesmanship,* talks of the importance of the "dominating business idea," and comments that the "most crucial process" going on in any company may be the continuing interpretation of historic events and adjustment of the dominating business idea in that context. And in a recent book on organizational structuring, Henry Mintzberg mentions culture as a design principle, but only briefly, calling it (unfortunately) the "missionary configuration" and giving it a regrettable futuristic slant: "The missionary [structural] configuration would have its own prime coordinating mechanism—socialization, or, if you like, the standardization of norms—and a corresponding main design parameter—indoctrination. . . . The organization would have . . . an ideology. The perceptive visitor would 'sense it' immediately." But there's nothing as futuristic about it as Mintzberg implies. Procter & Gamble has been operating that way for about 150 years, IBM for almost 75. Levi Strauss's predominantly people-oriented philosophy started with an unheard-of "no layoff" policy following the 1906 San Francisco earthquake.

Andrew Pettigrew sees the process of shaping culture as the prime management role: "The [leader] not only creates the rational and tangible aspects of organisations, such as structure and technology, but also is the creator of symbols, ideologies, language, beliefs, rituals, and myths." Using strikingly similar language, Joanne Martin of Stanford thinks of organizations as "systems composed of ideas, the meaning of which must be managed." Martin has spurred a great deal of practical, specific research that indicates the degree to which rich networks of legends and parables of all sorts pervade top-performing institutions. HP, IBM, and DEC are three of her favorite examples. The research also indicates that the poor performers are relatively barren in this dimension. Warren Bennis also speaks of the primacy of image and metaphor:

> It is not so much the articulation of goals about what an [institution] *should* be doing that creates new practice. It's the imagery that creates the understanding, the compelling moral necessity that the new way is right. . . . It was the beautiful writing of Darwin about his travels on the *Beagle,* rather than the content of his writing, that made the difference. Because the evolutionary idea had really been in the air for a while. Not only were there parallel mentions of it, but Darwin's uncle had done some of the primary work on it. . . . Thus, if I were to give off-the-cuff advice to anyone trying to institute change, I would say, "How clear is the metaphor? How is that understood? How much energy are you devoting to it?"

The business press, starting sometime in 1980, has increasingly used culture as a metaphor of its own. *Business Week* legitimated the practice by running a cover story on corporate culture in the late summer of 1980. Now the word seems to pop up more and more frequently in business journalism.

Perhaps culture was taboo as a topic following William H.Whyte, Jr.'s *The Organization Man* and the conformist, gray flannel suit image that he put forward. But what seems to have been overlooked by Whyte, and management theorists until recently, is what, in Chapter 12, we call the "loose-tight" properties of the excellent companies. In the very same institutions in which culture is so dominant, the highest levels of true autonomy occur. The culture regulates rigorously the few variables that do count, and it provides meaning. But within those qualitative values (and in almost *all* other dimensions), people are encouraged to stick out, to innovate. Thus, "IBM Means Service" underscores the company's overpowering devotion to the individual customer; but that very formulation also provides remarkable space. Everyone, from clerks on up, is prodded to do whatever he or she can think of to ensure that the individual customer gets taken care of. In a more mundane setting, Steven Rothman, writing in *D&B Reports,* quotes a Tupperware dealer: "The company gives me great freedom to develop my own approach. There are certain elements that need to be in every party to make it successful, but if those elements are colored by you, a Tupperware dealer—purple, pink and polka dot, and I prefer it lavender and lace—that's okay. That freedom allows you to be the best you are capable of being." So, in fact, the power of the value is in large measure that it encourages practical innovation to carry out its spirit to the full.

EVOLUTION

To the extent that culture and shared values are important in unifying the social dimensions of an organization, managed evolution is important in keeping a company adaptive.

We are confronted with an extraordinary conundrum. Most current theory is neither tight enough nor loose enough. Theory is not tight enough to consider the role of rigidly shared values and culture as the prime source of purpose and stability. It proposes rules and goal setting to cover these bases. At the same time, most current theory is not loose enough to consider the relative lack of structure and the need for wholly new management logic to ensure continuous adaptation in large enterprises. Instead, it habitually proposes structural rules and planning exercises—both forms of rigidity—to hurdle this need.

Both problems proceed from the inherent complexity of large organizations, yet both have been banished by the excellent companies on an ad hoc basis. Big institutions are too complex, really, to manage by rule books, so managers, to simplify the problem, use a few transcending values covering core purposes. Adaptation is also too complex to manage by rules in a big enterprise, so astute managers simply make sure that enough "blind variations" (i.e., good tries, successful or not) are going on to satisfy the laws of probability—to ensure lots of bunt singles, an occasional double, and a once-a-decade home run.

We need new language. We need to consider adding terms to our management vocabulary: a few might be temporary structures, ad hoc groups, fluid organizations, small is beautiful, incrementalism, experimentation, action orientation, imitations, lots of tries, unjustified variations, internal competition, playfulness, the technology of foolishness, product champions, bootlegging, skunk works, cabals, and shadow organizations. Each of these turns the tables on conventional wisdom. Each implies both the absence of clear direction and the simultaneous need for action. More important still, we need new metaphors and models to stitch these terms together into a sensible, coherent, memorable whole.

James March, as we noted, has proposed as a concomitant to his "garbage can" metaphor a model of decision making in which "streams of problems, solutions, participants, and choice opportunities" swirl around, occasionally resulting in decisions. Moreover, he suggests that "[we] need to supplement the technology of reason with a technology of foolishness. Individuals and organizations need ways of doing things for which they have no good reason. Not always. Not usually. But sometimes. They need to act before they think." Leadership in such a system, March asserts, would play a different role: "Rather than an analyst looking for specific data, we are inclined to think of a monitor looking for unusual signals." March sums up his views more attractively when he notes that "such a vision of managing organizations is a relatively subtle one. It assumes that organizations are to be sailed rather than driven, and that the effectiveness of leadership often depends on being able to time small interventions so that the force of natural organizational processes amplifies the interventions rather than dampens them." And in his loveliest image of all, he says that "organizational design is more like locating a snow fence to deflect the drifting snow than like building a snowman."

Karl Weick chooses to describe adaptation in terms of "loosely coupled systems." He argues that most management technology has wrongly assumed tight coupling—give an order or declare a policy, and it is automatically followed. "The more one delves into the subtleties of organizations," says Weick, "the more one begins to question what order means and the more convinced one becomes that prevailing preconceptions of order (that which is efficient, planned, predictable, and survived) are suspect as criteria for successful evolution." He suggests that two evolutionary processes are at the heart of adaptation. "Unjustified variation is critical," he states,

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Simultaneous Loose-Tight Properties

Simultaneous loose-tight properties, the last of our "eight basics" of excellent management practice, is mostly a summary point. It embraces much of what has come before and emerged, to our pleasant surprise, through the process of synthesis. It is in essence the co-existence of firm central direction and maximum individual autonomy—what we have called "having one's cake and eating it too." Organizations that live by the loose-tight principle are on the one hand rigidly controlled, yet at the same time allow (indeed, insist on) autonomy, entrepreneurship, and innovation from the rank and file. They do this literally through "faith"—through value systems, which our colleagues Phillips and Kennedy have suggested most managers avoid like the plague. They do it also through painstaking attention to detail, to getting the "itty-bitty, teeny-tiny things" right, as Alabama's inimitable football coach, Bear Bryant, stresses.

Loose-tight? Most businessmen's eyes glaze over when the talk turns to value systems, culture, and the like. Yet ours light up: we recall ex-chairman Bill Blackie of Caterpillar talking about Cat's commitment to "Forty-eight-hour parts service anywhere in the world." We are drawn back to a minus 60° chill factor day in Minneapolis–St. Paul, where 3M's Tait Elder talked to us about the "irrational champions" running around 3M. And we see Rene McPherson speaking to a class at Stanford. He is animated. The class asks him for the magic prescriptions with which he mastered

productivity problems at Dana. He sticks his hands out in front of him, palms upright, and says, "You just keep pushing. You just keep pushing. I made every mistake that could be made. But I just kept pushing." You suspect he is serious: that really *is* all there was to it.

You think of Tom Watson, Sr., coming in after a hard day of selling pianos to farmers, and reporting to his headquarters in Painted Post, New York. And you think of what he became and why. You picture J. Willard Marriott, Sr., at that first food stand in Washington, D.C. And you see him now, at eighty-two, still worrying about a single lobby's cleanliness, although his food stand is a $2 billion enterprise. You picture Eddie Carlson working as a page boy at a Western International Hotel, the Benjamin Franklin in 1929, and marvel at the legend he has become.

Carlson doesn't blush when he talks about values. Neither did Watson—he said that values are really all there is. They lived by their values, these men—Marriott, Ray Kroc, Bill Hewlett and Dave Packard, Levi Strauss, James Cash Penney, Robert Wood Johnson. And they meticulously applied them within their organizations. They *believed* in the customer. They *believed* in granting autonomy, room to perform. They *believed* in open doors, in quality. But they were stern disciplinarians, every one. They gave plenty of rope, but they accepted the chance that some of their minions would hang themselves. Loose-tight is about rope. Yet in the last analysis, it's really about culture. Now, culture is the "softest" stuff around. Who trusts its leading analysts—anthropologists and sociologists—after all? Businessmen surely don't. Yet culture is the hardest stuff around, as well. Violate the lofty phrase, "IBM Means Service," and you are out of a job, the company's job security program to the contrary notwithstanding. Digital is crazy (soft). Digital is anarchic (soft). "People at Digital don't know who they work for," says a colleague. But they do know quality: the products they turn out work (hard). So "Soft is hard."

Patrick Haggerty says the only reason that OST (hard) works at Texas Instruments is because of TI's "innovative culture" (soft). Lew Lehr, 3M's chairman, goes around telling tales of people who have failed monumentally—but gone on, after decades of trying, to become vice presidents of the company. He's describing the loose-tight, soft-hard properties of the 3M culture.

We have talked about lots of soft traits, lots of loose traits. We have mentioned clubby, campus-like environments, flexible organizational structures (hiving off new divisions, temporary habit-breaking devices, regular reorganizations), volunteers, zealous champions, maximized autonomy for individuals, teams and divisions, regular and extensive experimentation, feedback emphasizing the positive, and strong social networks. All of these traits focus on the positive, the excitement of trying things out in a slightly disorderly (loose) fashion.

But at the same time, a remarkably tight—culturally driven/controlled—set of properties marks the excellent companies. Most have rigidly shared values. The action focus, including experimentation itself, emphasizes extremely regular communication and very quick feedback; nothing gets very far out of line. Concise paperwork (P&G's one-page memo) and the focus on realism are yet other, nonaversive ways of exerting extremely tight control. If you have only three numbers to live by, you may be sure they are all well checked out. A predominant discipline or two is in itself another crucial measure of tightness. The fact that the vast majority of the management group at 3M consists of chemical engineers, at Fluor of mechanical engineers, is another vital assurance of realism, a form of tight control.

Intriguingly, the focus on the outside, the external perspective, the attention to the customer, is one of the tightest properties of all. In the excellent companies, it is perhaps the most stringent means of self-discipline. If one is really paying attention to what the customer is saying, being blown in the wind by the customer's demands, one may be sure he is sailing a tight ship. And then there is the peer pressure: weekly Rallies at Tupperware, Dana's twice-annual Hell Weeks. Although this is not control via massive forms and incalculable numbers of variables, it is the toughest control of all. As McPherson said, it's easy to fool the boss, but you can't fool your peers. These are the apparent contradictions that turn out in practice not to be contradictions at all.

Take the quality versus cost trade-off, for example, or small versus big (i.e., effectiveness versus efficiency). They turn out in the excellent companies not to be trade-offs at all. There is a story about a GM foundry manager who led a remarkable economic turnaround; he painted the grimy interior of his foundry white, insisting that he would pay attention to quality (and housekeeping, safety), and that cost would follow. As he pointed out: "To begin with, if you are making it with good quality, you don't have to make everything twice." There is nothing like quality. It is the most important word used in these companies. Quality leads to a focus on innovativeness—to doing the best one can for every customer on every product; hence it is a goad to productivity, automatic excitement, an external focus. The drive to make "the best" affects virtually every function of the organization.

In the same way, the efficiency/effectiveness contradiction dissolves into thin air. Things of quality are produced by craftsmen, generally requiring small-scale enterprise, we are told. Activities that achieve cost efficiencies, on the other hand, are reputedly best done in large facilities, to achieve economies of scale. Except that that is not the way it works in the excellent companies. In the excellent companies, small *in almost every case* is beautiful. The small facility turns out to be the most efficient; its turned-on, motivated, highly productive worker, in communication (and competition) with his peers, outproduces the worker in the big facilities time and again. It holds for plants, for project teams, for divisions—for the entire company. So we find that in this most vital area, there really is no conflict. Small, quality, excitement, autonomy—and efficiency—are all words that belong on the same side of the coin. Cost and efficiency, over the long run, *follow* from the emphasis on quality, service, innovativeness, result sharing, participation, excitement, and an external problem-solving focus that is tailored to the customer. The revenue line does come first. But once the ball gets rolling, cost control and innovation effectiveness become fully achievable, parallel goals.

Surprisingly, the execution versus autonomy contradiction becomes a paradox, too. Indeed, one can appreciate this paradox almost anywhere. Studies in the classroom, for example, suggest that

THE ROLE OF THE NUCLEAR REGULATOR IN PROMOTING AND EVALUATING SAFETY CULTURE

June 1999

LE RÔLE DE L'AUTORITÉ DE SÛRETÉ DANS LA PROMOTION ET L'ÉVALUATION DE LA CULTURE DE SÛRETÉ

Juin 1999

NUCLEAR ENERGY AGENCY
ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

AGENCE POUR L'ÉNERGIE NUCLÉAIRE
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FOREWORD

The Committee on Nuclear Regulatory Activities (CNRA) of the OECD Nuclear Energy Agency (NEA) is an international body made up of senior representatives from nuclear regulatory bodies. The Committee guides the NEA's programme concerning the regulation, licensing and inspection of nuclear installations with respect to safety. It acts as a forum for the exchange of information and experience, and for the review of developments which could affect regulatory requirements.

In 1998, following the publication of the CNRA report on Future Regulatory Challenges, the Committee established a Task Group to advance the discussion on how a regulatory organisation recognises and addresses safety performance problems that may stem from safety culture weaknesses. This report is the first in a series produced by the Task Group and focuses on early signs of declining safety performance, and the role of the regulator in promoting and evaluating safety culture. A follow-up paper, currently in preparation will amplify the discussion on the response strategies available to a regulatory organisation in dealing with safety culture problems.

The report was prepared by Dr. T.E. Murley, on the basis of discussion and input provided by the members of the Task Group listed below:

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Mr. Samuel J. COLLINS (United States of America)

Dr. Michael CULLINGFORD (United States of America)

Dr. Klaus KOTTHOFF (Germany)

Mr. Philippe SAINT RAYMOND (France)

Mr. Mike TAYLOR (Canada)

Mr. Christer VIKTORSSON (Sweden)

Mr. Christopher WILLBY (United Kingdom)

Mr. Paul WOODHOUSE (United Kingdom)

Mr. Roy ZIMMERMAN (United States of America)

Dr. Gianni FRESCURA (OECD Nuclear Energy Agency)

INTRODUCTION

The term Safety Culture was first introduced by the International Nuclear Safety Advisory Group (INSAG) in 1986 in its "Summary Report On The Post-Accident Review Meeting On The Chernobyl Accident." An early definition was given in the INSAG-4 report in 1991:

"Safety Culture is that assembly of characteristics and attitudes in organisations and individuals which establishes that, as an overriding priority, nuclear plant safety issues receive the attention warranted by their significance."

Thus it is understood that safety culture refers to an organisation's basic safety values, attitudes toward conservative operation, quality, professionalism, continuous learning and improvement processes as well as an environment in which workers are free to raise safety concerns without fear of retribution.

By now there is an extensive body of literature on safety culture in many countries as well as international organisations such as the International Atomic Energy Agency (IAEA) and the OECD Nuclear Energy Agency. The bulk of this literature is concerned with defining the attributes of a good safety culture and describing how nuclear plant operators can develop those attributes.

It has become clear that safety culture involves everyone whose attitude may influence nuclear safety, not only the utility operators but also the regulatory body. The aim of this document is to focus on the dual role of the regulatory body in both (a) promoting safety culture, through its own example and through encouragement given to operators, and (b) evaluating the safety culture of licensees through performance or process based inspections and other methods.

Defining and establishing an effective safety culture and recognising related trends is still a recent initiative, undergoing development and review within operator organisations and regulatory bodies. As more studies are performed and experience is gained in this area, the role of the regulator in promoting and evaluating safety culture will continue to evolve and mature.

The audience for this report, therefore, is primarily nuclear regulators, but the information and ideas may also be of interest to governmental authorities, operators, other industry organisations and the general public.

IMPORTANCE OF SAFETY CULTURE TO NUCLEAR SAFETY

Our understanding of the essential aspects of nuclear safety has evolved and deepened over the four decades of commercial nuclear power experience. In the early years the primary focus was on basic physics and engineering principles, safety system design features, codes and standards, and general design criteria governing such matters as redundancy and diversity of safety systems.

The accident at the TMI-2 plant in 1979 showed that more attention was required on the human factor aspects of safety such as operator qualifications and training, emergency operating procedures, accident mitigation, and emergency planning.

It was several years later, in the aftermath of the 1986 accident at Chernobyl, that the importance of safety culture came into clearer focus. That accident showed that lack of a safety culture can lead to operator behaviour which breaches multiple barriers of the entire defence-in-depth safety fabric. That is, when the basic safety values, norms and attitudes of an entire organisation are weak or missing, then one can have procedures ignored, operating limits exceeded and safety systems bypassed, no matter how well they have been designed and built.

We now know that a good safety culture is essential for overall nuclear safety. However it does not represent the whole of safety – a robust design, competent management of the technology and work processes, and compliance with regulations are also required for safety.

Safety culture must permeate all levels of an operating organisation. At the top of the corporation, management commitment to safety has a profound influence on the safety culture of the entire organisation, and senior management must establish a set of values emphasizing safety and quality, making it clear that workers should not have a conflict in their daily tasks between safety and electrical production goals. The employees will keenly watch whether the senior management's actions match their words in this regard.

For the plant management it means, for example, establishing an organisation which facilitates openness, confidence between employees and managers, and control of quality in all activities. For the operating staff, safety

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culture means a feeling of personal accountability for safe operations, having a questioning attitude, effective communication between different departments, and following the rules and procedures.

At the time when in many countries there is an increasing competitive pressure which leads operators to search for every means to lower production costs, a robust safety culture is more than ever necessary to sustain safe operation in the face of these economic pressures.

ROLE AND ATTITUDE OF REGULATOR IN PROMOTING SAFETY CULTURE

In discussing the role of the regulator we must keep in mind that the operator has the responsibility for safely operating the nuclear power plant. Nothing the regulator does should ever diminish or interfere with that basic principle of responsibility for safety.

There are differences among countries not only in national cultures but in the form of safety regulation, which may range from a highly prescriptive system to a more performance-based system, depending on the laws and regulations of each country. But regardless of the system of regulation, the regulator has the responsibility for independently assuring that nuclear plants are operated safely.

The nature of the relationship between the regulator and the operator can influence the operator's safety culture at a plant either positively or negatively. In promoting safety culture, a regulatory body should set a good example in its own performance. This means, for example, the regulatory body should be technically competent, set high safety standards for itself, conduct its dealings with operators in a professional manner and show good judgement in its regulatory decisions. Some of the attributes of a good regulatory safety culture are the following:

- a clear organisational commitment to priority of safety matters;
- clear lines of responsibility within the regulatory body;
- a program of initial and continuing training to maintain regulatory staff competence;
- a personal commitment to safety from every staff member;

- good communication and co-ordination between organisational units of the regulatory body;
- clear guidelines for conducting safety reviews;
- clear guidelines for conducting safety inspections;
- clear regulatory acceptance criteria;
- a commitment to timely regulatory decisions;
- a commitment to regulatory intervention that is proportionate to the safety circumstances; and
- the use of risk insights in decision-making.

Although it is beyond the scope of this paper, one should note that the government can also play a key role in the safety culture of the regulatory body. In particular, it is important for the government to maintain a strong separation between safety regulation and energy policy.

In a sense, it is easy for regulators to emphasize safety culture within their own organisations. After all, safety is the primary purpose of the regulatory body. What is more difficult for the regulator is finding the right balance of firmness but fairness in dealing with the operator. In addition to enforcing safety regulations, the regulator should make sure he/she has a positive effect on the operator's safety culture.

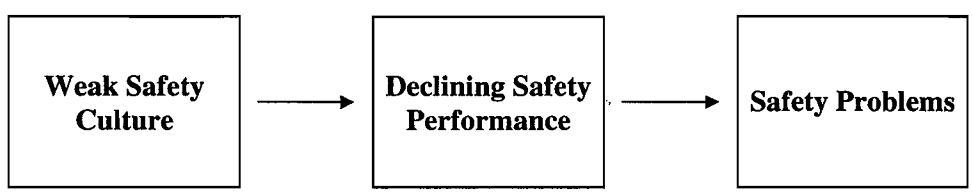
The regulator can promote safety culture in the operator's organisation just through the mere fact of placing it on the agenda at the highest organisational levels. The operator's priorities are influenced by those matters regarded as important by the regulatory body. Thus, the regulator can stimulate the development of a safety culture by providing positive reinforcement for good performance and high quality in plant work processes, by encouraging good safety practices, by promoting the examples of operators having a good safety culture, and by recognising initiatives of industry organisations.

ROLE OF REGULATOR IN EVALUATING SAFETY CULTURE

When discussing this concept with operators, the regulator should recognise that it is not really possible to quantitatively measure safety culture. Some operators have found it useful to conduct surveys evaluating safety culture attributes in order to provide management with insights regarding the underlying safety values and attitudes of the workforce at their nuclear plant. But this is a tool that is generally regarded as not yet appropriate for use by a regulatory body. Instead the regulator can evaluate the outward operational manifestations of safety culture as well as the quality of work processes, and not the safety culture itself. The role of safety culture performance indicators in such evaluations will be determined by each regulatory body.

One of the most difficult challenges in assessing the safety performance at a nuclear power plant is to recognise the early signs of declining safety performance, before conditions become so serious that regulatory sanctions must be imposed or, worse, a serious incident or accident occurs. Most nuclear plants collect and publish a standard set of performance indicators such as Automatic Trips, Safety System Failures, Forced Outage Rate and Collective Radiation Exposure. Unfortunately, these are lagging indicators, and by the time negative trends in the performance indicators are evident, the plant is well into a stage of declining performance. Furthermore, the indicators are at such a high level that they give few clues regarding the underlying weaknesses causing the declining performance. For this reason, it is important that the safety regulator have the capability to inspect and recognise early signs of declining performance.

The regulatory evaluation strategy is based on the performance model shown below, where it is assumed that when a weak safety culture exists for a period of time, signs of declining safety performance will appear. If the root causes are not found and corrected, actual safety problems will eventually appear. Therefore, the regulator will have to look for signs of declining performance and subsequently evaluate whether there are signs of a weak safety culture, which may be the root cause of the declining performance.



In carrying out this role, the regulator may use new techniques in addition to the traditional regulatory tools and methods developed over the years to evaluate safety performance. Experience in several countries has shown that a good approach is to have senior on-site inspectors who can observe the day-to-day operations of the plant. These observations can be augmented by periodic specialist team inspections that include experienced inspectors who bring a fresh perspective to the site.

To facilitate the recognition of declining plant processes and performance, the regulator may perform periodic safety assessments of a facility. This should be a systematic assessment of performance based on co-ordinated discussions and reviews by the regulatory staff. The assessment may include the following:

- observations by site inspectors and specialist inspectors;
- reviews by regulatory safety specialists;
- reviews of trends in event reports;
- review of the effectiveness of operator's controls to identify, correct and prevent problems. These controls include: safety review committees, root cause analysis programs, corrective action programs, and self-assessment programs;
- review of work backlog and delays in implementing prescribed actions;
- assessment of day-to-day incidents, which can reveal both organisational weaknesses and inadequate response by individuals; and
- review of operating events to look carefully for safety significant events or conditions that may be precursors to serious accidents. Often it requires an analysis using Probabilistic Safety Assessment (PSA) methodology to fully understand the safety significance of a complex event.

When the outcome of a safety assessment suggests the onset of declining performance, the regulator may decide upon a special surveillance program for the plant. This could include regulator meetings with plant management and staff to discuss the assessment findings and to better

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understand any special circumstances facing the plant (such as budget or personnel changes). The purpose of these meetings is not to place the operator on the defensive but to encourage improvements.

A key to having good inspection findings to make the safety assessment insightful and accurate is for regulatory management to give their inspectors guidance on what to look for. While it is not possible to present a complete list of performance weaknesses at a nuclear power plant, the following list gives a general idea of early signs for which the inspectors may look.

Early signs of declining performance

Management

- inadequate capital investment in upgrading plant equipment;
- inadequate resources for operations and maintenance;
- frequent deferral of needed improvements;
- high number of operator work-around items;
- poor oversight and control of contractors.

Operations

- operator errors due to inattention to details;
- loss of system configuration control (e.g., valve alignment errors);
- misalignment of electrical and mechanical systems;
- errors in reactivity manipulations;
- operator errors due to training inadequacy;
- failure to perform equipment checks and surveillances;
- failure to follow operating procedures;
- decision-making dominated by concern for production;
- large number of employee grievances;
- plant restart after an incident without full analysis;
- failure to stay within allowed range of operating parameters.

Maintenance

- large backlog of overdue maintenance work items;
- large backlog of inoperable equipment;
- inadequate control of maintenance work;
- reactor trips caused by maintenance errors;
- leaking valves;
- poor housekeeping;
- poor material condition of plant equipment;
- failure to follow maintenance procedures.

Engineering design and safety analysis

- inadequate qualification of equipment for accident conditions;
- inadequate fire protection design and equipment qualification;
- superficial evaluation of anomalous equipment behaviour;
- inadequate response to operating experience including other plants;
- inadequate support of operators with timely safety analyses;
- poor preparation of plant modifications.

Plant documentation

- plant changes not incorporated into design basis documents;
- large backlog of design change modifications;
- large backlog of procedure changes;
- outdated safety analyses.

Radiological controls

- poor planning of radiological protection for maintenance work;
- inadequate radiological posting of work areas;
- worker overexposures and contaminations;
- inadequate radiological training of workers;
- weak ALARA programme;
- upward trend in collective radiation exposure;
- upward trend in effluent discharges.

Outage activities

- poor planning of work activities;
- poor control of work activities throughout the site;
- failure to maintain adequate shutdown cooling;
- high collective radiation exposure;
- poor industrial health and safety record.

Event analysis

- failure to recognise potential accident precursors;
- no formal program for analysing operating events.

Regulatory relations

- long delays or failure to meet regulatory commitments;
- failure to maintain operation within current licensing basis;
- inadequate response to regulatory correspondence.

When several of these signs are present at a nuclear plant for some time, and seem to be correlated, careful evaluation of each situation is needed. In some cases these signs of deep-seated problems can be masked for years by high plant capacity factors, while the problems continue to build up a growing backlog of corrective action work. Eventually the cumulative backlog becomes so large that the organisation cannot deal with it but is simply reduced to coping with day-to-day problems as they arise. Then a triggering event, which a healthy organisation might find easy to handle, causes a virtual functional collapse of the organisation. In other cases, a careful evaluation of the signs will show clearly that safety performance is declining.

In any case, without an outside influence to promote changes in the way of doing business (e.g., organisational structure, programs and procedures, personnel, or backlog reduction) it is likely that performance will decline to the point that a serious safety concern is presented.

It is true that even a good operating plant may show signs of some of the problems listed above from time to time. But the fundamental strengths of their organisations will soon find, analyse and correct the problems. That is why they are good operating plants.

A key insight from periodic safety assessments may be for the regulator to recognise the signs of a weak safety culture as a root cause of declining performance. The change from good safety performance to poor performance is rarely, if ever, a sharp decline over a short period of time. The initial root causes are often subtle and may only be recognised in retrospect.

Thus, it is important for the regulator to also look for signs of a weak safety culture that may be the root cause for actual declining performance. All of the conditions described below have their nexus in ineffective management of nuclear plants. This may take the form of misguided policies, weak leadership, or inadequate standards to guide employees' conduct of work.

Signs of potentially weak safety culture

Management

- lack of clear organisational commitment to safety;
- lack of management awareness and involvement in plant activities;
- lack of proactive approach to safety issues that arise;
- lack of nuclear experience among top managers;
- incomplete information reaching the top managers;
- not receptive to outside views – isolated;
- lack of depth in talented managers;
- unwilling to face difficult problems and correct them;
- lack of teamwork between functional organisations.

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Programmes

- ineffective work planning and scheduling;
- ineffective corrective actions – recurring problems;
- cumbersome work control processes;
- quality assurance not an integral part of plant activities;
- training not an integral part of management planning;
- no formal program for analysing events including other plants.

Self-assessment

- outside organisations regularly find problems first;
- quality assurance audits are ineffective;
- superficial reviews by safety organisations;
- do not learn from the experience of others;
- management does not want to hear bad news;
- insufficient incident analysis – no experience feedback.

Accountability

- responsibility for fixing problems is not clearly assigned;
- schedules not established or routinely missed;
- decision-making is too slow;
- poor work performance is tolerated;
- ineffective internal inspection.

Regulatory relations

- management policy to dispute and defy the safety regulator;
- policy of minimal compliance with regulations;
- practice of delaying or deferring regulatory commitments.

Isolation

- little participation on standards or other committees;
- no exchange of personnel or information with other plants;
- no participation in technical conferences;
- no awareness of safety research advances.

Attitudes

- complacency;
- "the hypnosis of excessive self-confidence";
- not receptive to outside suggestions;
- technical arrogance in relations with regulator;
- provincialism – no managers from outside;
- self-satisfaction with current performance – no need to look for problems.

A nuclear plant that has several of the weak safety culture conditions above, in addition to signs of actual declining performance, indicates that further regulatory attention will probably be needed.

REGULATORY RESPONSE STRATEGIES

The regulator has to find the proper balance between intervening too early or too late when signs of either a weak safety culture or actual declining performance are observed. If intervention is too early the operator may not agree on the nature and extent of the problems, or the regulator may pre-empt operator initiatives to improve. If intervention is too late, the declining performance may not be arrested before serious safety problems become evident.

How the regulator deals with declining safety performance depends, of course, upon the laws, regulations and customs of each nation. What is discussed here is a graduated approach of escalating regulatory attention that experience in several countries has shown to be effective in dealing with declining performance.

When a few early signs are observed, a graduated approach would be for the regulator to monitor the situation and document the inspection findings carefully so that trends can be seen. It is especially important that inspectors evaluate thoroughly all significant operating events at a plant. If the signs persist or new signs appear to be correlated, the regulator may decide to place the plant under special surveillance, which means special attention through focused inspections and requirements for periodic progress reports on technical and programmatic improvements. The regulator should meet with plant management to inform them of the reasons for the surveillance, areas where improvements are needed, and the need for regular progress reports on improvements.

If the special surveillance and enhanced inspection program over a period of several months continues to find signs of declining performance, further regulatory action will probably be needed. These performance problems are rarely self-correcting without sustained outside intervention. A further action for the regulator might be for a meeting with the highest levels of the operator's management to stress the seriousness of the concerns and to describe the detailed basis for these concerns about declining performance. This meeting could be followed by an official letter describing the purpose of the meeting and its conclusions.

If performance continues to decline, the regulator will likely be faced with the need for enforcement sanctions. The precise form of such sanctions depends upon the laws and regulations of each regulatory authority. Clearly, however, a regulatory body must have the ability to take enforcement actions, including the authority to order a nuclear plant to be shut down if judged necessary to protect public health and safety.

Nuclear Regulation
Réglementation nucléaire

OECD OCDE

Regulatory Response Strategies for Safety Culture Problems

Stratégies d'intervention de l'autorité de sûreté en cas de dégradation de la culture de sûreté

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FOREWORD

The Committee on Nuclear Regulatory Activities (CNRA) of the OECD Nuclear Energy Agency (NEA) is an international body made up of senior representatives from nuclear regulatory bodies. The Committee guides the NEA programme concerning the regulation, licensing and inspection of nuclear installations with respect to safety. It acts as a forum for the exchange of information and experience, and for the review of developments which could affect regulatory requirements.

In 1998, the Committee established a Task Group to advance the discussion on how a regulatory organisation recognises and addresses safety performance problems that may stem from safety culture weaknesses. In 1999 the Task Group published a report entitled "The Role of the Regulator in Promoting and Evaluating Safety Culture".

As a sequel to that report, this publication explores possible regulatory response strategies for dealing with declining safety performance when the outward manifestations of that performance suggest that there may be fundamental safety culture problems. Il also discusses the resumption of normal surveillance after enhanced regulatory attention and intervention.

This publication was prepared by Dr. Thomas E. Murley, on the basis of discussion and input provided by the members of the Task Group listed below:

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Dr. Michael CULLINGFORD (United States of America);

Dr. Klaus KOTTHOFF (Germany);

Mr. Philippe SAINT-RAYMOND (France);

Mr. Lynn SUMMERS (United Kingdom);

Mr. Mike TAYLOR (Canada);

Mr. Christer VIKTORSSON (Sweden);

Mr. Roy ZIMMERMAN (United States of America);

Dr. Gianni FRESCURA (OECD Nuclear Energy Agency).

INTRODUCTION

An earlier NEA report* discussed the role of the regulator in promoting and evaluating safety culture in an operator's organisation. It also discussed how the regulatory body can recognise early signs of declining performance. This report places emphasis upon those situations where there are signs of actual safety performance problems, which may or may not be reflected in declining operational performance. Thus, the purpose of this report is to explore possible regulatory response strategies for dealing with declining safety performance when the outward manifestations of that performance suggest that there may be fundamental safety culture problems. This report also discusses the resumption of normal surveillance after enhanced regulatory attention and intervention.

When a nuclear power plant begins to show signs of declining safety performance, a possible root cause may be that the operator's organisation has elements of a weak safety culture. This situation poses a difficult challenge for a regulatory body for several reasons. In the first place, it is not really possible to measure quantitatively the safety culture of an operating organisation, since safety culture refers to fundamentally unmeasurable characteristics of an organisation's basic safety values and attitudes. Secondly, not every regulatory body has the resources nor the intention to look into safety culture and the associated management issues. Some regulators may prefer to focus inspections and assessments on observable safety performance indicators while others may prefer to focus on directly observable safety management policies and processes. Finally, it is seldom clear from the early signs of safety performance problems just what the root causes may be, and operators may object to regulators probing into safety culture areas that may be emotionally sensitive for some operating organisations.

Thus, the regulator has to use careful judgement in diagnosing the root causes of apparent declining safety performance and in finding the appropriate threshold for regulatory intervention. If intervention is too early, the operator may not agree on the nature and extent of the problems, or the regulator may pre-empt operator initiatives to resolve their own problems. If intervention is too late, the declining performance may not be arrested before serious safety problems become evident.

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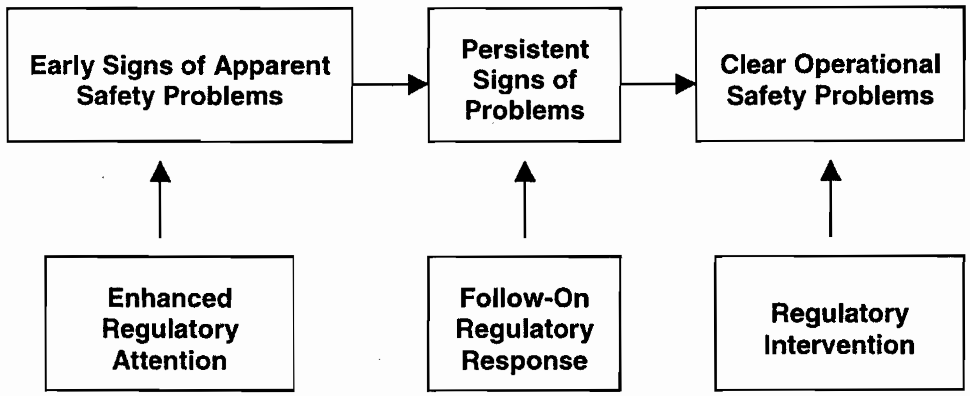
* *The Role of the Nuclear Regulator in Promoting and Evaluating Safety Culture*, OECD/NEA, Paris, June 1999.

APPROACH

The regulatory response strategy is based on the model shown below, where it is assumed that the early signs of safety problems may be ambiguous but nonetheless may justify enhanced regulatory attention. If the problems persist, perhaps growing more frequent and more risk significant, a follow-on response will be called for. Finally, if the root cause issues are not corrected, and clear operational safety problems are evident, the regulator will have to increase the level of intervention. Regulatory intervention in this context means action to require the operator to take steps to improve specific performance problems – steps that the operator probably would not take without intervention by the regulator.



The model above is not meant to suggest that all causes of declining safety performance will inevitably follow this pattern. Even good operating plants may show some of the early signs of problems from time to time, but the fundamental strengths of their organisations will soon find, analyse and correct the problems. Other safety performance problems may be corrected easily by modest early regulatory attention. But these fortunate situations do not pose a safety challenge to the regulator, and for that reason the focus of this report is on those difficult situations where regulatory intervention is ultimately needed.

There may be other situations where a plant's operating organisation has a weak safety culture from the inception of operation, and the regulator may only recognise this weakness after an extended period of operational safety problems that become more risk significant over time. Even in these situations, the general regulatory response strategy described here would be applicable.

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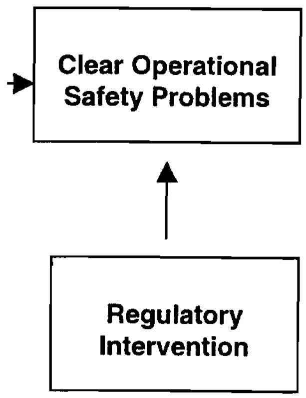

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It should be stressed that the regulatory body need not wait for obvious signs of safety performance problems before giving attention to a nuclear power plant. The normal, everyday oversight and inspection activities may be able to detect safety culture weaknesses or deficient safety processes that are the precursors to declining performance. Some regulators find it important that the operating events at a power plant be analysed to look for trends in performance and for apparent common cause problems that may have collective significance as precursors. They further find that a synthesis of these routine assessments, for instance on a yearly basis, is a helpful diagnostic tool.

ENHANCED REGULATORY ATTENTION

In the beginning stages of a plant's declining safety performance, it will generally not be clear whether the early signs are merely the type of everyday problems that all nuclear plants experience during their operation or that these signs may in fact be the early precursors of more deep-seated problems. Since the diagnosis is not known, the regulatory approach will have to be flexible but persistent in seeking the true state of affairs at the plant. The earlier referenced NEA report describes a number of early signs of declining safety performance that the regulatory inspector may look for when safety culture problems are suspected.

In many ways the ultimate effectiveness of the regulatory response to safety culture problems depends upon the approach taken during these early stages. Therefore, the strategy can best be described as a graduated approach. The regulator's normal inspection and oversight activities will have provided a substantial baseline of information about the performance and even the past safety culture at the plant. In light of the early signs of problems, the regulator may decide to analyse the plant's performance indicators more closely and to develop focused inspections aimed at determining the nature of the problems and their underlying causes. The inspection team may include a member or members with expertise in organisational factors. Often these inspections may be inconclusive but it is nonetheless important to document the inspection findings so that trends can be seen. It is especially important that inspectors evaluate thoroughly all significant operating events at the plant.

During the planning for this enhanced oversight, it would be appropriate to discuss with senior plant managers the observations of safety performance problems and the reasons for increased regulatory attention. The plant managers can provide their assessment of the situation and describe any initiatives they have underway or planned to improve performance. The regulator may suggest that the operator conduct a thorough self-assessment of the safety performance problems, but it is important that the enhanced regulatory oversight does not interfere with any ongoing self-assessment and corrective actions by the operator. Through the focused inspections, and periodic progress reports from the operator, it should become apparent in due course if the operator's corrective actions are being effective or not.

In some cases, this enhanced regulatory attention may be sufficient to promote corrective actions by the operator that correct any underlying safety culture problems. If so, this approach will have produced the desired safety result without undue intervention.

FOLLOW-ON REGULATORY RESPONSE

In some cases, the early attention by the regulatory body may not be effective in getting the safety performance problems corrected. The early signs persist, perhaps growing more frequent and more risk significant. There may be several possible reasons for this, but a likely cause would be that the safety culture problems are deep-seated at the plant and the plant management's actions have simply not been adequate to address the root causes. In any case, the graduated approach will lead the regulator to enhance further the oversight activities. This will probably mean closer observation of activities at the plant and additional in-depth focused inspections.

But the major focus of the follow-on regulatory response is to have discussions with corporate management to be sure they understand the nature and seriousness of the regulator's concerns. Based upon the findings of the focused inspections and the interactions with the operator during the early response stage, the regulator will have reached a preliminary judgement on how the plant managers view the situation and why their actions have thus far been ineffective. The goal of the discussions with corporate management would be to reach a mutual understanding of the nature of the performance problems, their apparent root causes, and the outline of plans for improvement. The corporate management might not be well informed of the detailed regulatory concerns, and the regulator may wish to suggest an independent assessment of the situation, such as a peer review or a third party assessment of the safety culture at the plant. This phase of involvement with corporate management may last several months and entail several meetings, but the result will generally be an agreement on a course of action for improvement on the part of the operator. The regulator will have to use judgement in allowing the corporate management sufficient time and latitude to correct the problems as they see them, bearing in mind that requiring a comprehensive improvement plan at this stage could result in delaying improvements the corporate management judges to be more fundamental, for example changes in the organisation at the site. Throughout this period, of course, there will be frequent meetings and ongoing inspections to monitor the situation at the plant.

Concurrent with these discussions and oversight activities, the regulator will have to consider under what conditions it may be necessary to intervene and take further actions. This is not to prejudge that the operator's corrective actions will be unsuccessful, but rather to be in a position to act promptly if the safety performance continues to decline. The general criteria for considering further intervention are along the following lines:

- Does the frequency of operating events and problems appear to be declining?

- Do the operator's corrective actions seem to be effective in producing real change?

- Does the safety culture at the site appear to be improving?

If the answers to these questions are mostly positive, it is reasonable to let the operator's actions continue to improve the situation, even if the pace of improvement is not what one would like. It is especially important for the regulator to remain objective in evaluating real progress at the plant and not get so distracted by promises of improvement that continuing decline is not recognised. If the answers to the questions above are objectively negative, it is likely that the threshold has been crossed where further regulatory intervention is necessary.

REGULATORY INTERVENTION

Up to this point the graduated regulatory response strategy has led to a steadily escalating oversight program and discussions with the operator concerning the nature and seriousness of the safety performance problems. The operator has been given opportunities to conduct self-assessments and to formulate corrective actions, but they have not been effective in improving performance. By this stage the regulator will know that there are deep-seated safety culture problems at the plant, which have resulted in operational safety problems.

The mere fact that the situation has deteriorated to this stage is evidence that the operator has experienced some degree of denial that the safety problems are as serious as the regulator believes. It may take some time for the operator to accept the nature and seriousness of the problems, to embrace the need for the improvement plan and to begin working through the often difficult changes needed to improve safety performance.

If the operator continues to deny the seriousness of the safety problems, the regulator will be faced with the need to intervene and take enforcement actions. The precise form of such actions will depend upon the laws and regulations of each country, and some regulatory bodies may wish to examine whether they have sufficient enforcement authority. In any event, the purpose of the next stage of the graduated approach is a regulatory intervention to require a comprehensive improvement program that addresses and corrects the underlying problems. There can be no avoiding a discussion of the safety culture issues with senior corporate and plant management. There will be two major goals in these discussions. The first goal will be to have the operator's organisation recognise and accept its fundamental problems as seen by the regulatory body. One may suggest that the operator seek outside coaching from a peer group. The second goal is for the operator to agree to develop a comprehensive improvement plan that analyses and provides corrective actions for the fundamental problems seen by the regulator. The plan should include:

- a detailed list of actions, with scheduled milestones and deadlines;
- the nomination by the operator of a person responsible for implementing the plan, with commensurate authority; and
- assurance of adequate resources to implement the plan.

At this stage the public should be informed of the overall problem if they have not been informed previously. The logical approach is for the regulator to send an official letter describing the previous meeting and confirming the need for an improvement plan. The plan itself may be made publicly available when the regulator and operator agree on its final contents.

Concurrent with these discussions, the regulator will have to face a fundamental decision concerning the plant. In some cases the regulator may conclude that the safety problems are so pervasive and deep-rooted that the plant is considered not safe to operate, or that it would be simply too difficult to produce the necessary changes while the plant is operating. That is, the comprehensive change actions needed would be too distracting for the operator to operate the plant safely. It would be best if there were mutual agreement with the operator on this point, but the regulator's judgement would have to prevail in this matter.

In either case, whether the plant is operating or shut down, the regulator will have to increase the oversight and inspection program even further. If the plant is operating, the normal safety inspections will have to be enhanced to look for signs of human errors due to distraction or work overload, in addition to monitoring the problems that led to the current situation. Beyond this inspection program, there will have to be regular meetings with the operator to monitor progress on the improvement plan.

RESUMPTION OF NORMAL REGULATORY SURVEILLANCE

By the time this stage has been reached, the regulator has had many months of enhanced oversight and dialogue with the operator concerning the reasons for the observed decline in performance. The operator has failed to correct the safety problems and the underlying safety culture weaknesses, the regulator has intervened, and the operator has developed an improvement plan and is implementing the actions in the plan.

The gradual resumption of normal regulatory oversight will be governed by the operator's pace of improvement. For those plants where the safety problems are less serious, and the improvement actions are carried out while the plant is operating, the enhanced oversight and inspection program can be gradually relaxed in step with the problem corrections and improving performance. In these cases there will generally be no need for formal relaxation criteria, other than a finding at some point that the improvement plan has been satisfactorily implemented. This finding would normally be communicated to the operator and may be made public. Although the regulatory surveillance has returned to normal, the regulator will likely want to conduct follow-on focused inspections to confirm that the problems are not recurring.

In those cases where the safety problems are more serious and widespread, and the plant is shut down, the criteria for allowing resumed operation will be described in a general way in the shutdown decision. That is, the criteria will state that the most safety significant problems must be addressed and resolved to the satisfaction of the regulator before operation can be resumed. As the detailed implementation plan is prepared by the operator and agreed upon, the regulator may publish more specific restart criteria for each of the significant problem areas. For instance, if one of the basic problems is a large backlog of maintenance work orders and engineering change requests, and the root cause is determined to be ineffective work practices, the improvement plan would include actions to revise the work planning and scheduling processes at the plant. The regulator in this instance would have to agree that the root cause has been addressed and that the changes appear to be effective. To give another example, if the root cause of radiological problems is found to be weak radiological protection training, the training program will have to be revised and the workers retrained. When the regulator has observed a period of improved radiological performance, he will conclude that that specific restart criterion has been met.

In these more difficult cases, the enhanced regulatory surveillance would be maintained until all the restart criteria have been met and the plant resumes operation. The decision to permit restart would normally be communicated to the operator and be made public. Even after operation resumes, the regulator will have to maintain a level of enhanced oversight for a period to confirm that problems are not recurring. There may also be a need to monitor continuing actions on improvement plan actions that were judged not necessary to complete before restarting. As operation is observed to be satisfactory, the regulatory oversight and inspection programme can be gradually relaxed to the normal surveillance program.

IMPROVING REGULATORY PERFORMANCE

As a conclusion of this response strategy, and in the spirit of improving regulatory performance, the regulator should conduct a retrospective self-assessment. Some of the questions that such a self-assessment could address are:

- Could the normal oversight and inspection program have detected the underlying safety culture problems sooner?
- Was the regulatory response to early signs of declining safety performance effective?
- Were the early communications with the operator as clear in describing the problems as they could have been?
- Were the interactions with the operator conducted professionally?
- Was the intervention timely?
- Was the intervention proportionate to the safety significance of the problems?
- Were communications with the public adequate?

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COMMITTEE ON THE SAFETY OF NUCLEAR INSTALLATIONS

NEA/CSNI/R(99)21/VOL1
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IDENTIFICATION AND ASSESSMENT OF ORGANISATIONAL FACTORS RELATED TO THE SAFETY OF NPPs

State-of-the-Art Report

September 1999

VOLUME 1

87617

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ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

Pursuant to Article 1 of the Convention signed in Paris on 14th December 1960, and which came into force on 30th September 1961, the Organisation for Economic Co-operation and Development (OECD) shall promote policies designed:

- to achieve the highest sustainable economic growth and employment and a rising standard of living in Member countries, while maintaining financial stability, and thus to contribute to the development of the world economy;
- to contribute to sound economic expansion in Member as well as non-member countries in the process of economic development; and
- to contribute to the expansion of world trade on a multilateral, non-discriminatory basis in accordance with international obligations.

The original Member countries of the OECD are Austria, Belgium, Canada, Denmark, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The following countries became Members subsequently through accession at the dates indicated hereafter; Japan (28th April 1964), Finland (28th January 1969), Australia (7th June 1971), New Zealand (29th May 1973), Mexico (18th May 1994), the Czech Republic (21st December 1995), Hungary (7th May 1996), Poland (22nd November 1996) and the Republic of Korea (12th December 1996). The Commission of the European Communities takes part in the work of the OECD (Article 13 of the OECD Convention).

NUCLEAR ENERGY AGENCY

The OECD Nuclear Energy Agency (NEA) was established on 1st February 1958 under the name of OEEC European Nuclear Energy Agency. It received its present designation on 20th April 1972, when Japan became its first non-European full Member. NEA membership today consist of all OECD Member countries, except New Zealand and Poland. The Commission of the European Communities takes part in the work of the Agency.

The primary objective of the NEA is to promote co-operation among the governments of its participating countries in furthering the development of nuclear power as a safe, environmentally acceptable and economic energy source.

This is achieved by:

- *encouraging harmonization of national regulatory policies and practices, with particular reference to the safety of nuclear installations, protection of man against ionising radiation and preservation of the environment, radioactive waste management, and nuclear third party liability and insurance;*
- *assessing the contribution of nuclear power to the overall energy supply by keeping under review the technical and economic aspects of nuclear power growth and forecasting demand and supply for the different phases of the nuclear fuel cycle;*
- *developing exchanges of scientific and technical information particularly through participation in common services;*
- *setting up international research and development programmes and joint undertakings.*

In these and related tasks, the NEA works in close collaboration with the International Atomic Energy Agency in Vienna, with which it has concluded a Co-operation Agreement, as well as with other international organisations in the nuclear field.

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COMMITTEE ON THE SAFETY OF NUCLEAR INSTALLATIONS

The Committee on the Safety of Nuclear Installations (CSNI) of the OECD Nuclear Energy Agency (NEA) is an international committee made up of senior scientists and engineers. It was set up in 1973 to develop, and co-ordinate the activities of the Nuclear Energy Agency concerning the technical aspects of the design, construction and operation of nuclear installations insofar as they affect the safety of such installations. The Committee's purpose is to foster international co-operation in nuclear safety among the OECD Member countries.

The CSNI constitutes a forum for the exchange of technical information and for collaboration between organisations, which can contribute, from their respective backgrounds in research, development, engineering or regulation, to these activities and to the definition of the programme of work. It also reviews the state of knowledge on selected topics on nuclear safety technology and safety assessment, including operating experience. It initiates and conducts programmes identified by these reviews and assessments in order to overcome discrepancies, develop improvements and reach international consensus on technical issues of common interest. It promotes the co-ordination of work in different Member countries including the establishment of co-operative research projects and assists in the feedback of the results to participating organisations. Full use is also made of traditional methods of co-operation, such as information exchanges, establishment of working groups, and organisation of conferences and specialist meetings.

The greater part of the CSNI's current programme is concerned with the technology of water reactors. The principal areas covered are operating experience and the human factor, reactor coolant system behaviour, various aspects of reactor component integrity, the phenomenology of radioactive releases in reactor accidents and their confinement, containment performance, risk assessment, and severe accidents. The Committee also studies the safety of the nuclear fuel cycle, conducts periodic surveys of the reactor safety research programmes and operates an international mechanism for exchanging reports on safety related nuclear power plant accidents.

In implementing its programme, the CSNI establishes co-operative mechanisms with NEA's Committee on Nuclear Regulatory Activities (CNRA), responsible for the activities of the Agency concerning the regulation, licensing and inspection of nuclear installations with regard to safety. It also co-operates with NEA's Committee on Radiation Protection and Public Health and NEA's Radioactive Waste Management Committee on matters of common interest.

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The opinions expressed and the arguments employed in this document are the responsibility of the authors and do not necessarily represent those of the OECD.

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The Expanded Task Force (ETF) on Human Factors members would like to express their thanks to all participants of the Boettstein Castle Workshop on Organisational Factors and to all who contributed additional information to the SOAR.

Organisation of the report

This report is divided in three volumes:

Volume I

Section I: "Introduction" provides background information on the development of the workshop and how the workshop was organized.

Section 2: "Organisational Factors" provides a description of the twelve factors identified in the workshop.

Section 3: "Assessment Approaches" discusses various methods for assessing organisational factors. (Details on Methods and frameworks used in different countries by utilities, regulators and researchers are presented in Volume II.)

Section 4: "Future Needs" describes research needs to enhance understanding and knowledge of organisational factors and its contribution to human safety performance and risk.

Volume II

Methods and frameworks used in different countries by utilities, regulators and researchers.

Volume III

Appendix II: Papers contributed by the participants.

All bibliographical references appear in both Volume I and Volume II.

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EXECUTIVE SUMMARY

The initiation of this State-of-the-Art Report (SOAR) on Organisational Factors Identification and Assessment comes from operating experience associated with a number of major events world-wide which caused power plants to be shutdown for a significant period of time. Root cause assessments of these events identified weaknesses in organisational factors as contributing to these events. There is general recognition that organisational factors need to be evaluated for their contribution to plant safety performance and risk to prevent their recurrence in events.

A special recommendation to create a SOAR was presented in the NEA report on Research Strategies for Human Performance [NEA/CSNI/R(97)24]. Based on this recommendation the Principle Working Group 1 (PWG1) requested, as a top priority, that the Expanded Task Force (ETF) on Human Factors develop a SOAR for the September 1998 meeting.

The ETF members were aware that it was a challenging topic. The field of organisational behaviour is not yet fully developed for the nuclear organisation. There is a need to collect and analyse operational and event data from the nuclear environment to determine the safety and risk significance of organisational factors, to identify assessment methods for those factors, and to gain peer review of the results to ensure credibility and acceptability of these methods and possibly their measures.

The first activity to help accomplish this task was a Workshop on Organisational Factors Identification and Assessment, hosted by the Swiss Regulatory Body, HSK. This SOAR reports on the results of the workshop. The workshop was held in Boettstein Castle, Switzerland, on 14-19 June 1998. Twenty-eight participants from twelve Member countries and Russia represented three different environments: nuclear utilities; regulatory bodies and inspectorates; and the research and academic community. The various approaches discussed in the SOAR reflect the perspective of these entities. It should be noted that the SOAR is a status report that provides an agreed-upon understanding of organisational factors important to safety from the perspective of the workshop participants and provides country-specific information on assessment methods and research. It does not reflect all the information in the field of organisational factors identification and assessment which would require more resources, time, and research to develop. It does, however, present a representative view of developments in this field. The task will continue with a broader charter until the end of 1999.

The SOAR addresses the following topics:

- identification of organisational factors;
- identification of methods for the evaluation of organisational factors;
- identification of methods for the evaluation of whole organisations;
- identification of gaps in knowledge and needed research to evaluate adequately the influence of organisation and management on safety and risk.

The workshop participants identified 12 organisational factors as important to assess in determining organisational safety performance. They are: external influences; goals and strategies; management functions and overview; resource allocation; human resource management; training; co-ordination of work; organisational knowledge; proceduralisation; organisational culture; organisational learning; and communication.

Different cultural backgrounds of participants using their own terminology sometimes made it difficult to have a common definition for certain factors. Some factors could be defined by consensus; other factors such as organisational culture, organisational knowledge, and organisational learning have a slightly different interpretation and will need further discussions to reach a common definition. Although the definitions of these factors may differ slightly for each country, it is important to emphasize that they were all considered to have an influence on plant safety performance.

The SOAR also presents information about assessment approaches used in the three environments:

- Two utilities detail their self-assessment practices.
- The regulatory bodies assessment approaches, as presented in the report, include a description of the context and framework of their assessment methods or approaches, and in some cases, more detailed information on their methodology.
- The researcher information comes from two types of research: university-based research (as well as from public and private laboratories) and contractor-based research which may be sponsored by the regulatory body or the utility. This information is introduced by a brief background of current research trends.

The assessment methods can be distinguished between two applications. The first application of the assessment method results from detection of organisational weaknesses in events or inspections, or from continuing deteriorating performance. The assessment tries to find root causes and contributing causes of the identified weaknesses in the organisation. This application is considered "reactive". The references for this approach are requirements of the regulatory body or utility commitments, or the legal framework. The second application assesses the organisational factors as leading indicators of performance problems. This application is considered "proactive", integrating information on organisational factors in order to capture mechanisms which are very important for the reliability of the organisation. This could be the decision-making process, change process, coherence of the organisation with the policy, etc.

Lastly, the participants identified several research needs for the identification and assessment of organisational factors, including the importance of international co-operation:

- assessing the impact of organisational factors on human safety performance;
- transferring of knowledge and developing a common metric amongst Member countries for comparing methods and audit practices;
- establishing a common understanding of specific organisational mechanisms, features and patterns;
- exchanging operational performance data for analysing the risk significance of organisational factors;
- exchanging information in two to three years to discuss progress in concepts;
- establishing theories and methodology, identifying risk significance and quantifying organisational factors.

The Boettstein Castle workshop discussions and the iterative process of information exchange between participants in developing the SOAR allowed the attainment of the goals of the ETF mandate, including the identification of research needs for CSNI consideration.

In 1999 the SOAR was supplemented by additional information contributed by countries and institutions which were not represented at the workshop.

TABLE OF CONTENTS

1. INTRODUCTION

During the past decade it has been widely recognized that different factors controlled by the organisation of a Nuclear Power Plant (NPP) have an important influence on the safety attitudes and the safe behaviour of individuals. Interest in these influences begun to increase with the development of the concepts of safety culture and quality management. The importance of organisational performance has been demonstrated when in several countries NPPs were shut down due to significant organisational problems. The increasing focus on organisational factors led to the consequence that event analyses more frequently identified organisational factors as root causes and contributing causes of events. The development of new root cause analysis methods such as Human Performance Enhancement System (HPES[1]), Human Performance Investigation Process (HPIP[2]) and Assessment of Safety Significant Event Team (ASSET[3]) have somewhat addressed this issue. The removal of an organisational problem is only the reactive part of the problem solving process. However, it is important for operators as well as for regulators to detect early signs of deteriorating safety performance in order to prevent the degradation of the safety of NPPs. In order to be proactive, the links between the organisational factors and the safe behaviour of individuals have to be identified, as well as the mechanisms which increase the reliability of the organisation to manage safety. To this end, a Workshop on "Organisational Factors Identification and Assessment" was initiated by the Expanded Task Force on Human Factors (ETF[4]). The objective of this workshop is to identify the organisational factors, their links to the individual and their influence on human performance, as well as the mechanisms important for organisational reliability.

The initiation of this task (TASK 7) of the ETF traces back to ETF's TASK 6 "Improved guidance for reporting of human and organisational factors". Task 6 proposed ways to improve the reporting and the coding of events reported to the Incident Reporting System Database (IRS). The main improvements identified were in the area of human errors which are now much more explicitly addressed and much more differentiated. In this context, it was recognized that organisational factors, as potential root causes of human errors, need to be identified and assessed in order to effectively prevent their recurrence.

The ETF prepared a task for the improvement of root cause analysis methods in the area of organisational factors. Similar activities were initiated by different organisations: The IAEA started a co-ordinated research program on Root Cause Analysis and the European Union (EU) developed a program for a "Concerted Action" in the area of organisational factors. This fact was taken into account in a NEA specialists meeting in August 1997 initiated by the Committee on the Safety of Nuclear Installation (NEA/CSNI). The results of the meeting are outlined in the report "Research Strategies for Human Performance" (NEA/CSNI/R(97)24, Feb. 98). This report includes recommendations on research issues, research co-ordination, and importantly, a recommendation to conduct a workshop on organisational issues

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1 Developed by the Institute of Nuclear Power Operations (INPO)

2 Developed by the US Nuclear Regulatory Commission (US NRC)

3 Developed by the International Atomic Energy Agency (IAEA)

4 ETF of the «Principal Working Group 1 on Experience Feedback and Human Factors» (OECD/NEA Nuclear Energy Agency)

in order to develop a State of the Art Report (SOAR). This SOAR would serve as a basis for CSNI's recommendations on future research activities.

The ETF discussed these recommendations during two regular meetings. ETF members recognized that different countries use different approaches for the evaluation of organisations and have different understandings of organisational factors. Furthermore, it was recognized that how much these factors influence human performance is not yet well demonstrated.

The ETF decided to focus on the following four topics:

1. Identification of organisational factors.
2. Identification of methods for the evaluation of organisational factors.
3. Identification of methods for the evaluation of whole organisations.
4. Identification of gaps in knowledge and needed research to adequately evaluate the influence of organisation and management on safety.

In its meeting in September 1997, the PWG1 approved the ETF's proposal to initiate TASK 7 with a workshop on these topics. The PWG1 strongly recommended that the time schedule for this phase of SOAR be reduced from two years to one year. This placed time constraints on the workshop organizers and on the possibility of covering all aspects of the topic. However, PWG1 members felt that it was important to have results available as soon as possible, acknowledging that there would be some lack in completeness.

The Swiss Federal Nuclear Safety Inspectorate (HSK) agreed to be the Task-Leader for TASK 7 and organizer of the workshop. The ETF members identified potential participants in their countries and communication between the organizers of the workshop and the participants was established. The organizers requested that each country respond to four questions prior to the workshop. The questions were:

1. "What are you doing with your method/approach?"
2. "Why are you doing this?"
3. "How are you doing this evaluation?"
4. "What is your experience (expectation)?"

The responses to these questions were distributed to all workshop participants prior to the workshop.

The workshop was held in Boettstein Castle, Switzerland, during the week 14 - 19 June, 1998.

Twenty-eight participants from twelve countries attended the workshop. The participants came from regulatory bodies, utilities and research institutes. The workshop was not organized in a classical way, i.e., it did not have individual presentations by the participants followed by discussions. Since all participants were provided with information contributed by each country in advance of the workshop, it began with discussions in three working groups.

This report summarizes the results of the workshop:

- Knowledge of organisational factors impacting safety, their identification and methods for their assessment.
- Organisational factors research in different countries.
- Identification of research questions.

This report should be seen as a representative overview of the topics based on the workshop participants' knowledge and experience. However, this report does not address the full body of knowledge and expertise that exists regarding organisational factors and human performance relative to safety and risk.

This report was prepared by the HSK in collaboration with the "Institut de Protection et de Sûreté Nucléaire" (IPSN) in Paris with contributions of the "University of Technology" (UTC) at Compiègne. A specialist on Work and Organisational Psychology did the compilation and structured the material from the notes taken at the workshop. The report was reviewed by the participants of the workshop and their comments have been reflected in the final report.

In its annual Meeting 1998 the Principal Working Group 1 decided that the report should be supplemented by additional contributions of countries and institutions which were not represented at the workshop. So, this last version of the SOAR contains additional information from Belgium, the Czech Republic, Finland, France, Japan and Spain which contributed to Volume II. The conclusions in Volume I were extended by some remarks extracted from discussions with ETF members.

2. ORGANISATIONAL FACTORS

Organisational factors have been defined in the area of organisational and behavioural sciences and they are listed in many publications. They were subject of research but the results are not widely known outside the research community. Furthermore only a few research results were translated into assessment methods.

This chapter presents an overview of the organisational factors regarded as important to safety by the specialists at the workshop. The different cultural backgrounds represented by the participants, using their own terminology and understanding of the factors, made it difficult to have a common definition for certain factors. Some factors are well known and could be defined by a consensus, other factors, such as "organisational culture", "organisational knowledge", "organisational learning" have slightly different interpretations and will need further discussions to reach a common definition. The workshop participants reached a consensus on twelve major factors. The order of the factors does not reflect their level of importance. The twelve factors are:

1. External Influences (from outside the boundary of an organisation),
2. Goals and Strategies,
3. Management Functions and Overview
4. Resource Allocation,
5. Human Resources Management,
6. Training,
7. Co-ordination of Work,
8. Organisational Knowledge,
9. Proceduralization,
10. Organisational Culture,
11. Organisational Learning,
12. Communication.

An organisational factor may be a process, representing an aspect of the dynamic part of the organisation, or the outcome of a process. For example in the "Human Resources Management" factor, the process requires that personnel are selected according to certain requirements, roles and responsibilities are assigned, and are periodically evaluated. All those processes can lead to the outcome that the right people are working in the right position, and further, this may reduce the risk in operation. There are some factors which can be seen both as process and outcome. For example "Communication" is on one hand a "process" with the outcome that personnel are receiving the information they need (vertically and horizontally) to perform their job effectively and safely. On the other hand, "Communication" is the "outcome" of managerial processes, such as the development and implementation of strategies and policies for the dissemination of information within the organisation.

Definitions of Organisational Factors

The goal of the workshop was to have a comprehensive list of factors which draws attention to the most important aspects of an organisation which can influence safety. There are interdependencies and overlays amongst the factors as they are in the organisational environment.

For each of the factors a "definition" is provided. "Aspects of this factor" characterizes the factor. "Further Clarification" of the factor provides additional information.

2.1 External Influences

Definition

"External Influences" are factors outside the boundaries of the corporate and operating organisations, which may impact the organisations' culture and performance.

Aspects of this factor

- Political situation.
- Legal system.
- Economic system (e.g. deregularization).
- Cultural aspects.
- Social and educational status of the work force.
- Other institutions and organisations (e.g. unions).
- Regulatory authorities.
- Public opinion and perception.
- Media reports.
- Employees' perception of their job status.

Further clarification

The mechanisms by which the organisation adapts to these "External Influences" are coping strategies which contribute to the organisation's culture. In many cases these influences can be introduced into the organisation by its own members. External Influences can be identified, observed and reacted to, but cannot be directly controlled or significantly changed by the organisation. Nevertheless these factors clearly influence the way an organisation meets its objectives. For example, it is particularly important for the regulatory body to understand and take into consideration the impact of its procedures, programs, policies, and regulations on the NPP's organisational culture and performance. However, "External Influences" are only mentioned briefly here and not discussed further because it is difficult to assess their influences on the organisation, and they are very country-specific.

2.2 Goals and Strategies

Definition

The top level organisational objectives that set priorities, allocate resources, promote safety, and establish long-range planning. Department and individual objectives should be tied to these goals and strategies.

Aspects of this factor

- Management policy and strategic planning in support of the mission of the organisation.
- Business planning process.
- Definition, prioritisation, and communication of goals and objectives.
- Development and implementation of higher-level plans.
- Definition of organisational structure, accountabilities, and authorities.
- Long term follow-up and control mechanisms, problem identification and resolution.

Further clarification

The "Goals and Strategies" factor appears to overlap with many other organisational factors in that other factors include establishing goals and objectives as one of their functions. However, as used here, "Goals and Strategies" is a function at the very top level of an organisation where long-term strategic planning takes place, which nevertheless, affects day-to-day work. This provides a framework in which all other planning and managing activities are established, prioritised and evaluated.

2.3 Management Functions and Overview

Definition

Arrangements of the upper management to organise, plan, control and monitor processes and activities supporting goals and strategies.

Aspects of this factor

- Identification, development and support of managers in order to allow them to carry out their functions as required. This may include identification of good managers with leadership skills and allocation of appropriate resources to support leaders.
- Empowerment, to enable managers to act on their authority.
- Promotion, and reinforcement of safety practices.
- Definition and establishment of goals and standards.
- Establishment of a framework for a reliable, traceable and efficient decision-making process.
- Establishment of an information management process to identify, acquire, distribute, store and operationalize necessary information in a precise and timely manner.
- Collection, tracking, trending and analyzing of safety and other performance information.
- Promotion of an organisational learning process to identify problems and to learn from past experiences and improve performance.
- Identification and resolution of problems (gather information to assess the situation, find solutions, evaluate different alternatives, implement decisions taking into account appropriate information and personnel, supervise execution, and monitor the results).
- Detection and management of possible internal conflicts between safety and economical benefit.
- Management of technical and organisational change.
- Planning and scheduling of the work processes including workload management.
- Establishment of an effective communication process with other interest groups, including the regulatory body, contractors, local public, media, trade unions, etc.

- Monitoring the resource allocation process which ensures that the right people are in the right position with the appropriate support.
- Establishment and monitoring of good work practices and processes (enforced by e.g. walk throughs, walk around, housekeeping standards, material conditions, etc.).

Further clarification

The "Management Functions and Overview" factor is a significant factor on its own and also overlaps with other organisational factors. Most of the other factors are managed at the middle, or even on a lower level in the hierarchy. Management Functions and Overview ensures, through controlling and monitoring, that all the crucial middle and lower management functions are accomplished. A manager on this upper level has the responsibility for monitoring whether all the crucial activities are carried out properly at all levels of the organisation.

2.4 Resource Allocation

Definition

Allocate, distribute and monitor financial, human, time and technical resources, to support activities required by goals and strategies.

Aspects of this factor

- Identification, acquisition and development of necessary know-how and technical resources.
- Balance between economic pressure, safety requirements and timetables.
- Prioritisation of goals.
- Organisational structure for resource allocation decision making process (degree of centralization).
- Control and monitoring process for human and technical resources.
- Logistics.
- Assignment of organisational (social) support.
- Involvement of Human Factors and other appropriate personnel in work design.
- Support of business planing.
- System support to operational functions.

Further clarification

The "Resource Allocation" factor is linked to the following three factors: Human Resources Management, Training, and Co-ordination of Work. Resource Allocation should ensure that resources are distributed in the direction of supporting safety. If resource allocation is inadequate, safety will be undermined. The Resource Allocation factor is particularly important during periods of reduced budgets and downsizing where there could be an emphasis on economic operation at the expense of safe operation. This factor is also addressed in the section about Organisational Culture.

2.5 Human Resources Management

Definition

Specify roles, responsibilities and accountabilities to meet organisational requirements and select, assign, develop and evaluate personnel (including contractor personnel) to meet those requirements.

Aspects of this factor

- Recruitment and selection of personnel based on predetermined qualifications including experience, education, and training.
- Attention to the psychological and psycho-physiological condition of available manpower.
- Assignment of personnel to roles, responsibilities and accountabilities as described in position descriptions and standards.
- Shift organisation rules.
- Working hours and overtime policies.
- Staffing policies and procedures.
- Adaptation of the organisation to changes in technology.
- Use and evaluation of contractors.
- Management of job rotation and promotion.
- Evaluation of motivation, performance and professional competence through formal appraisal process.
- Professional evolution, career development.
- Tracking reasons for staff turnover.
- Job security issues.
- Succession planning to anticipate and fill vacancies.
- Reward and recognition system.
- Appropriate support of personnel to do their jobs.
- Monitoring morale and attitude relative to a safety culture.

Further clarification

The "Human Resources Management" factor includes recruitment and assignment of personnel based on selection criteria, adequate definition of roles and responsibilities, training as required, evaluation of personnel on pre-established performance standards ensuring the right people in the right position and long-term development of personnel for continuous improvement in human resources.

Human Resource Management is linked with the two other factors Training and Co-ordination of Work and there is an overlap with the Organisational Knowledge factor as well. Human Resources Management needs to be aware of how organisational knowledge influences how employees do their work in practice versus how it may be prescribed.

2.6 Training

Definition

The process of identifying functions and tasks, and identifying the knowledge, skills and abilities required to accomplish those tasks in a safe and efficient manner, and the provision of appropriate training.

Aspects of this factor

- Organisation of the training process to ensure a continuous improvement in knowledge, skills and abilities to meet job requirements and organisational goals and strategies.
- Establishment and evaluation of different types of training, e.g. initial training, refresher training, remedial training and determine different strategies for training, e.g. class room, on-the-job, distance, self-paced, simulator, etc.
- Implementing training methods and developing training materials with consideration of the development of training media and psychological aspects of learning.
- Individualization of training.
- Implementation of a QA process for training.
- Continuous evaluation of training programs.
- Training according to actual needs
- Allocation of resources needed for training including the appropriate selection of instructors.
- Periodic training for career development.
- Monitoring the adequacy of instructors and materials.
- Training on new technologies as needed.
- Professional educational support.

Further clarification

Training is an important link to many of the other organisational factors and is especially important to meet organisational safety objectives. Human Resources Management helps determine training needs derived from long-term planning in accord with Goals and Strategies as well as the introduction of new or changing technologies and the availability of qualified personnel. Furthermore the content of training is dependent on certain task requirements defined in the Co-ordination of Work factor as well as the level of Proceduralization. In addition operational experience as described in the Organisational Learning factor should be addressed in training programs.

2.7 Co-ordination of Work

Definition

Process of planning, scheduling, integrating, allocating and implementing resources and responsibilities for co-ordinated work activities.

Aspects of this factor

- Organisation of inter-related work activities.
- Identification of roles, responsibilities and delegation of responsibilities.
- Shift work, shift turnover and team composition.

- Inter- and intra-organisational communication and co-ordination.
- Prioritization, planning and scheduling of work activities.
- Planning of work to allow an appropriate workload distribution.
- Logistics, assistance and support.
- Management of personal workload and work-flow.
- Traceability of work activities.
- Coordination of contractors with licensee employees.

Further clarification

The "Co-ordination of Work" factor defines in a formal way how work is to be carried out, taking into consideration the allocation of technical, financial and time resources. It sets the framework for the assignment of personnel to required tasks and the interactions between different positions. It defines the interdependencies of work activities and consequently their interfaces, and makes the interrelations between work activities explicit and traceable. This results in a common understanding of how things are done and how they relate to each other, i.e. Organisational Knowledge.

2.8 Organisational Knowledge

Definition

The understanding personnel have regarding the organisation's formal and informal processes, procedures, and practices, and the way in which work is actually accomplished in the organisation.

Aspects of this factor

- Understanding of the structure of the organisation and the different interfaces between organisational units.
- Knowledge about formal and informal communication channels and the interrelationships between an organisation's sub-systems.
- Individual awareness of roles and responsibilities and one's own place in the hierarchy of the organisation in the organisation.
- Implicit knowledge about work practices.
- Corporate memory of past experiences and organisational knowledge represented by the employees.
- Management of the communication of the organisational knowledge.

Further clarification

Organisational Knowledge was seen to represent two types of knowledge. The first type encompasses the views of the members of an organisation on the work reality, i.e., on how the organisation actually functions, which they gain by being part of the everyday working environment. This includes their knowledge of:

- the mission of the organisation,
- how budgets, time and technologies are distributed
- how people are assigned to their jobs

- when, how and why people attend training and educational programs
- the way work activities should be carried out formally
- attitude toward procedure adherence
- how the work practices are actually accomplished (which may be formal or informal).

The second understanding of Organisational Knowledge maybe characterised as "hidden knowledge" present in the memories of employees which is not captured unless it is made explicit and documented. Employees accumulate experiences and become more expert in their fields by doing their job day to day and this expert knowledge is only available to them because it is their stored knowledge. Organisational Knowledge or "Corporate Memory" often plays a more crucial role than documented procedures in official work practices.

2.9 Proceduralization

Definition

The process of identification, development, verification, validation, and implementation of rules, procedures and methods, based on standards for work activities and often on an analysis of functions and tasks.

Aspects of this factor

- Appropriate standardisation and formalization of recurring and critical work activities taking into consideration personnel experience and knowledge.
- Clear information of potential risks during activities.
- Presentation of procedures based on human factors and ergonomic principles and taking into account past errors.
- Participation of end users (i.e. operators) in the development, design and modification of procedures.
- Administrative aids.
- Administrative control, ensuring the quality of procedures in accordance with work practices and of the procedure modification process
- Good balance between the strict proceduralization and standardization of work activities and the skills and experience of the personnel.
- Influence of quality management systems on proceduralization.

Further clarification

The word Proceduralization is a neologism created to emphasize the process involved in developing and maintaining internal standards for work activities. Proceduralization is not only limited to control room procedures but also includes formalization and standardization of all work activities on all organisational levels (as for example quality assurance standards). Proceduralization includes identifying the functions and tasks in work processes, developing rules and procedures, verifying and implementing them, and finally evaluating and modifying them, if recognized as necessary. The Proceduralization process incorporates learning from past experiences, ensures participation of end users and Human Factors specialists and appropriate inclusion in training programs. This factor is linked to the Co-ordination of Work, Communication, and Training factors.

2.10 Organisational Culture

Definition

Refers to the shared assumptions, norms, values, attitudes and perceptions of the members of an organisation.

Aspects of this factor

- Safety culture as an aspect of the organisational culture where safety is a critical factor in the norms, values and attitudes of every employee throughout the organisation.
- Basic (shared) assumptions about how work has to be done in normal operations and in emergency situations.
- Safety awareness of individuals.
- Organisational support for employee socialization, i.e., important informal activities.
- Reward and recognition system reinforcing safety work performance.
- Attitude towards and interaction with the regulatory body.
- Awareness of implicitly sanctioning certain behaviours and disapproving other behaviours.
- Supervisors and peer employees acting as role models (i.e. showing acceptable behaviour).
- Psycho-social competence of..
- Open communication lines.

Further clarification

Every employee enters the organisation with a set of values and attitudes toward different aspects of work (of which one is safety). The personal values and attitudes of each employee is influenced by the oganisational culture, i.e., the commonly held assumptions, norms, values and attitudes about the work environment. The mission of an organisation reflects the organisational culture and is communicated throughout the organisation so that the employees follow the same objectives. The way management promotes safety and how safety is prioritized influences all levels of the organisation. Official work regulations as well as work practices and individual behaviour contribute to the employees' perception of the organisational culture. This perception subtly influences behaviour and contributes to the perpetuation of the existing organisational culture. Hence, the organisational culture factor is both process and outcome.

This important factor is not always tangible but nevertheless influences safety relevant behaviour in everyday situations.

2.11 Organisational Learning

Definition

A process by which organisations identify problems and learn from past experience and experience from other utilities in order to improve their future performance.

Aspects of this factor

- Feedback of operational experience and its utilisation.
- Proactive instead of a reactive behaviour.
- Transformation of individual tacit knowledge into explicit organisational knowledge.

- Questioning attitude.
- Promotion of common understanding of processes and responsibilities.
- Learning from generic issues.
- Identification, ownership and resolution of problems.
- Recurrent self assessment.
- Capacity and readiness to learn.
- Continuous improvement.

Further clarification

Organisational Learning is both process and outcome and occurs throughout the organisation. There are organisations that have recognised the importance of monitoring the process of Organisational Learning to enhance safety and which designate personnel with the task of promoting it. However, its main expression is through the organisation and all its members. Organisational Learning is related to the Management Functions and Overview factor, specifically to problem identification and problem solving, trending, monitoring and promotion of learning. It also involves Human Resources Management and Co-ordination of Work where feedback loops (one form of Organisational Learning) should promote a common understanding of roles and responsibilities with respect to work practices and processes. Furthermore it is associated with Training, where organisational experience and generic organisational issues can be addressed, and with Organisational Knowledge, where tacit knowledge coming from past experiences may be transformed into explicit knowledge[5]. An outcome or a sign of Organisational Learning is a questioning attitude by each individual in the organisation which also characterises the Organisational Culture.

2.12 Communication

Definition

Process by which information is exchanged, both formally and informally, written and verbal, within and across organisational boundaries.

Aspects of this factor

- Information flow between the organisation and other entities (e.g. the regulator and contractors).
- Information flow between different layers of the organisation, both vertical (between different level of management and employees) and horizontal (between different departments or projects).
- Intra-organisational communication i.e. within groups, between group members.
- Appropriate use of different means to convey information.
- Transfer of information in appropriate time.
- Awareness and effective application of the contents of message.
- Openness from top to bottom and vice versa.
- Formalization of the communication processes.
- Quality of the document management process.
- Tools and concepts to code and submit information.

[5] Some people use the terms of Organisational Knowledge and Organisational Learning interchangeably to express the same objective: To learn from past knowledge (experiences) to improve future performance.

- Informal and unofficial communication practices.
- Redundancy of messages.
- Managerial supervision of the communication process.
- Visual behaviour, written words, face-to-face communication.

Further clarification

The Communication factor is the strongest factor with the characteristic of being both process and outcome. Furthermore it is an aspect of all the other factors in that effective information flow is needed by them and the quality of communication within each factor will influence the quality of their function.

Communication is a component of all the other factors that can directly support or undermine safety, and it is, therefore, important to continuously monitor and analyse the quality of the communication process.

The safe operation of a nuclear facility is dependent upon effective communication processes.

3. ASSESSMENT APPROACHES

This chapter discusses first the methodological aspects of assessing organisational factors which may includes techniques, methods, models and frameworks. Then, a brief background will attempt to map the current research trends

3.1 Methodological aspects

Models or *frameworks* provide a structure for data collection, and uses the information gathered to present a picture about the interplay of different factors. It embodies the expected relationships between the various factors and certain outcome variables. Consequently it defines, what kind of data has to be collected, but it does not necessarily prescribe, what sort of method has to be used to get them.

A *technique* or a *method* is a structured way of gathering information or collecting data about organisational factors. Some examples are, document reviews, check lists, observations, interview protocols.

Analytical methods may be used to gather information, to analyse information, or they may be sources of information. Some examples are[6]:

- Human Reliability Analysis (HRA),
- Probabilistic Safety Assessment (PSA)
- Probabilistic Risk Assessment (PRA)
- Event and Barrier Function Model (EBFM)
- Function Analysis (FA) and Task Analysis (TA)
- Discrete Event Analysis (DE)
- Management Oversight and Risk Tree (MORT)
- A Technique for Human Error ANAlysis (ATHEANA)
- Professional Graphical Analysis (PGA)

6 Analytical methods are described in detail in the «System Safety Analysis Handbook» (1993), chapter 3 «Analysis Methods and Techniques»

Different perspectives

The participants of the workshop were representatives of three different environments; nuclear utilities, regulatory bodies and inspectorates, and the academic research community. The various approaches reflect the perspective of these entities.

The following section describes methodologies used by the three environments depending on their needs.

- *Utilities* are responsible for establishing the functions that are addressed by organisational factors. Utilities may evaluate or monitor organisational functions on a regular basis or through special self-assessments. These self-assessments may be initiated by the organisation itself or by the direction of the regulator. They may be conducted by the utility or by a consultant to the utility.
- *Regulatory bodies and inspectorates* are interested in three different kind of assessments. Reactive assessments following an event or continuing problems, proactive assessment of licensees to identify early signs of deteriorating performance, and regular inspections to assess licensees corrective actions
- The *research community* investigates organisations primarily from a theoretical basis Data is collected to develop certain assumptions and to test hypotheses. Following validation, research results may be used to develop measures for evaluating organisational factors and to improve assessment approaches. In addition, research results should contribute to understanding of the risk significance of these factors.

Methods and Techniques

There is a set of methods and techniques which are commonly believed to be useful in gathering data about organisational factors. As they can be found in the literature, a detailed presentation is not provided in this report. Some of the common methods and techniques are summarized below:

- Behavioural Observations: The investigator is present at the site and observes organisational behaviour, work practices through e.g., meetings, shift turnovers, etc.
- Checklists: This tool is used for walking through an organisation and focusing on certain issues.
- Structured interview: Individuals or groups are interviewed using a pre-developed protocol or questionnaire.
- Simulation: Individuals simulate an occurred or anticipated event.
- Rating scale: Verbal statements (sometimes anchored by behaviour descriptions) are rated by workers or experts based on their own perceptions.
- Document analysis: Provides information on history, present work processes and procedures depending on the focus of the investigation.
- Event review: Following an event investigators collect different types of information about the event help to determine the contributing and root causes of the event.
- Survey, questionnaire: Standardized method for gathering information.
- Focus group: Representatives from the same, or different, parts of an organisation come together in a group to discuss a specific issue or topic in a formal, facilitated situation.
- Trend analysis: Performance data is gathered over time and analyzed to determine trends.

Finally it is important to point to certain prerequisites which should be considered before using any of these methods:

- Determine the accessibility and sources of data.
- The techniques should be used with a model or framework to ensure that the collected data will be appropriately analyzed.
- The users of the method should be trained in the use of the method.
- The method should be validated.
- The organisation under investigation should have a clear understanding of the methods used.

3.2 A brief background of current research trends: a tentative mapping

In parallel to the industry and regulatory efforts towards a better understanding and evaluation of organisational factors affecting safety performance, the research community has also been involved in different projects and programs. Increasing, and systematically developing knowledge on high-risk organisations and their coping strategies with uncertainties is a priority for many researchers. Many of these programs have been developed with the support and/or in close co-operation with utilities or regulatory bodies (there are a few exceptions also). Some have also been developed within other industries (airlines, flight deck operations, chemical plants, off-shore platforms, transportation systems ... Gordon Rachael P.E (1998), Nivolianitou Z.S. & Papazoglou I.A (1998), Bea, R.G. (1998).). It should also be noted that the majority of these research projects are based on extensive field-work, combining various methods to collect and validate data (surveys, interviews, observations, task analysis and their subsequent methods of examination). Psychologists, sociologists, management specialists, human factors specialists and also anthropologists, economists and political scientists are contributing to the research efforts in this area.

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The organisations that this report examines are known as **"High Reliability Organisations"**, a notion first developed by La Porte, Rochlin, Roberts and Schulman (1987). The concept of **reliability** includes both safety concerns and availability requirements. The organisations in this category have the following characteristics : they provide important public services which include operating for periods of very high peak demands; failure of their task/production/ technology coupling can be catastrophic; trial and error learning in some areas are risky; social acceptance must be guaranteed. These organisations have received increasing attention over the last 10 years. And as result, they constitute one of the most dynamic research areas in organisational science (for an interesting review see Short and Clarke, 1992). Some of these research projects are presented briefly in this report, specifically projects represented at the workshop.

This section presents the research programs and projects that were communicated at the workshop. It is not our objective to review here all the research activities and projects in this area[7] but rather to give an overview of some of the promising and emerging research in this field: *Understanding the fundamentals of the social construction of organisational reliability.*

Organisational failure

Research on organisational reliability and on organisational factors influencing safety was initially framed mostly in terms of *organisational failure*. High-risk industries have been studied chiefly when they have failed rather than when they have succeeded, perhaps because their failure can hardly go unnoticed. The leader of this type of research is Charles Perrow, who's book *Normal Accidents* (1984) has greatly

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7 For a more detailed presentation see Sola, Vaquero and Garcès (1998), a literature review prepared by CIEMAT for CSN (Consejo de Seguridad Nuclear) .

contributed to placing organisational aspects of complex socio-technical systems in the foreground of public concern and on the research agenda. Perrow claimed that for technological and organisational reasons, high-risk industries cannot escape a "normal accident" (i.e an endogenously produced failure). In this view, there is no point in speaking about organisational reliability. As a notion it has been neglected in favour of organisational failure. However this perspective has serious limitations especially because high-risk industries do not fail so often. This raises the question of how their organisational strategies sustain such high levels of performance.

Organisational reliability

This is the perspective taken by the High Reliability Organisations' (H.R.O.) group based in Berkeley (California). HRO scholars (La Porte, Rochlin, Roberts, Schulman and to a lesser extend Wildavsky and Weick) are not so much interested in the fact that these organisations are doomed to fail sooner or later, **but rather in the conditions that allow them to fail so rarely**. They identified a set of selective criteria that according to them make HROs capable of sustaining such a high level of reliability. According to HRO theorists an HRO display four characteristics:

- Members of the organisation totally agree on its goals and objectives
- One can observe the use of redundant decision channels and use of redundant controls and supervision between staff
- Comprehensive training programs help employees develop their expertise in new domains
- The power to make decisions is both highly centralised and highly decentralised, meaning that anybody (even from the lowest rank of the hierarchy) can stop any kind of activity if he or she judges that installations or employees are at risk (See Rochlin, 1988 and also Perrow, 1977)

For HRO scholars these four criteria identify the capacity of an organisation to sustain a high level of reliable functioning.

Safety Culture and organisational Culture

Following the establishment of the INSAG 4 document (IAEA 1991) and the discussions that took place at that time (1990-1991) a couple of research programs have been developed in order to understand patterns of "safety culture", exploring the links between the organisation's culture and the safety performance.

For example, Weick (1987; with Roberts, 1993) and Rochlin (1988; with Von Meier, 1994) have extended the HRO research agenda with regards to the influence of organisational culture on reliability. For example, Weick (1987) has been able to identify a "story telling effect", reflecting the importance of developing an organisational culture allowing for plant personnel freely exchanging information about work-experiences (the bad ones as well as the good ones). Aldrich, and Pfeffer, (1976). Have focused on the organisations *and their environments*.

Also, belonging to this research perspective is the program directed by Norbert Semmer, [SITASC] a member of the workshop, whose research will be presented in the Volume II (Semmer & Regenass, in press).

Learning Organisation, Self-Correcting Organisation, Self-Designing Organisation, Self-Adaptive Organisation

Influenced by the contribution made by the "Situated Cognition" approach (Norman, Hutchins) and the related "Shared cognition" approach, concepts such as Learning Organisation, Self-Correcting, Self Adaptive, Self-Designing-Organisation have been developed to draw attention to elements of organisational design as well as organisational culture patterns capable of fostering and facilitating an organisation's strive to safety. From this perspective, a Self-Designing (Weick, 1977; Rochlin et al. 1987), or a Self-Correcting Organisation (Landau, 1973) or a Self-Adaptive socio-technical system (Rasmussen, 1994), can be described as an organisation which empowers its employees with explicit authority and resources to adjust rules and procedures in order to cope adequately with unplanned situations (Bourrier, in press).

Organisational factors in PSA/PRA

A new breed of PRA techniques are also taking up the challenge of answering puzzling questions about the influence of organisational factors on safety. Integrating organisational aspects into classic PRAs seem difficult. As Hollnagel (1998) explained in the workshop:

"At present we are therefore faced with the challenge to account for how an overall account of the factors that affect event occurrence and development can be included in the established methods of safety and risk assessment, in particular of how management and organisation factors can be treated in PRA".

Moreover, taking into account organisational factors require more than the usual cosmetic fixes that PRAs tend to affectionate. Again as Hollnagel claims:

"It seems rather doubtful whether the challenge to account for the influence of a wider set of factors can be addressed by extending the set of performance shaping factors one more time. Instead, one should consider whether the basic approach of PRA should be revised, i.e., developing a PRA+ ("PRA plus") approach. In the current understanding, all events take place in and are shaped by a context".

Most of the probabilistic approaches and studies focus mainly on human actions and performance during incidents or accidents and only few studies put the emphasis on pre-accidental errors or pre-initiator conditions (Mosneron-Dupin F (1992), Baumont, Ménage & Bigor, 1997). New PRAs like SHERPA (Embrey), IMAS (Embrey), SAM (Paté-Cornell) or WPAM (Davoudian, Wu, Apostolakis), or CREAM (Hollagel) and ATHEANA (NRC), MERMOS (EDF) are trying to take up the challenge.

Human Reliability Analysis used for PSA and PRA is based on past studies focusing on a single human behaviour and performance. New research is focusing on "errors of commission", more generally cognitive errors which lead to "inappropriate action" in respect to a determined framework or formal procedure. Yet, they appear perfectly rational and understandable given the context. This type of context is called an "error forcing context" (Hollnagel, 1996, 1998; Dougherty, 1998; Le Bot, Bieder, Cara & Bonnet, 1998).

In general, the different operating crew factors and their organisational environment are not often considered as Performance Shaping Factors. In addition, the organisational factors listed above are seldom taken into account to quantify their influences on systems availability and initiator occurrence.

A quantification using the number of occurrences collected in operational experience feedback systems (Martz & Picard, 1998) is mostly preferred (because easier) to the detriment of a quantification taking into account all the organisational factors which could contribute to the failure.

4. FUTURE NEEDS

On the last day of the workshop participants discussed future needs in the area of identification and assessment of organisational factors. Members of the workshop identified concerns and pending questions to include in the report. There was general agreement that although work in this area has begun in many countries and institutions, many questions remain and this issue needs further research efforts and resource allocation.

The research needs identified by the workshop participants have been broken down into four broad categories, as follows :

Category 1: Understanding specific organisational mechanisms, features and patterns

Workshop participants were also concerned about the impact of specific organisational mechanisms, on which they would like to have more understanding in order to better assess them. For example: how organisations are dealing with their institutional environment? On which assumptions do people react when confronted with uncertainties, difficulties, events? How does an organisation change?

This first category deals with the following questions:

1. **How does an organisation manage change?**
2. **What kind of strategies does the organisation use to cope with external factors?**
3. **What impact does the organisational environment have on?**
4. **What specific influences have management functions and strategies on safety and risk?**
5. **Based on which assumptions are people acting with uncertainty in their decision-making processes and what is the impact of conflicting goals on their behaviour ?.**
6. **What is the framework for addressing the main organisational issues to conducting a wide ranging assessment (for example for large-scale projects).**
7. **What are the tasks and the characteristics of the jobs of managers in nuclear organisations?**

Category 2: Understanding and assessing the impact of organisational factors on human safety performance

This category deals with the **initial question of the workshop**: i.e how to better understand the impact of organisational factors on human safety performance. Moreover, the identification of precursors (early warning signs) in organisational factors related to safety.

This category includes the following questions:

1. **What are the direct and indirect relationships between organisations and safety and between organisational factors and human performance? And what are the main mechanisms through which organisational factors should be used in order to decrease risk and improve safety performance.**
2. **What are the pre-cursors (early warning signs of deteriorating performance) in organisational factors related to safety?**

Category 3: Transfer of knowledge and development of common metric for comparisons

Transfer of knowledge concerns include several levels:

- A lack of knowledge transfer between the research community and the interested parties (utilities and regulators).
- A lack of a common metric in order to compare methods coming from various countries and various communities and institutions.
- A lack of transfer from other assessment methods, such as quality Assurance, Event analysis, and other performances indicators.

This category includes the following questions:

1. **How do we move from the theoretical models and techniques to the practical application of assessing a specific organisation?**
2. **How do we validate the research methods and how do we find a common metric to use all these methods?**
3. **How can assessment methods used in other areas be applied to organisational factors?**
4. **How to assess and evaluate organisational learning ?**

Category 4: Improvement of assessments conditions for plants

This last category deals with specific questions related to methods implementation. It echoes two series of concerns:

1) members of the workshop noted that a lot of audits are performed to assess safety, security, quality, and so on. These audits have some common points on management, policies, organisations, however they differ on performance indicators. In order to reduce the load on utilities, some common framework addressing the various modules should be developed.;
2) The audit activities have also to be evaluated in order to ensure their benefit to enhance human safety performance.

This category includes the following questions:

1. **How can methods and performance indicators, etc. appear in a common framework?**
2. **How can assessments be evaluated to determine if they lead to improvement in human safety performance.**

5. CONCLUSIONS

Organisational changes in NPPs are highly predictable in the near future, due to the deregulation of the energy market. They have to be managed carefully in order to maintain the safety level of the existing NPPs. Therefore, instruments for assessing the safety performance of nuclear organisations are first a need for utilities, and then for regulatory bodies. Indeed, deterioration in safety performance of organisations, even with small impact on the environment, are perceived by the public as a failure to ensure the safe functioning of nuclear activities and a lack of concern for the potential risks of nuclear energy. This perception reduces the level of credibility of the nuclear industry world-wide.

Understanding the reliability mechanisms of a nuclear organisation and identifying of the main organisational factors influencing safety will contribute to improving assessment methods. These objectives have to be pursued in order to give the organisations of nuclear installations valid instruments for assessing of their actual safety performance, and especially for evaluating of the consequences of planned organisational changes.

It is necessary for the utilities to detect early signs of degradation in the safety performance of their organisation in order to take remedial actions. This would prevent the accumulation of performance deficiencies which could lead to an intervention of the regulatory body with increased inspections, special requirements or even a shutdown of the plant. This proactive behaviour has not only a positive impact on safety, but also a long-term influence on the economy of the utility. Consequently, methods to identify these early signs of deteriorating safety performance have to be developed, shared and periodically evaluated, in the light of new research results from the fields of organisational behaviour and sociology.

During the Boettstein Castle workshop, there was a general agreement that the discussions were helpful for going beyond the assumption that it was possible to define "a" good organisation. It seems that the characteristics of reliable organisations differ from one country to another. These reliable organisations, in harmony with the country's culture, may have weaknesses or dysfunctions which in turn may be reduced by redundant mechanisms within the system.

To recall the atmosphere which characterised the workshop, people with different profiles (i.e organisational behaviour and sociology researchers, utility representatives, regulators or their technical support representatives, coming from 12 countries) searched to identify effective methods for determining reliability in organisations, in a predictive or proactive manner. The exchange of information between participants from these different environments led to an appreciation of how conceptual approaches must consider realistic concerns, how theories must be judged against pragmatic requirements, and for researchers, how to be responsive to the identified needs. The participants discussed experiences, identified common elements in approaches and addressed difficulties encountered in this field.

The current needs identified by these in-depth discussions concerned fundamental research questions, criteria for the development and validation of methods, and the standardisation of existing tools.

General remarks

The following are general remarks from the information exchange during the meeting:

- On the one hand, the vocabulary used in different countries can be very different for the same concept (e.g organisational learning) and on the other hand, the use of the same word can have different meanings (e.g. responsibility). Therefore, international collaboration in this field requires particular attention to the definition and explanation of concepts in order to foster mutual understanding.
- Each country has developed a particular system to control and audit safety based on the culture of the country (a framework, legal reference, academic background and knowledge of behavioural or human sciences, criteria for safety). Consequently, the introduction of a foreign method in a country must ensure that the method is discussed and appropriately integrated into the new field of application. The objective is to improve safety by enhancing methods while respecting each country's method of working.
- Defence-in-depth based on organisational reliability can benefit from co-operation between countries because each has developed an understanding of a particular mechanism which adds to the general knowledge base.

Comparison of methods

As regards methods of assessment, the main remarks were the following:

- The methods used in each environment (regulatory, utility self-assessment, research) are diverse. *The only one method* does not exist. The method has to meet the requirements of the scope of the evaluation and it has to be suitable to detect all specific aspects of the organization, specifically cultural aspects.
- One common property applies to all evaluation methods: The evaluation of an organization is not a desktop task. It requires a deep understanding of the organization, its structure and its key functions. This requires that the evaluators spend a lot of time with interviews in the evaluated organization.
- Concerning the most ten common methods, they are based mostly on document reviews, interviews and observations. These techniques require some training to be used effectively.
- Two types of representation of the influence of organisational factors on safety sustain implicitly the assessment methods. One claims that organisational reliability is embedded in the whole organisation design and intricacies; others believe that specific characteristics of safety organisation can be disentangled from the whole organisation in order to be the main focus of organisational assessment. This difference in the representation influences the nature of the view to organisational deficiencies. In the first case, insufficient planning and scheduling or resource allocation, dissent, compartmentalisation, power struggles and goal displacement are considered as influencing safety problems. In this first case, the organisation is considered as a whole, what has to be explained is its very functioning with a systemic approach. In the second case, the organisation deficiencies have to be described explicitly in connection with technical safety issues or pre-defined organisational factors. In this case organisational factors are often treated like technical aspects. The organisation is only seen through the prism of specific functions in a deterministic way.
- The assessment methods can be characterised either as reactive or proactive. A reactive assessment results from the detection of organisational weaknesses in events, or through a series of inspections. This assessment approach attempts to identify root, or contributing causes, of the organisational weaknesses. It may be based on requirements of the regulatory body or on utility

commitments, or on a legal framework. The proactive approach assesses the organisational factors as leading indicators of performance problems. Hence, this application integrates information on organisational factors in order to capture mechanisms or processes which are very important for the reliability of the organisation. This could be the decision-making process, change process, the coherence of the organisation with the policy, etc.

- The field of organisational factors is not an exact science. It is still in development. Therefore, gathering objective data, analysing the data and peer reviews of the results are required to ensure the credibility of the results. In addition, there is an urgent need for common definitions, for a common language in order to improve the objectivity of the evaluations and the discussions of their results.

Organisation reliability

- Organisational safety depends strongly on the effectiveness of the decision-making and problem-solving process and therefore on the knowledge and the behaviour of the managers of the organisation.
- To make effective use of organisational performance data coming from operational experience and events as valid input for research and the development of improved methods, the elements important for organisational reliability should be identified and taught during management training. This raises managers' awareness of the significance of organisational factors for the reliability of an organisation.
- Organisational safety depends very much on the ability of an organisation to learn from experience. Therefore, the way an organisation deals with unforeseen events, especially those with minor consequences, indicates the performance of the organisational learning process.

Future objectives for research and collaboration

The participants identified several research needs for the identification and assessment of organisational factors, as discussed in detail in Chapter 4. In addition to research needs, the need for strong international collaboration in this field was identified. The result of this collaboration should not be a common toolbox for the evaluation of organisational factors – a common instrument covering all cultural aspects and all countries seems unrealistic – but the international collaboration should result in a common pool of knowledge, accessible for interested experts in this field. This pool of knowledge may be used for information transfer, benchmarking purposes, the identification of specific common topics for research or further investigation, etc. In order to achieve this, the group came up with the following general recommendations:

- Develop a common understanding of specific organisational mechanisms, features and patterns in order to create a "common language" for organizational issues (This could help to reduce the impression of "subjectivity" of an evaluation in this area);
- improve the knowledge about organizational and human factors in the field of application (NPPs), make this knowledge applicable to non-specialists;
- foster international co-operation in this field;
- transfer knowledge and develop a common metric amongst Member countries for comparising methods and audit practices;
- exchange operational performance data for analysing the risk significance associated with organisational factors;
- exchange information in two to three years in order to share the progress of knowledge and to co-ordinate further collaboration in this field;

– undertake collaborative research on theories, methodologies, the identification and possibly the quantification of risk significance of organisational factors, and the impact of organisational factors on human safety performance.

A year after the completion of the Workshop Report we recognize from our experience and information exchange:

– Unfortunately there are almost no tools available for the self-assessment of organizations and neither research institutes (with the "only" interest to continue research) nor consulting companies (for commercial reasons) show a big motivation to improve this situation.
– Cultural differences betwen evaluator and the evaluated organization shall not be underestimated. They influence heavily the urgently required possibility of an understanding of the organization to be evaluated. As already mentioned earlier, even the application of a method from another country requires high attention.
– The organizations in NPPs are subject to change in the near future because of the need for optimization due to external economic pressure. At the time they are lost without tools for self-assessment and change-management. There is an urgent need for tools to help utilities to evaluate their future organizational changes (a) in advance and (b) to judge the effect of the change.

Final remark

In completing this SOAR we hope that we were able to contribute to a better understanding of the importance of organizational factors and their influence on nuclear safety.

From our experience in the last year, we recognize that the Boettstein Castle Workshop created a very valuable and well functioning network for questions in the area of organizational factors among the participants and the members of the ETF. This is, in our view, one contribution for a better international collaboration in this area and at the same time a further step to the creation of a common language in the area of organizational factors.

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7. APPENDIX

7.1 Acronyms and Organisations

ASCOT	Assessment of Safety Culture of Organisations Team (IAEA)
ATHEANA	A Technique for Human Error Analysis (US NRC)
BARS	Behaviour Anchored Rating Scale
BPR	Business Process Reengineering
CIEMAT	Spanish Research Centre on Energy, Technology and Environment (depending on the Spanish Ministry of Industry)
EDF	Electricité de France - Operator of the french NPPs.
FA	Function Analysis
FRAMATOME	French Vendor of NPPs
HFIS	Human Factors Information System
HPES	Human Performance Enhancement System developed by INPO (Johnson, 1980).
HPIP	Human Performance Investigation Process developed by US NRC
HRA	Human Reliability Analysis
HSE	Health and Safety Executive (UK)
INPO	Institute of Nuclear Power Operations (USA)
MBWA	Management by Walking Around
MORT	Management Oversight and Risk Tree (Knox & Eicher, 1992).
MTO	Man-Technology-Organisation
OSART	Operational Safety Review Team (IAEA)
PGA	Professional Graphic Analysis (Abramova, 1997)
PIF	Performance Influencing Factors
PROGNOZ	Obninsk Scientific Centre (Russia)
PSA	Probabilistic Safety Assessment
PSF	Performance Shaping Factor
PRA	Probabilistic Reliability Analysis
RCA	Root Cause Analysis
SAM	Systems, Actions, Management
SALP	Systematic Assessment of Licensee Performance (US NRC)
SLIM-MAUD	Success Likelihood Index Methodology Using Multi Attribute Utility Decomposition
STUK	Finnish Radiation and Nuclear Safety Authority
VTT Automation	Finnish R&D organisation (technical and technico-economic work for the industry and government agencies)
WPAM	Work Process Analysis Model

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NUCLEAR ENERGY AGENCY
COMMITTEE ON THE SAFETY OF NUCLEAR INSTALLATIONS

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IDENTIFICATION AND ASSESSMENT OF ORGANISATIONAL FACTORS RELATED TO THE SAFETY OF NPPs

Contributions from Participants and Member Countries

September 1999

VOLUME 2

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ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

Pursuant to Article 1 of the Convention signed in Paris on 14th December 1960, and which came into force on 30th September 1961, the Organisation for Economic Co-operation and Development (OECD) shall promote policies designed:

- to achieve the highest sustainable economic growth and employment and a rising standard of living in Member countries, while maintaining financial stability, and thus to contribute to the development of the world economy;
- to contribute to sound economic expansion in Member as well as non-member countries in the process of economic development; and
- to contribute to the expansion of world trade on a multilateral, non-discriminatory basis in accordance with international obligations.

The original Member countries of the OECD are Austria, Belgium, Canada, Denmark, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The following countries became Members subsequently through accession at the dates indicated hereafter; Japan (28th April 1964), Finland (28th January 1969), Australia (7th June 1971), New Zealand (29th May 1973), Mexico (18th May 1994), the Czech Republic (21st December 1995), Hungary (7th May 1996), Poland (22nd November 1996) and the Republic of Korea (12th December 1996). The Commission of the European Communities takes part in the work of the OECD (Article 13 of the OECD Convention).

NUCLEAR ENERGY AGENCY

The OECD Nuclear Energy Agency (NEA) was established on 1st February 1958 under the name of OEEC European Nuclear Energy Agency. It received its present designation on 20th April 1972, when Japan became its first non-European full Member. NEA membership today consist of all OECD Member countries, except New Zealand and Poland. The Commission of the European Communities takes part in the work of the Agency.

The primary objective of the NEA is to promote co-operation among the governments of its participating countries in furthering the development of nuclear power as a safe, environmentally acceptable and economic energy source.

This is achieved by:

- *encouraging harmonization of national regulatory policies and practices, with particular reference to the safety of nuclear installations, protection of man against ionising radiation and preservation of the environment, radioactive waste management, and nuclear third party liability and insurance;*
- *assessing the contribution of nuclear power to the overall energy supply by keeping under review the technical and economic aspects of nuclear power growth and forecasting demand and supply for the different phases of the nuclear fuel cycle;*
- *developing exchanges of scientific and technical information particularly through participation in common services;*
- *setting up international research and development programmes and joint undertakings.*

In these and related tasks, the NEA works in close collaboration with the International Atomic Energy Agency in Vienna, with which it has concluded a Co-operation Agreement, as well as with other international organisations in the nuclear field.

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COMMITTEE ON THE SAFETY OF NUCLEAR INSTALLATIONS

The Committee on the Safety of Nuclear Installations (CSNI) of the OECD Nuclear Energy Agency (NEA) is an international committee made up of senior scientists and engineers. It was set up in 1973 to develop, and co-ordinate the activities of the Nuclear Energy Agency concerning the technical aspects of the design, construction and operation of nuclear installations insofar as they affect the safety of such installations. The Committee's purpose is to foster international co-operation in nuclear safety among the OECD Member countries.

The CSNI constitutes a forum for the exchange of technical information and for collaboration between organisations, which can contribute, from their respective backgrounds in research, development, engineering or regulation, to these activities and to the definition of the programme of work. It also reviews the state of knowledge on selected topics on nuclear safety technology and safety assessment, including operating experience. It initiates and conducts programmes identified by these reviews and assessments in order to overcome discrepancies, develop improvements and reach international consensus on technical issues of common interest. It promotes the co-ordination of work in different Member countries including the establishment of co-operative research projects and assists in the feedback of the results to participating organisations. Full use is also made of traditional methods of co-operation, such as information exchanges, establishment of working groups, and organisation of conferences and specialist meetings.

The greater part of the CSNI's current programme is concerned with the technology of water reactors. The principal areas covered are operating experience and the human factor, reactor coolant system behaviour, various aspects of reactor component integrity, the phenomenology of radioactive releases in reactor accidents and their confinement, containment performance, risk assessment, and severe accidents. The Committee also studies the safety of the nuclear fuel cycle, conducts periodic surveys of the reactor safety research programmes and operates an international mechanism for exchanging reports on safety related nuclear power plant accidents.

In implementing its programme, the CSNI establishes co-operative mechanisms with NEA's Committee on Nuclear Regulatory Activities (CNRA), responsible for the activities of the Agency concerning the regulation, licensing and inspection of nuclear installations with regard to safety. It also co-operates with NEA's Committee on Radiation Protection and Public Health and NEA's Radioactive Waste Management Committee on matters of common interest.

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The opinions expressed and the arguments employed in this document are the responsibility of the authors and do not necessarily represent those of the OECD.

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Volume II

Contributions from Participants and Member Countries

Volume II contains contributions given by the participants at the workshop and additional information submitted from countries and institutions not represented at the workshop. It gives an overview on practices and activities in the participant's countries.

Chapter 1 contains an overview on methods used by utilities. Chapter 2 describes methods and the frameworks within they are used by regulators. In chapter 3 the research programs are described in a structured manner.

The bibliography in Volume II contains the authors referenced in Volume I as well.

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This report would never had been published without the help of all workshop participants who accepted the strong organisational constraints in the preparation of the workshop and continuously contributed to the state-of-the-art (SOAR) in written contributions and detailed reviews.

The Expanded Task Force (ETF) on Human Factors members would like to express their thanks to all participants of the Boettstein Castle Workshop on Organisational Factors and to all who contributed additional information to the SOAR.

Organisation of the report

This report is divided into three volumes:

Volume I

Section I: "Introduction" provides background information on the development of the workshop and how the workshop was organized.

Section 2: "Organisational Factors" provides a description of the twelve factors identified in the workshop.

Section 3: "Assessment Approaches" discusses various methods for assessing organisational factors. (Details on Methods and frameworks used in different countries by utilities, regulators and researchers are presented in Volume II.)

Section 4: "Future Needs" describes research needs to enhance understanding and knowledge of organisational factors and its contribution to human safety performance and risk.

Volume II

Methods and frameworks used in different countries by utilities, regulators and researchers.

Volume III

Appendix II: Papers contributed by the participants.

All bibliographical references appear in both Volume I and Volume II.

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1. UTILITIES

Two representatives from utilities, one from the Canadian Hydro-Quebec (HQ) and one from the French Electricity of France (EDF) described their approaches. The descriptions of the situation in the Czech Republic, in Spain and in Switzerland are done by members of the respective Regulatory Body.

1.1 Canada

Management Oversight and Risk Tree

The MORT analysis which was developed for mainly addressing conventional safety was adopted to scrutinise nuclear safety related events and is used among Canadian utilities. It is a fault-tree approach addressing important management functions supporting certain tasks. It is designed to analyse events but can also be used in a proactive way. It is regarded to be applicable to the assessment of Management Functions and Overview. The most useful aspect of it is its help as a check-list. In the United Kingdom another modification called SHORT-MORT is in use.

Human Performance Enhancement System

Another tool called Human Performance Enhancement System (HPES) is applied in most Canadian utilities (the same goes for the majority of utilities in the United States). The method is used for event analysis. Although it never has been done so yet, it seems to be worth trying it as a proactive regulator tool.

Root Cause Analysis

Another approach was presented in a distributed paper based on the analysis of around hundred very minor events within a period of one year. The root causes of these minor events were classified according to the following five families:

- overview and decision making
- communication
- organisational clarity
- human resources management
- culture.

All the families contain a dozen of key indications which should be chosen to describe the event.

The statistical analysis of these root causes gives a picture of the more frequent factors which appear in events and disturbances. This method is a kind of proactive method because the analysis of very minor events may indicate major deficiencies in organisation which could be root causes of more important events.

This data collection and the analysis are performed by a small crew of four persons in the Gentilly-2 plant.

Further details can be found in Loiselle (1998).

1.2 Czech Republic

Organizational factors are taken into account at the NPP Dukovany (4x440 MW, WWER type) in the framework of a large scale of more wide activities, such as :

- systematic following up the safe performance within the framework of operating experience feedback (OEF) program including application of ASSET and HPES methods and root cause analysis, evaluation of the impact of human and organizational factors on occurrence of operating events, implementation of corrective actions
- periodic auditing of documentation and activities
- training of operating and maintenance personnel and management
- forming the correct relations between the NPP and contractors maintenance personnel during operation and shut down
- self-assessment within the framework of regular ASSET and OSART missions
- improvement of the NPP organizational structure based on comprehensive expert analysis within the framework of PHARE projects (on improvement of OEF, QA etc.)
- PSA (mainly human actions and performance during accidents, incidents or activities during shut down)
- application of HRA, ATHEANA for assessment of data from operation and full scope simulator
- research: reliability-based maintenance, Accident Sequence Precursors, risk-based indicators,
- EF improvement, QA enhancement.
- co-operation with the regulatory body in its monitoring the safe performance by means of regular inspections as well as of reactive and proactive assessment of the licensee; regular reports on plant conditions and events.
- It is expected that after the start-up of the NPP Temelín (WWER type 1000 MW) next year, a special center will be formed in Czech Republic, which will systematically cover all aspects of the NPP safe performance including the impact of organizational factors.

1.3 France

The Nuclear Inspection Department of the French utility Electricity of France (EDF) has the mission to make a global evaluation of the nuclear safety. For that purpose, this department has developed an audit method which takes into account organisational factors. This approach was tested and is systematically used since 1995 on all nuclear power plants. Each plant is reviewed by EDF staff from the Nuclear Inspection Division every second year.

Global Evaluation of Organisational Factors

In order to evaluate the effectiveness of the organisational structures (i.e. sharing tasks and responsibilities, explicit (on paper) and implicit (real) organisation, observed behaviour of individuals and groups executing their tasks) the following aspects are reviewed:

- Organisation of safety management : policy, organisation, implementation.
- Operation organisation: Management, training, overview and control, operation practices, programme for future improvements, documentation.
- Maintenance organisation: management, training, programme for future improvements, quality of intervention preparation, co-ordination, intervention practices.
- Transverse aspects: engineering aspects, auditing and reviewing of activities, operational feed back analysis, modifications.
- Radioprotection aspects: management training, measure analysis, quality of preparation, radioactive source management, logistic control.

The following questions illustrate the type of investigation of EDF inspectors:

About site management: Is the site management only interested in developing work rules and procedures, or is it also interested in developing work values that are common to both the staff and the management? Does management consider both individual and group inputs for each different task? Are task requirements defined with the participation of the employees involved in the task in order to develop a referential that is common to both management and the employees?

About procedures: Are procedures, standards, and rules taking into account the characteristics of the employees, their skills, personalities, and individual and group goals? Are documents that support work (procedures, instructions, etc.) improved, complete, and do they contain sufficient details according to the needs of the users? Is operating experience feedback developed to ensure that developers and users of various rules and instructions are in agreement with the intent of these rules?

About resources allocation: Does the assignment of personnel to various tasks consider the individual employees' particularities (level of experience) and not only their « administrative » certifications?

The techniques used during these audits are documentation analysis, close observation of the field activities and interviews in order to complete the task observations. These interviews provide information about the causes of identified discrepancies.

After such an evaluation, the evaluated site has to define an appropriate way for improvements and has to take precise engagements for the deadlines of the proposed improvements.

The resources needed for each evaluation are the following :

- The **evaluation team** consists of about 20 members: 10 are Inspectors from the Nuclear Inspection Department and 10, so called « peers » that are coming from different nuclear sites. They meet together with approximately fifteen local delegates from the nuclear sites.
- Four weeks for preparation: All data concerning the nuclear safety of the evaluated site are collected and analysed. A report is written with the defined specials concerns. The last week of preparation includes a 3 day meeting with the complete evaluation team.
- Two weeks (10 working days) for evaluation on site.

- Four weeks for analysis and preparation of the final report. During this phase the results of the evaluation are transmitted to and discussed with the management of the evaluated site in order to make sure that the causes of the discrepancies are well identified and understood.

The main limitation of this approach is the duration of observations on site. Only two weeks are very often not long enough time for an in-depth observation of all organisational factors and especially for determining the causes of discrepancies. Because of the limited duration, the site management staff sometimes considers observations as not completely representative.

However, the general frame of nuclear safety level used for these evaluations appears very appropriated for the improvement of organisation.

In addition, one OSART Mission is conducted every year in one or two EDF plant.

1.4 Spain

The Spanish utilities (UNESA), in collaboration with the Spanish Nuclear Regulatory Body (CSN), and CIEMAT have started a five-years R&D project, entitled «Development of methods for evaluating and modelling the impact of organisational factors on nuclear power plants safety» (see chapter 3.3 for the project description).

1.5 Switzerland

In the framework of a self-assessment some Swiss NPPs have conducted reviews by an external consultant company in order to identify potentials for improvements of organisational performance.

2. REGULATORY BODIES

The largest sample of representatives at the workshop came from regulatory bodies and inspectorates. Even among this more or less homogenous group one can find very different approaches.

For each country given in the alphabetic order, first, the context and the framework will be presented, then the assessment approaches.

2.1 Belgium

2.1.1 Present context

In Belgium all NPPs, which are situated on 2 sites namely Doel and Tihange, are operated by the same utility Electrabel.

All plants are subject to regulatory control by AVN, which is the inspection and licensing organisation authorised by the competent ministries for this task.

For each of these units one AVN inspector is on an almost full time basis in charge of regulatory inspection activities. These inspections cover as well technical as organisational aspects of safe plant operation. In addition a senior inspector covers organisational matters which are common to all units and treated on site level, such as organisation of training, quality assurance, etc. . AVN inspectors have free access to all plant locations and operating documents and are free to talk to all NPP staff members (at least at the higher and lower levels of management). This situation allows AVN inspectors to get a good feeling of the organisational strengths and weaknesses at each unit and each site, even if such an assessment is not formalised in procedures.

Some organisational aspects, such as detected weaknesses in the areas of training, organisation of work, procedural support and communication practices are mainly assessed in a reactive mode and discussed with plant management in the process of the root cause analysis of incidents which occurred at the plant.

Weaknesses in the areas of training and technical support may also be also identified during other inspection activities such as:

- licensing exams of operators;
- analysis of plant modification proposals;
- verification of proposals to modify the Safety Analysis Report;
- discussions with staff personnel and unit shift personnel (in control room);
- These and other aspects, such as the organisational structures put in place, the role of management, the training programmes, the prioritisation of actions to improve safety and the deficiencies of safety culture which are observed by our inspectors during their daily inspections, are discussed on a more systematic basis in periodical meetings with high and middle level management representatives of the NPP.

Remarks and recommendations regarding technical and organisational matters, resulting from these inspection visits, are formally communicated to the plant managers by inspection reports. However, no formal response is usually required from the utility to these reports.

2.1.2 New developments

In a relatively new context of deregulation of electricity production and distribution, higher pressure is observed on the need to cut production costs. At the same time and in the same context the utility is in a process of a fundamental review of its organisation in the nuclear production field.

This situation brings new challenges to AVN and to its way of dealing with organisational factors assessment. A need is felt to improve the documentation of observed organisational deficiencies and the identification of generic problem areas, to make related assessments more objective and if possible to compare them to acceptable standards and to widen the scope of analysis in this field.

Recently a new process has been started at one of the sites with the intention to identify short and longer term objectives for an organisational safety improvement program for the next 5 years. In this process, workshops are organised by the utility in which AVN management and senior inspectors together with utility high level managers participate. The first workshops held have already resulted in the identification of short term objectives for improvement such as, for instance, the definition and communication by the utility of clearer management expectations with regard to safety especially in the organisational area, the definition of a policy regarding independent safety assessment, the improvement of quality of safety justifications for proposed plant modifications, the definition of a policy regarding knowledge management, improvement of the quality of training including knowledge of Technical Specifications.

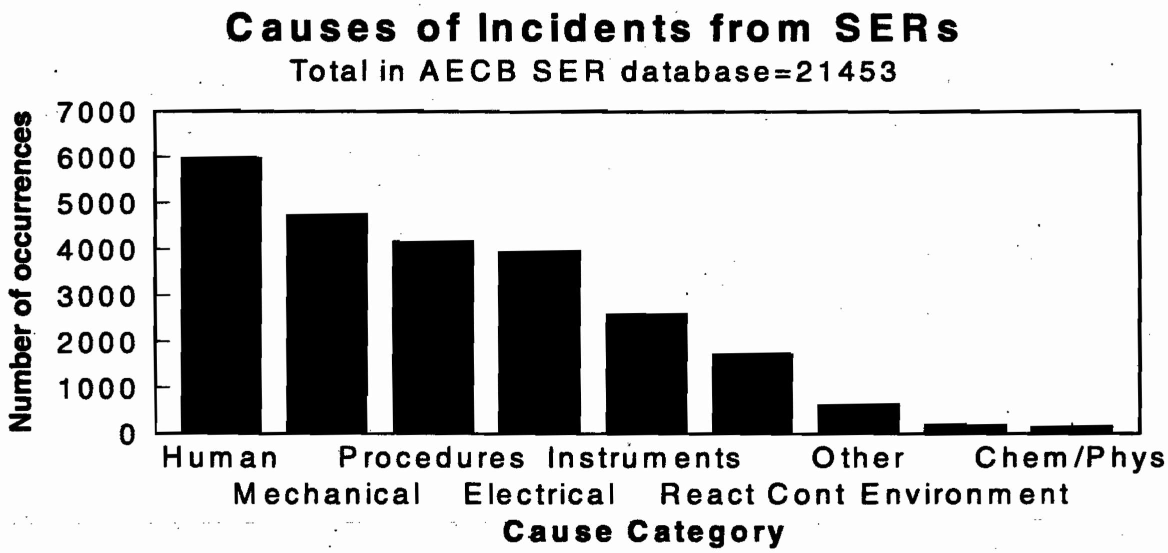
After completion of this exercise, AVN will have to review its present inspection practices regarding the licensee's management systems, and especially organisational factors, addressing as well the general approach and its scope. One of the objectives of these inspections will be to verify that plant management fulfils its earlier commitments. Methods for objective assessment in this area will have to be explored, but it is the intention to make use of techniques and practices addressed by the WGIP (CNRA).

2.2 Canada

2.2.1 Context and Framework

In recent years, analysis of "high profile" incidents both within as well as outside the nuclear industry have focused attention on the importance of organisation and management factors in the etiology of incidents. Most of these data highlight the negative effects on safety culture of "poor" O&M (e.g. TMI, Chernobyl, Herald of Free Enterprise, Piper Alpha, etc.), although we should not forget that there are positive lessons to be learned from organisations with robust safety cultures (e.g. the way in which Sunoco, an Ontario based oil company, dealt with a major fire, caused by a lightning strike, at its Sarnia refinery in 1996).

Nuclear Safety is predicated on the concept of "defence-in-depth". All of these defences, however, rest on an O&M foundation. AECB Staff believe that if that foundation is flawed, then there are potentially serious problems for the entire defence system. To monitor the effectiveness of licensees' managed processes on achievement of the nuclear safety goal, the AECB has established a set of objective performance indicators. One such indicator utilises data from Significant Event Reports (SERs).



Canadian Licensees are obliged to provide the AECB with Significant Event Reports (SERs) about certain incidents which occur within their facilities. The AECB maintains a database of information, including cause categories, pertaining to these events. The graph displayed in Figure 1 below shows the number of times each category has been identified as a causal factor in the event database. As can be clearly seen, Human Performance causes are the most prevalent.

Figure 1

Figure 2 shows trend plots of the percentages of events in each cause category of the database for the fourteen year period from 1982 to 1995. Interesting points are that the contributions to the total database from Instrument , Electrical and Reactor Control causes have reduced over the period, however, the contribution from Human causes has increased. Although there are many possible reasons for this change in the shape of the database over time, it was clear to AECB Staff that there is an urgent need to address the Human issues involved in the significant events.

For the reasons discussed above (the growing realisation of the importance of O&M on safety and the "track record" as evidenced from event data) AECB management decided that a proactive approach was required to develop a systematic, objective process for assessment of licensees' organisation and management. In 1996 the AECB embarked on a three year project to develop an O&M assessment method which can be used by AECB staff as part of the normal regulatory process. Although the envisaged product is primarily for AECB staff use, it will be freely available to licensees who, it is anticipated, will also make use of the method for self assessment purposes.

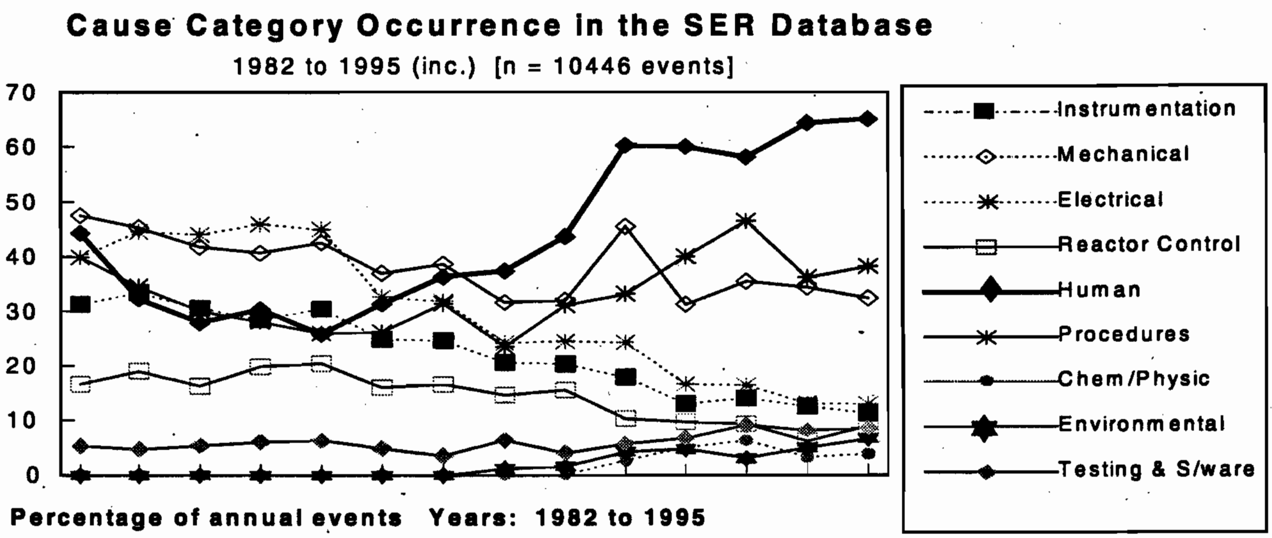


Figure 2

2.2.2 *Method and Approach*

2.2.2.1 *Project Strategy*

- Retain world class consultant

  Expert consultants, Human Performance Analysis, were retained to undertake the research and development work involved. These consultants, under the direction of Dr Sonja Haber, have extensive experience in the subject area having conducted similar work for the US NRC which resulted in the successful development of an assessment method called NOMAC.

- Use validated techniques

  AECB Staff believe that any techniques used in the overall method must have a solid track record gained from having been well-tried, tested and accepted by the nuclear community.

- Consult with stakeholders

  Consultation with stakeholders is essential throughout the course of development of the assessment method to ensure that the end-product meets the needs of the users and is accepted by the licensees in our non-prescriptive regulatory environment.

  The major stakeholders were identified as being:

  - AECB staff
  - Licensee organisations

- Fieldwork with licensee organisation(s)

  The method must have been successfully tested in a real environment prior to acceptance by AECB as a part of the regulatory process.

- Pilot study

  The complete assessment method must be successfully demonstrated in a Regulatory Pilot Study. This must identify where the method can be used by "non-experts" and where „expert specialist" resources are necessary to produce consistent and reliable assessment data. These data must be subjected to analysis and a standard format regulatory report (termed a Board Member Document) produced. The result of this phase of the project will determine whether the method is deemed acceptable for inclusion in the regulatory process, or whether additional research work is required.

- Modify and roll-out

- Monitor and adjust (long term)

2.2.2.2 Methodology Development

The model used in the development of the assessment method has been termed the Canadian Adaptive Machine Model (CAMM). It is based on the principles of the US NRC's NOMAC, suitably modified for the Canadian nuclear environment. The ultimate purpose of the method will be to assess Licensees O&M systems and processes as a standard component of our formal regulatory process.

This will apply to all aspects of the nuclear life cycle (research, design, uranium mines, fuel fabrication, power reactor operation and decommissioning). Although the work done to date has largely been carried out in a "research" context, we have already had the opportunity to carry out a field trial of the methodology in its entirety at one nuclear power plant. Additionally, AECB Staff have used some tools from the methodology in three actual regulatory assessment activities. Two of these were associated with licence renewals for a uranium mine and for a nuclear energy research site. The last involved assessing a major nuclear power generation licensee's reorganisation proposals.

2.2.2.3 Prerequisites

A number of prerequisites for the method were specified. These were:

Objective Measures: It was considered important that the techniques chosen rely on structured and objective observations and not subjective judgements. One criticism of many investigations into the area of organisational performance has been that the results of the investigations are not replicable due to the large degree of subjective judgement inherent in the methodology used for conducting the investigation. By providing methods that are more objective, the collected data and any conclusions drawn from the data are more defensible, replicable, and allow for comparative analysis (either over time at the same organisation, or across organisations).

Quantitative and Qualitative: Both a quantitative and qualitative assessment of the organisational dimensions under study is important for an adequate understanding of organisational performance. Specifically, quantitative data provides objective measures of the dimensions under study while qualitative data allows for descriptive statements which help in the characterisation of the quantitative assessment.

High Scrutiny and Use: Because the methods are being developed for regulatory application, the methods chosen must be able to withstand substantial peer scrutiny and must have undergone extensive use.

The methodology must be capable of being continuously refined and adjusted to be effective in the variety of situations which the AECB regulates (e.g. NPPs, Mines, Fuel Fabrication, Isotpoe Production, Decommissioning, etc.).

Documentation: standards, criteria and processes must be clear and unambiguous to both assessors and licensees. Also, the documentation produced must create a traceable history over the long periods of time associated with organisational/cultural issues.
The method should be as non-resource intensive as possible.

The method must focus clearly on NUCLEAR SAFETY requirements. The adoption of any particular management philosophy is the prerogative of the licensee, however, the AECB must be satisfied that the approach adopted is conducive to ensuring nuclear safety. The assessment method must therefore be able to provide accurate assessment data regardless of the prevailing organisation and management style.

There is a requirement to develop baselines for individual facilities against which the AECB can return some time later and identify the effects of change. The method must be sensitive to this requirement. In addition, the method must provide the AECB with the ability to compare one facility against another in a consistent and valid manner.

Safety vs Production and Quality: Although the primary interest of the AECB is Safety, we cannot ignore the impact of our regulatory requests on licensees Production and Quality goals. The assessment method must give us insight into this.

Sensitive to needs of all groups: although the method must assess Organisation and Management this does not mean that focus is only on the "management" group. It is essential that the AECB understands the effects on safety of the management process from top to bottom and across all levels of the organisation. The assessment method must allow us to identify this.

2.2.2.4 Focus Areas

High Reliability Culture: From recent international level work done in this area we are beginning to be able to accurately describe high reliability culture characteristics. We believe this to be a focus area of particular importance as we move more into a "risk based regulation" environment.

Creativity vs Proceduralization: Traditionally nuclear facilities have focused on Proceduralization. We know from experience, however, that this is no guarantee of nuclear safety. Analysis of human action continuously reveals a tendency towards Creativity which we cannot, and should not, eliminate. AECB Staff believe, that control can only be fully achieved through an appropriate "balance" of proceduralization and creativity so as to enhance, rather than detract, from nuclear safety. The AECB must therefore be able to measure and assess how successful nuclear organisations are in achieving this.

Task Complexity - what do we mean by this and how can we measure it.

Organisational layering and shifting roles - an example here is "Teamwork" and how its introduction can affect the more "traditional" systems of work.

Communications - almost a cliché -but it is vital that we understand them.

Organisational flexibility - how does the organisation respond to the changing environment.

2.2.2.5 Factors Assessed by the Method

The factors (or dimensions) which we assess are as follows:

Centralisation:
Centralisation refers to the way decisions that affect the operation of the facility are made and who makes those decisions. Particularly, the degree to which decisions are made within a small circle of high ranking individuals versus decisions made by many, at all levels of facility operations.

Coordination of Work:
Coordination of work refers to the planning, integration, and implementation of the work activities of individuals and groups.

External Communication:
External communication refers to the exchange of information, both formal and informal, between the facility, its parent organisation, and external organisations (e.g., AECB, the public).

Formalization:
Formalization refers to the extent to which there are well-identified rules, procedures, and/or standardised methods for routine activities as well as unusual occurrences.

Goal Setting/Prioritisation:
Goal setting/prioritisation refers to the extent to which facility personnel understand, accept, and agree with the purpose and relevance of goals.

Interdepartmental Communication:
Interdepartmental communication refers to the exchange of information, both formal and informal, between the different departments or units. It includes both the top-down and bottom-up communication networks.

Intradepartmental Communication:
Intradepartmental communication refers to the exchange of information, both formal and informal, within a given department or unit. It includes both the top-down and bottom-up communication networks.

Organisational Culture:
Organisational culture refers to facility personnel's shared perceptions of the organisation. It includes the traditions, values, customs, practices, goals, and socialisation processes that endure over time and that distinguish an organisation from others. It defines the "personality" of the organisation.

Organisational Knowledge:
Organisational knowledge refers to the understanding facility personnel have regarding the interactions of the organisational subsystems and the way in which work is actually accomplished within the facility.

Organisational Learning:
Organisational learning refers to the degree to which individual facility personnel and the organisation, as a whole, uses knowledge gained from past experiences to improve future performance.

Performance Evaluation:
Performance evaluation refers to the degree to which facility personnel are provided with fair assessments of their work-related behaviours. It includes regular feedback with an emphasis on improvement of future performance.

Performance Quality:
Performance quality refers to the extent to which facility personnel adhere to their job requirements, carry them out correctly, and take personal responsibility for their actions and the consequences of those actions.

Personnel Selection:
Personnel selection refers to the degree to which the organisation effectively identifies and selects personnel who can meet the demands of the job and the degree to which the facility has personnel who can perform both the routine and unique aspects of their positions.

Problem Identification:
Problem identification refers to the extent to which the organisation draws upon knowledge, experience, and current information to identify potential problems.

Resource Allocation:
Resource allocation refers to the manner in which the facility distributes its financial resources. It includes both the actual distribution of resources as well as individual perceptions of this distribution.

Roles and Responsibilities:
Roles and responsibilities refers to the degree to which facility personnel's positions and departmental work activities are clearly defined and carried out.

Safety Culture:
Safety culture refers to the characteristics of the work environment, such as the norms, rules, and common understandings that influence facility personnel's perceptions of the importance that the organisation places on safety. It includes the degree to which a critical, questioning attitude exists that is directed toward facility improvement.

Time Urgency:
Time urgency refers to the degree to which facility personnel perceive schedule pressures while completing various tasks.

Training:
Training refers to the degree to which facility personnel are provided with the requisite knowledge and skills to perform tasks safely and effectively. It also refers to facility personnel's perceptions regarding the general usefulness of the training program.

2.2.2.6 Tools Incorporated

The following tools, all previously validated, were incorporated into the method:

Functional Analysis - This method provides a description of the organisational workflow. Data to implement this method is obtained primarily through documentation review, interviews, walk-throughs, talk-throughs, and some observation of organisational activities such as meetings.

Structured Interview Protocol - This tool is a standardised database of questions, built from many different sources, all of which deal with the impact of organisational factors on safety performance. While not all questions are asked of each person interviewed, this methodology allows the organisational investigator to select relevant questions from a previously established database to assess pre-identified issues. This methodology makes it possible to address the organisational dimensions of relevance based on hypotheses formulated from the model.

Behavioural Checklists - Behavioural Checklists have been utilised by a variety of researchers of organisational issues (11,12). Based on the organisational dimensions identified as important for assessment from the model developed, key behaviours are identified which are representative of the dimensions and which are readily observable. The key behaviours were identified based on issues identified by the model as well as from the expertise of individuals with extensive background in the investigation of the impact of organisational factors on safety performance.

Behavioural Anchored Rating Scales (BARS) - BARS are performance evaluation devices that incorporate behavioural examples with general performance dimensions. Specifically, each scale or BARS represents one area of performance or one organisational dimension. Each BARS contains a definition of the dimension and a 5-point scale, with behavioural statements anchored to each point. The behaviours act as "anchors" for defining the various levels of that dimension.

BARS are generally thought to be a superior technique to traditional rating scales (i.e., 1 = poor, 5 = excellent) for the collection of information related to organisational performance.

Survey Techniques - The use of this technique allows data to be collected using a well-developed standardised questionnaire to assess various aspects of organisational factors. The particular survey that is proposed for use in this project allows an assessment of both organisational and safety culture and has been implemented across a variety of high-risk industries.

2.2.2.7 Current and Future Work Plan

Our experience from the 1996/97 field trial was very favourable, to the extent that another year's funding has been approved to complete the development of the method as a standard regulatory "tool". Particularly important was the feedback from the licensee whose organisation and management was assessed. Although pointing out areas where further development work is required prior to total acceptance, the licensee agreed that the process was systematic, fair and, most importantly, provided valid data resulting in an accurate assessment. (This is particularly important because of the non-prescriptive regulatory process used in Canada).

In the three instances where parts of the methodology were used to provide information in support of regulatory decisions, those assessments were reported to have made valuable contributions.

The 1998/99 research plan comprises of the following four major activities:

- Development of organisation and management "standards" for the Canadian nuclear industry.
- Field trial of the finalised assessment method against the "standards" in at least one nuclear facility.
- Develop a regulatory protocol for organisation and management assessment
- Train AECB staff and commence implementation.

The first of these activities, Standards Development, is already well under way. It has involved consultation with licensees in a series of "workshops" to define and agree on what can be classified as "minimally acceptable" for a comprehensive set of factors which affect organisation and management.

The Field Trial will be done at a multi-unit NPP station. It will result in the preparation of a Board Member Document (BMD).

With regard to the development of a formal Regulatory Protocol for routinely carrying out O&M assessments, it is extremely important that this method is used, and seen to be used, as a **component** our integrated regulatory assessment process. How we do this will require clear and precise stipulation, systematic and controlled implementation, and regular follow-up monitoring.

An appropriate training programme for AECB Staff will be developed following a Systems Approach to Training (SAT).

2.3 Finland

2.3.1 Context and framework

Finland's nuclear power plants are located on the south and west coast of Finland. The state-owned Imatran Voima Oy (IVO) operates two 445 MW VVER-440 type pressurised water reactor units (Loviisa 1 and Loviisa 2) near the city of Loviisa. On the west coast of Finland Teollisuuden Voima Oy (TVO) operates two 710 MW ASEA-ATOM type boiling water reactor units (TVO I and TVO II) in Eurajoki. Both utilities are currently (summer 1998) involved in the process of increasing the electrical output of their stations. These four reactors generate about 30 % of Finland's annual electricity needs.

Regulation of the use of nuclear energy in Finland is based on the Nuclear Energy Act (990/87) and regulation of the radiation practices on the Radiation Act (592/91). Further requirements are given in Nuclear Energy Decree (161/88) and the Decision of the Council of the State «General Regulations for the Safety of Nuclear Power Plants" (395/91). According to the legislation the Finnish Radiation and Nuclear Safety Authority (STUK) sets safety requirements and verifies compliance with them. STUK has in this respect developed a comprehensive set of safety guides, the so called YVL-guides.

The object of regulating radiation practices is the use of radiation and radioactive substances in health care, industry, research and teaching. A safety licence in accordance with the Radiation Act is mandatory for the use of ionising radiation. The licence is granted by STUK. Before a decision on granting a licence is made, the applicant must demonstrate that the place where the radiation is used, the sources of radiation and the protective equipment meet safety requirements. Wherever radiation is used, there shall be nominated a person responsible for radiation safety as well as competent staff.

The regulation of nuclear power plants covers the entire life cycle of each facility, from design all the way to decommissioning. The primary objective of regulation is to ensure that the reactor remains under control in all conditions.

The operating organisations have a full and undivided responsibility for the safety of nuclear power plants. In accordance with defined inspection programmes, STUK verifies that their operations and related support activities are appropriate and in compliance with safety requirements.

STUK emphasises the significance of the users' voluntary work in ensuring the safety of their practices. A sound safety culture is built through knowledge, training and motivation. According to STUK's approach it would mean failure if shortcomings had to be rectified by enacting compulsory measures.

2.3.2 Methods and approaches

The YVL-guides provide a basis for the regulatory activities performed by STUK. The guides cover all the main areas of nuclear power plant operation giving instructions and recommendations e.g. on general safety principles, quality assurance, reporting, documentation, personnel qualification and training, outages, plant modifications, inspections and safety assessments, nuclear fuel management, utilisation of operational experience, safety classification, accident analyses, PSA, fire and radiation protection, and emergency preparedness. The YVL-guides are regularly updated to reflect new experience.

Each Finnish nuclear power reactor is refuelled once a year, and at the same time the entire plant is overhauled. STUK reviews the respective plans and assesses the technical upgradings which are carried out to increase safety and reliability. The results of the work are inspected before the plant is restarted.

STUK has been very active in the field of safety culture since the beginning of 1990s when the concept of safety culture was formally included in the Finnish nuclear safety regulations. Finnish experts were also involved in drafting the INSAG-4.

After the Decision of the Council of the State had entered into force in 1991, STUK conducted detailed assessments and prepared Safety Evaluation Memorandums for both TVO and IVO power plants. In the memorandums following topics were addressed:

1. Past decisions of the corporate and plant management where it had been necessary to make a choice between the options of shutting-down the plant (or extending the outage) for acting on a certain safety concern, or continuing operation and taking actions later (e.g. during the next scheduled outage).
2. General housekeeping activities at the plant, and tolerance to minor disorders such as small water or oil leaks in non-nuclear safety systems.
3. Resources invested in maintaining a high level of safety: personnel, external technical support, work spaces and tools, spare part and material storage.
4. Efficiency of the management system ensuring the implementation of approved plans and procedures.
5. Co-operation and information exchange between organisational units.
6. Methods for maintaining and upgrading plant personnel's professional skills and knowledge.

7. Adequacy and current status of the safety relevant plant procedures, and regard given to those procedures in daily work.
8. Rewards to the plant personnel for good performance and attitude to human errors.
9. Preparedness of the plant management to be subject to an assessment of their own performance, and their attitude to critique.
10. Individuals' attitude to their duties and problems encountered in various tasks.
11. Openness in uncovering and solving problems.
12. Systematic assessment and development of plant safety.
13. Resources invested in safety relevant plant modifications and research.

2.4 France

2.4.1 Context and Framework

In France, there is only *one* utility for power generation, (Electricity de France, EDF) running about nineteen nuclear sites with fifty seven nuclear power units (all pressurised water reactors having a very similar design). Other nuclear installations concern research and fuel reprocessing units.

The safety authority is the DSIN (Direction de la Sûreté des Installations Nucléaires), the regional inspectors are part of the DRIRE (Direction Régionale de l'Industrie, de la Recherche et de l'Environnement). The IPSN (Institut de Protection et de Sûreté Nucléaire) is a research institute which supports DSIN and DRIRE in their regulatory activities.

For many years, the DSIN and the DRIRE have organised inspections on plants where different issues in the human factor area and organisation are reviewed in detail :

- training process (EDF members and sub-contractors),
- outage activities (maintenance tasks, periodic tests, start-up tests, radioprotection issues, sub-contractor quality assurance).
- documentation quality with emphasis on operation documentation

In addition, if events or inspections reveal organisational deficiencies, specific inspections are performed in order to evaluate the seriousness of the deficiencies.

For the general framework , a legal guideline (Arrêté qualité du 10 Août 1984) describes more or less the main aspects of NPP's organisations. Within this framework, detailed below, all nuclear utilities have to be prepared to be inspected on organisational issues by DSIN and DRIRE inspectors.

More specifically, when the nuclear installations inform the safety authorities of changes in the roles and responsibilities of units, or when a new role is created, DSIN ask IPSN for an in-depth analysis of this policy or commitment change.

For example, in the past, IPSN has made some safety analyses about organisation changes :

- Safety Organisation of the research institution in France,
- new maintenance organisation in 1990,1992 and 1993 (Baumont, 1995).
- new organisation of operating teams from 1993 through 1995 (Charron & Tosello, 1995).
- Subcontractor organisation (ongoing).

In parallel to these safety analyses, IPSN carried out ergonomic studies on site to complete their analyses. The method used is described in the appendix. New reviews on the same issues or on new organisation changes could be planned again.

In the next few years, the new organisation changes which are going to analysed are the following :

- Human factor specialist systems on the plants
- The decentralisation process from EDF head-quarter to plant management

During the years after the implementation of the changes, the result of such change are inspected issues by DSIN and DRIRE.

All these inspections (usually one day, rarely two days, with an average of three people) are done on site and include document reviews, interviews and observations. IPSN experts participate actively in these inspections.

2.4.2 Methods and approaches

The main reference in France for organisation audits is the legal guideline «Arrêté qualité du 10 Août 1984» which prescribes the requirements to ensure design, construction and operation quality for the safety of nuclear installations. This legal guideline describes in seven chapters the main elements in a nuclear installation's organisation, which are summarised below:

Chapter 1 gives «general provisions» in three articles:

- The first article mandates how to construct a system:
  - to define the quality of the structures, equipment and components, the quality of the systems which associate them, and the quality of the operating conditions,
  - to ensure that a system is organised to define the quality of the above-quoted elements,
  - to implement and maintain this quality, to verify it and to analyse and correct discrepancies,
  - to plan activities based on procedures which come from documentation records.

  The system begins at the conception step of the installation and is completed during the entire life of the installation.
- The second article prescribes how to identify activities which influence the quality of the above-quoted elements.
- The third article defines who is responsible for the utilities and define what a sub-contractor is.

Chapter 2 defines the responsibilities of utilities and subcontractors, the prescription of their relationship and the monitoring of subcontractors.

Chapter 3 gives the general principles for the organisation and the requirements to obtain and maintain the quality which influences safety:

> The performance requirements have to be defined for each activity which influences the quality.
>
> For these activities, the technical and human resources have to be adapted to the quality defined, the skills and the abilities of personnel have to be adequate for the activity, taking into account their nature and their influence on safety. Technical tools have to be qualified. For each activity, the organisation has to identify the missions and the duties of the concerned personnel or units and their relationship to each other.
>
> A system is developed and implemented in order to ensure the technical control of each quality based on performance requirements and to control the result of activities, in order to ensure that corrective and preventive measures have been identified and implemented after events or detection of discrepancies.
>
> A system is in place for verifying implementation of the above requirements. The persons in charge of this system have to be sufficiently competent in technical aspects, have to be independent of the operational managers and have to refer to persons with authority in quality implementation. Inquiries and verification through samples have to be organised periodically. This verification is both for technical aspects and organisation. This system ensures that the means are implemented to draw lessons learnt from abnormal situations and to initiate remedial actions.

Chapter 4 is related to documentation on activities and describes in detail which type of document have to be established, updated, and used. The storage, protection and accessibility conditions are mentioned as being important.

Chapter 5 concerns events and anomalies. Criteria for such anomalies have to be defined as well as reporting conditions and necessary documentation on these anomalies.

Chapter 6 gives requirements about particular items such as studies carried out on safety aspects.

Chapter 7 explains the implementation modalities of this legal guideline.

This legal guideline which surveys a many organisational factors, associating them in a specific order, gives the main axes of the approaches for the assessment of organisation as a whole or on specific aspects. Depending on the problems encountered in events or during inspections, the main details given in an article or in one or several chapters can help to build a particular assessment method.

In this legal guideline, some important organisational aspects are not well developed, such as co-operation, transfer of information, management duties, time allocation. The importance of these factors have been investigated in IPSN studies, based on the activity observation at the plants.

In addition, IPSN is trying to improve the methods used in order to evaluate the organisation as a whole based on the results of past studies. In addition, a bibliographical review has been completed.

2.5 Germany

2.5.1 Context and framework

In Germany, 19 units (BWRs and PWRs) on 14 sites are being operated by various licensees. Pursuant to Section 24 the Atomic Energy Act AtG is implemented by the responsible authorities of the federal states («Länder»)of the Federal Republic of Germany (FRG) on behalf of the Federal Government. I.e. the «Länder» of the FRG are in charge of licensing and supervising the units on their territories, and of ensuring that the safety requirements are met. Lawfulness and expediency of the decisions taken by the «Länder» (i.e. the consistent application of rules and regulations, norms and standards as well as of the state of science and technology) are subject to federal supervision by the Federal Ministry of the Environment, Nature Conservation and Reactor Safety (BMU). Licensing and supervising authorities are assisted by expert organisations and commissions.

The German regulations do not only cover technical aspects, they also address human factors, training and organisational issues. The organisation implemented by the licensees is required to assure safe and reliable operation. Although no particular organisational structure is prescribed, all German utilities implemented the same type of structure (except minor differences). Specific sectors of nuclear power plant organisations are regulated in detail, e.g.:

- operator qualification and training,
- organisation, performance and documentation of maintenance tasks and of radiation protection measures,
- operating experience reporting, analysis and feedback, which is an important part of organisational learning.

Organisational factors have always been taken into account in the analysis and feedback of operating experience. In response to particular events the licensing and supervising authorities e.g. imposed changes in the organisation of the plant concerned.

Main principles of safety culture have always played a major role in the German nuclear industry. Among them are e.g.:

- high priority of safety,
- clear definition of responsibilities and tasks,
- blame-free response to human error etc.

Personnel of the licensing and supervisory authorities and of technical inspection agencies (TÜVs) frequently inspect nuclear power plants. Particular tasks related to nuclear safety like e.g. periodic tests have to be carried out in the presence of such inspectors who have to control the correct and assess performance of these tasks and their outcomes.

Human and organisational factors can be included in these inspections in order to detect deficiencies and early signs of degradation. Results are fed back to the utilities for further investigation and improvements.

The German utilities have implemented a so-called «Human Factors System» which allows to identify and to analyse deficiencies and/or event causes not only in the human factors but, to some extent, also in the organisational domain. For some utilities, OSART missions and WANO peer reviews were carried out.

2.5.2 Methods and approaches

Because of the increased relative importance of human performance for the safety of nuclear power plants, supervising authorities, independent experts and licensees have strengthened their commitment to this subject since years.

Although there was and is no reason to call in question the licensee's organisation in general, the experience gained from the evaluations of operating experience, OSART-missions, results of probabilistic safety analyses, findings of investigation of events and occurrences often show how to further improve the licensed plant condition, including organisational factors.

Accordingly licensees installed the so-called Human Factor System (HF-System) in 1996. In this system, a systematic root cause analysis is applied to operating events and other occurrences to determine those human factors (including organisational, technical and personal factors) that caused or contributed to an error.

A person on site is in charge of Human Factors issues. He/she is required to have a good knowledge of the plant and additional qualification particularly in the following areas:

- root cause analysis,
- ergonomics,
- psychological factors related to work,
- in interviews and observation techniques,
- documentation and reporting etc.

This person is integrated in the organisation of the licensee and is supported in his work by other persons e.g. from the operation and maintenance area and gets the necessary information after an event.

All reportable events of the plant are studied in detail. Events which did not occur in the plant itself are analysed whether there is an influence of human actions and whether it is transferable and applicable, to the licensee's plant(s).

Further inputs to the HF-System are hints and information about occurrences and possible week-points in organisation, technical equipment and human actions, which are voluntarily reported by the plant personnel themselves. It is also possible that independent technical experts which carry out on-site inspections on behalf of the supervising authority can feed the HF-System with information obtained by walk throughs, document reviews and observation of periodical testing.

If there is an influence of human failures, the following points will be analysed:

- what are the reasons for the incorrect actions, and
- are there possibilities to improve the organisation, procedures, technical devices, etc., to reduce the probability of incorrect actions?

This is done by using proven methods according to the state of the art (for example interviews, observations, document reviews, simulations).

By order of the supervising authority for the nuclear power plants in Bavaria the TÜV Energie und Systemtechnik GmbH, Munich evaluated the usefulness of the licensee's HF-System. The evaluation of the HF-System shows that it is a necessary complement to the already existing activities of the licensees. It will also contribute to optimise organisational factors and to prevent occurrences and events in the future.

An appropriate implementation of the HF-System within the licensee's organisation is crucial, because it determines whether important safety-relevant organisational deficiencies can be found out or not. The supervision by the supervising authority focuses not only on the licensee's actions based on the HF-System, but also covers all the licensee's actions and measures that are relevant to human performance and to some extent, organisational factors.

This HF-System is under continuous improvement according to practical needs and experience.

2.6 Spain

2.6.1 Context and Framework

There are several principles which support the Consejo de Seguridad Nuclear (CSN) approach to this issue. They are the following:

- The organisation and management of nuclear power plants is a direct responsibility of the licensee.
- The regulatory body must not replace the licensee's responsibility.
- Performing their respective functions, regulators and licensees must know in depth the organisational and management factors which influence the safety of nuclear power plants.
- In this context, the institutional and management aspects which affect safety are established in the Operating Organisation Manual and the administrative requirements of the Operating Technical Specifications, two official documents whose modification is subject to CSN approval. At the plants, responsibility for safety is assigned to line management, although there are groups or committees such as the Plant Safety Committee and the Owner Safety Committee which ensure that suitable priority is given to safety matters.

In addition to normal quality assurance systems, the operators are beginning to implement safety culture and management evaluation programs, such as the Model of the European Foundation for Quality Management (EFQM).

The CSN monitors the efficiency of management and organisational activities through several methods, like the results of its inspections (ESFUC program) and of operating experience.

Notwithstanding, there is no organisational model underpinning the selection and combination of the methods used by the CSN. Being aware of this limitation the CSN started in July 1996 a research project to make a state-of -the-art review of the impact of organisational factors in the safety of NPPs and to delineate a research plan to develop methods and tools. After a year the project provided an analysed data base with several hundreds of entries and a research plan. The five-year research plan, a joint undertaking of the CSN, the utilities and the CIEMAT, was initiated in 1998 (see chapter 3.3 for a project description). With such a project, the CSN aims to the assimilation/development of tools to:

- Proactively analyse the influence that organisational factors have in the safety of the plants (process-based).
- Reactively analyse the organisational factors that have caused, or contributed to, the occurrence of significant incidents (performance-based).
- Reduce the PSA limitations in addressing the impact of organisational factors (risk-informed).

If this tools have been always convenient, the liberalisation of the electricity market already implemented in Spain since January 1998 makes even more important the development and implementation of the previously indicated tools, both by the utilities and the regulatory body. It is also considered very important that the tools be accepted as fair, practical and reliable by both the regulatory body and the utilities.

2.6.2 Current methods and approaches

As indicated above, currently there is no organisational model underpinning the selection and combination of the methods used by the CSN for assessment of organisational factors, neither an application of the methods up to the point of identifying specific organisational factors.

Performance is assessed through a combination of methods. Most of them are not specifically oriented to the assessment of organisational performance, but they allow to obtain some feelings about such NPP performance:

- There is a programme (ESFUC program), to assess the performance of the utilities, closely delineated according to the old Systematic Assessment of Licensee Performance (SALP) that takes as fundamental data base the inspection findings.
- Operational experience is continuously reviewed. Every event leading to a Licensee Event Report is reviewed by a multidisciplinary panel of experts, and it is classified in categories according to significance, generic nature or interest. The significant events are usually subject to a detailed review.
- The process used by the utilities to review and feedback the lessons of their own events, and
- hose of the industry applicable to their facility, is audited every one or two years.
- Resident Inspectors maintain a close surveillance of the activities of the utility regarding the safety of the plant. They issue a monthly report including their activities and findings.
- A set of performance indicators is compiled and an annual report is issued. Given the fact that most of the Spanish NPPs are from the US, the set of indicators used is the one developed by the NRC. This allows for the comparison of results from the Spanish plants against similar plants from the US.
- Design modifications, changes in technical specifications, new safety analysis (f.i. PSA) are reviewed in significant detail by the CSN staff allowing to obtain an overall picture of the licensee technical capabilities and processes of work.
- Meetings CSN-utilities are carried out at different organisational levels to discuss technical issues. Periodically the utilities present to the CSN their strategic plan.

- There is an inspection plan covering the different safety topics. The results of the inspections are an input to the assessment of the utility performance.

Brief description of the ESFUC program

The application of inspection programs by the CSN with regard to the activities of the licensee and his contractors (main vendor, engineering, manufacturers) constitutes the regulatory instrument for the checking, and enforcement where applicable, of effective awareness of the priority that the licensee is required to give to safety issues. The CSN has in place a systematic approach to evaluation of the behaviour of the plant organisations, through application of the ESFUC program. This program established periodic evaluation of plant operation and of its organisation in the five following functional areas: operation, radiation protection, maintenance-surveillance, technical support and emergencies. In performing this evaluation, consideration is given to the following criteria following each inspection, these going further than the corresponding checks on the system or components being inspected:

- Management commitment to improving quality and safety.
- Operator´s capacity for self-evaluation.
- Considerations of safety implications in the resolution of technical issues. Effectiveness of corrective actions.
- Operating events related to the issues and activities inspected.
- The human resources of the organisations.
- Training and qualification programs.
- Deviations, and breaches of safety standards or conditions and non-compliance with programs.

The aspects evaluated are closely related to the attitude of the organisation and of those responsible for it towards safety issues and the priority given to them. The ESFUC reports drawn up by the CSN categorise the operation of the plant and of its organisation in each of the aforementioned areas. The guideline for the development of the program contemplates that these reports be sent to each licensee for knowledge thereof and implementation of the appropriate actions. The results of application of the ESFUC program are used by the CSN to plan inspections for the next period, the aim being to effectively assign the resources of the organisation.

2.7 Sweden

2.7.1 Context and Framework

At present, in mid 1998, there are 12 nuclear power units, 9 BWRs and 3 PWRs, in operation in Sweden. There are four licence holders and two dominating owners with large shares of the electricity market. The NPPs employ altogether about 3 500 persons.

The Swedish Nuclear Power Inspectorate (SKI) exercises supervision in compliance with the Act on Nuclear Activities. According to the Act the licensees have the full and undivided responsibility to take all measures necessary to achieve safety. SKI shall define the detailed purport of this responsibility and supervise how the licensees execute it, by creating its own well-founded view on the safety status of the installations and on the quality of licensee safety work. The more detailed mission objectives of SKI include to provide a clear definition of requirements, check compliance with requirements by supervision focusing on organisational processes and activities, initiate safety improvements and maintain and develop competence at licensees, SKI, and nationally. The regulatory strategy thus prescribed assigns equal weight to technical and organisational factors influencing safety and that regulatory inspection and supervision efforts should largely focus on the quality of plant safety management.

After the TMI-2 accident, the Swedish Government set up a special Committee which recommended a substantially reinforced and more co-ordinated programme on human factors, both with regard to regulatory and research activities. As the programme developed, the term "human factors" (or "man-machine" as was the concept used) was found somewhat inadequate to describe the programme and the issues addressed. The programme was thus renamed as addressing the interaction between Man, Technology and Organisation, MTO for short. Specified areas within the MTO-programme included organisational issues and safety culture, quality assurance, competence and training, control room work and design, procedures, maintenance, incident- and risk analysis.

The MTO-group at SKI, consisting of five behavioural scientists, in the beginning of 1990s worked out tools for inspection in the areas of maintenance programs, quality systems and assessment of the learning processes of an organisation. The group is currently deeply involved with inspections and reviews which are performed in mixed teams with the technical and engineering staff of the Inspectorate. In addition, long term research and development programmes concerning new knowledge and criteria to be used in SKIs reviewing of new technical and organisational solutions at NPPs are on the agenda.

In 1998 new general safety regulations have been issued for nuclear installations. The regulations are supplemented with general recommendations on their application. Some of the provisions are the same as applied earlier but on a number of issues the requirements have been extended and reinforced. This applies in particular to human factors and organisational issues. New or reinforced requirements are thus issued on for example the licensees responsibility to

- provide working conditions supporting safe behaviour
- provide competence and adequacy of staff
- perform safety reviews of both plant modifications and organisational changes
- submit the reviewed modifications and changes to SKI, which can add further requirements
- perform systematic analysis of events.

2.7.2 Methods and approaches

Considerable progress has been made in the past few years, learning from experience in applying process based oriented tools and methods for regulatory supervision of major plant modifications and of plant organisational improvement programs (SKI Inspection Guidebook-Maintenance, 1994; Quality Systems Inspections Handbook, 1993; Dahlgren & Olson, 1994; Olson & Thurber, 1991).

The guidebook developed by SKI for assessing Maintenance Program Effectiveness provides one approach in assessing aspects of Management Functions and Oversight. The assessment of the maintenance program status requires:

- identifying the essential elements of effective maintenance programs. The elements are organised into the following five resource functions; people, tools, material, information and co-ordination
- viewing the maintenance program as a system of interrelated elements and activities with linkages within teams, within each element and function, and between maintenance and other departments
- evaluating the goals and the plans to achieve the goals within each element.

The guidebook contains a list of general questions and related information under each heading in order to assist the inspector in preparing the inspection. On each page there is an improvement figure to remind him of gathering information on the:

- past: what has been the performance in the past
- present: what is the current performance situation
- future: what are the performance goals and what are the plans to reach these goals?

The guidebook is also used by utilities in self-assessments in order to develop baseline documents.

The learning of an organisation is assessed by SKI by addressing the following dimensions (Dahlgren & Ohlson, 1994; Olson & Thurber, 1991):

- problem recognition: the ability to recognise that performance problems exist
- problem diagnosis: the ability to accurately characterise the nature of the problem
- solution formulation: the ability to come up with viable solutions
- solution implementation: the ability to put solutions into place
- assessment and feedback: the ability to monitor the effects of the solution and to make adjustments as required.

Strengths and weaknesses are explored in all dimensions and in their supporting organisational aspects such as goal setting, communications, co-ordination, resource allocation etc.

The framework has been used in both normal and topical inspections of for example management and practise of training and evaluation, in-service inspections, plant experience feedback of events relating to the interaction of man-technology-organisation as well as management and practise in handling plant modifications.

Triggered by several indicators of deficiencies in safety management at one site SKI conducted an extensive inspection project focusing on a number of areas of importance to safety. This inspection project covered the areas mentioned above and also included organisation and safety culture, internal safety assessment, feedback of operating experience, management of plant human factors work, management training, and control room work.

The inspections focused both on the formal system and actual practise. Instructions and other documents were reviewed and structured interviews were performed on-site with management and staff. Mixed teams of inspectors with background in plant operations and expert reviewers including experts on the interaction man-technology-organisation carried out the inspections. Feedback of SKI findings, conclusions and recommendations were given to management and staff, in meetings on-site, in order to create a common understanding of organisational processes and any deficiencies with regard to safety and quality, stressing the licensee ownership of safety work.

Based on these experiences SKI has decided to submit one site a year to a similar in-depth inspection effort, even if there are no indicators of deteriorating safety performance.

2.8 Switzerland

2.8.1 Context and framework

Switzerland operates two BWRs and three PWRs on four sites. Inspectors of the Swiss Federal Nuclear Safety Inspectorate (HSK) have regular contacts with the plants for inspections and discussions on special issues and the safety evaluation of the plants.

The Swiss Federal Nuclear Safety Inspectorate (HSK) has issued regulations on the Organisation of NPPs and on the Training of licensed NPP personnel. They describe the basic requirements on the organisation of Swiss NPPs but they don't provide a structured method nor clear criteria for the evaluation of organisations. In the case of periodic safety reviews and in the case of the detection of organisational weaknesses in inspections and especially in the event analysis the HSK does a deeper investigation of organisational issues by doing document reviews, additional inspections including interviews of people at the plant.

At the time there is no formal system in force for the observation of organisational factors.

In two Swiss NPPs OSART Missions have been conducted in 1994 and 1995 as well as the corresponding follow-up missions. The plants have taken the OSART results very seriously and special programmes have been initiated in order to improve organisational and safety performance. In 1999 and 2000 the two remaining plants will undergo a OSART review as well.

2.8.2 Methods and approaches

After the Three Miles Islands (TMI) accident the Swiss Federal Council asked the HSK to evaluate if an accident like TMI would be possible to occur in Switzerland. Besides technical investigations, the HSK initiated 1981 an in-depth evaluation of organisational factors in the Swiss NPPs, based on an «organisational climate» model. Members from nuclear power plants, delegates of the Swiss Federal Nuclear Safety Inspectorate (HSK) and a psychological institute developed questionnaires and interviews for the overall assessment of social climate aspects. The result of this investigation was rather positive and there was no need for a follow up.

Nowadays deeper investigations on organisational issues are done in the case when events or inspections reveal organisational deficiencies. In these cases a group of HSK inspectors go to the plants for interviews, document reviews and further inspections. The findings are discussed with the plant managers and depending on the severity of the issue, the utility is required to propose solutions for the resolution of the problem. Clear deadlines are set and surveyed for the proposal as well as for the implementation of the solution.

Recently a project has been started at HSK with the aim to involve Technical Inspectors (inspectors on technical issues, non human factors specialists) in the observation of organisational and human factors issues during their regular inspections. Important factors will be identified and criteria developed in order to detect early signs of deteriorating safety performance. It is planned to gather information corresponding to these criteria with the help of observations obtained during technical inspections, walk through and meetings. Human Factors experts will either be part of the inspection team or will interview the inspectors after they have finished their inspections. All findings will be collected by the Human Factors Department of HSK. Periodically this department will discuss the findings with the management of each plant. This will help the plants management to have an alternative view additionally to their own assessment.

In the field of safety culture a research project financed by the regulatory body (HSK). It will be used for analysing minor incidents that could have resulted in more severe accidents. Based on document reviews and interviews scenarios are created, where people will be asked what they would have done in a given situation. Furthermore managers will be asked, how their people would have reacted to certain incidents. This method will conducted as self-assessments in the plants. One key factor is confidentiality and anonymity. Such an method will fail if individuals believe that they will be identified.

2.9 United Kingdom

2.9.1 Context and framework

The legislative framework within the UK requires that no one should use a site for the construction or operation of a nuclear installation without a licence from the UK's Health and Safety Executive. The Nuclear Safety Directorate is that part of the Health and Safety Executive responsible for ensuring that nuclear power related activities are carried out in a safe manner. NSD makes day to day judgements about the organisational aspects of licensees through the routine regulatory site activities of its inspectors. There are also occasions when the corporate management system is examined for its adequacy in ensuring nuclear safety.

Applicants for nuclear site licenses are required to demonstrate to the satisfaction of NSD that they are capable of discharging the duties placed upon them under the UK's Health and Safety at Work Act and the Nuclear Installations Act in a proper manner. Similarly, existing licensees need to be capable of demonstrating compliance with conditions attached to their nuclear site licences. This is usually done through a combination of the administrative arrangements which outline the management organisation, the systems used to manage safety on the site, the written safety case for the plant (or plants) which describes the design and the expected behaviour of plant both when operating and in fault conditions.

The current arrangements for granting nuclear site licences are described in a UK publication 'Nuclear Site Licences - Notes for Applicants.' In this document is a request for a 'Management Prospectus'. The purpose of the prospectus is to demonstrate that the user of an installation has an adequate management system to discharge the obligations connected with being the holder of a licence.

The thrust of the UK's Health and Safety at Work Act, the Management of Health and Safety at Work regulations and the licensing requirements of the Nuclear Installations Act is that the operator should manage safety. Additionally, the scope of the NSD standard licence conditions, the HSE guidance on licence conditions and the HSE publication, Safety Assessment Principles for nuclear plants cover important aspects of managing safety. The non prescriptive wording in the 35 conditions attached to a site licence is intended to encourage licensees to adopt a proactive approach to the matter of developing arrangements that suit their individual circumstances and risks while demonstrating that safety is managed effectively.

2.9.2 Methods and approaches

The Health and Safety Executive has developed a general systems approach which is described in its document "Successful Health and Safety Management". NSD has taken this document and produced a nuclear version entitled 'Managing for Safety at Nuclear Installations'. This is used by inspectors to audit organisations. Inspections are based on documentation reviews, interviews and walk throughs. This approach is also the reference for helping utilities to build their organisation systems. Every function in an organisation (e.g. Training or Communication) can be assessed as a dynamic management process. The starting point is to first look at what is formalised in the process.

There are six major steps included in the process:

Policy: Goals have to be set by the management. The characteristics of an effective health and safety policy are that it:

- supports human resources development
- minimises the financial losses which arise from avoidable unplanned events,
- recognises that accidents, ill health and incidents result from failings in management control and are not just the fault individual employees,
- recognises that the development of a culture supportive of health and safety is necessary to achieve adequate control over risk,
- ensures a systematic approach to the identification of risks and the allocation of resources to control them,
- supports quality initiatives aimed at continuous improvement

Organising for health and safety involves establishing responsibilities and relationships. The structures and processes in organisations have to establish and maintain management control within an organisation though:

- managers who lead by example,
- a clear allocation of responsibilities for policy formulation and development, for planning and reviewing health and safety activities and for implementation of plans and for reporting on performance,
- allocation of people with necessary authority and competence who are given the time and resources to carry out their duties effectively,
- ensuring that individual are accountable for their responsibilities and are motivated by a system of target setting and positive reinforcement,
- provision of adequate supervision, instruction, and guidance,
- payment and reward systems which avoid conflict between achieving output targets and health and safety requirements,
- promote co-operation between individuals, safety representatives and groups so that health and safety becomes a co-operative effort,

- involving personnel in policy formulation and development and in planning, implementing, measuring, auditing and reviewing performance,
- making arrangements for involvement at the operational level to supplement more formal participative arrangements,
- ensure effective communication by means of visible behaviour, written material and face to face communication,
- secure the competence of employees.(through recruitment, selection, placement, transfer and training and the provision of adequate specialist advice),

Planning and implementing: There is a need to establish, operate and maintain systems which:

- identify objectives and targets,
- set performance standards for management actions (control, competence, communication and co-operation),
- eliminate the risks by substitution of safer premises, plant and substance and where this is not reasonably practicable, control the risks by physical safeguards which minimise the need for employees to follow detailed systems of work or to use protective equipment,
- establish priorities for the provision and maintenance of control measures by the use of risk assessment techniques giving priority
- to high risk areas or adopting temporary control measures to minimise risk,
- set performance standards for the control of risks both to employees and to others who may be affected by the organisation activities, products and services,
- ensure the adequate documentation of all performance standards.

Measuring performance: There is a need to establish active monitoring, reactive monitoring and reporting and response systems, which:

- measure the achievement of objectives and specified standards and reflect risk control priorities by concentrating on high risk activities,
- collect and analyse information suggesting failures in health and safety performance,
- ensure that information from active and reactive monitoring is evaluated by competent people to identify risk situations and ensure that appropriate remedial action is taken,
- investigate to ensure that;
- reports arise from active and reactive monitoring systems, the identification of immediate and underlying causes of events,
- the referral of information to the level of management with authority to initiate the necessary remedial action, including organisational and policy change
- the adequate analysis of all collected data.

Review performance and audit systems in order to ensure that:

- information is obtained by the use of in-house auditing systems or external auditors on the validity and reliability of the management planning and control systems,
- appropriate remedial action is taken and progress in implementing remedial action is followed through according the plan,
- the overall effectiveness of policy implementation is assessed internally in particular on;
- assessment on degree of compliance with performance standard,

- identification of areas where standards are absent or inadequate assessment of the achievement of specific objectives,
- accident and incident data with analyses of immediate and underlying causes, trends and common features.

The model is used by looking at vertical and horizontal slices through an organisation. For example, in assessing the managerial approach to training, staff are questioned about the training policy, the responsibilities for training, the competence, co-ordination, communication and control aspects, who plans the training, who reviews it and who carries out internal and external audits of the process. In this way, gaps in the dynamic process can be identified.

One area which has become more important in recent years is the management of change. Privatisation and mergers within the nuclear industry have meant that the scale and rate of change is greater than ever before. Change is always occurring, but to ensure that safety is not degraded, the Nuclear Safety Directorate has produced internal guidance on assessing the implications of change and carried out a number of management of change inspections. Features of such a process are; what needs to occur before change can take place, e.g. reduced workload, retraining; what indicators are to be used to monitor the change and; what contingency plans are in place should the anticipated activities not occur.

Increased contractorisation has also led to a need to assess how licensees are using contractors. Again, internal guidance has been produced and licensees have to demonstrate to NSD that whilst they may employ contractors, they have effective control and supervision over their activities and corporate expertise and memory is not lost to the contracting company.

The regulatory approach is therefore to assess licensees human factors, quality assurance and management of safety activities in order to ensure that robust, transparent and auditable systems are in place. Checks are made through routine site inspection activities coupled with targeted inspections at both sites and corporate facilities. NSD human factors and management of safety specialists are members of these teams. They also review the management prospectuses for new licensees or when an existing licensee is considering changing its organisational structure.

2.10 United States

2.10.1 Context and Framework

The NRC licenses the construction and operation of nuclear power plants; develops, implements, and enforces the rules and regulations that govern nuclear activities; inspects facilities to ensure compliance with regulations; and conducts research to support its programs. The NRC maintains at least two resident inspectors at every operating nuclear reactor site and supplements inspection activities with staff from any of its four regions and from NRC headquarters.

2.10.2 Methods and approaches: Organisational Performance Assessment

The NRC monitors and assesses the performance of power plant licensees to verify that plants are operating safely. The NRC uses various methods to do this including: inspections at licensee facilities to gain independent assurance that licensees are operating safely and licensees report to NRC on their plant's conditions and events. NRC's on-site inspectors prepare reports on a plant's performance covering all aspects of nuclear plant operations. NRC prepares a summary of plant performance approximately every twelve months and uses this guide for determining the plant's need for additional inspection attention. NRC also developed eight performance indicators for monitoring the safety performance of licensees and to improve its ability to predict declining performance.

NRC conducts performance-based inspections on facility operation and design and on the basis of inspection results, draws conclusions about organisational performance. The current NRC inspection program assesses compliance with existing regulations and develops performance insights by observing the conduct of operations, material condition of the plant, performance of licensee personnel, quality of engineering work, and the licensee's performance in problem identification and resolution. The NRC inspection program also involves evaluation of operational events to identify root causes such as human error, design deficiencies, and weak administrative controls. The NRC then assesses overall plant performance and infers licensee organisational management performance based on a comprehensive review of inspection findings, licensee amendments, event reports, enforcement history, and performance indicators.

NRC also conducts limited scope evaluations of organisational performance in response to specific operational events or adverse human or program performance trends. When evaluations in this area have been conducted in response to specific events, they have typically been conducted as elements of Special Inspection Teams, Augmented Inspection Teams, and Incident Investigation Teams. If there is evidence of declining performance, other types of inspections are conducted. NRC may require that the licensee conduct a self-assessment (may be done in-house or by a consultant). NRC staff will then review the self-assessment and the recommended corrective actions for addressing the identified problems, to determine its adequacy. Hence, NRC's references to organisational performance are usually made retrospectively.

When the NRC evaluates aspects of organisational performance whether for event follow-up or continuing declining performance, it may use one or more of several assessment methods which include: various Inspection Procedures, e.g., IP40500 "Effectiveness of Licensee Controls in Identifying, Resolving, and Preventing Problems"; guidelines, e.g., NUREG-1545 "Evaluation Criteria for Communications-Related Corrective Action Plans"; document reviews including Licensee Event Reports (LERs) and Inspection Reports and use of the Human Factors Information System (HFIS) an automated database of human factors information for each nuclear power plant; direct observations; interview protocols; the Human Performance Inspection Process (HPIP), an event follow-up process consisting of five modules: Procedures, Training, Organisation/Management, Communications, Human Engineering, Supervision (see further description under Research); MORT. Depending on the scope and purpose of the inspection, some of the organisational factors that are evaluated may include: goal and objective setting; roles, responsibilities and accountabilities; communications and coordination; decision-making and problem-solving; management support; human resources programs; work processes; procedures program; planning and scheduling; self-assessment and problem identification; staffing and workload; working hours and overtime; training and development; human-system interface issues; corrective action and improvement programs; organisational learning; safety culture.

Another aspect of organisational performance is the Safety Conscious Work Environment (SCWE). The SCWE is an aspect of the safety culture that addresses the trust and confidence of nuclear power plant employees in its management's ability to resolve employee concerns without fear of discrimination. Review of a licensee's SCWE is done on a case-by-case basis, through the review of allegations of chilling effect; special task forces; inspections of licensees' Employee Concerns (EC) programs on an as-needed basis; or by ordering a licensee to perform a survey of its Safety Conscious Work Environment (SCWE).

Lastly, NRC's Inspection Manual includes a number of Inspection Procedures which, when conducted, can provide information from which to infer organisational performance at the licensee's facility. These include Training and Qualification Effectiveness, Emergency Operating Procedures, Feedback of Operational Experience Information at Operating Plants, Fitness for Duty, Management Effectiveness-Security Program, Plant Operations, Allegations Review, Resolution of Employee Concerns, Licensee Self-Assessment Related to Team Inspections, Organisation, Licensee Management of QA Activities, Prompt Onsite Response to Events at Operating Power Reactors, Corrective Action, Operational Safety Team Inspections, Augmented Inspection Team Implementing Procedure.

3. RESEARCH PROGRAMS REPRESENTED AT THE WORKSHOP

Type of research

It is useful to distinguish two categories of research represented at the workshop. In the first category, that we will call **«University-based research»,** the research agenda is partially influenced by the sponsors. Results are published in academic journals and contribute to the research field (e.g., social psychology, sociology of work, organisation theory, organisation behaviour and so on...). The direct application of the results is often not the primary objective but eventually may lead to this. The following programs belong in this category:

- Program from the University of Bern (Switzerland): A Situational Approach to Assess Safety Culture
- Program from the Swiss Federal Institute of Technology (Switzerland): A Sociotechnical Model of Safety Culture: Total Safety Management
- Program from the University of Technology of Compiègne (France): A Sociological approach to study Organisational Reliability

In the second category, called «Public and Private Laboratory or contractor based research», the links between the sponsors (Utilities, regulatory bodies, government agencies...) and the research team are much closer. The research plan and the tasks are agreed upon and must meet the sponsors' specific needs. Belonging to the second category are the following projects:

- The CIEMAT project (Spain): Developing methods and models to evaluate the impact of organisational factors on Nuclear Power Plant safety
- The VTT Automation project (Finland): Evaluating Organisational Reliability through Process Modelling
- The Brookhaven National Laboratory project (USA): Organisational Processes and Nuclear Power Plant Safety
- The Obninsk Scientific Centre «Prognoz» (Russia): A Longitude Verification of the Organisational Factors's Influence on Nuclear Power Plants' Reliability
- The OECD Halden Reactor Project (Norway): The integration of Organisational Factors in PRA/HRA
- The Korea Institute of Nuclear Safety Project: Organisational Factors, identification and assessment
- Central Research Institute of Electric Power Industry project (Japan): Examination on Establishment of Safety Culture in Organizations Operating Nuclear Power Plants
- Institute of Human Factors, Nuclear Power Engineering Corporation project (Japan): Method of Analysis and Evaluation of Human Error Events

NRC: Organisational Factors in Performance Reliability

- NRC's Organisational Performance Research
- NRC: Evaluation Criteria for Communications-Related Corrective Action Plans
- Root cause Investigation Improvements
- Human Reliability Analysis
- Management and Organisational Factors in PRA

Category 1 - University research based

Program from the University of Bern (Switzerland): A Situational Approach to Assess Safety Culture

Main researchers:	Norbert Semmer, and Alex Regenass
Sponsors:	Program sponsored by the Swiss Federal Nuclear Safety Inspectorate (HSK Hauptabteilung für die Sicherheit der Kernanlagen) and the Swiss Utilities.
Objectives:	Developing a situational method for the management of Swiss Nuclear Power Plants in order to assess themselves the safety culture of their plant.
Publication:	Semmer and Regenass (1998)

The research background:

Semmer and Regenass argue that many approaches to the study of *safety culture* focus on values and social norms and their underlying assumptions. Most existing research tools and instruments are designed to collect data on norms and assumptions. However social science research has long demonstrated that the correlation between general preferences and specific behaviour is rather modest. In fact way too thin to actually predict the behaviour that will effectively be chosen by the actor. As the researchers explain: «Responses to general questions do not guarantee that the aspects salient in the measurement situation are the same ones that are salient in a real-life situation. Moreover, it has been shown that actors do not behave according to one single norm, they are rather confronted to different and often competing norms. Which norm will dominate cannot be determined from understanding the norms, but rather by careful consideration of situational aspects».

The research apparatus:

The Situational Approach suggests that the emphasis should be put on collecting data on actual practices, real dilemmas and decisions (what is also called «theories in use») rather than on social norms.

Acknowledging that values and assumptions are expressed in situations, Semmer and Regenass propose a situational approach, in which subjects are not directly questioned about values and norms, but are confronted with dilemma that stems from conflicting social norms and various costs and benefits associated with different types of behaviour. The subjects are asked what they would do in such a situation, what they think others would do, what reactions they would expect their behaviour to elicit from others, and so forth.

Interviews are conducted with various experienced people at the Plant, who are deliberately asked to tell what they would have done in front of various scenarios (like recurrent minor incidents or day-to-day difficulties). They are asked to describe what they would have done, how they would think about it, what their colleagues were thinking at the time; if there was a consensus or rather conflicting views on the issue, etc.

This kind of information is crucial for the researchers because it helps them to understand the conditions under which certain choices and alternatives are considered, rejected and finally adopted. It is only in a second stage that the researchers will link the practices and observed behaviours with social norms.

The research status:

The research is still in development, especially the last part of the project which will attempt to link observed practices and social norms.

Program from the Swiss Federal Institute of Technology (Switzerland): A Socio-technical Model of Safety Culture: Total Safety Management

Main researchers:	Gudela Grote and Cuno Künzler, from the Work and Organisational Psychology Unit, Swiss Federal Institute of Technology (ETH)
Sponsors:	various industries
Objectives:	This research is aiming at developing a method devoted to assessing *safety culture* as well as the overall organisational makeup of high risk organisations. The original research was based on the study of four chemical companies and one transportation company and was extended by studying petrochemical plants in connections with insurance audits.
Publication:	Grote and Künzler (1996 and 1997)

The research background:

The researchers are combining a theoretical framework - the *socio-technical systems approach* founded by Emery and Trist (Emery, 1959) with an audit methodology. It is the researchers' claim that mixing the two can be fruitful to assess safety culture but more importantly the organisation as a whole. It is Grote and Künzler's opinion that models of safety culture - that have flourished after INSAG 4 - suffer from a lack of integration into general models of organisation and of organisational culture. In addition the connection between safety-related characteristics of a system and more general characteristics like job and organisational design and the use of technology, is missing. It gives the impression that safety can be looked upon and promoted as something detached from the make-up of the sociotechnical system as a whole.

For Grote and Künzler, the socio-technical approach describes work systems as having a technical and a social subsystem which together determine how well the primary task of a work system can be accomplished. In this perspective, maximum effectiveness can be achieved, only if the two sub-systems are jointly optimised. Both researchers argue that on at least two levels the Socio-technical approach can be linked to safety: a) The definition of the primary task; b) the degree of self-regulation of sub-units in the system. From this follows: a) the definition of the primary task should include safety, to foster - in analogy to the Total Quality Management approach - a Total Safety Management; b) A high degree of self-regulation of work teams is beneficial to safety, because it fosters flexibility, initiative and ownership, which are all crucial qualities to adequately deal with problems or incidents.

Therefore, a model of safety culture should be incorporated into a more general model of organisational culture, emphasising complex interactions between an organisation's material and immaterial reality. Secondly, characteristics of the work system not directly related to safety should be included, especially characteristics of job and organisational design influencing the degree of self-regulation on the shop floor.

Research apparatus:

Field-work has been performed in 4 chemical plants and one transportation company, with the use of mixed methods and tools (observations, interviews, questionnaires). Two main results emerge:

- The integration of safety into day-to-day operations is easier in organisations whose primary task is defined in terms of quantity, quality *and* safety of production, as opposed to organisations whose primary task is only defined in terms of quantity and quality.
- There is evidence that safety awareness, organisational and technical design are positively correlated.

Research status:

This group is now involved into the creation of a more specific list of indicators, which is the basis for the development of a questionnaire that in conjunction with interviews and work place observations can be used in safety culture audits.

Currently, the group is looking in depth at incident-inducing as well as recovery factors in commercial aviation in order to test basic assumptions of the Total Safety Management model in another work environment.

Program from the University of Technology of Compiègne (France): A Sociological approach to study Organisational Reliability

Main researcher:	Mathilde Bourrier, Department of technology and human sciences
Sponsors:	Program sponsored by the C.N.R.S. (Centre National de la Recherche Scientifique) and by I.P.S.N. (Institut de Protection et de Sûreté Nucléaire).
Objectives:	This research is an attempt to contribute to the study of Organisational Reliability in High-Risks Industries through a sociological analysis, using organisation theory and anthropological methods. The goal is to identify crucial social nodes, supporting and fostering Organisational Reliability in a given organisation. Using the concept of «Strategical compromises», that have proven to be at the core of Organisational Reliability, the research primary task is to determine the conditions under which these compromises are emerging in order to assess their strengths and weaknesses, their costs and benefits. This will give access to a deeper understanding of dysfunctional patterns in organisations for early detection.
Publication:	Bourrier (1994, 1996a&b, 1998 and in press)

The research background:

Too often, organisational analyses are carried out only after a catastrophe has occurred. While very interesting, this perspective has serious limitations: it is always easier to explain and reconstruct events after they have taken place. It is more essential to understand the mechanisms of «normal» functioning, because having a correct perception of their «normal» operation can help to prevent future dysfunctions and possible errors. In this way, it should be possible to predict in what areas failures are more likely to occur. To do so, organisational reliability should be researched through the study of social interactions and professional relations. Bourrier's claim is that Organisational Reliability is highly dependent upon the «quality» and the «nature» of social relations, which are driven in turn by self-interest and «deal», and hence by power and strategies (which could introduce dissent, compartmentalisation, power struggles and goals displacement, poorly reliable features of most organisational life). This research suggests that Organisational reliability should be investigated and seen as a property of the social systems embedded in «reliability-seeking organisations». The social construction of organisational reliability can best be analysed through a systemic analysis thus helping to focus on systemic effects.

Research apparatus:

This research began in 1991 based on a study of the organisation of maintenance and outage activities in four nuclear power plants, 2 in France and 2 in the U.S. Three to Five months were spent at each site collecting information, observing job sites progression and conducting a total of 300 interviews with plant personnel from all the categories involved in scheduled outages.

The «Strategical Analysis Method», which focuses on the collection and the analysis of work practices rather than on actors opinions on their work, was used (For a description of this method, see Friedberg, 1972). This approach allows to combine anthropological methodology (study of situated practices) and classic systemic analysis of work.

Research status:

Under development, new field-work is programmed, focusing on other parts of the Nuclear socio-technical system (including regulators). Comparisons with other high-reliability organisations (airlines) is also under discussion.

Category 2 - Public and Private Laboratories research based

The CIEMAT project (Spain): Developing methods and models to evaluate the impact of organisational factors on Nuclear Power Plant safety

Main Researchers: Rosario Solá, Celina Vaquero, Isabel Garcés

Sponsors: This project is carried out by CIEMAT in collaboration with Spanish universities and sponsored by the Spanish Nuclear Regulatory Body (CSN, Consejo de Seguridad Nuclear) and the Spanish utilities (UNESA). Some of the tasks included in this project will be performed also in co-operation with other international institutions.

Objectives: Development of a five-years R&D project, entitled «Development of methods for evaluating and modelling the impact of organisational factors on nuclear power plants safety».

Publication: Solá, Vaquero and Garcés (1998)

Research background:

The CIEMAT project started off with a literature review[1] of the most important research lines and projects focusing on the impact of organisational and management aspects in the achievement of safe and reliable operation (see ref. 5 and bibliography). It is not our intend here to summarise the report written by CIEMAT but rather to mention its existence to members of the community. One of its main contributions is that it identifies clearly the diversity of responses given by different countries and institutions to a common and still obscure problem. Following this review, the researchers developed a five years project, laid down below.

The Five Years Project:

The main goal of the proposed R&D project is to increase the knowledge related to the way Nuclear Power Plants organise and manage their activities to enhance safety. Three sub-goals will be pursued:

- Development of preventive methodologies,
- Development of corrective methodologies and
- Development of models to include organisational factors into Probability Safety Assessments.

Associated with these three sub-goals, the researchers have laid out a five tasks planning. Part of these tasks will be performed in close co-operation with other institutions allowing for methodologies transfer.

Task 1 - The «Concerted Action»:

Developing and fostering international co-operation on this subject. The general aim of this task is to participate in a European forum, whose goal is to develop exchanges on the impact of organisation on NPPs safety and subsequently to draft a research proposal for the European Community V Framework Program.

Members of the «Concerted Action» forum are the following: Technology University of Berlin (Germany); HSE (Great-Britain); HSK (Switzerland), IPSN (France); Vattenfall Energisystem (Sweden); VTT Automation (Finland).

[1] The results of the literature review have been collected in a database.

Task 2 - «Development of organisational models, organisational factors identification and development of evaluation methods".

Its goal is the development of an organisational model which would allow the identification of organisational factors with impact on safety and lately, the development of preventive methodologies to assess the organisational performance.

This task will be conducted in co-operation with AECB (Canada).

Task 3 - «Analysis of the relationship between organisation and safety in refuelling outages".

The goal is to develop a preventive methodology devoted to the understanding of the organisational performance during refuelling outages.

This task will be achieved in co-operation with IPSN (France).

Task 4 - «Incidents and operating experience analysis methodologies". The objective of this task is to get a corrective tool which allow organisational problems identification and correction adapted to the Spanish environment.

Task 5 - «Development of models for the inclusion of organisational factors in Probabilistic Safety Analysis, PSAs".

Finally, this task will enable the researchers to develop models that incorporate organisational factors into Probability Safety Analysis. The task would be framed in the activities performed in the International Coordinated Program in PRA promoted by NRC, COOPRA.

Research Status:
Currently the R&D Five Years Project, included the «Concerted Action» task has started.

The VTT Automation project (Finland): Evaluating Organisational Reliability through Process Modelling

Main Researchers:	Björn Wahlström and Jari Kettunen, the «High Reliability Organizations Team» of VTT Automation.
Sponsors:	Mainly utilities and the Finnish Radiation and Nuclear Safety Authority (STUK).
Objectives:	To analyse and develop organisational practices in the field of nuclear power and other high-risk industries.
Publications:	Wahlström, Laakso and Tamminen (1987); Wahlström (1992, 1994 and 1996).

Research background:

It is the researchers opinion that despite the fact that it is now widely acknowledged that organisational factors have a significant impact on nuclear safety, a general framework and methods for a comprehensive assessment of organisational factors and management issues are still missing. VTT's approach is based on the application of systems engineering and behavioural sciences.

Research activities:

The research performed within the «High Reliability Organizations Team» at VTT Automation can be distinguished in the following main activities:

- Man-Machine Psychology
- Probabilistic Safety Assessment and Human Reliability Analysis
- Organisation and Management Studies

In the field of organisation and management studies the main objectives are:

- To identify the most important factors influencing organisational safety, reliability and efficiency
- To create feasible methods for modelling and evaluating organisational practices
- To establish indicators of organisational excellence and safety culture
- To develop practicable and reliable tools for self-assessment

In addition, VTT Automation tries to provide its customers with useful propositions for further actions whenever possible or adequate.

The main phases for evaluating organisational practices:

- Get acquainted with the organisation and the selected work process using available documentation.
- Create a preliminary model of the selected work process and evaluate it against generally applied standards and principles.
- Select an actual case that exemplifies the process under investigation and evaluate it against the process model.
- Interview people who are involved in the selected work process and who have participated in the selected case.
- Refine the process model and assess the selected work process on grounds of the new context specific information.

VTT Automation has conducted two international benchmarking exercises to assess plant modification and safety inspection processes in some Finnish, Swedish and British nuclear power plants. Experience from the studies demonstrates that the modelling approach facilitates the exchange of information by providing a common framework for business and work process description and analysis. These models have also proved to be efficient tools for building up a shared understanding of the process under investigation.

When evaluating organisational practices in some foreign utility it is very important to have a general understanding of the specific nuclear legislation and regulatory approach in that country. It is also advisable to pay attention to the prevailing economic situation and its implications for the nuclear industry.

The Brookhaven National Laboratory project : Organisational Processes and Nuclear Power Plant Safety

Main Researcher:	Sonja Haber
Sponsors:	Regulatory bodies including USNRC, and AECB (Canada).
Objectives:	After having identified the categories of organisational factors relating to Nuclear Power Plants' safety, the research in a second stage has been focusing on the design and the validation of methods for measuring these organisational factors. The third phase, currently under development, is an attempt to integrate those dimensions into Probability Risk Assessment or other safety assessment. All these tools are designed mainly for regulators, and constitutes a preventive methodology, that can be used both in evaluations and licensing processes[2].
Publication:	Haber, O'Brien, Metlay and Crouch (1991), Jabobs and Haber (1994)

Research Background:

The researchers' starting point clearly identified that: «..a complete understanding of the human factors issues affecting performance has to include the broader areas concerning the organisation itself, the atmosphere in which the individuals work, and the hardware and software with which they must interact», (Jabobs & Haber, 1994, p. 76).

Originally, sponsored by the NRC, the project started off with a primary task devoted to finding a consensus on the important organisational factors leading to safe power plant performance. Out of this broad literature review, Haber identified 20 factors or dimensions, directly in relation to safety (Haber, 1994; Haber et al, 1991).

The Brookhaven work used Mintzberg's Model called the «Machine Bureaucracy» as a framework capable of capturing Nuclear Power Plants organisational specifics. In its Model, Mintzberg distinguishes five functional elements within the organisation: the operating Core, the strategic Apex, the Middle Line, the Techno-structure and the Support staff. According to this model, nuclear power plants organisations have been analysed through the prism of 5 categories, split in 20 dimensions, all in conjunction with safety.

We will briefly mention these categories and dimensions (see table below). They constitute one of the first systematic effort to direct attention towards organisational areas, especially crucial to safety. The systematic use of these dimensions, supposedly important for the safety of all nuclear power plants, allow for comparisons between plants, and countries. However, the recent work done by Haber at the request of AECB in Canada showed that Mintzerg's model did not adequately describe the influences of corporate level and dynamic external processes on Canadian NPPs. Some adjustments had to be made which produced an hybrid model called CAMM (Canadian Adaptive Machine Model).

[2] For a good description of this research program see also Sola, Vaquero and Garcès (1998, pp. 2-10)

In a second phase of the project, several methodologies (Surveys, Behavioural Checklist, Structured interview, Behaviourally Anchored Rating Scale) have been used in order to evaluate each organisational dimension with plant personnel. By themselves, the organisational factors can help in locating areas within an organisation where «weak links» may exist.

CATEGORIES	**DIMENSIONS**
Administrative Knowledge	Coordination of Work Formalization Organisational knowledge Role and responsibilities
Communications	External communications Interdepartmental communications Intradepartmental communications
Culture	Organisational culture Ownership Safety Culture Time urgency
Decision Making	Centralisation Goal prioritisation Organisational Learning Problem identification Resource allocation
Human Resource Allocation	Performance evaluation Personnel selection Technical Knowledge Training

Tab.: Categories and Dimensions used in the Analysis of Nuclear Power Plant's Organisations.

Research status

Currently, these 20 dimensions are incorporated into Risk Assessment through the analysis of work processes. This phase is an extend of the Brookhaven National Laboratory work. It is mainly developed by Davoudian, Wu and Apostolakis, designers of the WPAM [Work Process Analysis Model] model (Davoudian, Wu & Apostoloakis, 1994a&b). The main goal of this project is to propose a **structured model** that can go beyond qualitative analyses. However, it has to be said that WPAM could only be developed because qualitative work had been done before. Along with Cornell's SAM [Systems, Actions, Management] model (Paté-Cornell & Fischbeck, 1993; Paté-Cornell & Murphy, 1996), and Embrey's SLIM-MAUD [Success Likelihood Index Methodology Using Multi Attribute Utility Decomposition] model (Embrey, 1992), WPAM I and II are first attempts to take into account in PRA the influence of organisational factors and maybe more importantly on common-cause effect of organisational factors.

NRC's Organisational Performance Research

NRC: Organisational Factors in Performance Reliability

Research Entity:	Brookhaven National Laboratory (BNL)
Sponsor:	USNRC
Objective:	The BNL project for the NRC is addressed under BNL research elsewhere in this report.
Publication:	NUREG/CR-5538/BNL-NUREG-52301 „Influence of Organisational Factors in Performance Reliability," 1991.
Research Status:	Completed.

NRC: Evaluation Criteria for Communications-Related Corrective Action Plans

Research Entity:	USNRC
Sponsor:	USNRC
Objective:	To provide guidance and criteria for NRC personnel to use in evaluating corrective action plans for nuclear power plant communications.
Publication:	NUREG-1545 „Evaluation Criteria for Communications-Related Corrective Action Plans," February 1997.

Research Background:

This document was developed by NRC staff based on previous research and is used to evaluate the „Communications" organisational factor. This document provides guidance and criteria for NRC staff to use in evaluating corrective action plans for nuclear power plant communications. It consists of evaluation criteria elements, interview protocols, and a communications observation protocol.

Research Status: Completed

NRC: Root Cause Investigation Improvements

Research Entity:	Performance, Safety and Health Associates (PSHA)
Sponsor:	USNRC
Objective:	To improve the HPIP to be more useful to NRC's inspection staff in their review of human performance issues.

Publication: The Human Performance Investigation Process (HPIP), NUREG/CR-5455, System Improvements, Inc. and Concord Associates, Inc., 1993. NUREG/CR of revised HPIP to be published.

Research Background:

The HPIP was intended to be used by NRC inspection staff who do not have a background in human factors to perform field investigations of the root cause(s) of human performance problems in events. HPIP consists of five modules: Procedures, Training, Management and Organisation, Human Engineering, and Supervision and includes techniques such as events and causal factors charting, barrier analysis, and change analysis. Several years of experience in applying HPIP demonstrated that the process has provided important insights regarding human performance contributions to events, however, it also showed that modifications could improve HPIP's usability. The tasks completed include a literature review of root cause analysis tools and techniques, a survey of NRC inspection staff to identify the strengths and weaknesses in HPIP, and an on-site (at a nuclear power plant) evaluation of HPIP.

Research Status:

Based on the results of the above tasks, one of the modules (Communications) in HPIP is being modified. This revised module will be pilot-tested and revised. An approach for enhancing the other HPIP modules will be described.

NRC: Human Reliability Analysis

Research Entity: Brookhaven National Laboratory, Wreath Wood Group, Buttonwood Consulting, Science Applications International Corporation, Sandia National Laboratory, NUS-Haliburton, John Wreathall & Co.

Sponsor: USNRC

Objective: A Technique for Human Error Analysis (ATHEANA), NUREG/CR-6350,BNL-NUREG-52467, was published in May 1996. This work was sponsored by the NRC and conducted by a multi-disciplinary team of contractors. ATHEANA is a second generation HRA method which was developed to provide a structured approach for analysing operating experience and understanding nuclear power plant safety, human error, and the underlying factors that affect them.

Publications: NUREG/CR-6350/BNL-NUREG-52467 „A Technique of Human Error Analysis (ATHEANA), May, 1996; NUREG-1624 Draft for Comment, Technical Basis and Implementation Guidelines for a Technique for Human Event Analysis (ATHEANA), May 1998

Research Background:

ATHEANA is a second generation HRA method based on a multidisciplinary framework that considers both the human-centered factors (i.e., performance shaping factors such as human-machine interface design, procedures content and format, and training) and the conditions of the plant that gave rise to the need for actions and create the operational causes for human-system interactions (e.g., misleading indications, equipment unavailabilities, and other unusual configurations or operational circumstances). ATHEANA was developed to address limitations identified in current HRA approaches by addressing errors of commission and dependencies, more realistically representing human-system interactions that have played important roles in accident response, and integrating advances in psychology, with engineering, human factors, and PRA disciplines.

Research Status:

ATHEANA has completed several stages of development including field testing. NUREG-1624 "Technical Basis and Implementation Guidelines for a Technique for Human Event Analysis (ATHEANA)- Draft for Comment" provides the concepts upon which ATHEANA is built, practical guidance for carrying out the method, and a description of the current status of the technique including the results of the field tests.

NRC: Management and Organisational Factors in PRA

Research Entity: The Idaho National Engineering and Environmental Laboratory (INEEL)

Sponsor: USNRC

Objective: To develop and demonstrate practical methods that allow for the integration of management and organisational factors in risk assessment activities.

Research Background:

INEEL conducted a „Workshop on Management and Organisation, Performance and the Regulatory Framework" in August 1997. The workshop participants were subject matter experts from diverse fields including risk management, human factors, organisation and management, and nuclear power plant operations. Key management and organisation issues and factors were identified along with candidate performance measures and ratings of technical basis for these factors. Following the workshop, an annotated bibliography was developed to provide information about the relationship between the identified factors and performance. In addition, INEEL developed a modelling framework „The Socio-Technical Contribution to Risk Assessment and the Technical Evaluations of Systems (SOCRATES)" which extended the findings of the workshop and was intended to aid conceptualising the role that organisational factors play in shaping plant performance and how they influence risk.

Research Status:
This research project has been discontinued due to changes in research priorities.

The Obninsk Scientific Centre «Prognoz» (Russia): A Longitude Verification of the Organisational Factors's Influence on Nuclear Power Plants' Reliability

Main Researchers:	Vladilena N. Abramova and Eduard V. Volkov
Sponsors:	State concern «Rosenergoatom» of the Russian Ministry of Atomic Energy.
Collaboration:	Russian NPPs and PPAL (Psycho-physiological Assurance Laboratories)
Objectives:	Identifying the influence of organisational factors on human performance effectiveness. The researchers developed a database, which groups together information on individuals working at «Rosenergoatom» nuclear power station over a 10 years period (more than 6000 individual investigations) and information on various organisational factors. Originally, the hypothesis of this research group was that the evolution and the variation of the psychological profiles of plant personnel could be explained by the influence of organisational factors. Abramova claims that her group has succeeded in confirming this hypothesis. Researchers are also interested by identifying psychological profiles that are more resistant, more robust to organisational change.
Publications:	Abramova, Volkov, Mefodiev and Gordienko (1998); Abramova, (1997, 1996, 1995); Abramova, Mefodiev and Volkov (1997); Abramova, Baumont, Frischknecht and Tolstykh (1996); Abramova, Belehov et al. (1990).

Research background:

The needs for psychological assessment in operational events in Russian nuclear power plants have led psychologists to use quantitative methods for analysis of "direct" and "indirect" (root-causes) causes of human error. The main focus of the practical method of investigation is on the individual who makes an error. In this method, NPP socio-technical system elements are considered as the external conditions, affecting correctness or errors of actions.

On one hand experience shows that a human error depends also on professional competence, motivation and some professionally important psychological qualities, his functional state, psycho-physiological qualities, characteristics of mentality, attention and memory. On the other hand, in an emergency situation successful personnel performance is mainly affected by psychological professional important qualities such as high level of self-control; thoroughness and conscientiousness and so on.

High-quality quantitative methods of human characteristics measurement and of the influence of characteristics on safety have also to be connected to organisation reality such as the socio-political situation and the socio-economic working conditions of the personnel of nuclear stations. They are also important factors of safety.

Hence, in the Human factor area, the Russians have always been strongly involved in measurements of Human Performance, using psychological methodologies and tools (such as «attitude questionnaires», «16 PF test scales», «MMPI» which are widely used in the psychological community). Nuclear power plants have all developed database on their personnel psychological profiles. It is not necessary to mention the traumatism that *Chernobyl* caused to a research community, mainly trained in psychology as Abramova and Mefodiev explain «..after Chernobyl accident, the psychological service needs to refocus on assurance of social-psychological condition of reliability and furthermore organisational influences on nuclear safety».

Research apparatus:
The originality of the «Prognoz» program is that it kept existing psychological database, and enriched it with a set of organisational factors over a 10 years period. Prognoz researchers can access the «Rosenergoatom» database on line.
They are considering the following Organisational Factors, divided in two categories:

- External factors
  - Political climate in Russia and in the NPP local region
  - Intention to safety
  - Distribution of responsibilities
  - Manager selection
  - Manager position
  - Analysis of NPP operation
  - Personnel training
  - Workload
  - Ergonomics characteristics
  - Socio-psychological work conditions
- Internal factors
  - Motivational factors defining motives and psychological attitudes to productive work and high safety culture
  - Professional knowledge, showing professional readiness to work
  - Professional behaviour
  - Psychological states of workers
  - Psychological state including affective states of stress, affect, frustration, loss of life sense and so on.

In addition the database contains information about events and incidents involving plant personnel.

The determination of the factors, influencing a worker psychological profile, is carried out in several stages.

- Determination of "zones of risk" in socio-psychological climate according to socio-political and socio-economic factors;
- Study of their condition;
- Prognosis of influence of the socio-psychological state of the personnel on NPP safety.

Some results:

Prognoz researchers have identified a quite robust psychological profile for people working in a Nuclear Power Plant: despite the variations from one individual to another, when they are aggregated, psychological profiles are very close. This result has to be compared with population profiles in general which do not show such a regular and robust profile when aggregated.

Prognoz has identified three different groups of people: a) a «risk» group; b) a group of statistical norm; c) a reserve group.

Prognoz has identified and described the psychological evolutions of a sample of 100 persons.

Prognoz in co-operation with utilities and with Psycho-physiological Assurance Laboratories (PPAL) contributed to the creation of NPP norms and regulations for measuring human factor parameters. They also contributed to change the personnel selection process according to the research findings.

This research centre contributed also to the establishment of worker support programs.

Research status:

The research program is now continuing and developing along the following lines:

- Analysis on dynamics of individual examination results an example of the mentioned 100 persons from of control room personnel: for risk group (30 person), group of statistical norm (40 persons) and reserve group (30 persons) during 10 years by a complex of techniques: Behavioural observations, structured interviews, document analysis, event review, questionnaire, workshop and trend analysis.
- Analysis of the dynamics of socio-psychological, socio-political and economical events for the period by questionnaires, document analysis and structured interviews.
- Analysis on the peculiarities of Nuclear Power Plant organisational transformations for the period by document analysis and structured interviews.
- Analysis of the characteristics of the socio-psychological climate in teams by structured interviews and questionnaires.
- Analysis of family events for the population under investigation by structured interviews.
- Determination of causal relationships between successful personnel activity and data sets given in the analysis by comparison of the results from the implementation of the complex of mentioned techniques with the results of individual psychological and psycho-physiological data of the personnel.

The OECD Halden Reactor Project (Norway): The integration of Organisational Factors in PRA/HRA

Main Researcher:	Erik Hollnagel
Sponsors:	The OECD country members
Objectives:	Hollnagel's research project is aiming at developing a new PRA, called CREAM [for Cognitive Reliability and Error Analysis Method], designed to take into account the organisational contexts of the events under study.
Publication:	Hollnagel (1996, 1998)

Research Background:

Hollnagel's project embraces a new challenge that is facing PRAs designers. Disasters such as *Chernobyl*, *Challenger* and *Bhopal* have contributed to placing organisational aspects of complex socio-technical systems in the foreground of PRA/HRA research agenda. Hollnagel argues that traditional PRAs cannot simply be extended to cover «organisation and management». As the researcher puts it: «At the present we are therefore faced with the challenge to account for how an overall account of the factors that affect event occurrence and development can be included in the established methods of safety and risk assessment, in particular of how management and organisation factors can be treated in PRA». A new PRA like CREAM (or ATHEANA) is an attempt to take up the challenge.

Some elements about CREAM:

The Cognitive Reliability and Error Analysis Method describes the context of the work situation being analysed (i.e., the PSA event tree) by means of 9 so-called Common Performance Conditions. Common Performance Conditions describe the general determinants of performance, hence the common modes for actions in a context. They include: 1) adequacy of organisation; 2) Working conditions; 3) Adequacy of Man-Machine Interface and Operational Support; 4) Availability of procedures/plans; 4) Number of simultaneous goals; 5) Available Time; 6) Time of day; 7) Adequacy for training and experience; 8) Crew collaboration quality. These CPC are then used as a basis for a qualitative identification of the likely error modes, followed by a quantification of the probabilities of their occurrence. The two steps must be carefully separated.

These Common Performance Conditions allow to capture important organisational aspects such as culture and climate, organisational structure, management style, worker attitudes, explicit and implicit goals, personnel training, organisational learning, communications, organisational problem identification and problem solving and general resources.

Status of the research:

Still under development.

The Korea Institute of Nuclear Safety Project: Organisational Factors, identification and Assessment

Main researcher:	Sok-Chul Kim, Safety Analysis Department
Objectives:	The goal of this research project is first to identify the influential factors in terms of organisational factors such as leadership of the shift supervisor, communicational quality, and procedural characteristics on team performance during an emergency situation such as LOCA or SGTR in nuclear power plant. The second and main objective is to use these results in order to refine the HRA methodology.
Publication:	Kim and Lee (1997, 1995); Kim et al. (1996, 1997)

Research background:

The research project agenda is based on the following statement: current human reliability analysis in Probabilistic Safety Assessment (PSA) has limitations in many respects. Notably, Performance Shaping Factors do not consider how crew organisational characteristics and procedure characteristics (in terms of their format) are impacting the way operators are using them. In EOPs, Operators are too often believed to work alone, while it is often the contrary: they are sharing sets of tasks. The accident of the Challenger space shuttle, the Three Mile Island and the Chernobyl made clear that ineffective team performance emerged as a specific area of interest for HRA. In a first phase, the project started with a literature review on PSA/PRA methodologies, which reveals that a complete understanding or consideration of organisational factors related to team performance does not exist in the nuclear safety field.

One should also notice that this project is part of a national long-term research project called «Development of Severe Accident Assessment Regulatory Technology for Nuclear Power Plants», which started in 1993.

Research apparatus:

In order to identify influential organisational factors on team performance, empirical research has been conducted at two types of nuclear Power plants: 1) Four Westinghouse PWRs Units ; 2) Two Framatome PWRs Units. Currently, 6 Candu plants and a couple of Korean Standardised Nuclear Power Plants (KSNP) are been investigated also. For this empirical investigation, two types of full-scale plant simulators [Kori Nuclear Training Center and Ulchin] were used with 19 on the job MCR crews taking part in simulators tests. Crews have been working on two famous scenarios - the LOCA and the SGTR.

All crew behaviours were videotaped for time-line analysis and to evaluate team-work and communicational quality of the crew during the accident mitigation process. Experience and expertise levels of each crew has been investigated for identification of organisational characteristics through questionnaires prior to simulator testing.
Nineteen teams of 122 individuals coming from three different sites participated in the study.

According to Crews' organisational characteristics, in terms of age, academic background, current position, seniority, past experience, the crews were split into three categories:

Cat 1 - The first one, includes 6 crews shows a strong Shift Supervisor (seniority of at least 5 years in the position)

Cat 2 - The second one, includes 10 crews shows an equal or less experience from the shift supervisor and the STA's part compared with operators.

Cat 3 - The third one, includes 3 crews, shows that some members of the crew have a deficit of experience, especially STAs or operators.

The main empirical results show that according to each crew profile, management of the accident mitigation differs. Other parameters are also studied by Kim, like procedures' format and degree to which task allocation is specified in EOP, however we will not report on these ones (for a complete description of the protocol and the results, see Kim's contribution to the workshop, «Empirical approach for team performance evaluation on crew composition and procedure types»).

Teams belonging to cat 1 showed good inter and intra-communication and fast-recovery actions, related to performance measures based on the directions given by the shift supervisor. Some differences were found between plant type and the way work is allocated.

Teams belonging to cat 2 showed a delay of 10 minutes as compared to teams in cat 1, in isolating faulted steam generator.

Teams belonging to cat 3 showed a greater delay and a difficulty to manage the accident scenario. However, results show that no group were found to have committed significant error which might have caused an accident: All groupS identified the SGTR scenario in less than 150 seconds.

The research results have led to the following recommendations:

It is very important that shift supervisors or STAs have initiative in the process of accident mitigation in order to best supervise team co-ordination

In recruiting MCR crews, the difference of the relative experiences or expertise level among the crew members should receive proper consideration

Task allocation should be clearly specified in the EOP

Research status

The research continues on CANDU and Korean design plants. The introduction of the results have still to be integrated into PRAs.

Central Research Institute of Electric Power Industry (Japan): Examination on Establishment of Safety Culture in Organizations Operating Nuclear Power Plants

Main Researcher:	Taketoshi Taniguchi
Sponsors:	Electric Utility Companies of Japan
Objectives:	The purposes of the research project are to analyze the features of nuclear power management system of Japanese electric utilities, the mechanism of its molding and functioning from the viewpoints of organizational science and culture, and to identify the parts with the universality and the rationality to maintain them and the parts that are difficult or fragile to maintain under the changing environments surrounding nuclear power, and then examine the organizational issues that should be grappled with to make further improvement of total performance of nuclear power plant operation.
Publication:	Taniguchi, Tomioka, Echizen, Enomoto and Kondo (1995), Tomioka, Echizen, Enomoto, Taniguchi, Kondo (1995), Taniguchi (1998)

Research Background:

Safety depends not only upon the technologies being employed, but also on the performance of the organizations managing the technologies. Nuclear safety culture is a key element of the overall cultures of organizations operating nuclear facilities. Not having a safety culture would like plowing a field and forgetting the seed. The importance of clarifying the mechanisms with which the organizational culture works to maintain a high level of safety is increasing because the culture is changing, inherently affected by social change that is symbolized by different behaviors between generations. Organizational and safety culture eventually manifest themselves in operating performances.

Research Apparatus:

Main instruments of the research were the questionnaire surveys and interviews conducted on the employees working at the department of nuclear power of the head offices, nuclear power stations and construction offices of three electric utilities. The design of the questionnaire has been done based on the hypothesis of management style and individual behaviors that drew from the literature surveys on the Japanese cooperate management system and a case study of scram reduction program of nuclear industry. The questionnaire consists of about 60 questions in total intended to find the following cultural elements; 1) consciousness of quality and safety of Japanese NPPs, 2) cultural elements of organizational system such as leadership, teamwork, distribution of authority and responsibility, communication, decision making system, information sharing, learning etc., 3) cultural elements of individual behaviors such as moral, self-realization, social recognition, economic incentives, a sense of duty, etc.

As the first sample group for the questionnaire survey, we chose current middle or senior class managers (301 people) who experienced both bottom positions of the organization in the '70s and '80s, when the Japanese plant performance improved significantly, and managerial positions thereafter. Therefore, we believe that their culture should be typical in terms of influencing the safety records. The second sample was the rank and file employees (634 people) working at four nuclear power stations who should play an active part hereafter. Two survey data have been analyzed statistically and compared with in terms of the utility companies, generations (or posts), and the sort of occupation, respectively.

Some Results:

The excellent safe operation of Japanese nuclear power plants in the last two decades may be said to be a result of the synergistic effect of the excessive response and adaptation to stringent societal pressures against nuclear power and the management system and the morale of the people concerned. The management system, which can be called a spontaneous and cooperative type, has been structured in an extremely ingenious way, centering the up-and-down behaviors of middle or senior managers. The core elements of the system emphasized from the viewpoint of a safety culture are teamwork, provision of motivations, information sharing, and organizational learning.
Concerning the employees' attitudes and consciousness of works, differences or gaps can be observed significantly in some respects between elder and younger employees, although there are some commonalities such a recognition that teamwork is very important for ensuring safety.
In order to develop and strengthen the safety culture in the utility companies, especially power stations, the following should be examined.

a) Implementation of a senior management program focused on acquiring basic knowledge of behavioral sciences and risk communication,
b) Careful consideration to the respect of autonomy of the employee,
c) Re-establishment of an organizational learning process
   - Development of the opportunity of essential learning, in particular for younger employees,
   - The activation of the argument and encouragement of questioning attitude by middle class managers,
   - Reconsideration of a consistent, comprehensive and continuous education system that includes the social safety, the plant safety from the working safety as well as on-the-job training,
d) Clear indication of the safety goal as an organizational standard or value in the public place,
e) Improvement of social understanding of nuclear power

Research Status:

Completed.

Institute of Human Factors, Nuclear Power Engineering Corporation (Japan): Method of Analysis and Evaluation of Human Error Events

Main Researcher:	Toshio Hasegawa
Sponsors:	Agency of Natural Resources and Energy, Ministry of International Trade and Industry
Objectives:	To collect, analyze, evaluate and disseminate operational safety related events in Japan for prevention of recurrence of the same events and also prevention of similar events.
Publication	T. Furuta and T. Hasegawa (1991), T. Hasegawa and A. Kameda (1998)

Research Background:

Electric utilities in Japan are obliged to promptly report incidents and failures occurring in commercial nuclear power stations to the Government (MITI: Ministry of International Trade and Industry) according to the laws and notifications.
Most events occurring in nuclear power plants have a human factor contribution and should be analyzed from this point of view. Analysis of the operating experience on human errors becomes important internationally due to the following reasons:

- the relative portion of human impacts is increasing while the technical impact is decreasing;
- events are showing human impacts that are not fully addressed in the current human reliability analysis (e.g., commission errors).

Research Apparatus:

The human error classification scheme adapted from J. Rasmussen is adopted. Based on an information processing model for human performance, it provides a multi-faceted classification scheme consisting of error modes, error mechanisms, and causes of error or situational factors causing error as follows.

1. Error mode:

   These are human error forms classified by an action or a phenomenon which can be observed from outside. They can be divided into omission error and commission error.

2. Human error mechanism:

   This term is to describe the occurrence of human error through the human internal cognitive information processing by two dimensional schemes; the first is the stage of cognitive information process (i.e., Detection-Identification, Judgement-Decision Making, Action) and the second is the level of cognitive control (i.e., Skill, Rule, Knowledge-based level).

3. Causes of error or causal factors:

   This term intends to describe the external factors that cause human errors. This is further divided into direct causes and indirect causes where the former triggers the occurrence of human error and is called the initiating event and the latter is relevant to the way in which an error occurs, and is called the influence factor. Based on experience and knowledge up to now and on the results of analysis and evaluation of events etc., causes of error occurrence are classified by an individual, a task, a site environmental, an organizational and a management characteristic factor. These factors make it possible to classify the initiating event and the influencing factor as a latent root cause.

Based on the above classification scheme, the systematic chart of analysis and evaluation of human error events is derived and then analysis sheets for human error events are formulated in order to extract the facts from the incident and failure reports submitted from utility companies.

Some Results:

An analysis is made for the human errors occurred in the nuclear power plants in Japan from 1966 through 1995. Preventive measures are also discussed against human-induced incidents and failures.

Among 863 incidents and failures reported to MITI from 1966 through 1995, 199 human error events are identified for 49 nuclear power plants in Japan.

The annual ratio of the human error events to the incidents and failures has fluctuated around 20% since 1976.

The work types for the human error events are that maintenance is the largest (55%), construction is the second (21%) and operation is the third (17%).

The employee types for the human error events are that the maintenance personnel are given first rank, where the number of events related to mechanics amounts to nearly 50.

The contents of work for the human error events are that the number of the human error events is the largest for the assembly phase of maintenance work and amounts to 34.

The error modes consist of the omission error and the commission error, where the former includes lack of necessary actions and the latter includes wrong or untimely actions. The number of the omission errors is considerably smaller than that of the commission errors, what seems to be in conflict with the conventional data in the human reliability analysis. Among the commission errors, the largest is the excessive/insufficient operation. The second largest is the unexpected contact/fall in the commission error. It indicates that work-environment might cause this type of errors during plant periodic maintenance.

In the mechanisms of errors for the human error events, the confusion in action in the skill-based errors is the largest. The oblivion of isolated item in the rule based error and the wrong inference for judgement in the knowledge-based error are the same and the next largest.

The causes of errors for the human error events contain five characteristic factors, each of which consists of two hierarchical levels. The habitual action of the subjective factors category in the individual characteristics is the largest among the causes of errors. The regulation/work planning of the management factors and the work performance incapability of the individual characteristics are also major factors among the causes of errors.

Research Status:

On going. Completed for events from 1966 to 1995.

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ORGANIZATIONAL FACTORS RESEARCH LESSONS LEARNED AND FINDINGS (1991)

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Executive Summary

This report compiles lessons learned based on three years of Organizational Factors research by Nuclear Regulatory Commission (NRC) staff and contractors to support risk assessment, leading indicators of plant safety performance, and inspection and evaluation initiatives of the agency. The goals of the research are a knowledge base and analytic tools to (a) assess the influences of organizational factors on risk, (b) to monitor plant safety performance by means of leading organizational indicators, and (c) inspect and evaluate plant safety performance as part of the NRC regulatory oversight process. The lessons learned summarized below were compiled from responses to each of six areas by NRC staff overseeing the research and contractors conducting same. Verbatim written responses of NRC staff and contractors to each area are contained in Appendix A along with the names of respondents and their affiliations. A summary of an earlier discussions of these six areas during a May 1991 information exchange meeting is contained in Appendix B. Lessons learned to date from the research suggest that:

(1) No **unitary** organizational factor will explain plant safety performance, however, collectively four primary organizational factors appear to explain that performance in a systematic if general way. These primary factors include communication, organizational learning, management [or significant other] attention, and the external environment. Several other **secondary** and tertiary factors were also identified which, individually and in combination, appear to affect plant safety performance in more situationally determined ways.

(2) **Technical knowledge** gained from the research suggests that (a) a socio-technical system combining properties of a machine bureaucracy (standardized work, direct supervision, vertical communication) with emergent processes (e.g, organizational learning), is a reasonable descriptor of nuclear power plant organizational functioning during normal operations, (b) research should extend beyond the plant level, (c) data from currently mandated NRC reporting systems are not adequate for plant organization and management assessments, and (d) industry direct participation in the research is crucial for its success.

Prototype Products anticipated by the end of September 1992 include tools for PRA, plant performance monitoring, and NRR and AEOD inspections and evaluations. More specifically, they will include tools for (a) modeling plant operating characteristics, (b) actively gathering plant data on factors representing these characteristics, (c) compiling data available to the NRC on factors representing these characteristics, and (d) scaling data to achieve quantitative and qualitative measures on these factors for use in reliability assessment, plant performance monitoring, licensing, inspection and evaluation activities of the NRC.

(3) The majority of NRC staff and contractors involved in the research recommend **moving beyond the plant** to better account for overall variations in plant safety performance. Most frequently mentioned beyond plant entities are the (a) parent corporation, (b) parent utility, and (c) public utility commission.

(4) All respondents consider **plant access** critical to the success of the research. The majority of the respondents consider the NRC itself to be the main obstacle to gaining access to the plants, that is, placing certain plants off limits, involving too many NRC entities in the process, and a less than enthusiastic attitude of middle level management toward the research.

(5) Respondents presented 16 lessons learned **actually doing research in a regulatory environment** where an adversarial relationship is perceived to exist between the regulator and the industry regulated. While a number of positive lessons learned were cited, the three most frequently mentioned lessons learned were of a critical nature that is (a) NRC middle management resistance to the research, (b) industry suspicion of NRC motives for doing the research, and (c) lack of appreciation on the part of NRC concerning the differences between the scientific and regulatory goals of this research given the NRC's regulatory and enforcement missions.

(6) Respondents generally support the **scope and direction of the organizational factors research** activity, however, they offered at least 20 suggestions for improving its value to the agency and industry. Included among the more frequently mentioned are a need for (a) more explicit project/activity integration, (b) more explicit ties between anticipated products and specific agency and industry applications, and (c) studies identifying common organizational factors influencing public and industrial safety, and productivity and efficiency.

A more general conclusion based on the material provided for this report is that organizational factors research can be conducted in a regulatory setting and produce useful results. Technologies pioneered in other academic, commercial, and military settings can be adopted for use in a nuclear regulatory setting. The future success of this effort depends upon the cooperation of regulators, contractors, and the nuclear industry. Each in its own way can be expected to be a beneficiaries of the results. By regulators for moving beyond educated speculation to assessments of plant safety performance that are not only objective but instructive to both the regulators and the plant. By the licensees for self improvement. By the contractors, especially the 12 universities currently involved in the work, to collate and expand on the findings to the benefit of commercial, public, and military operators of complex high reliability socio-technical systems.

ORGANIZATIONAL FACTORS RESEARCH LESSONS LEARNED

1. SECTION 1: INTRODUCTION

Purpose: This report brings together lessons learned and state of knowledge gained, to date, from the Nuclear Regulatory Commission's (NRC) Human Factors Branch Organizational Factors research activity, as seen by NRC contractors and NRC staff immediately involved in the research for up to three years. Contractor and NRC personnel who participated in this study are listed at the beginning of Appendix A along with their affiliations. More specifically, this report responds primarily to six questions concerning the current status and direction of the research:

(1) organizational factors that influence plant safety performance,
(2) user products status,
(3) the plant as the appropriate unit of measurement,
(4) importance of industry and plant participation in the research,
(5) lessons learned doing this type research in a regulatory setting,
(6) appropriateness of current and planned research.

Such a report is needed and deemed timely to serve as one basis for NRC staff and Commission discussions regarding the future direction and scope of the activity. The primary sources of information for this report are the 12 non-NRC teams conducting a total of 14 organizational factors projects, and 3 RES project managers directly involved in the research. All are legitimate experts in the field, have first hand experience doing Organizational Factors research in a regulatory environment, and to date have had no other direct forum for presenting their perspectives beyond their formal project reports.

Background: Accidents inside and outside the commercial nuclear industry domestic and foreign, have suggested that institutional or organizational factors play an important role in the safe operation of complex high reliability socio-technical systems. Recognizing this fact, the NRC has been pursuing Organizational Factors research within its Office of Nuclear Regulatory Research (RES), Human Factors Branch, since FY 1988. The research was initiated at the request of Dr, Thomas Murley, currently Director of the NRC's Office of Nuclear Regulatory Regulation (NRR), for methods to systematically integrate the influences of organization and management into probabilistic risk assessments (PRAs). Subsequent requests from RES and NRR seek tools to review the adequacy of organization and management factors in PRA studies. Additionally, requests for research on leading indicators of plant safety performance influenced by organizational factors were received from from the NRC's Office of Analysis and Evaluation of Operational Data (AEOD). Finally, requests for research were received from NRR in June 1991, to apply technical knowledge and tools emerging from the current

Organizational Factors research in developing methods/protocols for conducting inspections and diagnostic evaluation of plant safety performance.

The goals of Organizational Factors research therefore, are to develop analytic tools and data to support both regulator and licensee initiatives in this area, and a better understanding of the factors that shape organizational performance as it pertains to safety. Its currently emerging products include:

(1) methods for modeling, gathering data, and quantifying the influences of Organizational Factors on plant risk, and

(2) leading indicators of plant safety performance.

Knowledge of organizational factors and products currently emerging from the research will also be used during FY 1992 as one technical basis for developing NRC:

(1) licensing and inspection methods/protocols for systematically evaluating plant management performance, and

(2) diagnostic evaluation methods/protocols standardizing where possible the organization and management assessment process.

Additionally, knowledge of organizational factors and products emerging from the research are viewed as being useful to NRC licensees (the industry) for self monitoring and for optimizing their safety performance.

Focus and Scope of Research: Organizational Factors research is based on a belief that hierarchically related groups, through their actions and patterns of decisions, operate to prevent and respond where necessary to off normal nuclear power plant events. Further, that the patterns of their decisions and actions are influenced by factors in the organizational context within which these hierarchically related groups function. Therefore, the research focuses primarily on:

(1) the total plant organization,

(2) formal subdivisions of that organization down through the team level,

(3) technical support programs such as maintenance and training believed to significantly influence overall plant safety performance, and

(4) selected functions and roles such as management also believed to significantly influence plant safety performance.

The products of the research are intended to enhance plant reliability and risk assessments, plant safety performance trending, and other licensing and evaluation initiatives pursued by the NRC and its representatives, and the nuclear industry.

During the past three years, lessons learned and findings from the research have been considered in a variety of NRC activities and programs including diagnostic evaluations, performance indicators, and reliability assessments. Additionally, these lessons learned and findings are also being studied by the nuclear industry (participating plants), by other Federal government agencies such as Department of Energy (DOE), and by international agencies such as the United Kingdom Health and Safety Commission and the Swedish Nuclear Inspectorate, all interested in improving safety performance through organizational change.

Lessons learned and findings, and recommendations presented in this report, were derived primarily from 14 individual research projects. These projects are being directed by three NRC staff scientists within the Human Factors Branch. They are staffed collectively by multidisciplinary teams composed of some 85 subject matter experts of 2 Department of Energy laboratories, 15 private consultants, 5 commercial consulting firms, 12 universities, 2 national research academies and institutes, 2 foreign research institutes, and 4 industry based peer review groups. In addition, three workshops and information exchange meetings have been conducted to date, involving a wide range of NRC staff and Commission participants, and participants from the utilities, their unions, their vendors, and their representative groups such as NUMARC. A summary of the most recent May 22-24, 1991 Organizational Factors information exchange meeting, is contained in Appendix B.

During the past 18 months, 7 reports of the research were published, 8 others are scheduled to be published by the end of CY 1991. Three SECY papers (89-141, 90-349, 91-105) are among those reports published to date, two of which (89-141, 90-349) were followed by presentations to the Commission. Currently, a fourth SECY paper is being prepared on the current status of Organizational Factors research and is scheduled for presentation to the Commission in December 1991. Also during the past 18 month period a dozen technical papers emerging from the research were presented to domestic and foreign professional organizations. Finally, the research was recently presented to the United Kingdom Health and Safety Executive comprising all UK regulatory agencies, and to the parent Health and Safety Commission's Advisory Committee on the Safety of Nuclear Installations. These presentations have triggered a series of international information exchanges and cooperative efforts on Organizational Factors and safety.

Research Integration: The scope and magnitude of the current Organizational Factors research activity necessitates its configuration in a meaningful way to ensure that resources are husbanded to the extent possible, and that intermediate and final results (technical knowledge and tools) are recognized and made available to users in a timely manner. Figure 1 depicts the integration of the various Organizational Factors research projects into a larger framework for achieving those ends.

Using the figure as a basis for discussion, the Organizational Factors activity has been directed toward two main goals over the past three years. The first goal, at (1), are methods for integrating the influences of organizational factors in PRA as requested by our regulatory office NRR and

ORGANIZATIONAL FACTORS RESEARCH ACTIVITY

(plant organization, formal sublements down to team level, technical support programs, special functions such as management)

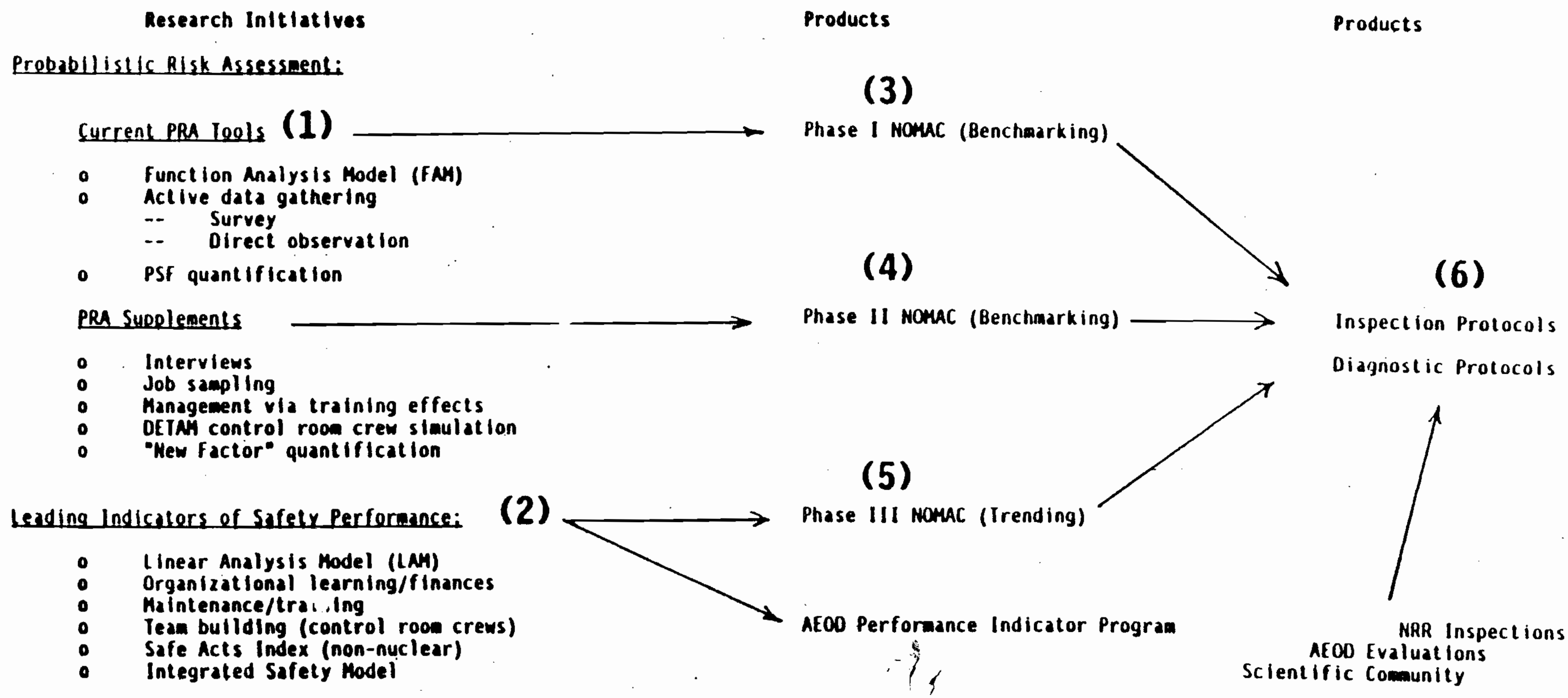


Figure 1

later by other groups within RES. The second, at (2), are leading indicators of plant safety performance as requested by AEOD. An initial method, at (3), known as the Phase I Nuclear Organization and Management Analysis Concept (NOMAC), for incorporating organizational factors in PRA has been developed and is undergoing testing. It involves function analysis modeling (FAM), survey and direct observation data collection, and PRA quantification based on the Success Likelihood Index (SLIM-MAUD) technology. In parallel with Phase I NOMAC other supplementary tools for accomplishing organizational factors integration in PRA are also in progress. Involved is data collection by means of interviews and job sampling, and using training effectiveness as a symptom for management performance. Also involved are data collection and quantification by means of a stochastic computer code called Dynamic Event Tree Analysis Method (DETAM) which focuses on the control room crew and its interfaces with the equipment. Finally, involved is a quantification method which treats organizational factors as a separate entry in the risk equation.

During FY 1992, research on certain aspects of these tools will continue, and to the extent possible, they will be incorporated into the Phase I NOMAC package -- to form a Phase II NOMAC, at (4). You will note that both Phase I and Phase II NOMAC are intended to provide a snap shot (or benchmark) of organizational factors influences on risk. Also during FY 1992, we are beginning work to investigate the feasibility of using leading indicators of plant safety performance, developed as part of this Organizational Factors research activity, as surrogates for the benchmarking data to allow NRC management and staff to trend organizational factors performance on a risk basis, at (5). The resulting package will be known as Phase III NOMAC.

The second goal, at (2), are leading indicators of plant performance. During the past three years we have been focusing on leading indicators of the total plant organization (learning, resource availability), technical support programs (maintenance, training), control room crews (team building), non-nuclear indicators for application in nuclear plants (Safe Acts Index), and an Integrated Safety Model for interpreting both leading and direct indicators individually, and in combination, vis-a-vis safety. Leading indicators work has proceeded based on three assumptions. First, that indicators have to be supportable with ata currently collected by the NRC or readily available from other sources such as the U.S. Department of Energy. Second, that correlational relationships between the leading indicators and at least one of the seven direct indicators currently used by the NRC are required for the former to have quantitative validity. Third, that the indicator have acceptable credibility (face validity) with potential users, that potential causal factors for its fluctuation be known, that credible information on lag time between an unacceptable level on the indicator and unacceptable plant safety conditions be available, and that differences between acceptable and unacceptable levels on the indicator be established. For the most part, candidate indicators have been identified using a Linear Analysis Model (LAM), or extensions thereof, which hypothesize relationships believed to exist between and among plant organizational content/context, intermediate outcomes such as productivity and regulatory compliance, and safety represented by the seven direct indicators currently used by the NRC.

A third "new" goal, at (6), of FY 1992 Organizational Factors research is to support enhanced procedures for doing NRR inspections and AEOD diagnostic evaluations in the area of organizational factors.

Summary of Lessons Learned and Findings: Six organizational factors research issues, stated as questions to the respondents listed at the beginning of Appendix A and followed by their deidentified verbatim responses, are the focus of this report. The six questions are listed below each followed by a summary of responses. An expanded discussion of responses received is contained in Section 3. of this report.

(1) What organizational factors appear to influence safety performance, and how might this knowledge assist regulators?

Four factors were identified as influencing plant performance in a generalizable way. These include:

- **Communication** (commonly understood organizational goals across and between management and worker personnel, and means to achieve those goals)

- **Organizational Learning** (processes and attendant resources identifying and solving problems or prospective problems, and learning from the experience)

- **Organizational Focus** (management [significant other] attention and oversight, and application of available resources)

- **External Factors** (parent corporation, parent utility, regulating bodies)

Several other **secondary** and **tertiary** factors were also identified which, individually and in combination, appear to affect plant safety performance in more situationally determined ways. (See Section 3. for a detailed discussion of these secondary and tertiary factors.)

Respondents feel that this knowledge will be helpful to regulators and to licensees across a broad range of activities. Included among these activities are:

- Data and methods for NRC diagnostic evaluations
- Guidelines for plant self assessments
- Data and methods for HRA in PRA

(2) What is the status of products being developing in terms of their implementability in NRC regulatory activities either directly, or through additional technology development and implementation research?

Respondents listed technical knowledge gained to date, and products anticipated during the period September 30, 1991 to September 30, 1992.

Technical knowledge gained thus far from the research suggests that:

1 a socio-technical system combining properties of a machine bureaucracy with emergent processes, is a reasonable descriptor of plant organizational functioning during normal plant operations,

2 research should extend beyond the plant level,

3 data from currently mandated NRC reporting systems are not adequate for plant organization and management assessments, and
4 industry direct participation in the research is crucial for its success.

Products anticipated by the end of September 1992 include tools and technical insights for PRA, plant performance monitoring, and NRR and AEOD inspections and evaluations.

1 modeling plant operating characteristics,

2 actively gathering plant data on factors representing these characteristics,

3 compiling data available to the NRC on factors representing these characteristics, and

4 scaling data to achieve quantitative and qualitative measures on these factors for use in reliability assessments, plant performance monitoring, licensing, and inspection and evaluation activities of the NRC.

(3) Should we continue to focus our attention at the plant level, or should we go beyond the plant level? If we look beyond the plant level, where should we be looking (e.g., local governments, public utility commissions, utilities, parent corporations, the NRC, other)?

The majority of respondents recommend moving beyond the plant either immediately or in the near future. Most frequently mentioned external agencies are:

- Parent corporation
- Parent utility
- Public utility commission

(4) How important is accessing plants to do Organizational Factors research? What types of problems have been encountered, if any, in gaining access to plants attributable to each of the following: parent utility; plant; utility groups such as INPO, EPRI, and NUMARC; NRC research project manager; NRC management; your own management?

All respondents consider plant access critical to the success of the research. The majority of the respondents consider the NRC itself to be the main obstacle to gaining access to the plants, that is, placing certain plants off limits, involving too many NRC entities in the process, and a less than enthusiastic attitude of middle level management toward the research.

(5) What lessons have been learned to date doing Organizational Factors research in a nuclear regulatory setting, that is, working with and for the NRC and with the nuclear industry?

Respondents presented 16 lessons learned doing research in a regulatory environment where an adversarial relationship is perceived to exist between the regulator and the industry regulated. While a number of positive lessons learned were cited, the three most frequently mentioned lessons learned were of a critical nature and include:

1 The NRC has been a stumbling block for achieving a common understanding of the research by the NRC and industry, and in the latter's understanding of how it can be useful to the industry in achieving plant safety.

2 The industry is suspicious but wants to cooperate with the NRC in this research; however, industry cooperation depends on whether or not it understands how the research results will be used by the NRC.

3 There is a general lack of appreciation within the NRC of the differences between the scientific and regulatory goals of this research, given the NRC's regulatory and enforcement missions.

(6) To what degree do the Organizational Factors research activity's current focus and out-year plans, methods for doing the research, and sought after products over the next 2-3 years address issues you believe are important to plant efficiency, and the NRC regulatory mission of enhancing safety?

Respondents generally support the scope and direction of the organizational factors research program, however, they offered at least 20 suggestions for improving its value to the agency and industry. Included among the more frequently mentioned are a need for:

1 more explicit project/activity integration,

2 more explicit ties between anticipated products and specific NRC and nuclear industry applications, and

3 studies identifying common organizational factors involved in public and industrial safety, and productivity and efficiency.

Report Contents: The remainder of this report provides a detailed discussion of the material summarized above. Section 2., Methodology, discusses information gathering to support this report and the manner in which that information was analyzed to achieve lessons learned, findings, and recommendations. Section 3., Findings and Recommendations, presents a detailed discussion of the lessons learned and findings, and recommendations for future consideration by the NRC. Appendix A contains verbatim responses, submitted by contractors and RES project managers, to the six issues which are the subject of this report. Identifying information has been removed from each of the contractor and RES project manager submittals. Appendix B is a summary of the most recent NRC Organizational Factors Information Exchange Meeting held at Pennsylvania State Univeristy during May 22-24, 1991.

2. SECTION 2: METHODOLOGY

The purpose of this section is to describe how information was gathered for the report, and how it was analyzed to achieve the lessons learned and findings, and recommendations presented in Section 3.

Information Gathering: Information was gathered from contractors carrying out the research and from RES project managers directly involved in overseeing the research. Information from the contractors was sought for two reasons. First, they are legitimate experts in the field. Second, they have first hand experience doing Organizational Factors research in a nuclear regulatory setting. RES project manager inputs were sought because these managers have expertise in the field, and they intersect the perspectives of the researchers and the NRC regulators. Inputs from NRC sponsors (e.g., NRR, AEOD), oversight groups (e.g., RPRG, NSRRC), and NRC management were not sought because forums for their perspectives are already available.

Twelve contractor teams and three RES project managers were asked to respond, in writing, to six issues pertaining to NRC Organizational Factors research. Each was also asked to add to this list of issues, additional issues he/she felt appropriate, and to also respond to those additions. Written responses were received from all 12 of the contractor teams (representing some 21 researchers/practitioners) on each of the six issues. Their deidentified responses are reproduced verbatim in Appendix A. Three RES project managers directly involved in overseeing the research were also asked to respond, in writing, to each issue. Their deidentified responses on each issue are also reproduced verbatim in Appendix A co-mingled with contractor responses.

Information Analysis: Responses from the contractor teams were analyzed for content and frequency of response. Identical responses on individual issues seeking a consensus provided by half more than half of the 12 contractor respondents and 3 NRC project managers were considered **Primary**. Identical responses on individual issues seeking a consensus provided by less than half of the respondents are considered **Secondary**. Responses to other issues not necessarily seeking a consensus (e.g., product availability) are presented in a form most appropriate to the issue.

Corroboration of responses from above was then sought from two sources. First, a draft of Section 3. was compared with the proceedings of a May 22-24, 1991, Organizational Factors Information Exchange Meeting, at State College, Pennsylvania, participated in by these same contractors and representatives of the NRC, nuclear industry, and foreign regulators. One subject of that meeting was the six issues discussed in this report. The main body of the proceedings, "NRC Organizational Factors Contractors Second Annual Meeting," is enclosed to this report as Appendix B. Response patterns in Section 3. were determined to be consistent with the proceedings. Subsequently, responding contractor teams and NRC project managers were provided copies of draft Section 3. and Appendix A for their review. Minor revisions in Section 3. and the Appendix were made on the basis of these reviews.

3. SECTION 3: FINDINGS AND RECOMMENDATIONS

Responses and recommendations pertaining to each of the six lessons learned and findings issues are presented below. Respondents were asked to take into consideration:

(1) quantitative and qualitative analyses they have performed as part of their research,

(2) serendipitous learning they experienced interacting with the plants and the NRC while doing the research, and

(3) perspectives they brought to the research from their experience doing similar work in other industries and environments.

With this in mind, a summary of responses to the six questions is as follows:

(1) What Organizational Factors appear to influence safety performance, and how might this knowledge assist regulators?

(Reference Appendix A, pps. 1-19)

Respondents concluded that there is no unitary Organizational Factor for explaining plant safety performance. Rather clusters of factors (profiles) made up of primary factors supplemented by situationally determined combinations of secondary factors best explain performance. Respondents also concluded that an extensive overlap may exist between organizational factors that influence public safety, those that influence industrial safety, and those that influence productivity and efficiency.

Primary Factors: Four Organizational Factors were identified as influencing plant safety performance in a generalizable way. They are presented in descending order of priority based on frequency of their citation in the responses.

- **Communication** (commonly understood organizational goals across and between management and worker personnel, and means to achieve those goals)

- **Organizational Learning** (processes and attendent resources identifying and solving problems or prospective problems, and learning from the experience)

- **Organizational Focus** (management [significant other] attention and oversight, and application of available resources)

- **External Factors** (parent corporation, parent utility, regulating bodies)

Secondary Factors: Nine additional Organizational Factors were identified as influencing plant safety in more situationally determined ways. They are presented in descending order of priority.

- Technical Ability of Managers
- Resource Availability and Allocation by the Plant or Utility
- Perceived Commitment (of managers by workers)
- Coordination of Resources (cost to benefit)
- Organizational Structure (which provides a context for management and leadership)
- Management Stability (rate of changeover)
- Incentive Programs
- Standardization of Work
- Formal Decisionmaking

Knowledge to Assist Regulators: Respondents cited the following activities as potentially benefiting from the findings and products of Organizational Factors research. They are presented in descending order of priority based on the frequency with which they were cited in the responses.

- Data and methods for NRC diagnostic evaluations
- Guidelines for plant self assessment
- Data and methods for HRA in PRA
- Guidelines for NRC examiners
- Guidance to NRC and industry senior management
- Data and methods for NRC SALP assessments
- Basis for educating the engineering community on behavioral aspects of plant performance

(2) What is the status of products being developing in terms of their implementability in NRC regulatory activities either directly, or through additional technology development and implementation research? This issue addresses product availability as a function of time. Products here are treated as both technical knowledge and tools for doing organizational analysis. Responses are not presented here in any particular priority order.

(Reference Appendix A, pps. 20-27)

Technical Knowledge:

- A socio-technical system combining elements of a machine bureaucracy (standardization of work, direct supervision, vertical communication), and emergent processes (e.g., organizational learning), appears to be the best explanation of a power plant organization during both normal and emergency operations.

- Focusing solely at the plant level does not account for important sources of safety performance variance.

- Plant performance data available from current NRC reporting requirements do not fully support analysis of organization and management performance.

- o Industry must become a participant in organizational factors research and a primary user of organizational research results and products if plant safety performance is to be optimized.

Products as Analytic Tools:

The products listed below will have completed the research phase of their development on the dates stated. They will have undergone testing for their: (1) practicality, (2) acceptability to potential users, and (3) usefulness for addressing the PRA, leading indicators of plant safety performance, and/or inspection/evaluation issue(s) for which they were developed.

Subsequent to these dates, products will undergo technology implementation. That is, they will undergo transition and transfer to their users. This transfer process will involve: (1) case study follow-ups to earlier technology evaluations, (2) user packaging (e.g., automation, situational alternative configurations) based on user feedback, (3) user documentation, and (4) user support systems providing training and clearinghouse functions.

Products Anticipated as of September 30, 1991.

For supporting leading indicators of plant safety performance:

- o Behaviorally Anchored Rating Scale (BARS) for assessing control room crew performance during abnormal operations.
- o Report of and user procedures for a Linear Analysis Model (LAM) linking plant programs, intermediate outcomes, and safety.

Products Anticipated as of December 31, 1991.

For supporting organizational factors in PRA:

- o Report of and user procedures for a NOMAC Function Analysis Model (FAM) for describing plant operating characteristics.
- o Report of and user procedures for data gathering tools employing direct observation and survey techniques.
- o Report of organizational factors important for accident management.

For supporting leading indicators of plant safety performance:

- o Report of and user procedures for leading indicators of plant safety performance as a function of organizational learning and corporate resource availability.

Products Anticipated as of March 31, 1992.

For supporting organizational factors in PRA:

- Report of and user procedures for data gathering tools employing interview and job sampling techniques.

- Report of and user procedures for a algorithm integrating Organizational Factors in PRA, using a performance shaping factor approach.

For supporting leading indicators of plant safety performance:

- Report of user procedures for an Integrated Safety Model (Diamond Tree and Onion) for interpreting the safety significance of direct and leading indicators of safety performance individually and in combination.

- Report of and user procedures for a prototype Safe Acts Index as a leading indicator of plant safety performance.

Products Anticipated as of June 30, 1992.

For supporting organizational factors in PRA:

- Report of and user procedures for an expanded NOMAC incorporating data gathering tools based on interview and job sampling techniques.

For supporting leading indicators of plant safety performance:

- Report of and user procedures for leading indicators of maintenance program safety performance as a function of emergency safety system actuations, and daily power fluctuations.

For support NRR and AEOD inspections and evaluations:

- Initial user procedures for evaluating organizational learning as part of inspections and diagnostic evaluations.

Products Anticipated as of September 1992.

For supporting organizational factors in PRA:

- Report of and user procedures for a method to assess the effects of management on risk as a function of training program effectiveness.

- Report of and user procedures for data gathering based on a job sampling technique, and an algorithm for assessing the effects of Organizational Factors on risk as a separate entry in the risk equation.

For support NRR and AEOD inspections and evaluations:

- Initial user procedures for evaluating organizational factors other than organizational learning as part of inspections and diagnostic evaluations.

(3) Should we continue to focus our attention at the plant level, or should we go beyond the plant level? If we look beyond the plant level, where should we be looking (e.g., local governments, public utility commissions, utilities, parent corporations, the NRC, other)?

(Reference Appendix A, pps. 28-32)

Based on experience to date doing organizational factors research in a nuclear regulatory setting, all of the 15 respondents recommend that the research consider factors (entities) beyond the plant level in order to achieve more complete and accurate assessments of plant safety performance. The majority of respondents recommend that the research consider these external factors immediately. A minority recommend that the research be allowed to mature further before expanding its scope to external factors.

Both groups recommend the following factors (entities) be included, now or in the future, in a descending order of priority.

- Parent corporation
- Parent utility
- Public utility commission
- Nuclear Regulatory Commission
- Local government agencies

(4) How important is accessing plants to do Organizational Factors research? What types of problems have been encountered, if any, in gaining access to plants attributable to each of the following: parent utility; plant; utility groups such as INPO, EPRI, and NUMARC; NRC research project manager; NRC management; your own management?

(Reference Appendix A, pps. 33-38)

Based on experience to date doing Organizational Factors research in a nuclear regulatory setting, all of the 15 responses consider plant access as critical to the success of their research. Organizational Factors research, unlike individual and small group centered research, cannot be conducted in contrived or laboratory settings. The organization must be studied in its natural environment, a plant setting. Regarding plant access to date, the following experiences are reported. They are not presented in a priority order.

- The plants for the most part are cooperative if they believe the research to be non threatening to them.

- If left to their own devices, contractors feel they can gain access without a lot of problems.

- Poor performing plant should be included in the research.

- The majority of the respondents consider the NRC itself to be the main obstacle to gaining access to the plants, that is, placing certain plants off limits, involving too many NRC entities in the process, and a less than enthusiastic attitude of middle level management toward the research.

- Involvement of industry in the research to be very important. The majority also feels that the NRC is the prime hinderance in achieving this goal.

(5) <u>What lessons have been learned to date doing Organizational Factors research in a nuclear regulatory setting, that is, working with and for the NRC and with the nuclear industry?</u>

(Reference Appendix A, pps. 39-49)

Responses to this question focused on respondent perceptions of the NRC and the industry. They are presented in their order of priority ranging from 12 out of 15 responses down to 1 out of 15 responses.

- The NRC has been a stumbling block for achieving a common understanding of the research by the NRC and industry, and in the latter's understanding of how it can be useful to the industry in achieving plant safety.

- The industry is suspicious, but wants to cooperate with the NRC in this research, however, its cooperation depends on whether or not it understands how the research results can be useful to it.

- There is a general lack of appreciation within the NRC of the difference between the scientific and regulatory goals of this research.

- The wide philosophical gap between engineers, PRA practitioners and behavioral scientists does not seem to be closing very fast.

- The timeframe for conducting the research is very extended, especially in instances where plant participation od required. This involves coordination with the NRC and plants, setting up working agreements, and getting NRC approvals.

- While the research is well organized and focused, it needs more long term and predictable support from higher level NRC management. There is continuing uncertainty whether or not the NRC will continue the research.

- Research is hindered by a lack of teamwork, mutual support, and understanding among units within the NRC -- RES, NRR, and AEOD.

- The earlier that the industry is brought into specific research projects the more it will support their goals and objectives.

- o While a wide array of plant performance data are available, documentation of data is often inadequate, and may consist of idiosyncratic knowledge held by an individual.

- o The NRC research staff has been very supportive in making specific and general goals of the research clear.

- o Research has attracted an exceedingly capable group of researchers. This cadre provides a very rich and rewarding opportunity to learn from one another.

- o Success is failure. The better the research on the impact of organizational factors (success), the more likely the industry will put pressure on the NRC to cut the funding for future research (failure).

- o The farsighted approach the NRC has taken to this work potentially enhances the chances of its success.

- o NRC contract administration is a severe hinderance in achieving milestones in a timely manner.

- o All NRC research need not lead to regulation.

- o The impacts of the research will take years to observe because of the changes in management attitudes required.

The following suggestions were made for dealing with some of the above perceptions. They are presented in order of priority.

- o The NRC should clearly state to the industry how it intends to use the results of Organizational Factors research.

- o The NRC should coordinate with and involve industry and its representatives (NUMARC, EPRI, INPO) in all aspects of the research.

- o "One-on-One" workshops should be held between engineers and behavioral scientists to overcome philosophical gaps in their approaches to plant safety performance assessment.

- o The NRC should learn before it moves to regulation.

(6) <u>To what degree do the current Organizational Factors research activity's current focus and out-year plans, methods for doing the research, and sought after products over the next 2-3 years address issues you believe are important to plant efficiency, and the NRC regulatory mission of enhancing safety?</u>

(Reference Appendix A, pps. 50-56)

Respondents generally support the scope and direction of the current NRC

Organizational Factors research activity. In addition to their responses to other questions which can be used to improve the activity, respondents offer the following additional suggestions for improving the scientific credibility of the activity while at the same time enhancing the usefulness of its findings and products to the NRC and industry. Comments and recommendations are not presented in priority order.

- A better operational definition of plant safety should be developed.
- Organizational groups (Sections, Departments, Functions) larger than control room crews but smaller than the total organization should be studied.
- External plant influences should be studied, also the causal aspects of plant efficiency and productivity.
- Research should focus more closely on technology transfer of products developed to date, to NRC and industry users.
- Non- or negative results should be reported to the scientific and user communities.
- Efforts should be made to minimize overlaps in the research and to bring closure to results that have been achieved to date.
- An integration report should be prepared, among other things, as a means to defining future research.
- A study should be done to assess the impacts of Diagnostic Evaluations on safety.
- A study should be done to assess the impacts of an aging work force on safety.
- A study should focus on poor performing plants to establish a poor performing plant profile.
- Research should attempt to identify factors that allow good plants to remain good plants. Why do good plants stay good?
- Quantitative and qualitative validations of performance indicators should be continued with "new", post 1987-88 data.
- A resident inspector organization and management training curriculum should be developed from results of the research to date.
- A study should be done to examine similarities and differences among organizational factors bearing on industrial and public safety.

- The activity should encourage and find new ways for engineers and behavioral scientists to work together to solve Organizational Factors issues of concern to the industry and the NRC.

- An in-depth study should be done of similarities and differences between industry and NRC concerns in the area of Organizational Factors and safety.

- Data from programs involving (e.g., root cause analyses and effective spare parts policy) should be examined for use in developing leading indicators of organizational performance.

- Focus of the activity should be away from PRA and toward support to licensing and diagnostic evaluation programs.

- An Organizational Factors training course should be developed from results to date, for general use at the Chattanooga Technical Training Center.

Concluding Note: A more general conclusion based on the material provided for this report is that Organizational Factors research can be conducted in a regulatory setting and produce useful results. Technologies pioneered in other academic, commercial, and military settings can be adopted for use in a nuclear regulatory setting. The future success of this effort depends upon the cooperation of regulators, contractors, and the nuclear industry. Each in its own way can be expected to be a beneficiary of the results.

- By regulators for moving beyond educated speculation to assessments of plant safety performance that are not only objective but instructive to both the regulators and the plant.
- By the licensees for self improvement.

- By the contractors, especially the 12 universities currently involved in the work, to collate and expand on the findings to the benefit of commercial, public, and military operators of complex high reliability socio-technical systems.

APPENDIX A

NRC Contractor and Project Manager Responses

Verbatim responses to each of the six questions posed are presented in the following pages. Each question is presented followed by each of 15 responses (e.g., A-1 thru O-1, A-6 thru O-6). Responses are ordered randomly for each question. The following individuals contributed participated in responding to each question.

Dr. James Thurber, American University
Dr. Richard Osborn, Wayne State University
Dr. Frank Landy, Pennsylvania State University
Dr. Richard Jacobs, Pennsylvania State University
Dr. John Mathieu, Pennsylvania State University
Dr. Sonja Haber, Brookhaven National Laboratory
Dr. Mary Nichols, University of Minnesota
Dr. Alfred Marcus, University of Minnesota
Dr. Joseph Montgomery, Pacific Northwest Laboratories
Dr. George Apostolakis, University of California at Los Angeles
Dr. Jya Syin Wu, University of California at Los Angeles
Dr. Oscar Grusky, University of California at Los Angeles
Dr. David Okrent, University of California at Los Angeles
Dr. Nathan Siu, Massachusetts Institute of Technology
Dr. Erasmia Lois, USNRC, Office of Nuclear Regulatory Research
Mr. Carl Johnson, USNRC, Office of Nuclear Regulatory Research
Mr. Joel Kramer, USNRC, Office of Nuclear Regulatory Research
Dr. Vojin Joksimovich, Accident Prevention Group
Dr. Douglas Orvis, Accident Prevention Group
Dr. Susan Van Hemel, Star Mountain, Inc.
Dr. Edward Connelly, Concord Associates, Inc.
Mr. John Wreathall, Science Applications International Corporation
Dr. Mohammed Modarres, University of Maryland
Dr. Ali Mosleh, University of Maryland

Question No. 1: **What organizational factors appear to influence safety performance, and how might this knowledge assist regulators?**

Response A-1: Our research hypothesizes that small-scale group characteristics/ processes (e.g., structure, distribution of technical ability, communication) influence the dynamic development of accident scenarios. To date, our results show that this is true at least to a limited extent; we expect that future work will better define the relative importance of these factors in complex scenarios. In addition, it may be found that this work, even in its present form, can be useful to provide insight for NRC examiners and crew performance evaluators.

Note that most of the factors used in our model are, in principle, measurable.

In practice, on the other hand, some of the factors (e.g., an operator's confidence in his superior) may be quite difficult to accurately estimate. However, if enough such information can be obtained, the model can be used in a number of ways. Naturally, it is anticipated that the model would be used to improve PRA estimates of risk. Further, the model could be used to define distributions of work and emergency operating procedures that better reflect the ability of crews. It might even be used to define optimal "styles" of response to a given accident. Of these applications, the development of emergency operating procedures seems to be of most immediate use to regulators. The others should be useful too, however (in the same sense that regulators are interested in PRA as a supplementary tool).

Response B-1: Although some OFs [organizational factors] may affect all levels of safety, the term "safety performance" must be clearly defined before specific OFs can be linked to it. Since we are approaching the OF research from the perspective of PRA/HRA, we are directing our efforts toward identifying and quantifying the influences of OFs on nuclear (or public) safety.

The PRA process identifies and quantifies the probabilities of various accident sequences that can lead to releases of radionuclides to the public. Such accident sequences comprise the concurrent or sequential failure events of equipment or humans that initiate the sequence or prevent successful control of the plant or mitigation of accident consequences.

From our experience in the nuclear industry and with consultation with our behavioral scientist and utility consulting group, we have derived an interim framework to represent the interaction of OFs at various levels in a nuclear utility starting from "external influences" through the corporate and NPP managerial levels down to "output variables" representing behaviors by individuals and crews that lead to various "unsafe acts". For our initial research, we are focusing on OF influences on operator reliability and effectiveness of operator simulator training. This initial narrow viewpoint will be broadened to cover other equally important aspects.

At the NPP level, we have identified in our framework four categories of "causal variables": 1) Structural; 2) Programs; 3) System Values and Norms; and 4) Processes. The first two can be regarded as "hard" or "engineering" aspects while the last two can be regarded as "soft" or behavioral science elements. The plant level OFs are, in turn, driven by OFs from the corporate level and from external influences.

In developing a quantitative PRA, estimates of component failure rates and the probability of various "human errors" reflect the quality of programs and resource allocation implicitly through the use of plant-specific actuarial data or explicitly in synthesis techniques using "performance shaping factors" (PSFs). The identification and quantification of the cultural and behavioral aspects of OFs ("soft" elements) and their influence in PRA is the more challenging part of the current research.

Our framework provides for quantification of effect of "causal" and "intervening" variables on the likelihood of "unsafe acts" being committed by personnel. The effects of the "causal variables" are expected to be manifested in "managerial behaviors" at the NPP level. We anticipate that use of an instrument, e.g. the Wilson scale, will reveal the pattern of behaviors at representative levels in the NPP. "Intervening variables" are associated with the values, social styles, competence and commitment of NPP personnel. Standard instruments exist for measuring values and social styles; some development is needed to scale commitment and safety motivation. The intervening variables operate on the managerial behaviors to affect the personnel perceptions of the organization and to produce "output variables" related to the behavioral tendencies of personnel to enhance or diminish the NPP risk profile. For example, we would relate output variables to operator reliability as measured at the simulators.

Given that we are successful in quantifying the influences of causal and intervening variables or operator reliability (and subsequently to maintenance, perhaps), the NRC could use instruments for management behaviors and personnel perceptions as two barometers of NPP safety tendencies.

Response C-1: The perspective we bring is that the nuclear power plant as an organization is a "system" within a context, which is the utility. It is the performance of the plant that is important (i.e., our dependent variables must be plant performance), but the context is of unavoidable importance. The plant should be viewed as a behavioral, technical, and economic system. In our view the latter cannot be escaped. The most important aspects of the plant to understand for purposes of this research are the processes which relate to safety performance and improvement. Organizational factors, in their static form, take on importance by way of their influence on the core processes. The core processes which we think need to be understood are the following:

a) Learning process--this is the process by which the plants (and utilities) recognize problems, determine root causes and solutions, and communicate results;
b) Processes by which managerial attention is focused, signaled, and communicated; similarly, ways in which managerial attention is distracted from safety are important; how problems are prioritized;
c) Resource allocation process--how resources are allocated, what affects allocation, and the effects of resource allocation;
d) Processes of managing change--results of our research depicts NPPs as inertial organizations, which is both good and bad. It means the effective plants tend to stay effective - ineffective plants stay that way also. If we can understand what locks the system into these beneficent or vicious cycles, we must also seek to understand how managers can free them from vicious cycles. Even the good plants, we suspect, are constantly managing change--albeit incremental change--to adapt to new situations. If new ideas are to be implemented, or if vicious cycles are to be broken, it requires processes for successful implementation of change.
e) Processes of communication
f) Processes for coordination and integration--these are essential to problem recognition, problem solving, and learning.

We would like to address specifically the issue of utility level data and measurement. To begin to collect this data in an obtrusive manner would be highly controversial. Over the next several years of the program, we don't believe that it is needed. The decisions of strategic level utility managers manifest themselves in visible and measurable commitments to corporate strategies, visible allocations of resources, and corporate performance itself. What these executives say, what they intend, how they decide are not as important as the actual measurable behaviors, nor as important as what people in the plants perceive. The performance of the plant is directly influenced by what the plant personnel believe is true.

Response D-1: Attached to this letter is a list that we have developed based on our literature reviews. This list is extensive and contains many entries that are either difficult to assess or still in the development stage with respect to definition. At this point our project is attempting to answer the very same questions you are asking; how can each of these be measured? and given successful measurement, how can the knowledge of these factors be used to assist the utilities and regulators in their mutual attempts to operate nuclear power plants at a higher level of safety.

Our approach to many of these variables (goal priority, regulatory relationships, union-management relationships, speed of conflict resolution, tolerance for sub-standard equipment, general housekeeping, procedural clarity and updating, disciplinary and incentive systems, to name a few) is to first define what we mean by each of these labels and then look to several different members of the organization, across several different levels to provide perspectives on the variables. At this point we are looking at three different measurement methodologies and hope that by using the different assessment procedures and by asking different organizational members, we can come to agreement about the variables and how to most efficiently assess each one.

At the conclusion of our work, we see the potential for our measurement procedures to both benefit the nuclear power organizations by providing them with valuable tools for self assessment. Additionally, we believe our measurement devices will add to the ongoing procedures used during Diagnostic Evaluations conducted by AEOD. Other applications are also possible including the use of our measures as assessment tools following LERs and other events that occur in the context of operating a nuclear power plant.

ORGANIZATION FACTORS RELEVANT TO SAFETY

Strategic Apex:

1. Goal Priority
2. Responsiveness to Performance Change
3. Safety vs Bottom Line Orientation
4. Hardware vs Human Relations Emphasis
5. Regulatory Relationships
6. Industry Competition
7. Public Opinion
8. Union-Management Relations
9. Board Nuclear Review Commit.
10. Nuclear Safety Review Commit.

11. Independent Safety Engin. Group
12. Onsite Review Organization
13. Formalization
14. Coordination/Integration
15. Cooperation
16. Interdependence
17. Centralization
18. Safety Culture
19. Long Range Plans

Inter-Departmental:

1. Agreement on Goal Priority
2. Ownership vs. Blaming Others
3. Linkages with Contractors
4. Speed of Conflict Resolution
5. Formalization
6. Coordination/Integration
7. Cooperation
8. Interdependence

Ergonomic:

1. Engineering Design and Technical Support
2. Tolerance for Sub-Standard Equipment
3. Ineffective Trending
4. Method for Employees to Identify Potential Problems
5. General House Keeping

Decision-Making

1. Procedural Clarity/Completeness
2. Procedural Updates
3. Proactive vs. Reactive
4. "At Right Level"
5. Methods for Setting Work Priorities
6. Updating Documentation and Drawings
7. Abuse of Priority Status
8. Management Support for Lower Level Problem Solving

Personnel

1. Accountability
2. Job Standards
3. Administrative Burdens
4. Disciplinary Systems
5. Incentive Systems
6. Promotion/Hiring systems
7. Performance Evaluation Systems
8. Job Rotation
9. Training
10. Feedback Systems
11. Assessment of Contractor Capabilities
12. Supervisory Skills
13. Pay Equity
14. Recognition/Reward Systems
15. Overtime Policies
16. Timeliness of Key Replacements

Intra-Departmental:

1. Vertical Communication

2. "Right First Time"
3. Departmental Goals
4. Employee Input Mechanisms
5. Open Problem Solving
6. Management by Walking Around
7. Teamwork
8. Morale
9. Goal Priority
10. Shift Turnover Practices
11. Work Planning/Scheduling

Miscellaneous:

1. Root Cause Analysis
2. Effectiveness of Plant Onsite Review Committee
3. Performance Evaluation Programs (PEPs)
4. Deviation Event Reporting System
5. Performance Scheduling and Tracking Program
6. Surveillance Scheduling and Tracking Program
7. Inventory Control and Updating
8. Work Package Planning and Updating
9. Preventative Maintenance and Control
10. Quality Assurance Audits
11. Percentage of Managers Reporting Off Site
12. Clashing Cultures
    a. Engineers vs Non-Engineers
    b. Nuclear Navy vs Non-Nuclear Navy
    c. Employees vs Contractors
13. Housekeeping/Documentation Procedures
14. Regulatory Orientation
15. System Wide Understanding
16. Deep Technical Knowledge

Response E-1: My understanding of organizational influences on safety is in terms of systematic processes that underlie the management of safety: the core processes of awareness, competence, and commitment. Of these the greatest is awareness. Ignorance of a safety hazard often results in no "hazard management" process being in place to defend against it, as was the case in TMI (small LOCA thermal hydraulics), Chernobyl (potential effects of experiment), and major catastrophes in other technologies. In these cases, individuals may be aware of the potential hazards, but the decisionmaking "system" was not (as in the case of cold temperature influences on O-rings on the Challenger). Once awareness is generated, even moderately competent or committed organizations will have some measure of defense; it is then a question of the reliability of the defense. Empirical evidence of the importance of these factors is provided in the work by LaPorte, et al, in the High Reliability Organization Program of NSF.

These core processes are operating at all levels of the organization, and their local influences are such that the consequences of deficiencies in awareness, commitment, and competence are different for the different operating parts of the organization. As a result, measurement of these processes has to cast in terms of their local effects, as in the case of programmatic performance indicators. The selection of these indicators requires careful evaluations and, as been seen, is not intuitive. Such information can be seen as a source of inputs to diagnostic plant evaluations, can make SALPs more systematic, and provide an objective basis for identifying potential problem plants.

Response F-1: We clearly know that organizational factors influence plant safety (See NUREG/CR 3737; Perrow 1984; Starbuck and Milliken, 1988; incident and accident reports, and the AEOD diagnostic evaluations) and we know how organizational factors affect plant safety (See NUREG/CR 3215; NUREG/CR 5437; Haber, et. al., 1988; and Osborn and Jackson, 1988). We are learning more about measuring organizational factors and their linkage to the performance indicators (Minnesota project). The central research question must be clearly stated as: "Given the organizational factors are linked to plant safety performance, what should utility mangers and NRC do to assure that these factors contribute to, rather than detract from safer performance" (Olson and Thurber, Minnesota project). Research strongly suggests that effective organizations can and must be substantially different depending on the demands of the specific context and the history of the organization. Our research does not suggest that a common, detailed organizational design be applied to all NPPs. An idealized model (as used in several research projects) can inform and guide the regulatory process, it does so more by providing an inventory of organizational factors and relationships among those for factors for consideration on a case-by-case basis. NRC should use the organizational factors for a measuring, monitoring, and training program. The development of programmatic performance indicators, including organizational and management performance indicators is part of that effort.

The process of organizational learning or organizational improvement is not well understood. When NPP performance has degraded to the point that it raises substantial NRC concern, the NRC needs to be in a position to accept with some confidence that the utility's plan for improvement is sound. Does the improvement plan have a chance for success or not? How do you judge that? Few objective criteria exist at this time for evaluating these plans.

Our effort to understand and document the organizational context of learning in NPPs is focused on these questions. We are beginning to understand the relationship between organizational learning and safety performance in NPPs. This research will help AEOD and others to evaluate the ability of a plant to improve its level of safety performance through learning. Our learning model includes several stages: solution formulation and implementation; organizational constraints; assessment and feedback. We have found that for a NPP to learn, they must have the technical and analytic skills and the formal information management programs necessary to characterize problems, define solutions, and measure the success of the solutions. For these to be successful, the NPP must provide an organizational context that allows for a focused application of these resources and programs. The NRC must be able to evaluate the organizational context and management strategy for learning and safety performance improvement in order to determine whether plants can improve from degraded levels of performance or not. The central question is how can we make the core processes in a NPP work better. How can NRC evaluate whether the NPP is a problem solving/learning organization? The

Olson-Thurber activity will provide the NRC with a method and protocol to assist NRC is answering these questions.

Response G-1: A significant amount of research has been devoted to ascertaining the influence of organizational factors on safety performance, and there is certainly no shortage of papers on this issue. From our viewpoint, however, this question cannot be addressed without considering the measuring instruments available to researchers and the applicability of these instruments to specific organizational and management practices in regards to their effect on safety. Our "Principal Function Model" looks for the cause-effect relationship between organizational factors and performance at a real-world operational level at the plant. The organizational factors are grouped into three causal types that are important to plant safety:

a. Factors that affect the design and maintenance of the normal and emergency processes or operations, which run both vertically between different organizational levels and horizontally across various departments at the plant. These factors include, for instance, how the processes are defined, how often they are reviewed and revised, how much emphasis is given to safety in these processes, and how closely plant personnel adhere to these predefined processes at the working level.

b. Factors that determine the quality and compliance within each specific level at the plant. Factors in this category include technical and managerial knowledge necessary for personnel at different points of a given work process, and the attitude toward following instructions and procedures. Training and management styles, for example, definitely play important roles in this aspect.

A specific concern is on the issue of deep technical knowledge. Mistakes and slips are often made when people fail to recognize that the plant should be viewed as an interrelated organic whole, instead of a set of unrelated individual pieces. Without deep technical knowledge, plant personnel may fail to realize that while some events are inconsequential, other events could lead to catastrophic consequences. Therefore, in addition to knowledge on how specific systems function, people should also bring to the work situation knowledge about system interactions and plant safety. We further argue that this deep technical knowledge should be appropriate for the particular position a person holds in the plant. For example, the Senior Reactor Operator (SRO) should have a deeper technical knowledge of safety system operations than does a maintenance journeyman.

c. Factors that impact the coordination of multiple levels and departments. Communication both within and between levels and departments, plant morale, and leadership of high-level management are some factors which determine the coordination of activities among multiple organizational and management entities.

In order to measure these factors and their impact on plant safety, we are currently concentrating on the following three areas:

a. Identification of the "principal functions" within a NPP. These are work processes routinely practice at the plant during normal operations, as well as anticipated events. The design of these work processes is important to plant safety in the sense that it lays out the framework within which tasks are carried out at the site. For example, every NPP follows a similar pattern for corrective and preventive maintenance. Minor differences between the design of these processes may contribute to different safety records across plants.

Once the principal functions are identified, the research team then focuses its data collection on the following components of the work process:

i) Actions/events in work processes that could lead to initiating events which may result in undesired plant conditions, contribute to the unavailability of safety functions, or increase the likelihood of operator errors.

ii) Key personnel involved in each task of the work process. Typically, each work process can be viewed as a work flow shifting from one department to another and from one knowledge base to another.

iii) Characteristics required in each "as-designed" task. For example, the technical knowledge needed to perform the task, the importance of compliance in performing the task, and the importance of communication skill in this type of work.

iv) The importance of each task in terms of successfully achieving the goal of the work process.

v) The safety awareness shown in these work processes and the organizational factors which impact that awareness. This indicator can be used as a measure of safety culture at the as-designed level.

vi) The importance of each work process as it is designed in terms of plant safety.

Findings at this level can, later on, be combined with the measurement of the performance of the individual at each task and used as a safety index of the plant performance.

b. The measurement of the performance of individual tasks. These data can be used to assess the discrepancy between the actual performance of a task and the desired performance of it. For example, if the predefined work process assumes that a certain task requires a deep understanding of certain system functions and their inter-dependence within a general safety-concern, the lack of such knowledge by the individual who carries out the task could hinder achieving a higher level of safety at the plant. Each discrepancy from the designed behavior should go through a cause-effect analysis, in which the influence of corporate, plant, departmental and work-group influences can be identified.

c. The measurement of how well multiple tasks are coordinated and the organization factors that affect such coordination.

The knowledge gained through the analyses of these data can be used to assist regulators in many ways:

a. The ranking of work processes and tasks can help NRC inspectors and AEOD analysts to prioritize their activities and resources.

b. The analysis of cause and effect relationships among organization factors, tasks, and work processes can also be used an indicator of potential weak points in a plant's management/organization that may need improvement or further investigation.

c. The improvement of current PRA evaluations of plant safety by:

i) Identifying O/M factors that could lead to initiating events, increased unavailability of safety functions, and increased operator errors.

ii) Increasing to our understanding of the correlation among component failures and operator errors.

iii) Developing an algorithm that links organizational factors with various elements in the PRA models (i.e. initiating events, operator actions, and safety system responses) that are used to evaluate plant safety.

Response H-1: Organizational factors undoubtedly affect the safety performance of the plant. However, we feel that we are not at a stage to identify a ranking of these factors and their effect together. There has been a number of organizational factors which have been identified, qualified and quantified which have shown to be important (e.g., Minnesota work). We feel that more research is needed to have a full understanding of the underlying mechanism, reasons and extent to which they affect safety performance. We can envision a situation where certain well-defined organizational factors can be incorporated into traditional licensing and plant inspection processes. As stated earlier, this requires better understanding of organizational factors and their effect. Further research in this area is also recommended. Especially if the underlying reasons can be better defined, the results of the organizational factors research can be better communicated with the engineering community.

Response I-1: The organizational factors influencing safety in NPPs should not differ fundamentally from those influencing safety in other industries. NPPs have special safety concerns and are highly regulated, but are not fundamentally different from other organizations designed to perform similar functions. The process safety programs developed in the chemical and petroleum industries have probably covered most of the technical organizational factors quite well; they seem to have reached quite a good consensus on the key factors. On the most basic level these deal with technical knowledge and with the programs and procedures put in place to ensure that the knowledge is applied in the service of safety. These factors may generally be measured effectively by well designed audits or reviews.

Factors beyond the technical ones are concerned with the organization's commitment to place the highest priority on safety, and the effectiveness with which that commitment is translated into action at every level of the organization. The level at which these should be measured may be decided by one's theory -- measure at the level where you think the most important effects occur; or by practicality -- measure where it is possible to perform reliable observations of phenomena which logically can be expected to indicate commitment to safety and effectiveness of safety management.

Our project has concentrated on the observable behaviors of workers as indicators of overall safety awareness and of the effectiveness of safety programs. We feel that behaviors also may serve as an index of the strength of organizational safety culture, which is an "emergent" phenomenon dependent upon commitment and upon effective policies, programs, communications, etc.

It has become clear in our research that the variables commonly included in definitions of organizational culture are very important in safety performance. Safety is an issue which does not appear explicitly on the company's bottom line, and top management must make a conscious decision and commitment to give it priority in an organization. This decision and commitment must then be effectively communicated to all employees, with appropriate supporting structures and reward systems. All of these are features of the organizational culture. Therefore, cultural indicators may prove to be among the most useful and sensitive indicators of an organization's (and its management's) commitment to safety.

The corporation's commitment may also be evident in the managers it selects to implement its policies and procedures. Other indicators are required to judge how well this commitment is implemented on the plant floor. Some of the program projects are concerned with cultural indicators, but problems of definition and measurement may limit their short-term usefulness.

Response J-1: We have attempted to answer these questions in a long series of reports. Also enclosed are two articles that were not done on NRC projects. However, there is another, perhaps more important question, underlying this. How do we approach trying to understand something so complex as safeness in nuclear operations? It seems to me that we recognize the complexity and the indeterminacy of our research.

First, we need to recognize that safeness is more of a metaphor than a measured concept. Safeness means many things to many different people and may be measured in many different ways. We are interested in making sure bad things do not happen and promoting settings, actions and attitudes that appear to promote desired action. We need to recognize that the various aspects of safeness are not highly related. Once we recognize this, we can begin developing more specific models of various types of safeness. For instance, our recent work shows partial support for a specific learning model for selected safety indicators. A second related model was successfully used to explain variation in violation rates.

For the NRC recognizing the inherent separateness of various aspects of safeness has some profound implications. Perhaps the most important implication is the need to abandon some conventional myths that make the regulatory task much easier. Three come to mind. One, there are good plants (utilities) and bad plants (utilities). Two, if all plants (utilities) did what the "good" ones did, all would be safer. Three, the NRC can help fix the bad management and organization yielding less safe operations by direct intervention. If the existing research dispels these myths, NRC has progressed in important ways.

Second, we need to recognize that an organization is a social mechanism for creating meaning, taking action and serving both individual and collective interests. Much of what we study in organizations is emergent behavior at the collective level. For instance, the connections up and down the hierarchy as well as the linkages among units appear to be vitally important for some aspects of safeness. At times the connections and linkages are by singular individuals, at times by informal groups, at times by formal committees and at times by a symbolic understanding of others. In almost all cases the connections and linkages are problematical, incomplete, partially overlapping and quite fluid.

For the NRC this emphasis on emergent behavior also has profound implications. It means that regulators should abandon a mechanistic and deterministic view of management and organization as some type of machine run by individual managers. The deterministic composition and decomposition logic characteristic of engineering analyses and PRA, for instance, does not hold in organizational analysis. The organization is not a piece of equipment or merely a collection of individuals.

Third, we need to stress the systemic character of safeness as well as management/organization. Recognizing this calls for systematic, longitudinal examinations of all plants/utilities. A collection of one shot, highly focused casual looks at a single plant or utility are quite likely to yield an incomprehensible array of disjointed data. What we are examining is a network of variables that collectively impacts various aspects of safeness.

In sum, we need less emphasis on a listing of variables and more emphasis on (a) understanding the complexity of safeness, (b) the importance of emergent behavior across levels of analysis and (c) the systemic longitudinal analysis of safeness, management and organization across all licensees.

<u>Response K-1:</u> It seems to me that there are certainly a number of organizational factors (both positive and negative) that affect plant safety. I have included 4 figures from some previous work with a client in the nuclear industry, showing a model I came up with to explain problems related to control room crew performance. Figure 1 shows the overall model--that at any plant there are likely to be both positive and negative factors, that both types of factors influence attitude and morale, and that attitude/morale and safety performance have mutual casual influences on each other. Figure 2 provides some examples of positive aspects of the control room operators work. Figure 3 provides examples of some of the negative issues that were present,

such as "Administrative issues" (related to perceived heavy paperwork demands), "Re-qualification training" (referred to perceptions of poor training being provided), and so forth. Figure 4 shows a sequence of steps that were developed to deal with these issues.

The approach used in this study was to gather fairly extensive interview data from a single plant, conceptualize the issues, and develop a process by which to address the specific issues. These steps formed what was essentially an "action research" approach to changing the organization. The action research approach, being site-specific, seems quite different from the research approach being adopted by the research groups working with the NRC. The NRC-funded research groups seem to be looking for very general relationships among organizational factors.

From my own perspective, I feel that conducting action research at problematic nuclear plants--identifying key problems and developing and implementing solutions--would be a productive way to address organizational issues related to plant safety. I frankly do not have a clear sense of the regulatory issues that would be involved. Perhaps from a regulatory view, this suggestion would not be manageable. However, I could imagine plants with a poor safety record being required to initiate an action research process, identify their problems, and demonstrate improvements over time.

Response L-1: As we gain field experience through our research in this area, both for the NRC and other agencies, we are even more convinced of the applicability of at least the five organizational factors we have identified to date; communications, decision-making, standardization of work processes, management attention and oversight, and organizational culture. Our work in the accident management area also identifies a factor labeled external

Figure 1

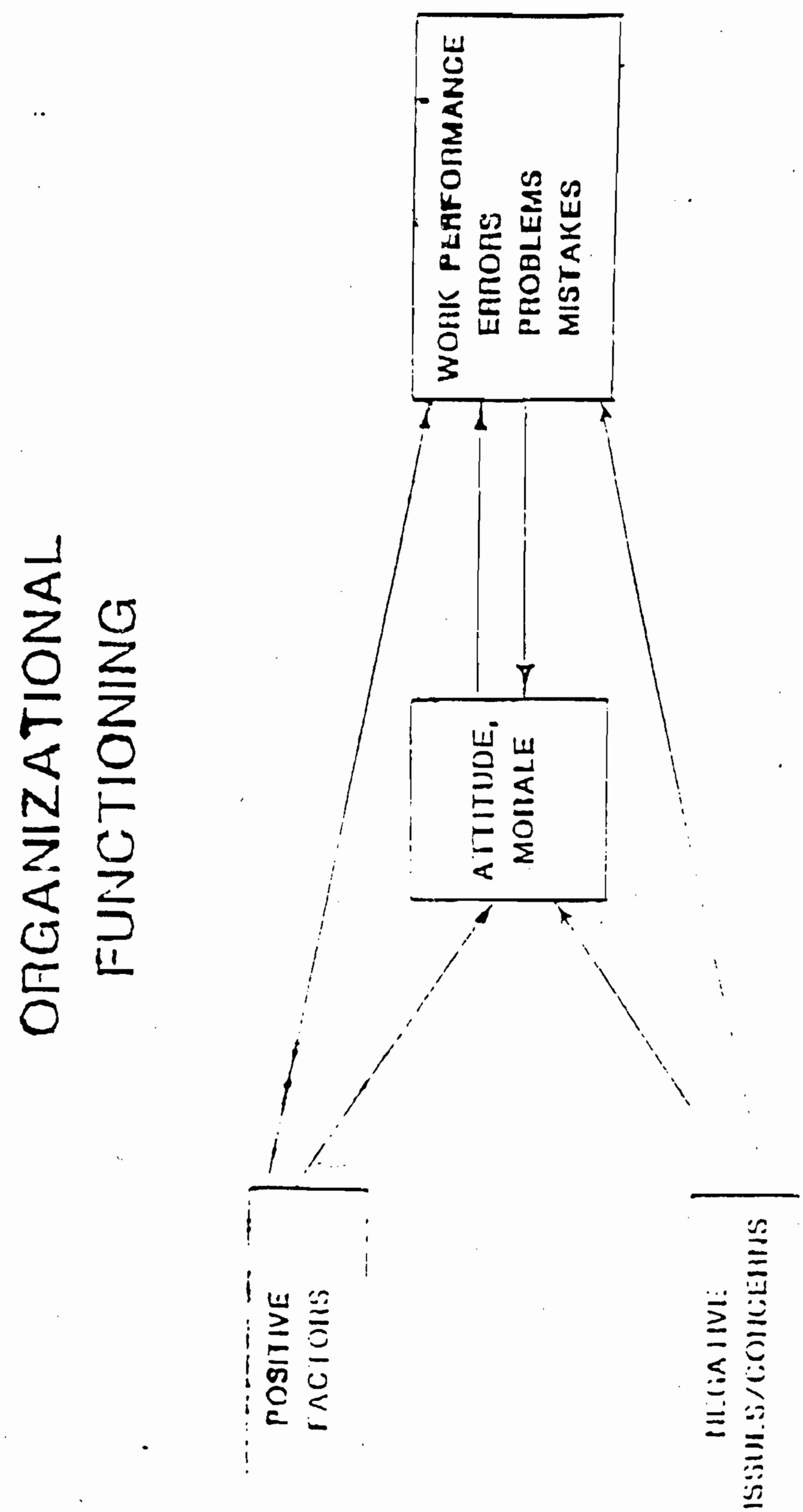

ORGANIZATIONAL
FUNCTIONING
WORK PERFORMANCE
ERRORS
PROBLEMS
MISTAKES
ATTITUDE,
MORALE
POSITIVE
FACTORS
NEGATIVE
ISSUES/CONCERNS

Figure 2

POSITIVE FACTORS

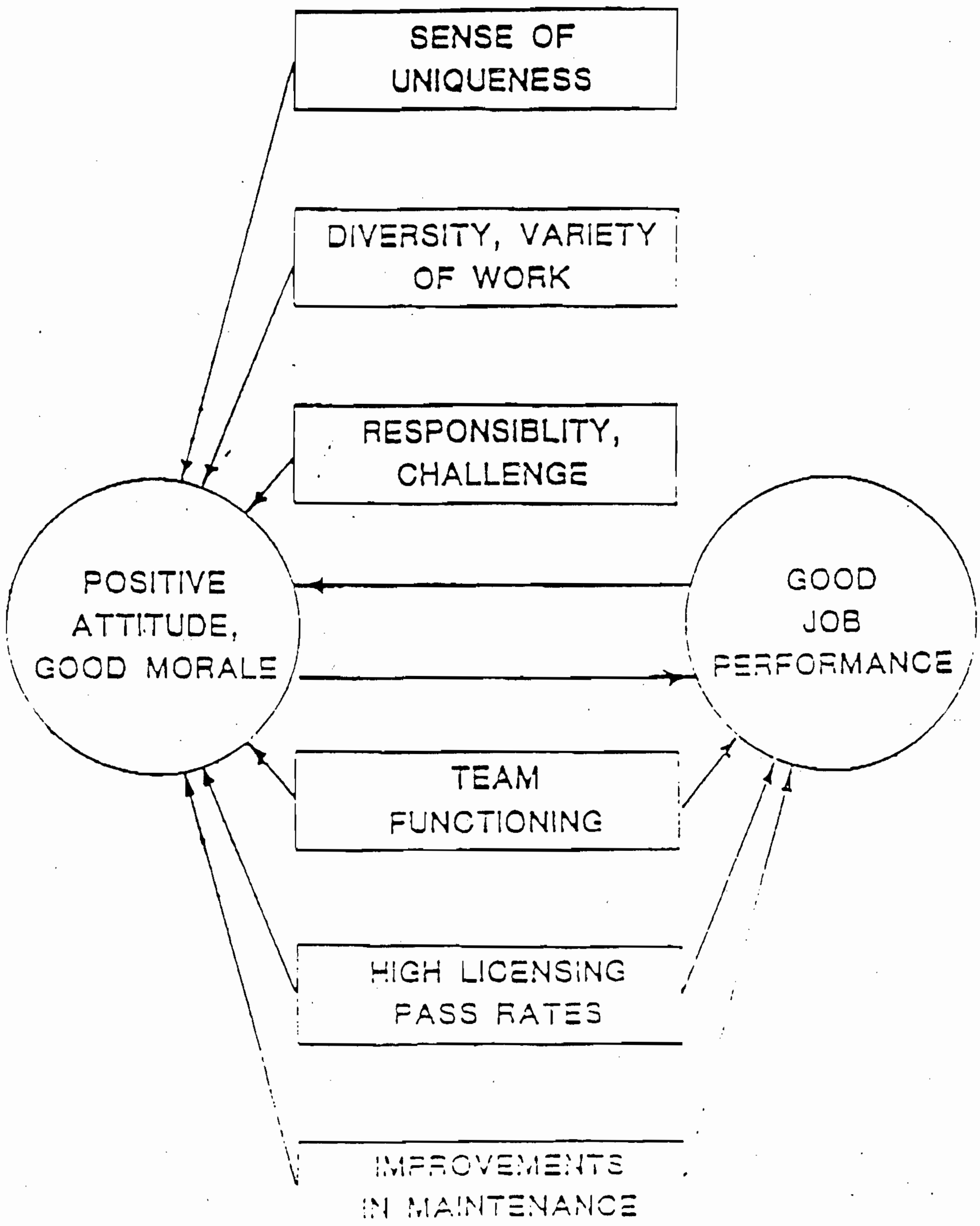


Figure 3

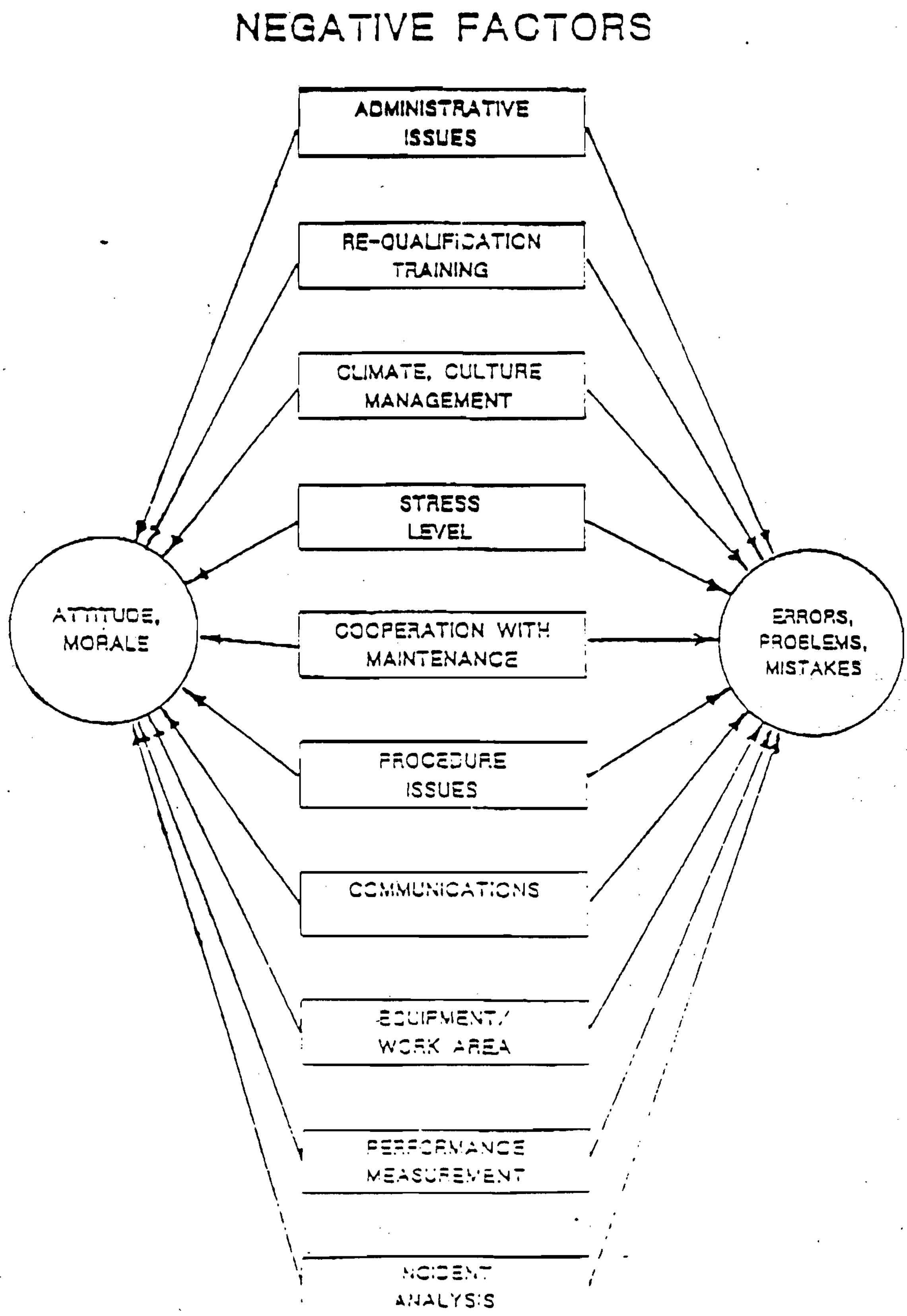
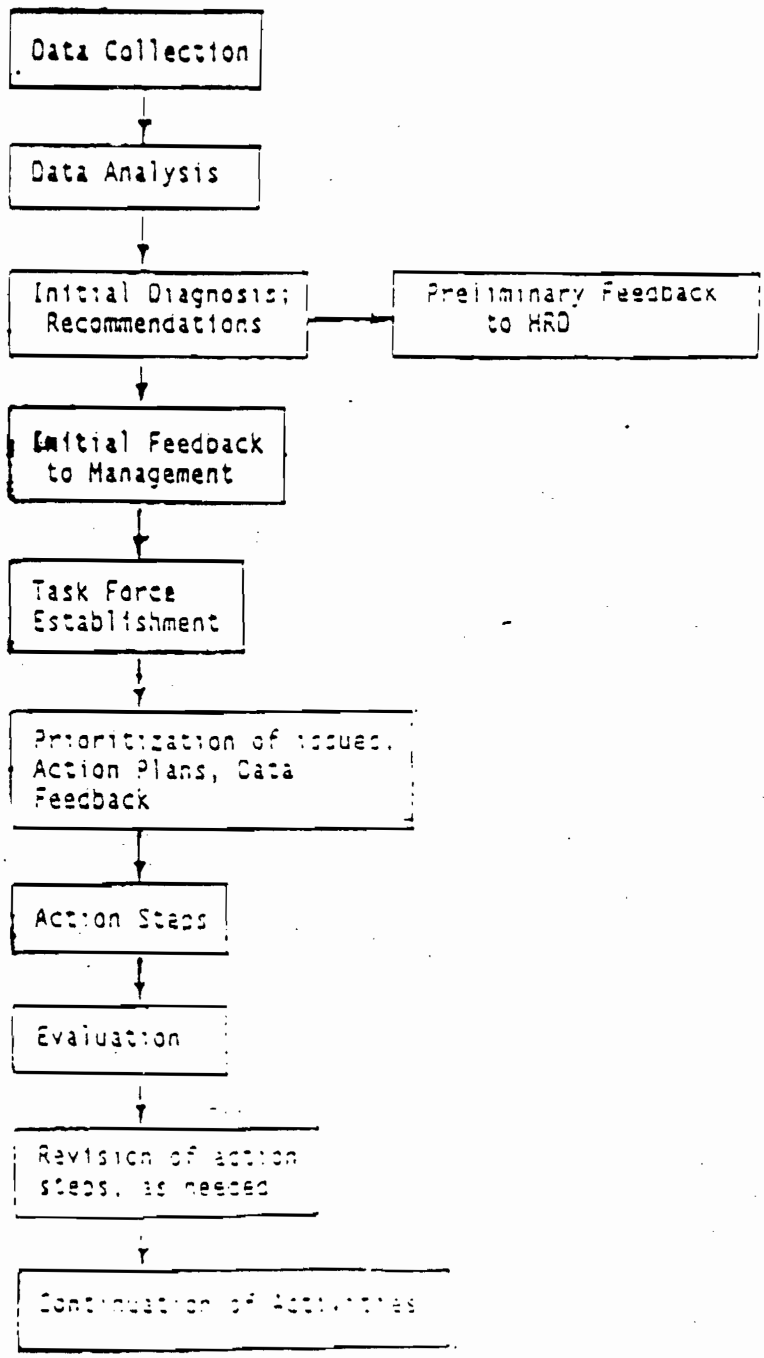

NEGATIVE FACTORS
ADMINISTRATIVE ISSUES
RE-QUALIFICATION TRAINING
CLIMATE, CULTURE MANAGEMENT
STRESS LEVEL
COOPERATION WITH MAINTENANCE
PROCEDURE ISSUES
COMMUNICATIONS
EQUIPMENT/ WORK AREA
PERFORMANCE MEASUREMENT
INCIDENT ANALYSIS
ATTITUDE, MORALE
ERRORS, PROBLEMS, MISTAKES

Figure 4

ORGANIZATION DEVELOPMENT PROCESS



relations which attempts to delineate the impact of outsiders to the facility on the facility's performance. These outsiders are defined as corporate, state, local and regulatory types, those outside of the immediate work flow at the facility.

We have also come to recognize the importance of learning for the organization. This variable can be subsumed under the standardization of work process factor. Part of the feedback process in modifying standards within the organization, should include the concept of organizational learning. Modifications can be facility-specific or industry-wide and will often result from a lessons learned strategy implemented by the organization. The success of that strategy indicates the success of the learning process for that organization and can be measured by reportable indicators (e.g., performance indicators).

Response M-1: The list of organizational factors that appear to influence safety performance is almost endless. We are not yet at the point where we can say what the "top 10" are that account for, let's say, "90%" of the variance (safety). As I look across all of our projects, we appear to be converged on such factors as organizational learning, debt/equity ratio, communications, decision-making, and management attention, involvement and oversight as being, for the moment, the consensus leading candidates. What % of the variance (safety) is accounted for by them is anyone's guess. I still have a problem, shared by most of the other researchers, of defining the dependent variable"safety". We've got lots of ways to measure these organizational factors, but can't answer the "best" part of the question yet. If we knew the answers to the first two parts of the question we would still be unable, at present, to index, scale or otherwise translate this knowledge to assist NRR and AEOD. However, I am hopeful that we can do this over the next 2-3 years. The potential use of the research to NRR and AEOD still lies in enhancing and systematizing inspection and diagnostic evaluation programs.

Response N-1: I will summarize my experience in saying that there is an overall organizational factor: *Management Commitment to Safety*.

An organization truly committed to safety (a) communicates clearly to all worker levels that safety is the #1 priority of the company, (b) sets specific goals for achieving and ensuring this #1 priority (c) creates the needed programs, (d) sets incentives, (e) sets feedback mechanisms, (f) sets learning processes, and (g) provides the needed financial resources.

A regulatory program can measure a company's commitment to safety through on-site observations, audits, and collection and monitoring of performance data. However, a regulatory agency, being a body external to the organization, can not institute management commitment to safety; it can only promote it by providing incentives to the licensees for such a total commitment to safety. The use of incentives, however, presumes a performance-based regulatory approach, which is not presently used by the NRC but which probably will be adopted in the future.

Response O-1: At the Penn State meeting, the breakout session that I attended discussed this question. The group decided that although we know the kinds of factors are generally important, we don't know a priori which of these are key for a particular situation or issue. Dick Osborn of Wayne State said we need a process to discover which factors are the key factors for a given situation.

The organizational factors that the group discussed as being generally important are as follows. (Several ways of categorizing these factors were discussed; this is one of them.)

1. Boundary conditions:
   Environment in which plant operates
   Funding available
   Regulatory constraints
   Context
   Size
   Extent of multiple power technologies
   Formal organization structure

   (At the start of a case study, it is usually not clear which of these boundary conditions are significant. However, since these "hard" data are easy to collect, they should be collected routinely on all studies. Unfortunately, what is usually done is to simply describe these environmental factors, and not go on to assess their impact.)

2. Organizational processes:
   Organizational values
   Focus on continuing improvement
   Respect for the individual
   Culture (constancy of purpose)
   Broad management understanding of systems engineering, statistical analysis, psychology, how people learn, how conflicts are resolved
   Communications
   Institutional learning

   (This "soft" information on emergent or core processes is difficult to collect and evaluate.)

3. Specific programs such as Aging, RCM, TQM, etc.

Question No. 2: **What is the status of products being developing in terms of their implementability in NRC regulatory activities either directly, or through additional technology development and implementation research?**

Response A-2: Our current project involves exploratory research and is not expected to directly affect the regulatory process in the short term. Additional development (e.g., improvements to handle errors during more complex scenarios, applications to other scenarios) could, in a few years, indeed lead to a product that can be used to assist regulators.

Response B-2: Using our nuclear safety background, PRA and HRA in particular, and combining it with the background of our behavioral scientist, we are developing a framework within which organizational factors, focused on nuclear safety, can be addressed in a systematic manner.

In a way, our products can be compared with SHARP. Of course, one should bear in mind that SHARP deals only with man-machine interactions where man is the operating crew of a nuclear power plant.

In the September 1991 time frame, our product should be viewed as a plausible hypothesis which badly needs to be firmed up and validated. Any direct or definitive use in the regulatory arena would be awfully premature. Nonetheless, some insights gained are likely to be valuable. Those could and should be used very selectively and in a non-prescriptive manner both in the regulatory process and the industry. We plan to point out those in our NUREG.

Response C-2: The products which our project will yield are products which describe the complex and comprehensive relationships among a number of organizational characteristics and performance on the NRC performance indicators. The organizational characteristics relate to past performance, problem recognition through NRC enforcement history, utility financial performance, plant resource allocations, utility business strategies, and power generation strategies. Thus our first and foremost products are knowledge. They include specialized knowledge of what leads to improvement or degradation or lack of change in plant performance on safety-related indicators. Applications of that knowledge could be extensive, after proper validation is completed. For instance, inspectors could be trained using the results of our studies as a way to think about power plant performance and degradation. Or NRC could publish short annual summaries for inspectors about organizational indicators at the utility level which we have shown to be important. These could be helpful in figuring out what performance trends are taking place, and if there is likely to be ruptures in these past trends. If problems seem possible, intervention by NRC and the utility then could be taken. The following is a summary of what we have demonstrated through our research, along with some speculation as to its usefulness in the regulatory process:

1. Safety is not a unitary performance outcome. There are multiple indicators of safety-related performance (measured in our study by the NRC performance indicators), they are not significantly related to each other over time, and they are predicted by different factors.

2. Our research has yielded sets of organizational factors which can be viewed as "profiles" which predict future rates of occurrence of scrams, safety system failures, significant events, and safety system actuations. Different outcomes are produced by different profiles. These profiles could be used for diagnostic purposes--such as to identify plants which should be identified more carefully.

3. Research results identify multiple, interacting sources of vicious cycles and beneficent cycles of performance. This, coupled with knowledge of how to implement change, could aid regulators as well as industry in understanding how to maintain good performance and break out of patterns of poor performance.

4. In addition to knowledge, our project will provide some immediately useful diagnostic tools focused on processes of organizational learning for possible use in inspections. These have emerged from the qualitative aspects of our research.

Response D-2: At this point we would have to conclude that the evaluation of our work will not be complete by September of 1991. At that time we will be ready to implement our measures in several plants across the country. Once year two of our work is completed we will be prepared to answer this question. One guiding principle we operate under is that our measurement procedures must be "portable" enough to allow for us to complete six assessments in the nine months allotted for this activity. This fact virtually guarantees that we will develop tools that can be implemented by the NRC for measuring the critical organizational variables we uncover during the current year.

Response E-2: Several classes of products are being developed in this research area. These are: products that generate awareness that there is an issue of importance; products that provide frameworks for evaluation; and products that are formal regulatory tools. The products that are presently expected are of the first two kinds; I do not expect formal regulatory tools to emerge in the next one or two years. As described above, however, the question of awareness is perhaps the most critical, and these projects should provide increased awareness by NRR, the Commissioners, and industry of the dramatic influences of organizational factors on safety. Perhaps you should consider a separate short-term task to evaluate all significant events in terms of the roles played by organizational factors. While each project is doing this in some form or other as benchmarking, I see benefit in having a short, focused study that says "here's the problem!". In other words, demonstrate there's a problem that needs fixing.

In turn, each project is providing a "personalized" framework for discussing organizational factors and their influence on safety. Each project may well have its own framework in the short term; however, there will be no coherence between them, which may cause confusion in the minds of those not familiar with the issues. This is part of the price for pursuing multi-disciplinary approaches as discussed above. Coherence will emerge as the topic matures, but maturity cannot be enforced at this stage. Perhaps it is better to focus on formalizing the "awareness" process?

Response F-2: The organizational factors research projects have a variety of deliverables ranging from basic research, to educational and training materials, to practical tools that may be used by NRC immediately. The basic research that has been accomplished is a major contribution to our knowledge about how management and organization is linked to NPP safety performance (See answer to Question 2). The result of theory construction, data collection, and hypothesis testing is impressive but these NUREG/CRs and scientific publications are primarily "awareness raising" and "informational" products. Few of the findings are at the stage that can be used as "practical tools" by NRC or the industry. None of the research findings from the performance indicators and probabilistic risk assessment (PRA) work should be used for the basis of regulatory action at this time.

NRC-RES projects are well integrated. The performance indicators work (Minnesota, SAIC, BNL, SAIC/Concord, SAIC/Maryland) are all studying different phenomena with some overlap. The overlap and redundancy is useful to all the projects. The performance indicator work feeds into the probability risk assessment work of UCLA, APG, Penn State, and MIT. The PRA work presents a useful framework, a reasoning process, that forces an explicit statement of the "theory of the plant". The PRA work is a good challenge to the performance indicators projects, but the models developed by the indicators people should not be forced into the PRA framework. Let both groups pursue the research question through their respective methodologies, using theory and data from each other. The projects need to produce practical tools that can be implemented immediately in order for overall organizational factors program to succeed. There are several examples of near term products that could be used by NRC. Our protocol on assessing the learning organization is a product that can be used by AEOD within three months. The Pacific Northwest Laboratory work on team performance by Joe Montgomery is ready to be implemented though their training program. Other studies are not ready for immediate "implementation" or do not have a client in AEOD and NRR yet.

Response G-2: The following short-term accomplishments from our project team should be available by the end of September, 1991:

a. Progress on the specification of our Principal Functions Model:

   i) Identification of actions/events in work processes that could: 1. lead to initiating events and to undesired plant conditions, 2. contribute to the increased unavailability of safety functions, or 3. increase the likelihood of operator errors.

   ii) Identification personnel involved in each task of the work process.

   iii) Identification of the characteristics required in each "as-designed" task.

b. A preliminary draft on the characteristics of NPP organizational factors and designs which are important to safety.

   i) A hierarchical, subdivided list of organizational factors and designs judged to be significant to safety.

ii) A taxonomy for the measurement of NPP organizational factors and designs.

c. Progress made on the collection of data and the development of measurement instruments:

i) Historical data from precursor studies to support the taxonomy.

ii) Instruments based on the concept of work process which will be tested at a NPP for their reliability and validity with the assistance of the plant's management and staff.

d. Some progress made on deep technical knowledge at the plant

i) A survey on what kinds and how much technical knowledge plant personnel holding different positions in the organization ought to have and actually possess. The participants of the survey would be plant personnel across different disciplines, departments, and organizational levels. The data would be analyzed to assess the discrepancy between the ideal level of technical knowledge a person in a particular position ought to have versus what that person actually possesses. In addition, we expect people holding different positions within the organization's hierarchy, from different disciplines and backgrounds, and with divergent "subjective" realities to have different expectations and judgments about the appropriate level of technical knowledge certain positions ought to have.

Response H-2: We are developing framework that enables NRC to identify the relationship between the existing performance indicators and safety. It will also define the meaning of "safety" for other research activities at NRC. Finally, it helps NRC to determine what additional performance indicators might be needed to cover the full spectrum of plant safety. The product of our research enables NRC to evaluate safety implication of performance indicators in groups (e.g., direct, indirect, lead indicators,....etc.). We expect to provide a document (pending contractual arrangement) describing the application of our approach.

Response I-2: The products we are developing should be useful both to the NRC and to the NPP industry. By October, the outlines of a Safe Acts Index (SAI)-type indicator for NPPs should be developed and should have been reviewed once by a panel of NPP industry and NRC experts. The processes of installing a prototype SAI indicator and validating it in an NPP setting, and of fine-tuning measurement methods and benchmarking of the indicator will require additional work after that date.

The Safe Acts Index-type indicator should be useful within the NPP and utility as a quick-feedback management tool both for monitoring plant safety and for managing worker safety performance. The data collection program should fit easily into overall quality improvement programs such as TQM. The experts who participated in our evaluation suggested that the use of similar indicators may already be common in "well-run" plants.

The NRC should be able to use the indicator in either or both of two ways. First, the short-term indicator data (indicator values over time) may be useful to the resident inspector or other NRC regional inspection/evaluation personnel as an additional data point for continuously trending safety performance. Second, long-term data on the effectiveness with which plant management uses an SAI-type indicator to manage safety may be valuable in periodic management evaluations such as SALPs, as well as in Diagnostic Evaluations or other ad hoc studies.

Response J-2: For the NRC our work would, with some additional technology transfer efforts, (1) help in the systematic description of management and organization, (2) call upon NRC staff to abandon clinical judgements of individual managerial competence, (3) alert NRC staff to more carefully articulate when and why they think a plant is in trouble (e.g. lack of resources, vicious cycle of reaction), (4) provide NRC staff some additional understanding on how long it takes for management and organizational changes to influence safety and (5) decouple description from regulatory action. The fifth is perhaps the most important.

Now it is implicitly assumed that research findings will be transferred into regulatory action. Much of our work would suggest that NRC staff might not need to intervene at all. Instead it might best help safeness by merely providing industry-wide data for utilities. To give a specific example, assume that we continue to find that the amount of discretionary cash and how utilities spend resources is related to specific aspects of safeness several years in the future. Armed with such information, utilities might well adjust their internal allocations and/or more successfully seek rate relief for specific safety programs. The NRC would be in a position to provide verifiable, independent analysis based on an industry-wide basis rather than purely subjective, case-by-case guesses based more upon hunches than data.

Response K-2: From a technical point of view, I believe that the Team Performance study will provide several useable products by the end of the fiscal year. The Behaviorally Anchored Rating Scales (BARS) of team performance have been subjected to a repeated revision and analysis process, and the results suggest that the scales are capable of assessing team performance. In addition, the videotapes and other training materials developed during the course of the study may be considered a product that can be used to assist in control room crew training.

Response L-2: The most useful product of the research being conducted in the organizational factors area, regardless of the contractor performing the work, are the insights on the organizational factors believed to be important to safety performance in the commercial nuclear power plant. These insights are useful for the NRC as well as for the industry in general.

In order to provide these insights with a greater confidence than currently exists, additional technology development and implementation research is needed. By and large each contractor doing work for the NRC is only examining one or two plants in their project. While some of the tools being used are similar, most are different enough that they require their own validation effort. Consequently, there will be a lot of data on tools that have only been used at one or two plants. In order to make the type of generalizations useful for the industry or the NRC, larger numbers of facilities will be required to participate in some way.

For the NRC, the tools that we have been developing can be modified to be used in their ongoing regulatory activities. The functional analysis and behavioral observation technique can be utilized by other types of assessment teams or inspectors to:

- Identify the functional organization of the facility,
- Identify key managerial and organizational positions within the facility,
- Focus on behaviors relevant to understanding the influence of the organizational factors believed to be important in safety performance and,
- Understand the patterns of interaction and communication within the facility and their impact on performance.

With respect to the survey instrument that we have been using, while in and of itself it may or may not be used in a regulatory application, the acquisition of a database across several facilities, would be very useful in developing a profile of the culture within these types of facilities. A normative data set could be derived, against which comparisons for particular facilities could be made in future applications. This database would also be very useful in developing insights into the "safety culture" issue within the industry.

The integration of this data collected from these tools into probabilistic risk assessment (PRA) is another potential product for both the NRC and the facility. The development of this method; however, is even more preliminary and will probably not be realistically useful within the same time frame as the other products discussed.

Among the industry, these instruments provide the same types of insights useful to the NRC. They also provide tools for self-assessment to measure the effectiveness of change/improvement management. The survey instrument in particular is a very systematic way of describing changes in the organizational culture of a facility from one point in time to another, thus an indication of improvement in safety and operability.

<u>Response M-2:</u> Products that organizational factors research contractors have or will have developed by September 1991 cannot be implemented directly right now in NRC regulatory activities without additional technology development and implementation research. Some of them like the OCA and BOT could now be used directly by the industry to improve both safety and operability; and may have a bigger impact on operability than safety.

Response N-2: This research is long overdue; the NRC only recently initiated organizational factors research in order to identify relationships of organizational performance and safety, to acquire a scientific basis for regulatory activities related to organizational performance, and to utilize scientific (as opposed to best judgment) methods in performing such activities. However, the NRC has long ago incorporated organizational factors in many programs. Examples are the systematic analysis of licensee performance (SALP), the diagnostic evaluations, and the senior management process for determining the problem plants. So, a first implementation of the products of this research product *confirmatory*.

The research is, also, producing new information regarding the importance of organizational factors to safety. For example, work at the University of Minnesota identified relationships between financial performance and safety performance. Until now, the NRC has considered that monitoring the financial performance of licensees was beyond its regulatory responsibilities. The University of Minnesota work, however, suggests that, this may cause the NRC to miss valuable information related to plant safety performance. The work identified profiles of plant financial performance that can be trended for proactive regulatory actions. (Plant profiles are determined in terms of "management attention" and "management strategies" expressed in terms of financial resource availability, either from profits or from borrowed money (management attention), and the way the money is allocated (management strategies) to preventive (before the fact) or corrective (after the fact) programs.) Thus an outcome of this research is an enhanced understanding of the organizational factors affecting safety not only in terms of observables such as programmatic processes and outcomes but also in terms of more esoteric factors such as management attention and resource allocation. This understanding will enable the NRC to base its regulatory programs on a firm scientific basis and make them proactive and preventive as opposed to reactive and corrective as they are now. Thus a second product of this work is *the incorporation of new information into the NRC's regulatory programs*.

Lastly, this work is developing new methods and tools. For example, a big portion of this work is to develop a methodology for incorporating organizational factors into PRA. This work will result in a tremendous improvement of PRA which, thus far, does not adequately consider such risk factors as human error and organizational performance. Since PRA is being used for decision making in most NRC and licensee activities (plant design, licensing, modification, life extension, and decommissioning) this work will improve the NRC's ability to reduce the risk throughout the plant's life. Also this work is enhancing methods for assessments of organizational performance such as SALPs, diagnostics, or other inspections and evaluations. In addition, the work is developing improved performance indicators with early performance detection capability. Thus, a third product of this work is the *development of new methods and tools* for improving existing regulatory programs.

Response O-2: Don't forget to list as a planned product the UKAEA guide on "Management at Risk". This is a guide for senior managers who are at risk from growing public pressures to ensure public safety and to protect the environment. The guide is based on case studies of ten disasters.

Also, one use of NRC research is to focus attention on an important area. The result is when industry recognizes that NRC is getting smarter in that area, industry also does work in that area and improves performance in that area

<u>Question No. 3:</u> **Should we continue to focus our attention at the plant level, or should we go beyond the plant level? If we look beyond the plant level, where should we be looking (e.g., local governments, public utility commissions, utilities, parent corporations, the NRC, other)?**

<u>Response A-3:</u> I have few opinions on this matter, the discussion at Penn State (leading to the "yes/no" answer) was reasonable.

<u>Response B-3:</u> Based upon our nuclear safety background, we feel very strongly that the NRC should not continue to focus research at the plant level. This view is fully supported by our utility consulting group. Simply stated, the plants cannot be extracted from the environment they operate in.

Our interim Organizational Logic Model uses the term external influences. They are subdivided into three categories: regulatory/industry, business climate and public relations. In the regulatory/industry category, we recommend that you look at least into NRC, INPO, PUC/PSC and utility structure (e.g., nuclear utility vs. electric generating utility) influences. Business climate can be, perhaps, treated as a single entity in the second category while the community relationship would be a good example for the third category.

<u>Response C-3:</u> In our view the concern of this program should be the safety-related performance of the plant. Thus we are quite satisfied that the "dependent" variables in our research remain at the level of the plant. However, it is quite clear from our research that factors which influence the safety-related performance of the plants lie both inside and outside of them. Thus the "independent" variables, if you will, cannot be focussed solely on plant variables. Specifically, our research shows that utility-level factors create a context for the plants that in turn influences how the plants perform on safety-related indicators. At minimum, utility-level variables should be considered. Our research also shows that past enforcement patterns for a plant influence future performance on certain safety-related performance indicators. Thus the NRC and its enforcement policies and procedures should be considered in future research. We have no direct evidence of possible influences on plant safety performance of bodies such as local governments or public utilities commissions. However, we have found that utility financial performance and issues which focus (or distract) managerial attention affect plant performance. Thus a very plausible argument could be made that local governments or PUCs could affect safety performance through their effects on financial performance, allocation of management attention, and allocation of resources.

<u>Response D-3:</u> Our group is unanimous in its conclusion that the plant level is the starting point for our research and many of the projects currently under NRC sponsorship. We are also in agreement that looking at the plant level, exclusively, is limiting. Many of the activities that occur at the plant level are the result of corporate goals, initiatives and programs. To not study what happens at the corporate/utility level is to ignore some of the critical decision making that impacts on plant level behaviors. Our experience with a utility and the fact that it operates more than one plant provides us with the perspective that we must go beyond the plant level. Many

of our key plant level employees report directly to corporate staff members and without access to those corporate staff members, we are missing a piece of the puzzle.

The argument advanced above can certainly be extended to local governments and public utility commissions, but at this point I would see these agencies as less important in the research process. We believe that while the main research focus should remain at the plant level, we must be flexible and allow for additional activities at the utility/corporate level. Perhaps the best example of this position is the fact that to simply gain access to TMI we spent several months in discussion with many different corporate level individuals. Many of these individuals, under the current research focus, are not part of our research sample. They helped decide that what we were doing was important to the organization and now they are out of the research picture. As key decision makers and individuals who are organizationally tasked with issues pertaining to nuclear power safety, we would be much better off including them in our research activities.

Response E-3: Given the range of products outlined above, the regulatory applications focus should be on the plant; that is the item that is under NRC's control. I do not foresee the opportunity to regulate utilities or broader aspects of corporations. However, the research aspect of the programs must recognize the broader context of plant activities, and the constraints and influences imposed by them. The telescope of risk management and the onion framework provide descriptions of the various levels of influence to be considered.

The principles of systems analysis include the constraint that the scope of the study should be determined by the domains of influence of the client (NRC), and the rest is the "environment". Therefore the scope is set by answers to the question "what are NRC's domains of influence?" PUC's? State governments? Other agencies? Utilities? NRC should focus on these as well as the question: "how does NRC influence its own behavior?" As Reason has espoused, you can only manage the manageable; you just have to know what is manageable.

Response F-3: There should be no artificial limits in selecting the appropriate units of analysis for our study of organizational factors and plant safety performance. NRC should include plant, sub-plant, and external plant organizational factors in their studies of NPPs. Researchers must be allowed to go beyond the plant to the corporate level. They should also study the impact of other organizational variables (such as NRC, PUCs, INPO, and NUMARC) on NPP organizational and safety performance. For example, the Olson-Thurber study is currently focusing on "within the plant" (units within plants) and utility level organizational factors in order to understand the impact of organizational factors on the capacity to problem solve, learn, and perform better.

Response G-3: As researchers become more sophisticated in their research on Organization Factors at the plant level, it is inevitable that they will soon find that factors from utilities, local governments, public utility commissions, parent corporations, unions, the NRC, and others, are of varying importance to the organization and management of NPP's. The NPP related departments at the parent corporation, for example, have significant impacts on operations at the plant level. It is necessary to address these factors when they are found to be related to plant safety. However, a detailed and wide-ranging investigation of every segment of the industry and the regulatory body will prove to be costly and will obscure the focus of the problem. If the problem becomes ill-defined, it will be less likely that the products of the Organizational Factors research teams will be of much use to the industry or to the NRC for enhancing reactor safety. It is much better to focus our current efforts at the plant level, or at most, the parent corporation level, until we reach a more mature understanding of the problem. Further research into areas beyond the plant will come as a natural consequence as our knowledge evolves.

Response H-3: We believe that there is a substantial improvement to be made in plant safety by carefully examining and implementing safety indicators within the boundary of the plant itself. This does not mean that other factors are less important. However, since we have not been able to fully understand the internal factors influencing plant safety, we must first emphasize them. Therefore, recognizing the importance of local governments, etc., it should be the long term objective of the NRC to study these factors. However, the plant itself should be the primary focus in the near future. We suggest more focused research on the "intermediate" factors at the plant level which are more tangible and better understood by the engineering community.

Response I-3: Some projects (Minnesota group, etc.) seem to be finding good reasons to look beyond the plant level for organizational indicators of NPP safety. Common sense supports the idea that business pressures, constraints and resource allocation issues originating above the level of the operating plant may affect the plant in ways which can influence safety. Features of organizational culture influence the organization's members in a top-down manner as well. Thus it may be impossible to either understand or influence many plant-level phenomena without performing research at the corporate level. However, we believe that plant-level indicators, though they do not explain or allow control of all variations in safety performance, can be very useful to the NRC for trending and problem identification.

To go beyond the corporate level, to the external environment, may be a fine idea in the abstract, but for the purpose of developing useful, practical indicators it is probably inappropriate. At most, one might wish to model or describe how the plant or utility responds to changes in certain critical variables in the external (physical, social, political/regulatory, and business) environment, and factor this information into indicator design. However, such a model seems a very ambitious undertaking for this program.

Response J-3: Of course you know my answer to this question. Utilities are granted a license to operate a nuclear reactor. Let us study how this industry manages and organizes for safeness. The boundaries between the plant and other units of analysis within the legal entity we call a utility are established, in part, by utility management. For instance, are we to ignore engineering support if it is attached to headquarters but include it in our work if it is attached to the plant?

As noted above we need to understand the environment, context, structure and in recent years we have added emergent processes that influence the efficiency, innovativeness, compliance and quality of licensees. The utility, nuclear operations, the plant and key components of each need to be studied to isolate the contexts for individual and group action.

Our recent work has shown that utility and plant characterizations are related to the rate of violations and the rate of incidents in nuclear reactor operations. If we seek to explain and predict the safeness of operating reactors, why not let the combination of sound theory and empirical evidence guide us.

Response K-3: We probably beat this particular issue into the ground during the meetings at Penn State. I realize the position the NRC is in regarding expanding the research agenda. Nonetheless, I think at least some of the research groups will need to consider issues above the plant level. Referring again to the action research project, I noticed that, while most of the issues raised by operators related to the plant level, several key issues were associated with the utility (or corporate level) and several issues were even linked with NRC actions and regulations. Unless the research agenda focuses more on micro-level organizational issues, it seems hard to imagine maintaining simply a plant-level focus.

Response L-3: Going beyond the plant level is a necessary step in order to completely understand the organizational factors affecting safety performance in the plant. The additional factor, discussed earlier, external relations, bears on this point. The way in which the plant deals with corporate headquarters, and the way in which corporate views the plant, will affect critical decisions impacting performance. Similarly, the relationship that the plant has with the local and state agencies, the community in which it resides, the public utility commission, and the NRC will impact performance.

The inclusion of these external forces, does not have to take away from the plant being the focus of the research. What is needed is an understanding of how these external forces influence the plant's safety performance. At this stage in the development of our understanding of the organizational factors at the plant level, we would argue against a full-scale organizational study of the corporate or other external organization. More information needs to be collected at the plant, before we can take on the whole utility, the NRC, or the state and local agencies. Some understanding in the functional organization of the plant should include those units in the "external realm" that are known to be involved. This could also be accomplished by using performance measurements or indicators of the relationship between the plant and these other organizations.

Response M-3: Everyone will agree that we should go beyond the plant level to the utility, to PUCs and the NRC itself. But as I and several others like Ike Grusky said at the Penn State meeting, now is not the time. The research must mature beyond the N=1 sample at the plant level first. The usefulness of our research products to date do not justify making the jump yet. It will probably take 2-3 years before we are ready.

Response N-3: We should definitely study utility factors beyond what the research has considered thus far. Our current experience is that it is very difficult to isolate a plant from its headquarters. For example, the University of Minnesota work indicates that safety is directly affected by decisions and priorities set in the headquarters. Furthermore, we should definitely include external factors such as local governments, public utility commissions, industry organizations, and the NRC. NPPs are highly regulated; they are under continual oversight and must comply with an awful lot of -- sometimes even conflicting -- rules and regulations imposed without a systematic process. Thus we would not know weather internal or external factors have more impact on safety and how plants deal with conflicting safety rules and regulations unless we incorporate the "beyond the plant" influences. However, when we incorporate these external factors in our research, I do not think that we should use the terminology "beyond the plant level" because it may create unnecessary political issues. Instead, we should consider them as part of the overall organizational factors.

Response O-3: Yes, we should address the corporate level.

However, if for some reason we are unable to study corporate-level organizational factors, then a fallback position could be to continue studying the plant including the plant's environment. The plant environment we can define to include, for example:

- the amount of funding for maintenance,
- the decision of whether to renew the license and therefore continue to maintain the plant; or not renew the license and possibly run the plant into the ground,

Question No. 4: How important is accessing plants to do Organizational Factors research? What types of problems have been encountered, if any, in gaining access to plants attributable to each of the following: parent utility; plant; utility groups such as INPO, EPRI, and NUMARC; NRC research project manager; NRC management; your own management?

Response A-4: Access to the plants (including personnel and records) is clearly vital. As mentioned in #1 above, we have been fortunate in this regard. However, our data base is not completely typical for U.S. crew response characteristics. Note that we spent some time trying to gain access to videotapes for U.S. SGTR exercises (created for the EPRI ORE project), but were unsuccessful. I suspect that, with some more effort, we could have gained limited access; the point is only that the information was certainly not easily available.

Response B-4: Our research thus far has not necessitated any direct access to the plants. This will be of paramount importance in the validation phase.

We have formed a Utility Consulting Group consisting of representatives from GPUN, PG&E, PSE&G and Yankee Atomic. The function of the Group is to meet with us to discuss the approach proposed by us and to provide suggestions based on the knowledge of individuals and respective individuals.

In the validation phase, we intend to approach the Group with a request for access to one of their plants and we do not anticipate any problems, of course, providing that the timing is right (e.g., outside refueling outages) and that we can demonstrate a potential benefit to the plant management.

Response C-4: Gaining access to plants is very important. Our problems with access, where they have occurred, have come from the utility level. We have received excellent cooperation from the utilities in some instances. Greater support for organizational factors research from high levels in the NRC research organization would be helpful, in our view.

Response D-4: There is no doubt that the plant level represents the single most important level for doing our research. Our ability to define and measure organizational factors has its core at the plant level. We further believe that other levels of the organization are of prime importance but would not be able to answer our research questions without access to the plant.

We have had some difficulty at the utility level in gaining plant access. This has primarily been a time factor, although the suspicion of the utility with respect to participating in NRC sponsored research required us to conduct several meetings to assure the organization of our intent.

Our particular research program has had very little interaction with INPO, EPRI or NUMARC. About the only formal contact we have had has been to request documents from INPO and be told that we are not a participating organization and therefore cannot have the requested documents.

We have had no problems with respect to NRC research project manager, NRC plant project manager or our own management in the conduct of our project. Our RES project manager has been a valuable source of information regarding NRC protocol and how we move from one phase of our research activities to the next. We have yet to meet with the NRC plant project manager. At this point in our research efforts, we can say that our ability to gain access to TMI is the result of our previous involvement with the organization and that we hope our efforts to gain access to other plants for year two of our work will meet with similar success. We are relying on our contacts (both from the behavioral scientists and nuclear engineers on the team) and those of our utility colleagues to facilitate this process. As was the case with securing the utility with which we are working, we feel it is more effective to downplay the role of NRC in our work than to try and use NRC as our calling card.

Response E-4: Access to plants is clearly important, since NRC's point of reference is the plant--that is, what is licensed. Not having access to plants would be like attempting surgical research but without access to patients.

This program manager has experienced only one case of difficulty in accessing plant personnel. In the earlier work on training indicators, informal agreement was reached (via collaboration with NRC/NRR) with a utility to discuss the concept with the utility training personnel. They were very enthusiastic about the concept. However, when the question was raised by them with utility management, collaboration was squashed, citing INPO's opposition to performance indicator programs at NRC. I therefore have particular problems with the current process.

Response F-4: It is essential to have access to NPPs if we are to learn about the relationship between organizational factors and safety performance. This is especially true if we are to learn about how NPPs learn and improve. If AEOD and NRR are going to improve their methods for accessing plants, there needs to be more research and testing of assessment methods through NRC Research. We have had serious problems accessing plants. The risk adverse environment of NRC is a problem in gaining access to NPPs. The solution has been personal contacts and a network of industry friends outside of the official NRC chain of command. NRC is risk averse about research in the plants. Utility executives and plant managers are usually supportive of the effort if they are assured that they will get some feedback from the site visit and that it is not intended as a NRC regulatory action against that plant. They do not seem to be concerned about the amount of time taken for interviews. NPP respondents have been candid and open in their responses to questions about how their organizations problem solve, learn, and improve.

Response G-4: The "Principal Function Model" which we are developing in this project requires a detailed understanding of the plant and its functions--the processes of operation, maintenance, testing, design changes, etc. Since these processes vary from plant to plant, consent and cooperation from all levels of the utility are crucial in getting meaningful results. Access to a plant, therefore, is a critical factor determining the success of the project.

Due to the short history of our research project, our experience with the industry is limited to our early contacts with plants and utilities. These experiences show that several factors influence the success of the early contacts with the nuclear industry:

a. The attitudes that INPO and NUMARC hold toward organizational factors projects play a major role in the acceptance of the researchers. An overly critical or skeptical position by INPO or NUMARC is likely to be magnified at the utility or plant level. This situation may virtually kill the project before it even gets a chance to start. An open dialogue between the NRC and INPO/NUMARC to let the industry know about the nature and goals of these projects is, therefore, crucial to successful research on plant safety.

b. The project team is still trying to determine the fine line between what are the permissible utilities and plants on which to conduct research and which are not, from NRC management's viewpoint. On one occasion, the research team found that the utility or organization that we contacted was not the "right" one. This situation resulted in the loss of valuable time and energy as well as the increased frustration of the research team.

c. As for access to a particular utility or plant, we found that the attitudes of the upper management of the utility and the plant toward the project are crucial to the success of the project. Our early contact with the FitzPatrick NPP reflects this belief. We have obtained direct access to the manager of the plant and also support from several previous high level managers at the site. The smoothness of this early contact is certainly a necessary condition for our future field data collection. However, our experience with another NPP was not as successful, because of the reluctance of senior and middle-level management to get involved in a project of this nature.

Response H-4: As we discussed this issue in response to question 1, we think this is a potentially limiting factor, in general. However, due to the nature and scope of our research and the type of information we need, we have not encountered difficulty in obtaining pertinent information. It would, however be crucial to maintain a high industry involvement in the planning, performance, and presentation of the results of sponsored research. This allows the industry to gain insights to the objectives and findings of your activities. It also gives them a chance to bring their perspective into the individual research activities.

Response I-4: We believe that access to plants is important to effective research. Our particular research does not at the moment require intrusive or lengthy observations at plants, but rather requires access to the experience and knowledge of plant personnel at various levels. Therefore, we can work with plant personnel or consultants outside the plant, if necessary, and certainly need not cause any interference with normal operations. Later phases of our work, as in fine-tuning measures, may involve some direct observation, but it would probably be best performed in conjunction with plant personnel whom we have briefed or trained.

One difficulty we have encountered is the NRC's apparent indecision on whether or not we may approach (or have NRC approach) plant management to arrange interviews or visits. We are not privy to the internal situations at NRC which lead to this, so we are not certain of the level at NRC where the problem originates. So far, plant personnel have welcomed the opportunity to work with us on the development of measures of training program effectiveness.

At the Penn State meetings we heard NPP personnel express an interest in being informed and involved early in our research. We feel that such inclusion of NPPs would be a good idea, and would lead to a more cooperative attitude on the part of the industry. However, as mentioned in our response to Question 1, the ambiguity of the NRC's position as a regulatory body and a sponsor of research may make a fully trusting, cooperative relationship difficult to attain.

Response J-4: In a very practical way nuclear utilities and plants are a natural experiment. Without a systematic description of each and every one, the experiment continues with little learning. Yet, at every stage of the research, obtaining the cooperation of industry has been extremely difficult. For instance, without an NRC project responsibility, I was able to contact utilities, work with utility management and learn from their insights and experience. Under an NRC contract I do not and can not even contact utility managers without going through an elaborate bureaucratic process.

The NRC should seriously consider a cooperative approach to organizational research. Consider the power of an organizational data base sponsored by INPO, EPRI, and NUMARC. The data base could contain industry-wide information concerning management, organization and measured aspects of safeness. It would allow both NRC and industry to detach attempts to explain and predict from regulatory actions/reactions. For industry such a cooperative effort would help prevent direct and inappropriate transfer of tentative research findings into command and control regulation. It would also help chart how changes in management and organization influence safety, efficiency and profitability. For the NRC, such a cooperative effort would provide a sound technical base for the more detailed clinical studies that are an every day part of regulating.

Response K-4: I agree that this seems to be an important issue In our study we have had relatively little difficulty getting access to Diablo Canyon and Limerick, but this has been because of the relationships between Tony Spurgin and Diablo personnel, and between Kathy Gaddy and Caskie Lewis (General Physics) and the Limerick Generating Station. Joel Kramer has been fairly creative in getting other research groups in to collect data with us--for example, two other research groups gathered data with us during data collection efforts at Diablo. We had to be careful not to inconvenience the plant, however, and to avoid making unreasonable demands on their time.

Response L-4: Access to the plants is very important in conducting organizational research. One of the key issues in this research area is the notion that these organizations, nuclear power plants, are unlike other organizations upon which most of the literature and results in organizational factors research is based. Consequently, empirical data needs to be collected from these facilities. Although time consuming and often resource intensive, the most useful organizational information comes from field research conducted in the particular organization of interest. Not enough of that data exists to date to say that we have an empirical base for our understanding of the organizational factors important in nuclear power plants.

With respect to problems in gaining access to plants, the root cause appears to be the NRC itself. Even if the contractors can negotiate the requirements for Fitness for Duty with the facilities, as contractors to the NRC, a letter from the NRC is often required to meet the background information and security requirements. RES is not capable of writing that letter and must find a sponsor in NRR, either through a user need or licensing, to write it. This process has created problems for us in obtaining unescorted access in our accident management research. Unescorted access is sometimes necessary for the types of research that we are conducting, but it would also place less imposition on the utility in not having to provide the contractors with escorts.

In the past, as contractors, we have not experienced much difficulty in gaining access to the plants. In fact, we have good relationships with many local utilities and have conducted several research projects at various locations. NRC's new process, requiring that the LPMs be contacted first, has created a new barrier and sometimes difficult step in maintaining the existing relationships with the utilities.

Response M-4: Everyone will agree that access to plants is critical to doing useful Organizational Factors research. The process we are now following while onerous is reasonable, but if HFB approval in NRR is added to the process, we could be dead in the water. Once most of our contractors like UCLA hear about this, their responses to this question would change to being even more negative. To put it succinctly, the problems in gaining access to plants are attributable directly to NRR mid-level management, namely, some NRR Project Managers and Directors and DLPQ. The Director, NRR, contributes to the problem somewhat by not permitting research at "bad" or "problem" plants. To an extent our Division Management does not fight hard enough for our cause. NRC Office Directors and the EDO may not be aware of the problem. The present Commissioners are probably aware of the problem. Let's continue to figure out the best way to ease or eliminate the restrictions by getting the industry to support the research at the highest levels of the NRC. We should not, however, forget that the research must be judged as being useful before we can really be successful in doing this.

Response N-4: It is imperative that participants in this research have plant access. The work takes advantage to a maximum degree of publicly available information (scientific literature and data). However, if it not combined with on-site plant visits and industry participation in the interpretation of the results, the work will be lacking in many aspects: (a) testing the validity of the methods and results, (b) improving the products, and (c) gaining industry support by demonstrating the value of this work as enhancing both the NRC and the industry goals.

My experience with plant access is that tremendous barriers have been imposed upon RES to communicating with licensees. Although I agree that licensees should be carefully approached, the existing processes are very tedious; this situation results in overburdening the NRC and contractor staff, wasting resources, and, hence, affecting the quality of the work.

Response Q-4: Plant access is important. In addition, a complementary approach to survey industry practice is to visit NRC regional offices. For example, our project on integrated surveillance starts with a survey of the extent to which plants already integrate surveillance with preventive maintenance. I'm arranging for visits to three regional offices to survey this information. This approach should give a broad view of current technology with a small expenditure of effort.

<u>Question No. 5:</u> **What lessons have been learned to date doing Organizational Factors research in a nuclear regulatory setting, that is, working with and for the NRC and with the nuclear industry?**

<u>Response A-5:</u> To discuss the advantages and disadvantages of working this environment, it is worth pointing out three characteristics that make our operating crew project somewhat different from the other projects: 1) we are supported by a grant rather than a contract, 2) the student working on our grant has strong contacts with a utility/plant, and 3) our work strongly interfaces with research efforts on individual behavior, and with research on PRA.

Perhaps because of the first point, we have had considerable freedom in approaching the problem, and have not been overly constrained regarding reporting requirements. We are extremely appreciative and grateful for this freedom; I think the results of our work show that we have taken advantage of it in a productive manner. On the negative side, I don't think that we have been diligent enough in keeping Joel and you informed on or progress. Clearly, we have to work harder on this issue in the future. (I'm not sure that administrative changes, e.g., more frequent reporting requirements, would be productive in the long run.)

Because of the second point, we have been able to conduct interviews with individual crew members, interview training instructors, and obtain video tapes for SGTR training exercises. I suspect that, without our student's contacts, this information would be much more difficult (although not impossible) to obtain.

Regarding the third point, I think our work is a little outside of the mainstream interest of other NRC contractors doing research on organizational factors. As a result, we have not been able to gain as much as we would like from discussions with the other contractors (whereas we have had very fruitful discussions with Emilie Roth and Harry Pople). Clearly, we need to be sensitive to issues addressed by researchers working on large organizations (and vice versa), so some interaction is useful. On the other hand, I think that it would probably be more productive - both for us and for other contractors - to spend more time interacting with groups interested in individual and crew training and performance as well as groups interested in the incorporation of human behavior into PRAs.

As a final comment on the research environment in this area, I am a little disappointed (but not overly surprised) that the gap between engineers/PRA-types and behavioral scientists does not seem to be closing very fast. It is also disappointing to see that some of the division seems to be motivated by fear of potential budget cuts in this research area. It would be nice if the different research groups could interact to a level where they could "buy in" to each other's approach, rather than just communicating and informing. Perhaps several "one-to-one" workshops would be useful.

<u>Response B-5:</u> Although we have been involved with a few contracts with the National Laboratories as subcontractors supporting NRC research, the current organizational factors work is our first direct contract with the NRC.

Historically consulting firms have been labeled, by and large, as either "regulatory" or "industry" supporters. Hence, we had some reservations about accepting work in this area.

Nevertheless, as practitioners of probabilistic risk assessment (PRA) and human reliability analysis (HRA) who have taken part in the evolution of risk analysis methodology over the past two decades, we realize how significant organizational factors are in the "anatomy" of catastrophic accidents and we believed that we had something to offer to the industry; working in the current NRC-sponsored programs in organizational factors appeared to be the most timely and most influential pathway for us to contribute. We firmly believe that the program, if conducted in a non-threatening and responsible manner, will be accepted by the industry as one means of improving performance.

To this end, we decided to involve several utilities in our research. Shortly after embarking on the research, we visited several NPPs to present our general approach and objectives and succeeded in assembling a "consulting" group of personnel from interested utilities to help us. (The charter for the group clearly states that their participation does not imply their endorsement of our framework.)

Much of these utilities' acceptance of our participation and their willingness to participate stems from their prior knowledge of our PRA and HRA work and of our safety philosophy; however, their participation also reflects the views of the utility management in 1) recognition of the importance of organizational factors in NPP safety and 2) wanting to cooperate with the NRC in the research so that any useful derived information may be disseminated.

As the research progressed, however, we have been instructed about 1) limitations regarding visits to certain NPPs, 2) avoiding data collection on "individuals" at an NPP, and 3) avoiding data gathering at the corporate level. Such restrictions provide difficulties in gathering sufficient amounts and varieties of data to validate our framework for linking OFs to terms in PRA models. As a result, the quality of our product may suffer to the point where the utility consulting group and NPPs might not feel they are benefitting any longer.

We believe the environment could be enhanced by the NRC's finding means to reduce the anxiety of nuclear utilities. This could be better achieved by a clear statement of the NRC's intentions for using one or more of the OF "products", how a specific OF research program contributes to these aims and to make clear how a utility's cooperation would help the given research but would not subject them to fines or penalties for items revealed during the research. One way would be to gain acceptance and cooperation through NUMARC (e.g., as promoted by NUMARC participation in the workshop at Penn State) and possibly involving EPRI and INPO downstream.

Response C-5: ADVANTAGES, there are a number of advantages to doing organizational research in this setting, including the following:

1. There is a rich array of data available from an entire industry (publicly-held utilities) allowing comparison across plants and across

companies. While data are not always what a researcher may need, it is nevertheless fairly abundant. We have also found NRC personnel to be quite open and informative about the nuances of the data - i.e., how its interpretation might be affected by changes in data collection methods, regulatory policies, etc. NRC personnel are knowledgeable and have been helpful in identifying data sources outside the NRC as well. On the downside, documentation of the data is often inadequate, and may consist of idiosyncratic knowledge held by an individual. This has led to considerable time costs for figuring out the data and making it useable for research. We understand there is now a data management system within NRC - we have not attempted to use that resource yet.

2. The supportiveness of the NRC Research Division to the fundamental research goals of the projects is a real advantage. While there is rightly emphasis on the need for applicability of the research, there is nevertheless a recognition of the importance of the discovery part of the research process--that we must "get it right" before we try to claim a product. We appreciate the recognition by NRC of the roles and responsibilities of NRC as distinct from that of the contractors. While we are expected to inform the NRC, we are not expected to do their jobs.

3. Your research organization has attracted an exceedingly capable group of researchers with whom we in turn have the opportunity to interact both formally (in the two year meetings that have been held) and informally. This cadre of colleagues provides a very rich and rewarding opportunity to learn.

DISADVANTAGES, there are a number of disadvantages to doing organizational research in this setting, including the following:

1. Disadvantages of working in this environment also exist. One is the sensitivity of the plants and utilities to allow researchers associated with the NRC access to plants, people and information. This is exacerbated by what we perceive to be the utilities' lack of trust in the NRC to use the results of our research sensibly. In particular, we believe there is fear that when NRC researches identify something that correlates with safety, the NRC will use it blindly as an enforcement tool. NRC could help itself and help us by clarifying the many ways in which it intends to use the results of this research, and explicitly addressing concerns about one-shot significant indicators being used as a club. During the meeting at Penn State, there was some discussion about not doing research on issues that are outside the "control" of NRC, which in our view reflects confusion even on the contractors' parts of the value of this research to efforts other than direct enforcement. If potential uses are unclear or debatable among contractors, the research is understandably threatening to utility and plant executives.

2. Another disadvantage we perceive is the lack of teamwork and mutual support among users in NRC - Research, NRC, and AEOD specifically. This adds considerable uncertainty and political pressure at times. It is one thing to serve the customer, it is another to serve an unwilling, or unsupportive, or in the extreme an antagonistic customer. Within NRC, a researcher would hope that everyone wants the research to be successful.

Response D-5: Perhaps the most surprising lesson we have learned is that the NRC has assembled a wide variety of talented investigators who are currently engaged in rather diverse approaches to the problem of nuclear power safety. This allows us to access investigators who have more experience in this type of work and discuss with them our ideas and their successes and failures in related areas. In our discussions at the State College conference it became very clear that the increased dialogue among investigators was important for all researchers in this area.

Additionally, one very important and central theme to our research efforts is the time frame involved in this type of work. Given that researchers must simultaneously satisfy the NRC and the participating organization, time frames become very extended. As an example, the time between an informal agreement between ourselves and a utility and the formal agreement was in excess of 60 days. As you are well aware, it took us about three months to get to the point of the informal agreement, so it was at least 120 days between the beginning of the dialogue and the confirmation that we could officially work within the plant. Add to this the time it takes to have our instruments approved by both sides and the required advance notice to schedule meetings at the plant, and you can see that six months only gets you ready to start a project, and that is if everything goes smoothly. I do not believe the time frame can be appreciably reduced, but both the researchers and the NRC need to be aware of this fact of doing this type of research.

Finally, as researchers, our affiliation with NRC seems to be a mixed blessing with respect to gaining plant cooperation. Most decision makers at the utility with which we are working see the fact that we have been awarded a contract from the NRC as a signal that we are engaging in important research, research that should be of interest to their future success. On the other hand, the utility is also very suspicious with respect to why the research is being conducted and how the results might be used in future regulatory actions. It would be safe to say that the NRC sponsored research simultaneously opens and closes doors for investigators. I believe we, as researchers, can do quite a bit to reduce the negative aspect of the situation by focusing our attention on the potential benefits to the plant. NRC can help in this effort by having a more clear cut distinction between basic research and research designed at future regulatory activities. At this point it seems that utilities consider all research geared toward future regulations.

Response E-5: From my perspective, there are many benefits in performing work associated with organizational factors research in the uclear power setting for NRC. NRC has taken a practical approach in permitting its contractors to pursue the objectives of the research programs without unnecessary constraints on approaches and unreasonable expectations of early answers. This area of research, the influences of organizational influences of safety, is one that is truly in its emergent state; no one method or technological discipline has any obvious ascendence over others, and it is therefore important that this research proceed in diverse and sometimes unpredicted ways. I have not experienced any other federal agencies, nor other organizations in the nuclear power community being so farsighted involving an area of technical (rather than political) importance. This openminded, multi-pathed approach will hopefully continue.

The difficulties in this area are two-fold; first is the effect of the apparent industry "mindset" that work in this area is potentially harmful, and second is the practical problem of the NRC contracting process. First, the reluctance of the larger industry community to accept the importance of this area sets difficulties in being able to have open and frank discussions in this area. While this can be expected in any research where people are being scrutinized, I have found this defensive response more extreme in the nuclear than, say, the chemical process industry. I believe that the "wooing" of the politically important groups in the industry is an important mitigative step, especially if benefits to those groups can be demonstrated from the research. I would suggest that if discussions can proceed in a quiet manner with NUMARC then mutually interesting products can be identified from the existing work. This is similar to the way in which NRC (AEC) sponsored research in PRA with WASH-1400, which is now an important methodology used by all utilities mostly to their own advantage. If a similar mutually beneficial perspective can be found, then I think the world would be a better place.

The difficulty with the NRC contracting process is that of apparent extensive delays between the NRC technical manager wanting a contractor to add or change scope, and the contractor being given authorization to implement these changes. My experience has shown delays of several to many (~5) months in being able to respond legally to these new directives. If possible, this research would be performed more effectively and at less cost if the contracting process were made more efficient. For example, delays in starting new phases or adding new staff play havoc with personnel planning in consulting organizations where staff with no project coverage for only a few weeks are potentially at risk for lay-offs. The recent economic climate has severely limited the willingness of commercial organizations to carry personnel without project coverage because of pressure from customers (including the US government) to reduce overhead costs. In other words, the delays in the contracting process can materially weaken the products.

Response F-5: The primary lesson learned about doing NRC sponsored research on organizational factors in nuclear power plants (NPPs) is that "success is failure." The better the research on the impact of organizational factors (success), the more likely the industry will put pressure on the NRC to cut the funding for future research (failure).

NRC Office of Nuclear Regulatory Research (NRC-RES) program managers have been well organized and focused on the important tasks to be done in this research area. However, there needs to be long term, predictable support at higher levels in the NRC (and with the industry) for organizational factors research to have a major impact on improving safety at NPPs.

A major advantage of the research environment associated with the NRC-RES is the commitment to the mission and understanding of the findings by the program managers. The two annual meetings of the contractors and consultants doing organizational factors work is an example of the strong support that NRC-RES gives to this area. Another advantage is the availability of data for basic research. NRC-RES projects allow us to test complex sets of hypotheses (models) that would not be possible without the support of NRC. Obviously the NRC-RES financial support to do the work is a major plus.

The major disadvantage of the research environment is the uncertainty about whether NRC will continue funding the area. This is not a complaint about competition, it is a comment about the political realities of the agency. Human factors is not high on NRC's research agenda. Organizational factors research has an even lower at NRC. At the upper management levels at NRC, there is a general distrust of the social sciences and behavioral science data. This often changes when an incident or crisis occurs that seems to be linked to human factors and management, but then judgments are made about complex organizational phenomena without data. The utilities often have more trust in our work because they see the importance of organizational factors in improving safety performance in the NPPs. Utility executives often hire management "consultants" and are used to working with behavioral scientists, unlike their counterparts at NRC. Social scientists in an engineering world will always have a tough time. Engineers in key NRC management positions are often skeptical of NRC-RES funded organizational factors research and do not used the research findings in their evaluation of NPPs.

<u>Response G-5:</u> Although we joined the NRC Organization Factors research program only last October, there are several lessons that we have learned within this short period.

a. Our contacts with NRC have been amicable and frequent. Access to NRC documents is easy and we are kept up-to-date on new NRC publications and activities. The project has benefitted greatly from this aspect.

b. We strongly feel that contact with different utilities is critical to our field experience and to the development of measurement instruments. This effort has been hampered, however, by ambiguous NRC instructions. There are, for example, restrictions on which NPPs the research team can visit. Although the NRC instructed us not to study plants with a poor safety record, it did not give us a list of such plants. After making contact with the Palo Verde NPP, the research team was informed by the NRC that it was rated as having a poor safety record. By not having a list of poor NPPs, we wasted valuable time and resources. Furthermore, a senior advisor, John Leonard (Vice President of Long Island Lighting Company), arranged for the research team to meet with the senior managers at the Nuclear Utility Management and Resources Counsel (NUMARC) and the Institute of Nuclear Power Operations (INPO). Even though the NRC states that we should work with industry personnel, it discouraged this meeting. We feel that the NRC should be encouraging such contacts between research teams and the nuclear industry.

c. Our experience with the response from the nuclear industry on the Organizational Factors research is mixed. Some utilities have shown a great deal of interest and enthusiasm, while others have clearly rejected our attempts to study their organizational and management system. The overall impression we have obtained from the industry is that these studies can only be useful and effective, if the research team works closely with people involved in the real-world and day-to-day operations of nuclear plants. Unless the research team makes frequent visits to nuclear power plants to gain detailed understanding of operations, maintenance, training, and other activities at the sites and develops workable measurement instruments, the result of these studies will be viewed as "purely academic" and produce limited influence in future plant management and operation.

We suggest that the NRC make the necessary approaches to the nuclear industry, particularly NUMARC and INPO, so that the industry is made fully aware of what is occurring in the area of Organization Factors research. With the collaboration of the industry and the research teams, these studies are more likely to be considered of some value by the industry.

Response H-5: We think that one of the strengths of working for NRC is that we are dealing with an independent body and, therefore, the research is more objective. On the negative side, since the work is performed for the regulatory agency, there is more difficulty in obtaining pertinent information from the industry. The environment can be further enhanced by recognizing the limitations stated above in defining the long-term objectives and expectations from the sponsored activities. In particular, we feel that the overall objectives of the research can be better served if the interactions between the wide range of research activities are better defined (e.g., between PRA related research and pure organizational behavior research).

Response I-5:

Advantages:

The prestige of the NRC eases access to some sources of information, compared with the access which would be available to independent researchers not doing NRC-sponsored work. This is not unique to the NRC, but would apply to many Government agency sponsors.

The NRC staff's understanding of the conditions under which our research is performed helps to ensure realistic expectations and appropriate assistance from the COTR [Contracting Officer's Technical Representative] and other NRC staff members. The community of contractors provides a helpful network of colleagues, and the annual meetings encourage information interchange among projects.

Disadvantages:

The NRC in some business communities is regarded as an example of government over-regulation; occasionally we receive a somewhat skeptical or suspicious reception because of this. This can usually be remedied by a discussion of the goals of our research, and of the openness of the NRC to new learning.

The political contingencies of the NRC's mission and activities lead to uncertainty regarding long-term goals of our projects, desired outcomes, the stability of the research program. Examples: question of whether we are doing research on "management" or not; issue of whether we may have to access to plants.

Possible improvements:

It would be helpful if the NRC could develop long-range agency mission and goals, commitments to long-term programs, independence from short-term changes in political climate.

Continue to develop more cooperative, trusting relationships with industry; we understand that this and the suggestion above may in fact be incompatible, depending upon the NRC's mission definition. Efforts to work with the industry in research on managing for safety currently may be confounded with the regulatory or disciplinary roles of NRC. Some research projects in this program have met with a very positive attitude from industry personnel. Perhaps it would be useful to determine those factors which seem to foster such a positive reaction and the factors which cause industry to react negatively to other research approaches, and apply what is learned to design of future projects.

Response J-5: The link between verified research findings and regulatory action is far from direct. Attempts to impose a regulatory philosophy on organizational research yields bad regulation and poor research. The NRC should seek to understand before it regulates. Thus, rather than concentrating on potential factors NRC believes it might control via intervention, it should seek to develop and test models that allow us to explain and predict measurable elements of the diverse, complicated concept we call safeness.

The projects essentially ask researchers to help improve safeness in a complex dangerous technology by developing and partially testing logically sound, empirically supported theories. Yet, NRC has started and stopped the research program so often that it has lost the diverse, integrated research teams it needs. Each time the projects are restarted, we see the same process. Individuals without a research history, starting from scratch, identify much the same variables as potential candidates for predicting safeness. Of course the variables are given slightly different labels. And a few plant visits are used to show that altering a few of the variables might make a difference. There is the need for a delicate balance between using a sustained cadre of experienced researchers and bringing in the ideas of less experienced scholars.

Consider the research program implied by NUREG/CR-3215 that was outlined in the early 1980's. If we had collected the data on organizational conditions throughout this period it is quite possible that we would be able to explain and predict major proportions of variation in some aspects of safeness. Further, new researchers could build upon prior work and more carefully select the licensees where demonstration projects might be most useful.

Organizational analysis combines basic and applied research. It is not the application of scientific findings from other disciplines. Thus, the time-frame for implementation is years not months. The long time-frame is not as much of a limitation as one might think since alterations in environmental, contextual and organizational factors may take years to influence safeness. NRC needs to consider a long-term program of research that yields a more complete understanding of the management and organization of nuclear facilities rather than building RFPs around a series of near-term products for immediate implementation.

Response K-5: One of the lessons we have learned is that type of research that we have been conducting for Team Performance is at the opposite end of the spectrum from more cut-and-dried laboratory research. For example, logistics and coordination issues have proven, at times, to be as difficult as the technical issues. '· have experienced difficulties monitoring and coordinating activities of the various members of the research team, resolving internal differences of opinion within the group, and obtaining and maintaining commitment from personnel at the nuclear plant at which data was collected.

In addition, the issue of conducting research that addresses NRR needs has been somewhat problematic. With Team Performance, for example, the NRR needs and interests which were initially driving the study have changed over time, until they seem somewhat ambiguous at this point. It feels unsettling to be unsure if what we are doing is going to be valued and/or utilized. Further, focusing on NRR needs led us to think primarily in terms of a product-orientation. One result was that we initially tended to view our work in fairly concrete, rather than conceptual or theoretical, terms and to overlook or discount some relevant areas of research. Overall, I think we should try to keep both the need for a product as well as the need to conduct genuine research in mind when we conduct additional research for the NRC.

Response L-5: The nature of the relationship between the NRC and the utilities permeates our role as contractors to the NRC and consequently sometimes limits the type of relationship that we can have with the facility. It is critical to gain the confidence and support of the facility you are working with in this type of research, and to do that within the context of a regulatory setting, as an extension of the regulator, is not an easy task. It can be facilitated by:

- Involving the facility early in the process,
- Providing the facility with products useful to their needs,
- Avoiding evaluative statements in the feedback process,
- Discussing the benefits of the results of the research in terms of how the regulators evaluate organizational factors in the future and,
- Stressing the fact that this is a research endeavor and not a regulatory process.

Even if a good relationship is established with the facility, issues still remain between the researcher and the regulator. These can include:

- Scientific goals versus regulatory goals,
- Bureaucratic protocols and barriers to gaining access to the facilities

and,

- Lack of acceptability of this type of research in an engineering environment.

Although the disadvantages of conducting this type of research within the regulatory setting seem significant, positive aspects include the public availability of information in a regulated industry and the financial support available because of the potential impact on public health and safety concerns.

An important step to enhancing or optimizing the environment in which this research is to take place, is for the regulator to try to inform the industry of its intentions in this area. The source of concern for many of the facilities is not knowing what the NRC intends to do with the information it collects in the organizational factors area. This may in fact be due to the NRC's own uncertainty about what role it will play with respect to organizational issues and their influence on safety performance.

Response M-5: For the most part, doing Organization al Factors research with and for the NRC can be quite frustrating for researchers because political issues and problems dominate rather than technical issues and problems. This is a natural given the industry we regulate, but is made even more difficult because of the sensitivity associated with the topics of organization and management. The environment could and should be enhanced by more frequent interactions at the Commission level, EDO level, and Office Director level within NRC and at higher levels within NUMARC (and INPO). Within NRC we've got to somehow force mid-level management to back off, if we are to accomplish our technical objectives which must emphasize useful products.

Response N-5: There are many advantages to performing organizational factors research within a regulatory setting:

1. Owing to the breadth of its regulatory applications (on-site observations, audits, inspections, in-depth evaluations, performance data monitoring, and risk assessments) a regulatory setting provides an environment for comprehensive, multifaceted, and multidimensional studies on organization and safety; it encompasses processes as well as outcomes, structures as well as mechanisms, overall effects as well as specifics. The work (individual projects) is performed by interdisciplinary teams; the behavioral scientists and engineers are working together for a sound product with respect to its scientific as well as its practical value. Also, the research builds on relevant work and is integrated through information exchange meetings and interaction among the individual project teams.

2. The integrity of the research processes and results is ensured because of established regulatory research rules and guidelines and careful reviews by many internal and external committees. Finally, the NRC's Office of Research (RES) provides an environment for a well thought out work planning and schedule.

The main **disadvantages** to performing organizational factors research in a regulatory setting result from the very tedious contractual processes as well as the unreasonably complicated process for coordinating plant visits by the researchers. Thus, the NRC provides a highly bureaucratic environment where, at every step, one has to go through many layers of signatures and checks. This results in a lot of frustration for participating contractor and NRC staff and affects schedules and milestones.

Response O-5: The importance of management to operational safety has long been recognized. For example, the most important regulatory response to the SL-1 accident in the 1960s was to require the operating organization to exert stronger management control over reactor operations. Another example is the importance placed on management in an IAEA report that describes internationally accepted safety principles. However, despite this clear recognition of the importance of management, NRC has done little research in this area. Therefore, in the area of organizational factors, where not much research has been done, current research can contribute substantially to our understanding. The fun of working on these relevant and worthwhile projects should help to attract top people to perform this research.

Question No. 6: **To what degree do the current Organizational Factors research activity's current focus and out-year plans, methods for doing the research, and sought after products over the next 2-3 years address issues you believe are important to plant efficiency, and the NRC regulatory mission of enhancing safety?**

Response A-6: The program, as a whole, is excellent, having breadth and depth. Some minor comments:

a) Program Focus. One of the program's foci, the quantification of risk impact, is viewed with extreme interest by many people. (At today's review meeting for the M.I.T. program on enhanced nuclear safety, for which John Carroll and Connie Perin are leading the management and organizational factors research element, a number of people from participating utilities were quite curious as to the progress of the work in this area.)

b) Program Focus. At the Penn State meeting, I heard a number of viewpoints concerning the measurement of "safety." Belonging to the school of thought that states that "risk" is, in principle, the best measure of safety (where risk may represent a vector quantity), I didn't quite understand the source of controversy. Since the definition of safety is central to the program, it seems worthwhile to get people to come to some consensus on this issue.

c) Research Methods. As mentioned earlier, engineers and behavioral scientists still need to close the gap between the two camps. The PRA groups need to have behavioral scientists on their teams, and the behavioral scientists need to have engineers on their teams. Some groups are doing this already; the practice needs to be extended to more groups.

d) Products. Connections between organizational factors and PRA models/results are extremely important. It appears that an upcoming issue, that of shutdown safety, will require definition of these connections even more than the issue of operating plant safety.

e) Plans, etc. One area that may have escaped detailed attention involves organizational factors for groups somewhat larger than the control room crew but smaller than the entire plant organization. If our model is to be used in conjunction with the larger scale studies, it seems that the connections between the two need to be better defined.

Response B-6: As pointed out by the U. of Minnesota group in NUREG/CR-5437, Organization and Safety in Nuclear Power Plants, there are several measures of "plant efficiency" that are used in the NP industry. These measures include availability, reliability, critical hours and forced outage rates as well as measures of thermal efficiency such as heat rate. The authors point out that several of the performance indicators used by INPO and the NRC are related to availability rather than safety. However, the correlation analyses reported in the NUREG showed that an efficiency measure like critical hours could not be correlated to forced outage rates and the authors concluded that efficiency is not related to safety. The group, as have others, pointed out that achieving high plant availability may be at the expense of safety. (It is noted that in the same document, page 65, the group defines another type of NPP efficiency which is related to backlog measures, i.e., maintenance requests, design changes, generic issue resolution and drawing update.)

We and our utility consulting group also conclude that availability or plant capacity factors taken alone are not valid measures of safety. It is noted, for example, that both TMI and Chernobyl were enjoying high capacity factors just prior to their respective accidents. However, some other measures of efficiency are related to safety such as forced outage rates (FOR) (which relates to potential initiators of accident sequences) and limiting conditions for operations (LCOs) (which relate to the unavailability of safety systems).

Analyses to improve "plant efficiency", e.g., to reduce the FOR, uses tools and models of reliability engineering which are closely related to analyses used in probabilistic safety (or risk) assessment. For example, both types of analyses seek to identify and quantify the root causes of unplanned transients (initiating events). Several of the current OF programs are addressing the PRA and maintenance modeling issues. Such transients do include some of the "performance indicators" being used by the NRC, such as automatic scrams or inadvertent initiations of safety injection systems.

Our personnel, with extensive background in PRA and plant availability analysis, believes that the current OF programs that address the causal aspects of efficiency and nuclear safety at the "hands-on" or operational level are more likely to support the NRC regulatory mission than some of the other programs that are oriented toward finding mathematical correlations of overall plant outputs versus financial resources. However, results of research on the effects of business climate, for example, may provide inputs as "external influences" to strengthen our framework.

Response C-6: Our response will focus on four issues which we believe are central for the program to address in order to meet the needs of NRC and the industry:

1. The first challenge is to develop vehicles for successful "technology transfer." Specifically, vehicles are needed for joint work by researchers and users, to take the research products and develop them into useful tools. Contractors should not be expected to do this alone, for they do not understand the users' responsibilities. However, neither can contractors throw results over the transom and expect users to make something useful of the research, for they do not understand the nuances of the results.

2. The search for organizational indicators of safety should be conceptualized as a two-stage search. Early research should be seen as identifying core processes that produce safety, and then the search should be focused on organizational factors that support or impede these core processes. This approach enables statistically significant results to be interpreted in an appropriate context, which is in terms of their impact on core processes that produce safety. I do not believe it is useful to think of a single organizational variable, per se, producing safety, nor to search for them as though they might.

3. We need to find ways to build on each others' work where appropriate, and to avoid reinventing the wheel. One specific hand-off which should occur is from organizational factors researchers to PRA methodologists, so that appropriate organization factors get incorporated into their models.

4. Despite cautions of some people, we believe researchers should engage in some pruning of dead branches of theory whenever we can. Mostly up to now researchers have engaged in expanding the number of factors we consider. However, some factors which we had reason to believe are important to safety will empirically show themselves not to be important as other related factors. Projects should communicate their non-results, and the program should take every opportunity to prudently narrow the list of factors in order to focus attention on the most promising areas.

5. There is some need to draw a conceptual diagram to show how all the projects relate.

Response D-6: After attending the State College conference it was clear that across all the current research programs we have a wide variety of approaches and variables under investigation. At this point our group is still trying to develop a cognitive map of how the projects go together and where the projects might be heading during the next 2-3 years. I believe a useful product would be a document showing how the current projects fit together and how future efforts will be built on the results of what we are doing now. As a new research team, we understand our project goals and we have some insight into the goals of several of the other projects. What we are looking to better understand is the linkages among the 10-11 projects that are currently under this research effort and how they may, in the future, feed into additional research efforts.

Response E-6: As discussed in the above question, I believe that the most important requirement in the next 1 to 3 years is demonstrate unarguably that organizational factors have a critical influence on safety, and that a small effort should provide a post-mortem of recent significant events showing they largely were the result of weaknesses in organizational factors. Awareness is the issue. Perhaps this could parallel the study undertaken by OSHA as a result of the Philips explosion in Channelview, Texas.

Response F-6: NRC-RES needs to deliver several practical tools for AEOD and NRR immediately (within six months) as well as a research agenda that provides results that can be implemented in the short term (within one to two years). The research agenda should focus on immediate problems facing NRC and the industry. Several ideas for immediate (one year) research objectives are discussed below.

The AEOD diagnostic evaluations need to be evaluated for impact. Did they have any impact on NPP performance? A formal evaluation would help AEOD and it would be another source of basic research that could produce better tools for evaluating NPP safety performance.

Other topics for important organizational factors research should be pursued within the two to three year timetable. Research should be done on the impact of the aging work force at NPPs. What has been the impact of the growing size of the work force at NPP sites? Although sensitive, more research should be done on poor performing plants. NRC Research should start research that in the following areas as soon as possible (ideally within three years): Why are NPPs that are good, stay good? The performance indicators work should continue with a focus on using new (more recent) data and feeding the variables into the PRA work. New performance indicators data needs to be added to the data base to test the hypotheses in our models. The data that we are using are old and in some cases coded differently than what is now being collected by the NRC. NRC should develop a training program for resident inspectors and others on organizational factors and plant performance. Acquainting the RIs with simple organizational factors that seem to be related to plant performance (e.g. the capacity of the plant to problem solve) would be a way for them to be an early warning system for potential safety performance problems. There should be a study of industrial safety/safety attitudes and its relationship to NPP safety performance.

NRC Research should promote the sharing of information and data among the contractors and consultants though E-mail, standard distribution of preliminary research products, and periodic meetings of the research group (e.g. American University and Penn State meetings).

Response G-6: The current NRC research activities on Organizational factors seem to emphasize basic research, such as hypothesis testing. These efforts are all very important during the early stages of research. However, it should also be emphasized that some of the currently funded projects need to have the NRC's regulatory mission more prominent in their research questions and designs. For example, there needs to be greater attention paid to the actual operations at a NPP and a linking of management activities to safety concerns.

Turning to the success of long term implementation, acceptance of the product by industry and NRC user-groups becomes a major consideration. It is, therefore, important to involve these users from the very early stages of the project. Their feedback on the development of the study is significant to the usefulness and reliability of the data collected, the credibility of the research team, and the willingness of the utilities/plants to implement the project's final results

Beyond facilitating contact between research groups and users, the NRC needs to continue the close interaction between behavioral scientists and engineers which is necessary for the success of Organizational Factors Research projects. This collaboration reduces the likelihood of an over-emphasis on either hardware or O/M factors. On the one hand, it is important not to oversimplify the problem by concentrating on the relationship between hardware and safety, which engineers tend to do. On the other hand, it is also important not to overlook safety to such an extent that the NRC and industry will respond to the project's results with: "Yes, but how does this relate to safety at NPPs?" An over emphasis on organization and management factors without relating them to safety concerns may lead to the dismissal of results by both the NRC and industry as not relevant to their activities. As stated in the previous paragraph, several projects face this problem unless they can more clearly show how their research into O/M factors relate to the safety concerns of the NRC and industry.

Response H-6: In our research, we have been able to identify a number of plant programs, and activities which have been demonstrated to influence efficiency and safety performance. For example, the "effective root-cause analysis program" and the "effective spare part policy" are shown to be influential. These factors can be more easily measured as compared to some other intangible measures such as "reward and punishment policies." We think that these "intermediate" factors have adequate lead time and yet can be readily justified and used by the NRC as leading performance indicators. We believe that during the next 2-3 years, you should pay more attention to evaluating these intermediate factors. This issue was also favored in our meeting last year at American University.

Response I-6: Many of the Organizational and Management research projects appear to be well-designed and to be focused on important questions of organizational contributions to safety performance. The program as a whole may be less integrated and coordinated than one might wish. Our impression is that the NRC has made an effort to support research from many viewpoints and theoretical bases. This is quite appropriate early in a research program. However, with the program under pressure to transition quickly into technology development and application, this diversity may prove burdensome.

Various projects are still approaching the safety problem from different angles, using different definitions of critical concepts, and producing "apples and oranges" results. Some explicit transition between this exploratory approach, where the program is essentially "brainstorming", and the later development and application of usable indicators would appear necessary, but perhaps it is not achievable at this time. There should be a point at which some approaches are judged worthy of further work and others are dropped or their status changed. The remaining developmental programs then must reach some consensus on definitions, critical variables, appropriate measures. If this is not done, the program products will be less useful and credible than they should be. The annual research meetings have included attempts to reach such consensus, but without sufficient preparation.

It may be that the exploratory phase of some projects needs more time. We would suggest that careful definition of the nature and goals of each research project from the start, i.e., as basic research or applied "technology development," should facilitate later evaluation of project results and progress, and should help avoid unrealistic or over-ambitious expectations of projects which are in early research stages.

Response J-6: To me this is very clear, although you will probably disagree. Collectively project reports suggest that individual, group and organization factors are important. These reports also suggest that there are important interactive effects across these levels of analysis. The question then becomes how to proceed. One way is to begin by attempting to isolate important individual factors and/or the roles needed for safe operations, the move to the group level and finally move to the organizational level. Another strategy is to reverse this sequence.

If all the nuclear utilities were essentially similar, the micro to macro sequence might make sense. However, there appear to be dramatic macro differences that have been empirically linked to safeness. If we start with individual factors and move up we are likely to get mired in a whole series of conflicting findings. The research will never be successful enough to progress to group and organizational levels of analysis.

Further, I do not think that the NRC has the money or access to seriously examine the potential importance of individual factors, roles or culture. The potential list of individual factors is far too large. Roles are embedded in larger group and organizational settings. To begin systematically measuring the concept of organizational culture requires intensive effort.

I think that quicker progress would be made by focusing on organizational and collective action. Research focusing on the context of operations, the social structures of action and the processes of problem formulation, analysis and implementation would then be followed by analyses of roles, individual factors and culture. With this sequence we could progress toward identifying what the setting variables suggest might be potentially important group and individual factors.

Response K-6: Although it does seem to me that the NRC research agenda is addressing a wide variety of important organizational issues, I have some concerns about the ability of this research to provide concrete products related to plant efficiency and safety. While I have an idea of how action research might be used to address safety issues, I do not have a clear sense of how to improve the current research agenda.

Response L-6: In spite of efforts to coordinate the research efforts in the organizational factor area through the annual contractors' meeting, the projects are still not well coordinated in their goals and objectives. A framework is needed that ties the various projects and their products together. Some efforts have been made to this end, but it should be discussed and worked out by the individuals conducting the research, not the users or sponsors of the research.

It became evident to some of us at this year's contractor meeting, that several projects are reinventing the wheel, and apparently unnecessarily. Unfortunately, that type of approach does not then lend itself to openness and sharing, but rather to proprietariness and secrecy. In the interest of maintaining this program area within RES, a more integrated and comprehensive framework is needed, with perhaps some contractors having very specific tasks to address the issues that will remain unresolved. In order to obtain increased validation of some of the tools that are being used, decisions may be necessary to focus limited budgets on obtaining that information, at the expense of other efforts within each project.

Response M-6: In my view, the big payoff is not in PRA, but rather inspection and diagnostic evaluation - even the SMM process itself. Now that we have the user needs for inspection and diagnostic evaluation, we should begin in FY92 with redirecting money from the PRA application to the other applications. I am not yet convinced that BNL, UCLA, Penn State, and even APG will be successful in the next 2-3 years. PRA application is likely to take more time and money than we thought. We could miss the big payoff. Speaking of big payoff, the biggest is probably improving industry self-assessment, not unlike improving our own inspection and other related activities.

Response N-6: My opinion is that the current work focuses only on safety from a regulatory point of view. The issue of plant efficiency is being touched in a peripheral and symptomatic way. One study (University of Minnesota) indicates that there is no relationship between efficiency and safety. Another study (SAIC on maintenance indicators) indicates the opposite, i.e., that efficiency and safety go together. My opinion is that efficiency and safety go together only if efficiency is being sought as a long-term objective of the plant; in this case safety becomes one of the most crucial efficiency factors. But they do not go together if efficiency is sought as a short-term objective; in this case, safety may be compromised in many ways for the sake for short-term profits. For example, we have seen cases where reliability and engineering support programs were abolished overnight to save resources.

Thus this question brings up a very important topic: *Efficiency versus Safety*! As the industry and the NRC become more aware of the impact of the regulatory burden on plant efficiency, this topic will become a high priority for exploration during the next few years. I think there is a need, first, to define explicitly the concepts of efficiency and safety and then determine how they are achieved, where are the overlaps (i.e., in what degree both objectives are achieved through the same process and practices), where are the disconnects, and how disconnects can be managed for an optimal utilization of plant and regulatory resources.

Response O-6: How about planning an organizational factors training course at Chattanooga? This could help raise NRC's sensitivity to organizational factors that can affect licensee safety performance.

APPENDIX B

NUCLEAR REGULATORY COMMISSION

ORGANIZATIONAL FACTORS RESEARCH CONTRACTORS SECOND ANNUAL MEETING

May 22-24, 1991

NUCLEAR REGULATORY COMMISSION
ORGANIZATION FACTORS RESEARCH CONTRACTORS
SECOND ANNUAL MEETING

May 22-24, 1991
Penn State University

REPORT OF ACTIVITIES

I. Introduction

As part of an effort to further the program of research sponsored by the U.S. Nuclear Regulatory Commission's Office of Nuclear Regulatory Research, a conference of contractors, commission personnel, and industry representatives met in State College, Pennsylvania to discuss current projects and future directions. The conference was designed to familiarize all participants with the research being conducted by the nine contractors and to share information that might enhance the individual research projects as well as the research program as a whole. This report provides details regarding the meeting participants, the presentations made by research contractors and the discussions that were held during the three day meeting.

II. Participants

The meeting was organized around the research teams currently under contract in the Organizational Factors research program. These teams included: Accident Prevention Group, Battelle Pacific Northwest Laboratories, Brookhaven National Laboratories, Concord Associates, Inc., Massachusetts Institute of Technology, Penn State University, Scientific Applications International Corporation & University of Maryland, Star Mountain, University of California at Los Angeles, and University of Minnesota & Wayne State University. Each team was asked to prepare and present a synopsis of its research design and progress to date. These presentations served as a springboard for specific project related discussions as well as more general discussions regarding difficulties in conducting such research and necessary steps for future research efforts.

In addition to the research contractors, the conference participants represented a variety of organizations with direct links to the research program. Representatives of the following organizations participated in the meetings: American University, Battelle Human Affairs Research Centers, General Public Utilities, National Research Council's Commission on Behavioral and Social Sciences and Education's Committee on Human Factors, NUMARC, Swedish Nuclear Power Inspectorate, and U.S. Nuclear Regulatory Commission. Attached to this report as appendix A is a list of all conference participants. (See page B-10.)

III. Conference Structure

The conference was organized around three broad goals. The first was to better understand the current research efforts being conducted within the Organizational Factors research program. Toward this end, each contractor gave a brief presentation of the research design, progress to date and upcoming milestones. A second goal of the conference was to gain input from industry and NRC representatives their expectations for this research program, and, if appropriate, commentary on individual research projects. To achieve this goal, the conference began with a statement of interests and expectations from the non-contractor participants. Additionally, following the last project presentation, a discussion on the interconnections among current projects was held. The final goal of the conference was to offer a perspective on a variety of research related issues. These included such topics as: 1) key parameters of organization and management, 2) lessons learned doing research in regulatory environments, 3) results achieved regarding organizational factors and nuclear safety, and 4) unresolved research issues. This last goal was achieved by small group meetings, presentations and conference wide discussion of six questions posed to each research team by Dr. Tom Ryan in a letter of April 15, 1991. A copy of the conference agenda is attached to this report as Appendix B.

IV. Conference Presentations

The pivotal activity of the conference was to provide all participants with a perspective on the type of research currently being funded by the NRC's Organizational Factors research program. This was accomplished by asking each contractor to prepare a 15 to 20 minute overview of ongoing research. Several conclusions can be drawn regarding the presentations and the program of research. First, the difficulties inherent in measuring both organizational factors and performance indicators. A long and animated discussion followed the contractor presentations that highlighted the need for a wide variety of research approaches. As questions were asked and contractors as well as other participants responded, it was clear that each project faces difficulties ranging from gaining plant access to problems in measuring variables that may impact on the overall fit of the research model. As examples, the Penn State project uses interviews with key respondents across 6 to 10 plants. One element of the research is to quantify the interrelationships of various departments. To the degree the plants have different departmental structures, this will complicate the sampling plan and cause difficulties in creating a standardized interview protocol. With respect to the Minnesota project, the factor of plant aging and the stability of the management team was discussed as a potential complicating factor in understanding plant performance. Finally, in looking at results from several studies, it was pointed out that data from five years ago may not be as informative now as they were when they were collected. The point here was that given the dynamic nature of the nuclear power plant organization, relationships between variables may change as a function of time and what we documented before may be less applicable now.

A second conclusion that emerged from the post presentation discussion was the difficult to understand relationship between plant safety and plant performance. Among topics discussed was the potential "culture" for safety (originating and operating at both the plant and corporate level) and a separate "culture" that is attached to profit (most likely originating at as well as operating within the corporate level but translated to and operating at the plant level). Issues were raised as to whether these were positively related, negatively related, or, perhaps, unrelated. One position is that the relationship changes over time. Another position is that the relationship is dependent on the specific safety indicator and economic indicator you examine. The Minnesota group offered data that indicated that corporate allocation of resources accounts for significant amounts of variance with respect to future plant performance.

The discussion of relationships between performance and safety as well as other discussions focusing on functional relationships between individuals and departments, set the tone for more dialogue regarding the appropriate level for studying organizational factors. Throughout the conference the issue of restricting study to the plant level became an important theme. While all participants understood the NRC mandate, most felt it was an artificial barrier that served to limit our potential for understanding. A third conclusion that emerged from the discussions was that if we are to understand how organizational factors impact plant performance, the plant is the appropriate level to begin our work, but it should not be a final resting ground. The existing evidence and the indications we have from our ongoing work all point to the value of going beyond the plant level.

While the above conclusions are drawn from transcripts of the discussions that followed the presentations, much of what was discussed is directly related to the presentations. For the purpose of better understanding the presentations and for the express purpose of continuing our shared understanding of the activities of each contractor, a copies of the presentations and associated transparencies are included as Appendix C of this report.

V. Conference Commentary

The concluding day of the conference was devoted to reports and discussions covering a series of questions posed by Tom Ryan in an April 15 letter to contractors. Much of that discussion not only addressed the six questions, but also revisited several key issues discussed during the first two days of the conference. The following pages detail the responses to the questions and the discussions that followed. To set the stage for this information, a few words about the process that was used seem in order. Conference participants were divided into six groups of approximately eight individuals per group. Each group was formed by selecting members from a variety of contracts and organizations. Each group was assigned a facilitator and was asked to select a recording secretary. The facilitator was tasked with leading the discussion and the recording secretary was asked to take notes and provide an oral report back to the conference as a whole, when it reconvened at the end of the session. All groups were asked to focus their attention on a particular question and were given the opportunity to discuss as many of the six questions as they desired. Each group was responsible for reporting back to the conference on at least their assigned question. The six questions and a synopsis of the report and discussion appears below.

1. What lessons have you learned to date doing Organizational Factors research in a nuclear regulatory setting, that is, working with and for the NRC and with the nuclear industry?

This discussion moved from a listing of advantages and disadvantages associated with working for the NRC to a more pragmatic presentation of activities we should engage in and those we should avoid. Among the "things to do" were the following:

a. early involvement of the utility at the strategic research level
b. identification of key insiders and a specific project liaison.
c. development of utility ownership of the project.
d. specification of deliverables to the participating utility.
e. quick delivery of a product the utility will perceive as a benefit from their participation in the research effort.
f. as complete as possible, disclosure of the purpose of the research, the way in which the data will be collected, aggregated and eventually used.
g. linking of research objectives to the objectives of the participating utility.
h. attempt to find out as much as you can to facilitate your understanding of the plant and the plant environment.

The list of "things to avoid" included:

a. Using evaluative statements and being perceived as harboring evaluative intent.
b. Using loaded terms - words, phrases and statements that carry specific meanings to employees of the utility.
c. Obscuring the line between research and regulation.
d. Appearing ignorant of organizational lines of authority, protocol, and procedures.

Among the difficulties inherent in doing this type of research is the fact that we have problems of simply gaining plant access. Even when we gain access to a plant, we may find it difficult to see the people we want to see. Scheduling becomes a problem from not only the constraints imposed by the participating utility, but also some of the hurdles that must be cleared within the NRC. In essence it was felt that research projects have enough trouble moving ahead with a single organization imposing certain demands (in the case of the Penn State project, GPU Nuclear). When a second organization (NRC) is added to the formula, at times, it seems impossible to meet the research timeline. Other difficulties that were cited included problems of "turf" battles within the utility and between the utility and the NRC, the conflicts that seem to be associated with a behavioral science perspective versus and engineering perspective, and the lack of acceptance of a behavioral science data base.

2. *From your viewpoint, what organizational factors appear to influence safety performance, how they can best be measured, and how might this knowledge assist regulators?*

The discussion of this question resulted in three conclusions. First, while the research efforts should be of value to the NRC, the idea of regulation based on findings was not appropriate. More to the point, the idea that research outcomes might lead to regulations concerning organizational factors seemed objectionable. This concept was replaced with the conclusion that research results may form the basis for more focused and informed procedures for conducting inspections and identifying areas within the utility for further review. Additionally, the notion of "self regulation" or giving the utilities valuable tools to self monitor was seen as a positive outcome of the research program.

The second part of this question, they were answered in reverse order, was not addressed and it was suggested that there was a need to answer the first part prior to specifying ways to measure organizational factors. This lead to the discussion regarding what are the organizational factors leading to safety. As Jon Olson said "this was a hopeless task". Nevertheless, the group did acknowledge that some lists exist and seem to identify important variables. APG presented a list. A second list was compiled by Penn State for use during the conference. This list is attached as appendix D of this report. Carrying the discussion further, the group stated that many individuals are interested in organizational learning and the general topic of experience and how experience leads to enhanced understanding and, potentially, higher levels of safety. Finally, the discussion moved toward how organizations learn, what factors might enhance this learning and how we might assess organizational learning.

3. *How do you assess the products you are developing in terms of their implementability in NRC regulatory activities either directly, or through additional technology development and implementation research?*

This discussion resulted in some apparent controversy. Some felt that much of what we have done and much of what we will be doing in some of the newer projects that are just getting underway have and will provide valuable approaches to better understanding the environment of the plant and the factors that relate to safety. The phrase used was providing processes for future use rather than helping to formulate regulatory products. Along these lines, the idea was that our projects are more concerned with how to collect numbers than the numbers themselves. Several participants took issue with this position and stated that PRA and other utility gathered data, NRC gathered data and other data collected by INPO, EPRI, and NUMARC, all assume that numbers are important and that our research efforts have already pointed to the importance of several indicators of safety and performance. While these apparently conflicting views resulted in a spirited discussion, the resolution was that much of what we are doing now may not be adequately summarized by a single scale or measurement procedure. Still other activities, PRA, radiological release, exposure levels, are functional measures that convey a great deal of information. The most important outcome of this particular discussion was a consensus that what we are doing is gathering information, collecting numbers and performing statistical analyses all in an effort to better understand plant safety. The current research efforts are not designed for evaluation of individual plants or for regulatory purposes. As potential products associated with the research efforts, it is hopeful that, in the future, many of the outcomes attached to the projects will result in improved diagnostic procedures to be used by AEOD, enhanced inspection protocols for NRR, and more systematic self-inspection activities to be used by any nuclear power plant.

4. *How do you assess the importance of accessing plants to do Organizational Factors research? What types of problems have you encountered in gaining access to plants attributable to each of the following: parent utility; plant; utility groups such as INPO, EPRI, and NUMARC; NRC research project manager; NRC plant project manager; NRC management; your own management?*

This discussion was not restricted to the response to this particular question. Bits and pieces of the question surfaced throughout the conference. Several conclusions were drawn regarding the discussions. The plant clearly represents the single most important level for doing this type of research. Our ability to define and measure organizational factors has its core at the plant level. However, it was further concluded that other levels of the organization are of prime importance and without both access to the plant and cooperation from the participating parent utility, we are severely restricted in our ability to provide an indepth analysis of research issues.

All participants from research organizations discussed their specific difficulty in gaining plant access. This has primarily been a time factor, although the suspicion of the utility with respect to participating in NRC sponsored research was cited by several as a serious problem. Several researchers felt it was more effective to downplay the role of NRC than to try and use NRC as a vehicle for entry into the organization.

As a result of the make-up of conference participants, it was clear that participating utilities (as represented by GPU during this conference) and NUMARC can be invaluable in gaining access to the plant and facilitating the research effort. With their cooperation and support the research team has an immediate connection with the organization, one that will assist in meeting project demands.

5. To what degree do the Organizational Factors research activity's current focus and out-year plans, methods for doing the research, and sought after products over the next 2-3 years address issues important to plant efficiency, and the NRC regulatory mission for enhancing safety?

The group reporting on this question presented a taxonomic answer that looked at the question from the perspective of types of products and classes of issues. Among the first type of products were those that are "awareness raising". This type of product simply suggests that there is an issue to be discussed without necessarily having an answer. The benefit of such a product is to suggest that there is something that requires further thought and study. An example of this came from the Minnesota project where one outcome was that organizational learning is something we need to study further. The second type of product was labelled "information providing". Products in this category provide us with information to make decisions, often on the basis of information gathered by our analytical methods. The third type of product was "regulatory programs". An important point made here is that much of what we are currently doing could fall into that category in future years but it is hoped that the focus on regulation will be broadened to include self improvement by the participating utilities rather than a more limited application via regulation.

The discussion regarding classes of issues was difficult to separate from the above discussion of products and was even more difficult to summarize. Among some of the topics were the issues of levels of the organization to be studied, defining who was the ultimate consumer of the research products and what role did the research play in legal decisions, PUC deliberations and other local, state and federal policy making bodies.

6. Based on your experience doing Organizational Factors research for the NRC, should we continue to focus our attention at the plant level, or should we go beyond the plant level: if we look beyond the plant level, where should we be looking?

This question was discussed over and over, throughout the conference. Vikki Briant of GPU gave a very powerful analogy when she commented that studying the plant is like tearing on a piece of cloth and pulling on a string. It can lead you in a variety of directions. When we study organizational factors at the plant level we invariably wind up looking at plant level factors, small group factors, factors that translate to the individual and factors that impose on the plant and operate at the organizational level. While it may be a mandate of the research program and it may even be an important place to begin our inquiry, we must be allowed to follow the string up to the organizational level. Eventually our plant level findings will require a deeper understanding of the higher level factors that might be acting as causal agents. We must now begin to conceptualize our research questions and plan our methods to incorporate this higher level of investigation and analysis.

VI. Concluding Statements

Several conclusions regarding the conference can be drawn from the information presented above, follow-up contacts with conference participants and many of the statements made during the conference.

1. The tremendous benefits of drawing together all the contractors to discuss project progress was repeatedly cited as a positive outcome of the conference. Contractors and other participants were uniformally agreed that there was a great deal learned from simply hearing about each project and then discussing the implications across projects. The value of this type of conference on an annual or semi-annual basis was clear to all who participated.

2. During the conference, contractors and other participants expressed a desire, even a need to better understand the fit among projects and the direction of the program as a whole. Many thought the conference was a step in the right direction. Tom Ryan gave his insights along these lines and said that such an understanding was what he would present to the commissioners in the Fall. At the very least it should be an agenda item for the next conference and perhaps an open discussion with Tom as the presentation leader/facilitator.

3. With conference participants from universities, research organizations, consulting groups, utilities, research councils and industry wide groups, it was clear that there is very much to be gained by pulling together such a diverse group. There exist a need for greater cooperation among these various groups, all of whom have a great deal of commitment to the common theme of Organizational Factors research and its impact on safety. Many participants discussed follow-up phone calls and meetings to help establish bridges between organizations. We can only hope that these intentions are followed and that future interactions will lead to greater intergroup cooperation.

2nd ANNUAL MEETING OF THE ORGANIZATION AND MANAGEMENT RESEARCH CONTRACTORS

Attendees by Organization

Accident Prevention Group

Vojin Joksimovich
Doug Orvis
Drea Zigarmi

American University

James Thurber

Battelle Human Affairs Research Centers

Jon Olson

Battelle, Pacific Northwest Laboratories

David Seaver
Joseph C. Montgomery

Brookhaven National Laboratories

Sonja Haber
Deborah Crouch

Concord Associates, Inc.

Paul Haas
Edward Connelly

General Public Utilities

Vikki Briant
Ray Germann

MIT

John Carroll
Nathan Siu
Connie Perin

National Research Council/Commission on Behavioral and Social Sciences and Education/Committee on Human Factors

Doug Harris

NUMARC

Robert Evans
Robert Whitsel

Science Applications International Corp.

John Wreathall

Swedish Nuclear Power Inspectorate

Kjell Andersson
Kerstin Dahlgren
Irene Blom

Star Mountain

Susan Van Hemel

UCLA

George Apostolakis
Oscar Grusky
Jya Syin Wu
Richard Adams

U.S. Nuclear Regulatory Commission

Carl Johnson
Joel Kramer
Erasmia Lois
Tom Ryan
Stuart Rubin
Ron Lloyd
Robert Palla
Mary Ann Biamonte

University of Maryland

Mohammad Modarres
Ali Mosleh

University of Minnesota

Alfred Marcus
Mary Nichols

Wayne State University

Richard Osborn

Other:

Shields Daltroff (Consultant)

PSU:

Frank Landy
Rick Jacobs
John Mathieu
Anthony Baratta
Gordon Robinson
David Hofmann

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REMARKS OF

JEFFREY S. MERRIFIELD
COMMISSIONER

AT THE

REGULATORY INFORMATION CONFERENCE
WASHINGTON, D.C.

MARCH 29, 2000

Contents

Good Morning. Thank you very much for the opportunity to speak to you today. This is the second Regulatory Information Conference that I have participated in since I became a Commissioner in 1998. This is not only a great opportunity for the NRC, the nuclear industry, and our stakeholders to share insights on the many safety and regulatory challenges we are facing, but it also provides an opportunity for the Commissioners to discuss their priorities as well as the course they would like to set for the agency. I will try to do just that. Today I would like to focus on 4 areas:

1. First, I'll look back at 1999 and give you my views on the state of the NRC.
2. Second, I'll share with you my priorities for 2000.
3. Third, I'll discuss the issue of organizational accidents.
4. And finally, I'll give you my perspective on the NRC's role as communicator and its challenge of enhancing public confidence.

State of the NRC

First, I'd like to share my views on the state of the NRC and look back at some of our most significant accomplishments of 1999.

The NRC is engaged in one of the most aggressive regulatory reform efforts ever undertaken within the federal government. During the fourteen years I have spent in Washington, I cannot think of a federal agency that has made more of a commitment to reinvention than the NRC has made during the last 18 months. We have become more risk-informed, we have reduced unnecessary regulatory burden, we have brought greater objectivity and predictability to our regulatory processes, we have held our managers and staff more accountable, and we have become more responsive to our external stakeholders. Some of our critics would have you believe our reform efforts amount to regulatory retreat. On the contrary, I would argue that these efforts are entirely consistent with our strong commitment to safety, since the changes we are making will allow our licensees and our staff to focus more attention on truly risk-significant aspects of the plants and spend less time on regulatory burdens that contribute little or nothing to safety.

I would like to outline a few reasons why 1999 was a year the NRC can be very proud of.

- We met or beat every milestone we set for the Calvert Cliffs and Oconee license renewals. The fact that the overwhelming majority of licensees have expressed an interest in pursuing license renewal speaks volumes of our success in establishing a thorough, predictable, and timely process.
- We met or beat every milestone we set for license transfers, such as those associated with Three Mile Island Unit 1, Pilgrim, and Clinton.
- We successfully improved the timeliness of our spent fuel cask certifications.
- We successfully set the course for the long journey we call risk-informed regulation.
- We moved forward on changing Appendix K so that it would remove unnecessary restrictions on plant operations and allow many licensees to seek power uprates.
- We published a final rule allowing licensees to amend their design basis to use revised source terms in design basis accident radiological analysis.
- We issued the final design certification rule for the AP 600.
- We successfully piloted a new reactor oversight program, one which institutionalizes the objectivity, predictability, consistency, openness, and risk insights that were missing from our previous inspection and assessment programs.
- Finally, we improved our planning and review efforts associated with applications for extended power uprate. Remarkably, during the 90s, we approved power uprates that resulted in over 1400 megawatts of new electric generating capability in the United States. I am proud to say that we did so in a manner consistent with our mission to protect public health and safety.

I could go on, but I believe I have made my point that the NRC has served the American people very well. However, the dynamic nature of the electric industry dictates that we live in a "what have you done for me lately?" environment. While 1999 was a success, I am under no illusion that it is time to celebrate. So, now let me focus on 2000.

Priorities For 2000

If David Letterman can have his top ten list, so can I. So, here are my top 10 priorities for 2000 in the reactor arena:

- **First** and foremost, we must carefully plan and budget our resources so that we don't fall victim to our own success in the areas of license renewals and license transfers. We must dedicate the resources necessary to build a robust and predictable regulatory infrastructure in these areas while at the same time providing the resources necessary to perform ongoing reviews in a thorough and even more timely manner.

- **Second**, we must go forward with the new reactor oversight process recognizing that it is very much a work in progress, but one which is far superior to the subjective and often unpredictable process we left behind. We cannot allow ourselves to be held hostage by those who demand perfection at the expense of improvement.

- **Third**, we must get our act together in the area of reactor decommissioning. We must get our arms around the numerous technical and regulatory issues associated with decommissioning, and bring realism, clarity, and consistency to our regulatory framework.

- **Fourth**, we must not fail in carrying out our regulatory responsibilities associated with dry cask storage of spent fuel. While we have been successful in improving the timeliness and predictability of our cask certification process, we need to achieve further process efficiencies and resolve the generic technical issues like credit for high burnup fuel.

- **Fifth**, we must bring realism to our physical security requirements without compromising on the protection of the plants. As a result of my plant visits this last year, it has become obvious to me that both we and our licensees are guilty of allowing regulatory creep to enter into the OSRE process. I have seen protective strategies that range from innovative to outlandish overkill. We must work to provide plant security requirements that respond to the realistic and clearly defined threats of modern society; nothing more, nothing less.

- **Sixth**, we **must** make the revised maintenance rule and 50.59 rule **work**. If our regulatory or inspection guidance is inadequate, or if inconsistency is allowed to find its way into either how licensees implement or how our inspectors regulate, the rules will fail. We cannot allow years of hard work on the rules be derailed by regulatory creep on the part of our inspectors or short cuts on the part of our licensees.

- **Seventh**, we must move forward swiftly, yet cautiously, in the area of risk-informed regulation. While I am optimistic that we can use risk insights to improve many aspects of Part 50, I am not convinced that there is sufficient industry support to justify the cost of making a wholesale change to Part 50. Although I am willing to provide the resources necessary to take the important initial steps, I will not support additional resources if there is not sufficient industry interest in using these alternative regulations.

- **Eighth**, we must reach **closure**, and I stress the word **closure**, on our fire protection initiatives. Clearly, none of our stakeholders - not the public, not our staff, not our licensees, and not Congress - feels good about where we stand in the area of fire protection. We must complete our work associated with both fire protection circuit analysis and our comprehensive regulatory guide, and reach closure on milestones that will ultimately lead us to a risk-informed NFPA standard.

- **Ninth**, we must improve the recruitment, the training, and the professional development of our staff. As our workforce ages, and as retirements continue, our corporate knowledge is threatened. At the same time, emerging technologies and new technical challenges associated with such things as plant aging, power uprates, and even the prospect of a new plant order, are on the horizon. It is essential that we have a staff that is capable of meeting these challenges.
- Finally, we, as an agency, must continue to make strides in the areas of fiscal responsibility and accountability. We have had great success in rightsizing our agency and in reducing our cost to licensees and the American taxpayers. Nonetheless, I believe we in the Commission have the obligation to scrutinize our budget line by line to ensure that we are utilizing only those resources necessary to effectively and efficiently carry out our mission; no more, no less. As stakeholders of the NRC, you should demand nothing less of the Commission.

Organizational Accidents

Now let me change gears and talk about the issue of organizational accidents.

Today, the outlook for nuclear power is arguably the brightest its been since the Three Mile Island accident. Competitive market forces have led to a resurgence of nuclear power by forcing dramatic improvements in the manner in which nuclear plants are managed and operated. Licensees have improved operator training, made significant process improvements, developed sound maintenance and corrective action programs, shortened refueling outages, and as a result, significantly increased generation. Plants today are operating better than ever before, with forced outage rates at an all time low and capacity factors at an all time high.

Despite this success, my message to the nuclear industry is the same one I frequently leave with the NRC staff - this is no time to celebrate. I recently read a book by Mr. James Reason entitled Managing the Risks of Organizational Accidents. I recommend this book as it is a stark reminder that success is fragile, and if not managed properly, can lead to the insidious buildup of latent conditions that could set the stage for organizational accidents.

I'll briefly try to capture the essence of Mr. Reason's message.

Our agency, the nuclear industry, and the public have been well served by the defense-in-depth principle. Successive layers of protection, one behind the other, each guarding against the possible breakdown of the one in front. However, no one defensive layer is entirely intact. Each one possesses gaps and holes created by combinations of active failures and what the author refers to as latent conditions.

Latent conditions include such things as poor design, gaps in supervision, undetected manufacturing defects and maintenance failures, unworkable procedures, shortfalls in training, and less than adequate equipment. They arise from decisions made by organizational managers, manufacturers, designers, and even regulators, and can lie dormant for many years. However, when the gaps produced by active failures line up with those created by latent conditions, successive defenses are compromised and a window of opportunity exists for a serious accident. While these windows of opportunity are rare, Chernobyl, the Bhopal chemical accident, and the Challenger accident have reminded us that they are indeed possible.

Despite our most recent successes, as the NRC moves forward with our regulatory reform efforts, and as the nuclear industry transitions into a deregulated electric market, we and our licensees must continue to wage an aggressive campaign against the buildup of latent conditions and we simply must not forget to worry. As Mr. Reason states in his book, "If eternal vigilance is the price of liberty, then chronic unease is the price of safety." The NRC and the nuclear industry simply must maintain a high level of unease. Let me now briefly touch on 3 aspects of plant operation I believe warrant chronic unease on the part of ourselves and on the part of our licensees.

First, licensees and the NRC must continue to challenge complacency. Now I'm not using the term complacency in the classic sense - it is clear to me that INPO and our licensees have their arms around that. Instead, I use it in terms of forgetting the past. As the industry reaps the benefits associated with improved performance, and as the NRC and the industry pursue greater efficiencies and regulatory reform, we must be careful not to roll back the safety improvements made over the last 20 years. We must ensure that lessons of the past do not get "reformed out" or "budgeted out" of our programs.

While the industry is performing well, it was not that long ago that many plants were plagued with operational problems. We cannot allow ourselves to forget about the Davis-Besse feedwater event, the fire at Browns Ferry, the Millstone saga, and the extended shutdowns of the 80s and early 90s. We cannot allow ourselves to lose sight of the fact that the performance improvements the industry is enjoying today came at very high price -- a price that we cannot afford to repeat.

The **second** area I believe warrants chronic unease is insularity. As the electric industry proceeds down the road toward deregulation, we are likely to see a dramatic shift in the ownership of nuclear plants across the nation. It is clear that many nuclear plants will be sold, resulting in a significant reduction in the number of plant owners. Overall, I hope this consolidation will serve as an opportunity to further improve the operational performance of these plants. However, this opportunity will be lost if consolidation and competition breed insularity and provincialism.

My message to you is this: As consolidation in the ownership of nuclear plants continues, the few large companies operating these plants must not become insular, they must continue to recognize the value of looking outside of their organization for solutions, and of sharing information outside of their organization for the common good of the industry. Plant managers within these large companies must never become comfortable benchmarking themselves only against their organizational peers, mistakenly believing that rest of the U.S. nuclear fleet and the international nuclear community offer few operational insights that cannot be more readily acquired from within.

For those who are so bold as to believe that all of the nuclear industry's solutions, all of its best practices, all of its operating experience, lie within your organization, I ask you this: "Are you bold enough to stake your assets on it?" I hope and expect the answer is no.

The **third** aspect of plant operation I believe warrants chronic unease is the relationship between the NRC's new reactor oversight program and how licensees manage plant performance. By almost any standard, the nuclear industry is performing better now than at any time in its history. This improved performance provided an opportunity for the NRC to rethink our approach to reactor oversight and led to what I believe are comprehensive and innovative changes to our oversight program.

As you know, the NRC's new oversight program will measure plant performance using a combination of objective performance indicators and a risk-informed inspection process. The strength of this new program lies in its emphasis on strong corrective action programs. I hope it clear to everyone that the purpose of the new oversight program is to measure and assess performance to assure the plants are being operated safely. Nobody should have any illusions that it is intended to assure operational excellence. Operational excellence is the responsibility of our licensees, not the NRC.

As we approach the final days before initially implementing the new oversight program, critics of the program and even the ACRS are voicing concerns that our licensees will manage their plants to the NRC's performance indicators, and that our indicator thresholds provide licensees little incentive to improve performance. I strongly disagree with the premise of these concerns, and have expressed so publicly on many occasions.

In contrast to some, I believe that the individuals that manage nuclear plants in the U.S. are sophisticated enough to realize that managing solely to the NRC's performance indicators is a recipe for failure. I believe it is clear to each of them that green is not good, and that the NRC's performance indicators are a mere subset of the indicators that must be monitored to ensure that plants are managed and operated efficiently and effectively. I believe that there is a common understanding in the industry that it is essential to identify performance trends early and to intervene long before a performance indicator threshold is reached.

I am not asking critics of the new oversight program to trust me, the NRC staff, or our licensees. I believe that its merits will speak for themselves. Clearly, I have a great deal of confidence that the objectivity and transparency of the new program will provide an even greater incentive to licensees to maintain the highest levels of performance. I also believe that we should not lose sight of the fact that our licensees have many other incentives to operate their plants well, including those associated with a deregulated electric market. How long do you think the market will tolerate multiple scrams, multiple unplanned shutdowns, or multiple safety system failures in a given year? I would argue that the market

is just as punishing a regulator as the NRC. The market demands operational excellence, outstanding equipment reliability, and high capacity factors at all times. Those plants that are content to operate on the border between green and white will fail to satisfy the demands of the market. They will simply be too costly and too unreliable to survive. For those licensees that prove me wrong and do manage strictly to the NRC's indicators and are content to operate on the border between green and white, I refer you to SECY-99-168. That paper explains all of the wonderful work we are doing in the area of decommissioning.

Communication and Public Confidence

Let me close today by briefly touching on an area that the NRC continues to struggle with. It is an area directly linked to one of the agency's key performance goals, yet is very difficult to measure, and even more difficult to influence. It is an area in which the NRC is extremely vulnerable, and thus one for which I believe the agency must rethink the way it is doing business. I am speaking about Enhancing Public Confidence.

In the past, the NRC approached public confidence in much the same way the Maytag repairman approaches his job. We were passive in our communications with the public. We allowed our critics to define what our agency was, what its actions meant, and how these actions should be perceived. As a result, the agency frequently found itself in the difficult position of playing catch-up. This approach had its roots with the old AEC. The AEC's organizational philosophy simply did not recognize a role for the agency in enhancing public confidence. The agency paid a very heavy price for this passive approach.

Many within the NRC believe that if they simply do their job well, public confidence will naturally follow. There is some merit to that approach. However, while I agree that the most effective way to improve public confidence is by **demonstrating** through our actions that the NRC is a credible regulator, I would argue that if we do not effectively convey to the public that we are a credible regulator, how are they to know? Who will carry that message for us?

I believe the NRC must become more proactive and forthright in its communications. We must be the first to communicate with the public about important regulatory decisions and must clearly articulate the reasoning behind them. We should change our organizational philosophy so that we no longer allow inaccurate assertions in the public arena to go unaddressed. When spent fuel casks are referred to as mobile Chernobyl's, I think we should rebut the assertion and clearly present the true basis for why we feel dry cask storage is safe. When opponents of the new oversight process or our decision on N+1 label them as regulatory retreat, we must accurately and promptly respond so that the public is not left with a mistaken understanding of our programs. When we are accused of wasting public monies in our pursuit of our international cooperation, we must explain why international involvement is vital to protecting public health and safety. How will the NRC ever enhance public confidence if we remain passive in the public arena? We simply won't. I sincerely believe that if we have a true and defendable story to tell, it is irresponsible for us not to tell it - a disservice to our licensees, our stakeholders, and our staff.

The NRC must also do a better job conveying to the public what we mean when we use the term "unnecessary regulatory burden". It has become the mantra for many of our regulatory reform efforts, yet few really understand its true meaning. It is a term that carries great weight, and one that also provokes great anxiety. Many in the NRC and the nuclear industry have reduced this important concept to a sound-bite, thereby losing a great deal of its meaning in the translation. If the word "unnecessary" is lost on our stakeholders, regulatory reform begins to look like regulatory retreat. How much public confidence do you think we engender with such a fatal flaw in our message? Very little!

The problem, as I see it, is that we inappropriately treat "reducing unnecessary regulatory burden" and "becoming more risk-informed" as two separate and unrelated goals. I would argue that the two goals are, in fact, closely linked. Think about it. The premise behind our efforts to risk inform our regulations and our efforts to reduce unnecessary regulatory burden is the same. It is that these efforts allow licensees and the NRC to spend less time on regulatory burdens that contribute little or nothing to safety so that more attention can be focused on truly risk-significant aspects of a plant. Very often, that premise is lost in the sound-bite. So, I encourage the NRC staff and the nuclear industry to ensure that when they discuss risk-informing Part 50, or the new reactor oversight process, or any of our other regulatory reform efforts, they do so in an accurate and responsible manner that explains why these reforms were made. If we communicate honestly and responsibly, our stakeholders will understand the safety benefits associated with our efforts, and burden reduction will be secondary to the discussion. If we fail to do so, naysayers will use our own words against us to distort our message. At the very least, this will add a great deal of unnecessary burden to our own reform efforts. At the very worst, the groundswell resulting from a lack of public confidence will manifest itself in regulatory gridlock - derailing our reform efforts. I hope you're not willing to accept such a heavy price. I know I'm not.

In closing, I want to thank you again for giving me this opportunity to share some of my thoughts with you this morning. I hope this conference has met or exceeded your expectations and I hope my remarks are useful. If you have any questions, I intend to stay at the conference for a while and I'd be pleased to discuss them with you between sessions. Thank you.

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NUCLEAR SAFETY

M. D. Muhlheim, Editor-in-Chief

Reactor Coolant System Blowdown at Wolf Creek on September 17, 1994

By John V. Kauffman and Sanford L. Israel

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Reactor Coolant System Blowdown at Wolf Creek on September 17, 1994

By John V. Kauffman and Sanford L. Israel[a]

Abstract: *On September 17, 1994, an inadvertent blowdown occurred at Wolf Creek reactor; about 34 822 L (9 200 gal) of reactor coolant passed through the residual heat removal (RHR) system to the refueling water storage tank (RWST) while the Wolf Creek reactor was shut down in Mode 4 on RHR cooling [2.5 MPa and 149 °C (350 psig and 300 °F)]. This event occurred because of concurrent activities involving manipulations of RHR valves while cooling down to begin a refueling outage. The inadvertent blowdown of reactor coolant was terminated in about a minute by closing one of the RHR valves that was being manipulated. Continued blowdown through the RHR system would have uncovered the reactor hot leg and introduced steam into the RWST header line, which is the water supply line for the emergency core cooling system (ECCS) pumps. The Nuclear Regulatory Commission Office for Analysis and Evaluation of Operational Data performed an event review to provide better understanding of the event initiation; operator response; potential engineering issues; and possible event progression without the initial, successful operator intervention.*

This article describes the plant conditions prior to the September 17, 1994, blowdown of reactor coolant at Wolf Creek reactor; initiation of the blowdown; the blowdown itself and operator response to it; and the results of the Nuclear Regulatory Commission (NRC) analysis of the human performance and engineering aspects of the event. This analysis was issued as an NRC AEOD Special Study, S95-01, "Reactor Coolant System Blowdown at Wolf Creek on September 17, 1994," in March 1995.

The Wolf Creek event disclosed a previously unrecognized design vulnerability: a piping arrangement whose inappropriate use while on residual heat removal (RHR) cooling could result in a fast loss-of-coolant event and a consequential common-mode loss of emergency core cooling system (ECCS) mitigation capability if an extended blowdown occurred through this path. The mitigation of an extended blowdown if the ECCS pumps have failed is uncertain. Uncertainties that affect a conditional core damage probability calculation for this sequence of events depend largely on values used for operator actions, uncertainties about common-mode impairment of ECCS equipment that takes suction from the refueling water storage tank (RWST) header, and the initiation of reflux cooling. The failure to control work activities resulted in the initiation of the event, which preliminary review indicates will be among the more significant ones of recent years from a safety standpoint.

EVENT NARRATIVE DESCRIPTION

Initial Plant Conditions

Shortly after 4:00 a.m. on Saturday, September 17, 1994, Wolf Creek was shut down in Mode 4, cooling down at the beginning of Refueling Outage VII. The reactor coolant system (RCS) was at about 2.5 MPa and

[a]U.S. Nuclear Regulatory Commission, Office for Analysis and Evaluation of Operational Data, Washington, DC 20556.

149 °C (350 psig and 300 °F). Two reactor coolant pumps (RCPs) were secured at least 8 h before the event. The steam generators were filled, but the condenser and condensate systems were secured about 2 h before the event. The cold overpressure protection system was armed 8 h prior to the event. The safety injection (SI) pumps, one of two centrifugal charging pumps, and the positive displacement pump (PDP) were secured and breakers opened as part of the cold overpressure protection.

About 4 h earlier, RHR train A was placed in service to cool the reactor. About 25 MW(t) of decay heat was being removed by RHR train "A" [10 371 L/min (2 740 gal/min)] with a mixed outlet temperature of 112 °C (234 °F) and inlet temperature of 150 °C (302 °F). Auxiliary feedwater was available.

The control room (CR) operators were busy. A second relief crew consisting of licensed and nonlicensed operators augmented the on-shift crew. Several activities were in progress, and several distractions occurred during the shift.

Prior to the outage, a chemistry sample analysis determined that the "B" RHR train boron concentration (about 1200 ppm) was lower than RCS boron concentration (about 2000 ppm). This lower concentration was attributed to check valve backleakage at the RCS pressure boundary. The procedure for start-up of an RHR train required RCS and RHR boron concentrations to be within 50 ppm, which necessitated raising the boron concentration of the "B" RHR train by recirculation to the RWST.

Earlier in the shift, at 9:25 p.m. on September 16, 1994, and again at about 3:00 a.m. on September 17, 1994, the shift supervisor (SS) held discussions with maintenance personnel involved with the retest of HV-8716A (see Fig. 1, simplified diagram) (RHR train "A" isolation valve in the crossover line to hot-leg recirculation loops 2 and 3). The SS granted permission to adjust the packing of HV-8716A, which would require stroking this valve to conduct valve testing, provided appropriate plant conditions existed as determined by the on-shift supervising operator (SO).

Reactor Coolant System Blowdown

Just prior to the event, the CR operators were deployed as follows:

- The on-shift SS was in his office performing administrative duties, while the shift SO was at his desk keeping the CR log and monitoring plant activities.
- The on-shift reactor operator (RO) was controlling the chemical and volume control system to raise the pressurizer level slowly in preparation for taking the RCS solid. This activity was complicated by a malfunctioning nitrogen regulator on the volume control tank (VCT).
- The on-shift balance of plant (BOP) operator was involved with aligning the "B" RHR train for recirculation to the RWST to increase boron concentration in the "B" RHR train. In addition, the operator tracked and occasionally compensated for sluicing between the component cooling water trains.
- One nuclear station operator (NSO) had discussed with the BOP operator the "B" RHR train lineup for recirculation to increase its boron concentration. This NSO was proceeding to BN 8717 (RHR pump return to RWST valve) with instructions to open it slowly in accordance with the procedure.
- A second RO was plotting the pressurizer cooldown rate, and a third, who had recently returned from adjusting the VCT pressure regulator, was controlling the "B" diesel generator (DG) 24-h run.
- The relief crew SO had been assisting the on-shift SO and was now at the radiation monitor panel involved with a surveillance, and the relief crew SS was standing near the feedwater system control panel.

An electrician informed the BOP operator that the packing adjustment on valve HV-8716A had been completed and requested that it be stroked for the valve test. The BOP operator conferred with the on-shift SO and received concurrence to conduct the stroke test. Meanwhile, the NSO had arrived in the valve room that contained valves HV-8716A and BN 8717. The electrician and the NSO were about 1 m (3 ft) apart, engaged in different evolutions. The NSO was going to open valve BN 8717 manually as part of the boration of the "B" RHR loop, whereas valve HV-8716A was going to be stroked open and closed from the CR.

In the CR, the BOP operator stroked HV-8716A for the first time. About 30 s later, the BOP operator pushed the open button to start the second stroke test at about the same time that BN 8717 was fully opened. Opening HV-8716A concurrently with BN 8717 created a flow path to blow down the RCS to the RWST.

The NSO noted flow noise when valve BN 8717 was initially cracked off its seat. He interpreted this as pressure equalization across the valve, which he expected. He also heard a loud noise like a water hammer. He then proceeded to open the valve slowly. At about the time the valve was fully open, he and the electrician heard a loud running RCPs, maximized charging flow, and isolated letdown. Hence their initial response relied on their training and their knowledge of general actions to be taken or rules governing reactions to a rapid loss of pressurizer level or LOCA event, in particular a LOCA in Modes 1, 2, and 3.

After the blowdown was stopped, the operators referred to alarm response procedures. Their subsequent plant recovery was based on various considerations and requirements such as technical specifications (TS), concerns for pressurizer surge line thermal stresses, and the ongoing test run of the "B" DG. Some important actions, such as emergency classification and declaration, were not considered, at least partially because the applicable procedure was neither entered during the transient nor checked after the plant was stabilized.

The licensee's review concluded that all personnel actions in response to the event were appropriate; however, emergency action levels should have been consulted immediately after the event. The licensee's review of the event also concluded that no emergency classification was warranted for this event.

Procedures and Their Use

Shutdown LOCA Procedure (OFN BB-031). Wolf Creek had an off-normal procedure, OFN BB-031, "Shutdown LOCA," that was intended for situations like this event. OFN BB-031 was formatted similarly to the Wolf Creek emergency operating procedures and was comprehensive—it contained 143 pages with 81 steps and 5 appendixes (about half of the pages were an identical continuous action page provided for operator ease of use). One of the symptoms for entry was an "uncontrolled decrease in PZR [pressurizer] level" during Modes 3, 4, or 5. OFN BB-031 was based on Westinghouse Owners Group (WOG) guidelines for a shutdown LOCA. The operating crew had received training on a shutdown LOCA scenario and other shutdown scenarios immediately before the plant shutdown.

Some of the operator actions directed by OFN BB-031 differed from the actions of the operators during the event; for example, step 2 and a foldout page both direct that, if any RHR pumps are taking suction from the RCS and pressurizer level is less than 4%, then the RHR pumps are to be stopped and placed in pull-to-lock. According to the licensee's bases document, the purpose of this step is to prevent damage to the pumps and allow for future pump operation. During the actual event the RHR pumps were not tripped. Leak identification and isolation are included in step 10, which describes what to do if pressurizer level has been restored or is greater than 4%. Another foldout page step helps determine the emergency classification level. On the basis of interviews, the on-shift SS did not consider making an emergency classification.

The diagnosis of the flow path by the relief crew SO and subsequent isolation terminated the event prior to loss of core cooling. The relief crew SO's engaging in diagnostic activities appears appropriate; he was not on shift and was not responsible for directing or supervising the implementation of the operator response to the blowdown. The on-shift crew did not implement the applicable procedure. The rapidity of the inventory loss, rather than a conscious decision, appears to be the reason why operators did not use the procedure. On the basis of interviews, the crew felt that the event was terminated and the plant stabilized once HV-8716A was closed; so referring to the procedure was not thought to be required.

Loss of RHR Cooling Procedure. A 150-page document, "Loss of RHR Cooling" (OFN EJ 015), developed in 1990 in response to Generic Letter 88-17, "Loss of Decay Heat Removal,"[1] reflects guidance developed by the WOG. Its entry conditions included loss of RHR flow, erratic RHR pump current, and erratic RHR flow oscillations. This procedure directed actions to recover RHR by stopping the pumps, refilling the RCS, and venting the RHR pumps. Near the end of the procedure, directions were given to use alternate heat removal methods.

Usability of Procedures. A review of several procedures related to this event raised questions about their usability; for example, the shutdown LOCA procedure, OFN BB-031, has 5 continuous-action statements on the left-hand page, and at least 17 other "check" steps appear within the body of the procedure, 2 of which are also continuous action. Similarly, the procedure for starting an RHR train (SYS EJ-120) contains 15 precautions and limitations at the beginning of the procedure and another 34 notes and cautions in the 46-page body. Some of these precautions and notes appear to be continuous-action-type statements.

In regard to OFN BB-031, certain critical actions, such as cold overpressure protection and tripping the RCPs, might not be implemented in a timely fashion while following this procedure. Operators tripped the running RCPs during the September 17 event. The licensee is modifying OFN BB-031 following the event. Planned changes include directions to trip the RCPs immediately for a rapid depressurization, enhancements to the RCP-tripping criteria, and enhancements to the SI reduction criteria for cold overpressurization or pressurized thermal shock (PTS) concerns.[2] The licensee plans further evaluations of the mitigation strategy of the procedure.

Licensee analyses subsequent to the event showed that, under some initial conditions, the operators may have only 3 to 5 min to isolate the blowdown path before steam in the common suction piping could degrade or fail SI, centrifugal charging, and RHR pumps. Thus, for some initial conditions, timely leak isolation could be very important. Leak isolation, however, is not the principal mitigation strategy in the applicable procedure. The applicable procedure, if used, would not have directed leak isolation within the time needed to prevent potential failure of ECCS pumps. The licensee offered reasons why leak isolation is not the principal mitigation strategy (e.g., isolation of RHR defeats low-temperature overpressure protection, and concerns exist about the ability of valves to be reopened to use RHR for cooling).

Operational Experience

The licensee identified three previous events, including one at Wolf Creek in 1983, similar to this event. According to the licensee, a 1990 Braidwood event most likely resulted in the placement of an operator aid in the CR at Wolf Creek that shows the location of valve BN 8717.

In the United States, in 1200 pressurized-water reactor years, at least 19 related loss-of-coolant events have occurred with varying blowdown rates while the reactor was on RHR cooling. Boiling and two-phase flow were not issues for most of these 19 events, which were identified in different studies related to shutdown cooling and do not represent an exhaustive search for data. In most cases, the flowpath was from the RCS hot leg through the RHR system back to the RWST via some common discharge line. In most plant designs, this discharge line is not connected to the RWST header line (ECCS suction line) as it was at Wolf Creek. The coolant loss was terminated when an operator closed a valve in the majority of these events. In a 1989 Braidwood event, however, the operator quickly isolated one of the RHR trains, but the 238 000-L (63 000-gal) loss continued over 2 h because the wrong train was isolated. For most events, temperatures less than 93 °C (200 °F) reduced the potential exposure to complications associated with boiling and two-phase flow.

Compressed Outage Schedule

On the basis of interviews with the licensee as well as the licensee's investigation of the event, several observations can be made. The additional work activities and workers involved in these activities likely contributed to a higher cognitive load for the on-shift crew that may have made the task of maintaining the "big picture" more difficult.

The compressed refueling outage schedule was several weeks shorter than previous outages at Wolf Creek. The amount of ongoing work during the shutdown and cooldown of the reactor prior to the outage was higher than typically experienced during other shutdowns proceeding to refueling. The crews expressed the opinions that work activities were well controlled and coordinated and that the extra workload was not a significant problem. Nonetheless, the lack of control of multiple work activities affected plant configuration control, which allowed the rapid blowdown of the RCS.

At Wolf Creek, one of the Operations Outage Supervisors who reviewed the schedule was concerned about the potential to discharge the RCS to the RWST. This concern was communicated to Outage Management and the SS on September 14, 1994. Positive means (such as equipment tagging) were not used to keep these activities separate. Thus the final decision to perform testing of HV-8716A rested with the operating crew SS and the SO and their "comfort levels."

ENGINEERING AND OPERATIONAL CONSIDERATIONS

During NRC review of the event, several engineering and operational considerations became apparent that have relevance to the successful mitigation of a hypothetical extended blowdown.

Thermal–Hydraulic Response

The mixed mean temperature of the water going to the RWST header line is a function of the flow split and the heat-transfer characteristics of the RHR HX. No RHR discharge temperatures were measured during the 66-s transient because the temperature transmitter is located next to the downstream flow orifice that lost flow during the transient. At the end of the transient, a temperature of 127 °C (261 °F) was recorded, presumably the mixed mean RHR temperature at the end of the transient.

The recorded 127 °C (261 °F) water temperature is near the saturation temperature of water in the horizontal RWST line [about 16.8 m (55 ft) below the surface of the water in the RWST]. The ECCS pumps, located 3 to 5.5 m (10 to 18 ft) below the RWST line, require 4.9 to 6.1 m (16 to 20 ft) of net positive suction head to preclude cavitation. After the event, the licensee stated that no assurance existed that the ECCS pumps would fulfill their function while drawing water from the RWST following the event.

NRC's initial concern about this event was that an unabated blowdown through the RHR system would have uncovered the reactor hot leg and introduced steam into the RWST header line, which would potentially disable the only source of water for all the ECCS pumps needed to mitigate a LOCA.

NRC performed simulation of the Wolf Creek event with an unabated blowdown using RELAP5 and a Seabrook plant layout. The 34 822-L (9 200-gal) blowdown in 66 s was approximated by a 0.01-m^2(0.1-ft^2)- or 10.7-cm(4.2-in.)-diameter hole in the bottom of a hot-leg pipe. This approximation was necessary because the RHR and RWST piping systems are not currently incorporated in the RELAP5 model. Two cases were run, with RCPs on and off. As expected, the vessel inventory transient for these cases was more benign than the analysis of the 15.2-cm (6-in.) break in a 4-loop plant analyzed in WCAP-12476, "Evaluation of LOCA During Mode 3 and Mode 4 Operation for W NSSS."

These calculations show a two-phase mixture in the hot leg starting at about 3 min. More than 30 min elapsed before core uncovery with the RCPs running. Even more time is available if the pumps are tripped. These time frames are uncertain, however, because the model did not account for two-phase pressure losses in the RHR system and the 61-cm (24-in.) RWST piping.

The licensee had Westinghouse Electric Corporation (W) perform thermal–hydraulic calculations to examine the conditions in the RWST header line if the blowdown had continued unabated. Review by the licensee indicated that analyses are very sensitive to nuances in the piping configuration. The licensee indicated that a revised W analysis showed a 90% void fraction in the RWST header line starting at 6 min and continuing until the blowdown path is isolated.[3] Under these conditions, the multistage SI pumps, which take suction from this line, would be expected to fail if operated. The potential mitigation of an extended blowdown under these adverse conditions is undetermined from phenomenological and human factors standpoints. If the blowdown path were not isolated, the licensee estimated that the core uncovery would begin in 30 min.

The licensee stated that the high-pressure pump manufacturer had estimated the pumps would last only 1.5 min if steam bound. The licensee also noted that voids in the RHR system at about 3.5 min create concerns about RHR pump operability because of vapor collapse and water hammer during RHR pump restart.

Use of Blowdown Mitigation Procedures

Which procedure the operators would open given an extended blowdown is unknown. A successful recovery from an unabated blowdown without ECCS pumps is not certain because of ambiguities in the procedures and questions about operator actions.

Procedure OFN BB-031, "Shutdown LOCA," would isolate the RHR loop and align it for injection at step 28. If the RHR-RWST discharge line is not isolated, however, the low-pressure RHR flow (if recovered) would still be directed to the RWST header and would not reach the RCS. If the RHR-RWST line is isolated, some of the ECCS pumps may be recoverable, depending on the prior operator action to activate these pumps as well as the pumps' survivability. Furthermore, all the pumps may not vapor bind because the ECCS pumps are started one at a time, the high-pressure pumps draw water from the bottom of the RWST header line, and the blowdown and pumping flow rates are relative.

At step 31 in OFN BB-031, direction is given to use the steam generators and the atmospheric relief valves as a heat sink if the hot-leg temperatures are not stable. This path is the most promising if the RCS is isolated. In the RELAP5 analysis, however, the hot-leg temperatures stay fairly stable if the coolant loss path is not isolated. At step 66, the operator is directed to the PDP, which could be used for charging flow if the centrifugal pumps are not operating. The PDP flow rate, however, is less than the decay heat boil-off rate. The operability of the charging pumps and the PDP is undetermined because the charging pump connected to the VCT had been switching to the RWST header line prior to the event because of other problems during the shutdown. Another concern is that the operators would become distracted when the ECCS pumps started failing and would try to restore failed pumps.

The licensee estimated that performing RHR pump venting would take 10 to 15 min if the pumps become vapor bound. Under better circumstances with coolant temperatures less than saturation, however, restoring

RHR cooling at Waterford took 3.5 h even with a ventable system.[4]

Alternatively, the operators could have been in OFN EJ-15, "Loss of RHR Cooling," which is primarily concerned with recovering the RHR system in the cooling mode. The isolation of the coolant loss path is directed at step 40. This procedure directs the use of the steam generators at step 43 for heat removal. It also activates the accumulators at step 70 at the end of the procedure. The RCS pressures at that time may preclude use of the accumulators.

Residual Heat Removal System WATER Hammer

The causes of the apparent water hammers heard during the event were not determined; however, questions of adverse effects raised by the water hammer issue include the following:

- What would happen if the blowdown progressed and steam came into contact with cold water in the RWST?
- What would happen when steam condenses in the RHR HX?
- Can excessive pressure pulses occur in the RHR system if the operator terminates the high initial blowdown rate quickly?

Boron Concentration Variances

The boron evolution was precipitated by stringent concentration requirements in the procedures. At the time of the event, procedure SYS EJ-120, "Startup of Residual Heat Removal Train," required that each train be sampled prior to being put into operation to ensure that the boron concentration is within 50 ppm of the concentration in the RCS, which is being borated continuously during shutdown. Train "A" was sampled, found to have a boron concentration greater than 2400 ppm, and put into service about 4 h before the event. Train "B" was sampled while the reactor was in Mode 3 and was found to have a concentration of 1230 ppm. The licensee considered borating the "B" RHR train prior to the outage; however, the TS prohibits closing the cross-tie valves, HV-8716A and HV-8716B, in Modes 1 and 2.

The licensee determined subsequently that the boron concentration in the "B" train would not cause a criticality problem even if introduced unmixed into the reactor core. To minimize the need to establish the system lineup that led to this event, the licensee has changed the boron requirements for putting an RHR train into service:

- If the concentration meets the minimum shutdown margin for boron concentration, operation of the RHR train is acceptable without additional action.
- If the boron concentration is less than 100 ppm lower than that required by the minimum shutdown margin and *two RCPs are operating*, operation of the RHR train is acceptable without additional action.
- For all other situations, the RHR train must be borated before use.

Check Valve Leakage

A contributing factor to the event was the check valve back leakage from the RCS into the RHR system while the plant was at power because this reduced the boron concentration in RHR Train B.

The leakage needed to dilute the boron concentration in an RHR train is quite low. A leakage rate of 0.038 L/min (0.01 gal/min) would displace the initial water inventory in an RHR train over 1 year. If the leakage rate is 0.38 L/min (0.1 gal/min) (less than TS limits on RCS leakage), the water inventory turnover could be accomplished in about 1 month. Thus, obtaining very low boron concentrations in an RHR train at the end of an operating cycle is possible. To dilute an RHR train, this leakage has to be past the third check valve from the RCS. This check valve is not leak tested during every refueling.

CONCLUSIONS

The following conclusions are based on a review of the event and information relevant to a potential extended blowdown if the problem had not been isolated quickly:

- Unrecognized Design Vulnerability

  The Wolf Creek event disclosed a previously unrecognized design vulnerability: a piping arrangement connecting the discharge of both trains of RHR to the RWST header line whose inappropriate use while on RHR cooling could result in a fast loss-of-coolant event and a consequential common-mode loss of ECCS mitigation capability if an extended blowdown occurred through this path.

- Control of Work Activities

  Operators failed to control work activities appropriately, and this failure resulted in the initiation of the event. Many factors affected operators' ability to control work activities.

- Initial Response

  The operating staff diagnosed the blowdown and closed a valve, which stopped the event.

- Mitigation of an Extended Blowdown

  The mitigation of an extended blowdown if the ECCS pumps are failed is undetermined. Uncertainties that affect a conditional core damage probability calculation for the Wolf Creek sequence of events depend largely on values used for operator actions, uncertainties about common-mode impairment of ECCS equipment that takes suction from the RWST header, and the initiation of reflux cooling. Preliminary review indicates the event is among the most significant events of recent years from a safety standpoint.

- Safety Significance of Design Vulnerability

  The potential safety significance of the design vulnerability was not fully understood or appreciated initially.

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The human performance improvement program at Duke Power nuclear stations

BY TOM SHIEL

A few years and a complete change of mindset helped turn around flagging performance at Duke Power's nuclear power stations.

A CONSCIENTIOUS EFFORT to get at the root of human performance shortfalls has led to the development of a system that has taken Duke Power's McGuire nuclear station from an average performer five years ago to one of the more efficient, reliable stations in the country.

Recent performance statistics prove the point. In 1998, the two-unit, 2200-MWe site outside Charlotte, N.C., generated a net 18 744 903 MWh of electricity—the most in station history. In 1999, McGuire-1 operated for a company-record 442 consecutive days. The station holds the company's record for longest dual-unit run—253 days from July 2, 1998, to March 12, 1999.

Refueling outages at the utility continue to get more and more efficient. McGuire-2 set the company standard in April 1999 with a refueling outage that lasted 33 days, 6 hours. That broke McGuire-1's record of 33 days, 19 hours set in 1998. Then, Catawba-1, operated by Duke Power, raised the bar by completing a 32-day outage in May 1999.

McGuire also set a new world record for lowest collective dose for an ice condenser plant during its September 17–November 5, 1999, refueling outage. The collective dose was 85.2 person-rem, eclipsing the old record of 94.5 person-rem set by Catawba during a refueling in spring 1999. "It was a great team effort by everyone working the outage," said McGuire site vice president Brew Barron.

Despite having two refueling outages last year, the station still recorded an 89.17 percent capacity factor and generated 17 184 838 MWh of electricity.

It's amazing what a few years and a complete change of mindset can do.

In the early 1990s, McGuire's performance was declining noticeably. Operational events were too frequent. Refueling outages between 1990 and 1994 lasted an average of more than 92 days for Unit 1, and more than 87 days between 1990 and 1993 for Unit 2 (there was no refueling outage for Unit 2 in 1994). Capacity factors fell to as low as 56.6 percent in 1990 and averaged 72.44 percent between 1990 and 1993. The plant's SALP (Systematic Assessment of Licensee Performance) scores, given by the Nuclear Regulatory Commission, had reached a point where company management knew that strong measures were needed.

"Just walking around the plant, one could almost feel the poor morale," an employee said. Duke Power's employee opinion surveys confirmed it: McGuire employees' overall satisfaction level ranked at the bottom of the company.

Why? What was causing such lackluster performance and poor morale?

Station and company officials found many causes, but it was clear that the heart of the problem lay in human performance issues.

In 1994, management determined that the station's processes and programs were to blame.

What does time pressure do to employees? What happens when they are doing things too routinely without any kind of change? Do employees become complacent or forgetful? Are they simply doing things out of habit? How can management establish a system to take people out of that habit mode?

At McGuire, Joseph Hussey (left), senior reactor operator, observes Paxton Fayssoux (center), reactor operator, as he prepares to run a nuclear service water pump in support of an auxiliary feedwater pump performance test. C. J. Washington (right), nuclear performance specialist, talks to personnel in the plant via cell phone while providing operations test technical support. (Duke Power photos by Marilyn Lineberger)

Tom Shiel is a senior communications specialist at Duke Power, in Charlotte, N.C.

Elaine Bare, work control coordinator at McGuire, and Bruce Dills, technical specialist, discuss maintenance work orders, which involve determining the need for red tags, procedures, and special equipment.

Answering these questions led to the formulation of some early initiatives. These included:

Risk Assessment—Station officials determined employees did not consider the consequences if something went wrong as they performed work. "We just didn't think about it as part of routine contingency planning," said Scotty Bradshaw, McGuire operations superintendent. To correct this, management established a process to review each work order and assign a risk code. Assigned risk now influences the pre-job briefing, personnel assignment, and supervisor/manager oversight.

Self-Assessment—"We realized that too often we waited for audit teams, NRC, or INPO [Institute of Nuclear Power Operations] to point out our problems," observed Dhiaa Jamil, McGuire station manager. "We set up an expectation and process requiring each group to take ownership of self-assessments within the group. We review processes and behaviors and identify improvement actions. We track actions to closure."

Human Performance Enhancement System (HPES)—McGuire had actually piloted the INPO HPES process. The station had a site HPES coordinator, but little support from the group level. The new initiative required that each group designate a human performance coordinator.

"Accountability for these initiatives was assigned to line managers," said Jamil. "They developed detailed implementation plans. Looking back, the initiatives appear to be fundamental in nature, but at that time they were not a conscious part of our processes."

Bringing about such a radical change in mindset was not going to occur overnight. The new structure itself required a very precise way of performing work. Before a job was done, there would be a pre-job briefing during which employees would talk about what they were going to do, how they were going to do it, why they were going to do it, what the risks were, and what the contingencies were.

"There were some who felt this new program was going to be cumbersome, delay work, and cause us to do a lot of additional work for no apparent reason," Bradshaw said. "The biggest barrier was the feeling among employees that this was just another program, and it would go away."

But it wasn't and it didn't.

A consultant hired to initiate the program told Duke Power officials it was going to take four to five years for the program to become established. "There would be some immediate impact, but long term, if you don't stick to it, there would actually be a negative turnaround," Jamil said.

"When this program was presented, we knew it would require a lot of work," said Bradshaw. "In reality, it forced us to plan better and give people enough time to do a good job of planning. And when you do a good job of planning, it doesn't take as long to do the actual work."

"Before our focus on human performance, we had difficulty meeting outage schedules many times due to human performance problems during the outages," noted Jamil. "We have established a positive trend of meeting outage schedules."

"These initiatives and others were put in place to help us," said Edgar M. "Mac" Geddie, who was McGuire station manager during the program rollout. "It's been said if you don't keep score, then you're just practicing. We wanted to be in the game and needed a measure. We decided to use our corrective action program cause codes to trend our improvement. The codes selected were work practices, verbal communications, written communications, and plant/systems operations."

"In the beginning, we called it 'Flawless Human Performance,' but we scrapped that notion because we are human and we will make errors," Geddie said. "Even INPO recognizes this. The issue is: Are there enough barriers or contingencies built in so errors don't become events? If you analyze an entire event, and study why that event happened, you'll find it wasn't just one mistake—it was five, six, or seven mistakes that occurred and there weren't enough contingencies or barriers built in to prevent the event from happening."

As the industry spotlight continued to intensify on human performance, McGuire joined with the other two Duke Power–operated nuclear stations, Catawba and Oconee, to obtain some "professional" help. By late 1994, McGuire officials were working with the station's consultant to perform a structured assessment of human performance needs. This common cause assessment identified the need for focused human error reduction training for technicians and supervisors.

Continued

Tony Williams (right), nuclear maintenance supervisor at McGuire, presents a pre-job briefing to Mark Yount (center), nuclear instrumentation and electrical specialist, and Donnie Rowland (left), nuclear maintenance specialist, before they perform an emergent work task.

The consultant trained a management team on how to implement a program that would affect performance to reduce the likelihood of errors or events.

"What we did then was train the rest of the organization by first training a critical mass of people so the program's concepts would stick," Bradshaw said. "For us, that was maintenance, operations, and chemistry. We had worker training and supervisor training. You end up training a very significant part of your organization. I would say 75 percent of the organization was trained during the first year."

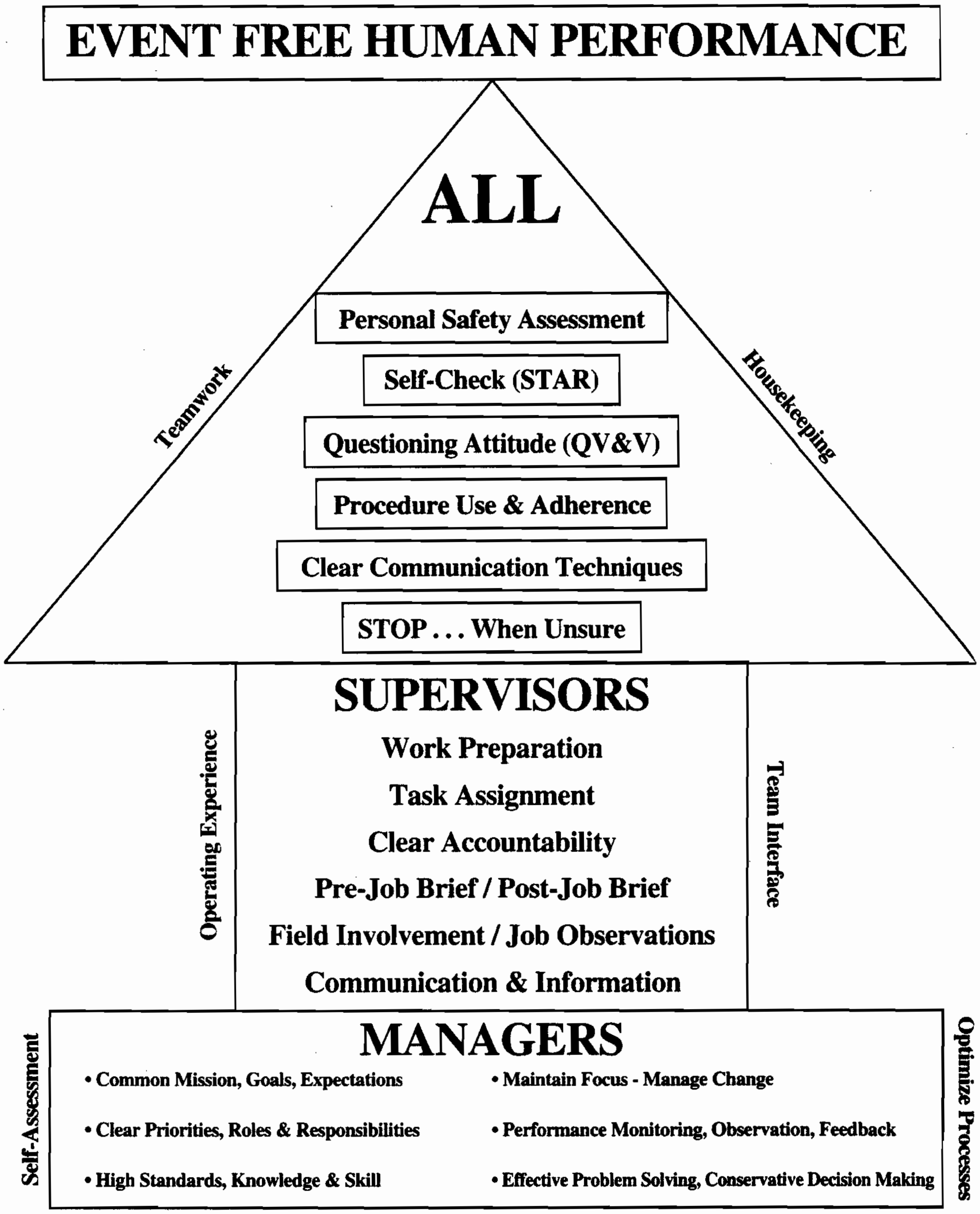
"We all basically have an understanding of why human beings make errors and what barriers need to be in place to prevent errors," he added.

Each Duke Power nuclear station set out to establish such a program, but by 1996, each had headed in a somewhat different direction.

Mike Tuckman, the utility's executive vice president of nuclear generation, saw the problem developing and stepped in to correct it.

"Why would you have a different set of expectations at each site, especially considering that you have employees traveling to each site to perform work?" he asked. A quality improvement team was created at the corporate level to establish a standard set of tools and expectations and a standard structure for how human performance would be maintained.

"There's a lot of support from upper management on this," Jamil said. "In fact, part of the incentives we have deal with events—events caused by equipment, and events caused by human performance issues. Even our incentive program is based on reducing the number of human events. There are good incentives to remain event-free." He added, "This has caused us to achieve consistency and renewed dedication to continuous improvement in human performance."



Human Performance Model. This graphic is worn by workers at all three Duke Power–operated nuclear stations. The concepts identified on the perimeter of the arrow are intended to support the tools inside that section of the arrow. QV&V™ is a registered trademark of Performance Improvement International (PII). (Source: Duke Power)

McGuire's program focuses on three key areas: prevention, detection, and correction.

Prevention involves establishing clear expectations and tools for managers, supervisors, and individual contributors. These are known as the six tools for event-free human performance. The keys of the six tools are:

Personal Safety Assessment—Each time an employee is starting a new job, he or she must understand the task he or she is about to perform and have the necessary safety equipment.

Self-Check (STAR)—After a project is completed, a review is performed to ensure that all aspects of the intended task have been covered. STAR stands for Stop, Think, Act, and Review.

Questioning Attitude (QV&V™)*—Ask questions about the task at hand and the procedures required to complete it. QV&V stands for Qualify, Validate, and Verify.

Procedure Use and Adherence—Make sure that proper procedures are being followed to complete a task.

Clear Communication Techniques—This includes using the phonetic alphabet when describing a process or procedure and making sure that equipment is color-coded.

*QV&V™ is a registered trademark of Performance Improvement International (PII).

STOP When Unsure—This is probably the most important of the six tools. If an employee has any question or concern about the task at hand, then he or she should stop and get answers before proceeding.

"We teach these tools in training, and management continually reinforces them," said Jamil.

Detection depends on conducting periodic common cause and management error common cause analyses and using leading, real-time, and lagging performance indicators. "During the process we accepted that, yes, management can make errors," he added.

Continued

Correction prevents recurrence of human errors by using a good root-cause analysis program for significant events and trends. Corrective actions must address the root cause to be effective.

Line ownership continues to be a "must" ingredient.

"Our nuclear sites have a human performance steering team, which is sponsored by the site vice president and led by the station manager," Jamil said. "The team consists of station superintendents and managers, supported by the safety review group and organization performance improvement group. The team provides overall direction for human performance improvement. At the group level, we have human performance review committees led by each group superintendent or manager. These committees conduct very specific reviews of trends and sponsor initiatives to improve human performance."

Performance is measured (keeping score) through an index composed of:

- Human performance Licensee Event Reports (LERs).
- Human performance–related NRC violations.
- Self-improvement culture surveys.

Specific initiatives include integrating the use of human performance tools in site organizations, integrating INPO fundamentals training, completing 100 percent initial human error reduction training, and finalizing management error common-cause analysis action plans.

Mike Rains (right), engineering supervisor, discusses McGuire's management observation program with Tom Ray (left), engineering supervisor. All management team members conduct monthly in-plant observations of field activities to observe tasks and coach for effective human performance, including safe work practices and appropriate use of procedures.

Parallel with and overlapping these efforts to improve human performance has been an initiative to improve equipment reliability at McGuire. The overlap aspect features a focus on prevention, detection, and correction. Also, as with human performance, the management, process, and work practice aspects of equipment reliability are being addressed.

"We continue to measure success, identify new problems and formulate new initiatives," Jamil said. "Our results show improvement, but the game is constant and requires all teammates to participate. We plan to continue improving our score." NN

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