

**Organizational Learning at
Nuclear Power Plants**

by

**John S. Carroll, Constance Perin,
and Alfred A. Marcus**

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**THE MIT INTERNATIONAL PROGRAM FOR
ENHANCED NUCLEAR POWER PLANT SAFETY**

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**Report of the Panel Meeting
Nuclear Power Plant Advisory Panel on Organizational Learning
MIT Sloan School of Management
Cambridge, Massachusetts
October 17-18, 1991**

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EXECUTIVE SUMMARY

The Nuclear Power Plant Advisory Panel on Organizational Learning provides channels of communication between the management and organization research projects of the MIT International Program for Enhanced Nuclear Power Plant Safety and plant personnel actively concerned with important operational issues, inside and outside the control room, relevant to safety. The Panel is conceived as an opportunity for plants to share their knowledge and concerns about aspects of management and organization, with a particular emphasis on self-assessment, learning, and the management of change. Further, the Panel seeks to identify opportunities for collaborative research with practical benefits.

At the first Panel meeting, 20 representatives from U.S. nuclear power plants and utilities and 14 MIT faculty, research staff, and students explored mutual interests and priorities in order to guide future research efforts. Professor John Carroll introduced the overall MIT research project. Three MIT researchers discussed their proposed research: Professor Alfred Marcus discussed quantitative analyses of improvements in U.S. nuclear power plant safety during the 1980s, and the need to conduct detailed studies of plant improvements and of utility strategies; Dr. Constance Perin discussed how work requires bridging across functions, levels, technical groups, and shifts within a social and cultural system, and proposed to study various plant programs in terms of their vertical relationships and institutional context; Professor John Carroll focused on the analysis of safety-relevant incidents through the application of knowledge distributed among various professional groups in the plant, and the need for research to characterize this knowledge and its relationship to performance enhancement. In addition, Professor Michael Golay discussed the organization and management implications of new reactor technology, and Professor Thomas Kochan summarized research on contractor training and safety in the petrochemical industry.

Roundtable groups discussed three topics of their own choosing: configuration control, proactivity and communication with management, and event trending (including root cause analysis and corrective action tracking). A wide-ranging discussion explored topics of mutual interest, their connections to safe operations and their potential for research. A variety of research opportunities were raised and discussed, along with next steps for continued communication between the Panel and MIT.

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Background

The MIT Sloan School of Management is conducting a research project on the management and organization of nuclear power plants, with special emphasis on how plants can maximize their abilities to learn from their own and others' experiences. This project is part of the MIT International Program for Enhanced Nuclear Power Plant Safety, a cooperative research effort developed to create new knowledge relevant to enhanced safety, which also includes research on the science and technology of service and maintenance and the role of public policy. Unlike other institutions concerned with safe performance, our interests are in research, education, and technology transfer. Funded by private utilities and foundations, we are in contact with but receive no financial support from industry groups or government agencies such as INPO, NRC, DOE, and IAEA. Current Program sponsors are listed in Attachment 1.

The Nuclear Power Plant Advisory Panel on Organizational Learning provides channels of communication between the MIT research project and plant personnel actively concerned with important operational issues (inside and outside the control

room) relevant to safety. The Panel is conceived as an opportunity for plants to share their knowledge and concerns about aspects of management and organization, with a particular emphasis on self-assessment, learning, and the management of change. The Panel offers interested parties, who are dealing with similar issues, a way to learn from one another and, in conjunction with the MIT research program, to identify important issues for research with practical benefits. Specific collaborative research relationships among plants and the MIT research team are on the Panel's agenda. Finally, MIT may be able to offer support for research and change efforts that plants may initiate.

In September, 1991, plants and utilities were invited to send a representative to the initial Panel meeting at MIT on October 17-18, 1991. The overall goal of meeting was to explore mutual interests and priorities in order to guide future research efforts. The preliminary agenda (see Attachment 2) was structured to enable the MIT team to present their research strategies and plans for discussion, and to invite plant participants to raise and discuss their own issues and concerns. A goal was to outline possibilities for collaborative research for mutual benefit. Finally, another goal was to develop specific next steps for the Panel in terms of the content, frequency, and modes of its future communication.

Meeting Summary

The meeting began with introductions of 20 representatives

from U.S. nuclear power plants and utilities, 9 MIT faculty and research staff, and 5 students. Attachment 3 provides a list of the participants. Professor John Carroll next summarized the objectives of the MIT Program on Enhanced Nuclear Power Plant Safety as a whole and the Organization and Management Project within the overall program. Each of the three principal MIT researchers then discussed the rationale for research they propose to conduct during the next 9 to 12 months. To provide other stimulating examples for the Panel's discussions, two MIT faculty presented reports, one on the organization and management implications of new reactor technology, and the second on safety implications of the use of contractors in the petrochemical industry.

One objective of the Panel Meeting was to hear plant representatives discuss how their own concerns and issues might be introduced into the research projects. In addition to general discussion and feedback about the MIT research projects, the MIT research team suggested seven topics as possibilities for Roundtable (break-out) discussions. Urged to suggest other topics, the participants added three topics of their own choosing: (a) configuration control, (b) proactivity and communication with management, and (c) event trending, root cause analysis, and corrective actions. A vote to determine the topics of the Roundtables led to the choice of those proposed by participants. Reports from each Roundtable were later presented to the Meeting as a whole.

This report briefly summarizes the five presentations, presents the issues raised by Panel participants during general discussion and Roundtables, and closes with a summary of the possibilities raised by the participants for continued Panel activity and support for collaborative research.

Understanding Industry Improvement

Professor Alfred Marcus summarized his analyses of U.S. nuclear power plant safety performance over time, using quantitative data from NRC, FERC, and other sources. The analyses show: (1) there has been continuous improvement in plant performance on various safety indicators during 1985-89, especially among below-average performers who are converging toward the better performers; (2) separate safety indicators such as SCRAMs, safety system actuations, and safety system failures are only weakly related, so that the concept of a "safe" plant must be carefully specified; (3) the strongest predictor of significant event and safety system failure improvement was more spending on the budget item of "Operations and Engineering Supervision" per installed capacity from FERC reports. However, the meaning of this result depends on knowing which activities are supported within this gross budget item. To investigate this, Professor Marcus proposed focused case studies of several plants that have made efforts to improve their safety records, particularly within utilities that have plants with differing performance records. Utility business strategy (e.g., whether the utility is diversifying away from nuclear power) and

regulatory relationships were also related to improvement. Thus, research must study utilities as well as plants, together with characteristics of the industry such as national and state regulatory relationships. For more detail, see Attachment 4.

Organizational Pathways Analysis

Dr. Constance Perin discussed a conceptualization of nuclear power plants as continuous learning and vigilance systems. Within plants, much of the work requires bridging across functions, levels, technical systems, occupational groups, and modes of operations (across shifts and tempos, in and out of outage), as well as to external institutions (corporate, regulators, utility commissions, vendors, contractors). Last year's studies at several nuclear power plants examined how such bridging integrates safety concerns across functions with an emphasis on maintenance work requests. As reported in our 1991 Annual Report, the research methods included intensive interviews, observation, and examination of documents on site. Considerable variation in organizational forms exists across different plants. This year, Dr. Perin proposes that we look at how various "programs" such as outage planning and implementation, fire prevention, and configuration control are organized. These case studies will emphasize vertical relationships and institutional context by mapping the organizational pathways along which flow resources such as people, information, rewards, and authority. The knowledge gained will help develop deeper understandings of how plants

balance efficiency and safety, stability and change, and proceduralization and training, negotiate the distribution of responsibility and accountability, and maintain effective learning. For more detail, see Attachment 5.

Making Sense of Plant Incidents

Professor John Carroll focused on the improvement of plant functioning through the analysis of safety-relevant incidents, which depends greatly upon the ability to interpret experience from within and outside the plant. Over time, categories of causes implicated in plant incidents have been grounded in technical aspects and man-machine and training issues. Only recently have the wider contexts of management and organization been examined; the Human Performance Enhancement Program has this broader focus. These categories constitute the knowledge or "mental models" of plant functioning necessary to understand and learn from operating experience. Such models are socially-distributed: no one person can know everything necessary about the plant. Due to differences in professional training and plant experience, different people will have different "mental models" of operations. Effective interpretation and change management requires the marshalling of these distributed partial models of the plant. Therefore, it is reasonable to conclude that a feature of effective operations will be mental models that individually and collectively diagnose problems effectively and promote recovery. Prof. Carroll proposed a research project to characterize the contents, depth, and distribution of mental

models in several plants, across functional and hierarchical divisions, and the relationship between this distributed knowledge and the capacity to learn, as reflected in safety performance. Brief but interesting incident reports would be selected and presented for analyses to a range of respondents in each plant, thus revealing respondents' mental models in the process of their use. For more detail, see Attachment 6.

Organizational and Managerial Issues in Advanced Nuclear Power Plant Designs

Professor Michael Golay summarized the international efforts to develop new technologies for performance improvements. Although performance implies a combination of safety and efficiency, new technologies tend to emphasize one or the other. Worldwide programs of advanced reactor design are varied and complex, yet the evaluation of these designs is dependent on the regulatory climate. In the U.S., the NRC seems more comfortable understanding the more evolutionary designs to improve economic performance, and less certain of how to evaluate more revolutionary designs for enhanced safety (e.g., passive safety). As a result, the safety-centered designs are receiving less support. Further, no one seems to be considering the implications of advanced reactor designs for organization and management, other than to create "hands off" designs with limited roles for people. For more details, see Attachment 7.

Safety, Contractors, and Training in the Petrochemical Industry

Professor Thomas Kochan summarized an OSHA-sponsored study

of safety and health issues relating to the use of contract labor in the U.S. petrochemical industry. Surveys of plant managers, direct hire and contract workers, contracting firms, and case studies of 9 plants revealed a lack of injury and incident data about the experiences of contract workers, a high and growing prevalence of contract workers, contract workers who are less experienced and lower paid than direct-hire workers, a lack of safety consideration in contractor selection, less training of contract workers despite their involvement in some of the more risky work, and a lack of plant management oversight of contract workers due partly to avoidance of legal and financial responsibility over contract workers. Most importantly, contract workers were more likely to experience accidents than direct hires; lack of training and communication of safety practices was implicated as a predictor of safety problems. For more details, see Attachment 8.

Issues and Concerns Raised

Discussion ranged over a wide variety of topics. The following list gives a flavor of the most frequent concerns. The following issues do not represent a consensus or prioritized ordering; these are opinions expressed by individuals and discussed by the group. There were considerable differences in whether particular plants were experiencing these as concerns. Of course, the categories and relationships among these issues could be elaborated in many ways.

1) Conflicting Demands for Error-Free and Efficient

Operations -- Nuclear power plants are expected to be "high-reliability" organizations, a category that includes air traffic control, aircraft carriers, and blood banks. Such organizations must try hard never to make serious errors, and to extract as much information as possible from each incident. Plants must quickly recover from and learn from small mistakes so they do not become big ones. The post-TMI period had intense attention to safety improvement from the public, regulators, etc. However, many utilities are reorganizing around a concern for cost reduction and competitiveness.

2) Communicating with Upper Management -- It is often difficult to get management attention, especially about "soft" people issues that do not fit into a task-oriented paradigm. There is a need to establish the credibility of those low in the organization or in the wrong parts of the organization. There are bottlenecks in the upward flow of information where the hierarchy is too strong. The MIT research could provide independent, objective corroboration of things that have difficulty being heard. Management should be more proactive and concerned with the long term, rather than reacting to immediate pressures from the NRC. Management should better communicate expectations about quality work and fill in the big picture, especially about jobs being on the line with respect to business performance. There is a disjunction between the cooperative system expected of employees and the command system that relates downward. Budgeting and allocating resources is a concrete way

management communicates, but plant personnel are not involved.

3) Lowering the Threshold of Self-Reporting -- Few "near miss" reports are turned in, yet these are very valuable for finding things before problems become more serious. In other countries, the craft are taken more seriously and participate more in reporting and fixing problems. The bottom of the organization knows a lot that is not reported because of a tendency to blame individuals, lack of confidentiality, sense of not being listened to because they are low status, or lack of follow-through (no feedback or follow-up actions). There is tension between the tendency to blame and punish, and the need to maintain a learning environment that addresses broader system-wide problems.

4) Coding, Interpreting, and Trending Incidents -- Several plants reported inconsistencies in coding systems, or difficulty coding some classes of information. Symptoms are more easily coded than causes, and symptoms tend to be the focus of mandated reporting. Since incidents such as mispositionings may have very different causes, what then is a "repeat"? Panel participants agreed that incident reviewers are looking beyond "personnel error" to the larger context, and that they have to gain skill in doing so. It is hard to evaluate the resulting information because there are few standards other than past performance -- how can a plant know how it's doing against other plants or know how good is "good enough"? What models are there for understanding combinations of performance indicators? Also,

corrective actions should be trended as well as events and causes.

5) Structuring Incident Analysis -- Some plants centralize incident analysis in one person or a dedicated group of evaluators (e.g., HPES program) who become expert. Others decentralize analysis and include those (e.g., foremen) who know more of the details, thereby spreading analytical knowledge through the plant and easing the way for implementing change. Should HPES analysis be more integrated with other problem solving activities (e.g., event analysis), and more widely disseminated into routine considerations, or should it be reserved for special circumstances?

6) Learning in Nuclear Power Plants -- How can learning be carried out in "trial and error" fashion given the great amount of public exposure and intensive scrutiny of all errors by outside parties? How can we avoid a "cover-up" or "blame" or "kill the messenger" mentality in such a setting? How to quickly recover from and learn from small mistakes so they do not become big ones? Are there other organizational analogies - aircraft carriers, blood banks, chemical plants, air traffic controllers? Imitating practices of others may have no bearing at different sites with customized features; can there be one best way of managing?

7) Motivation and Procedures -- The procedures and work preparation process is so complex and frustrating that people bypass the process. Occasionally they get caught. Additional

procedures undermine individual ability. Too much detail may be given in places where it is not needed, and too little where it matters. Handoffs of procedure-writing to contractors may create mismatches and miscommunications. Even with good procedures, how can we move from a rule-bound mode to one of active thinking where training and professional expertise play as much of a role as mindless verbatim compliance with procedures?

8) Locating Expertise and Responsibility -- There should be ownership and expertise, but the challenges should be proportional to training to avoid anxiety or boredom. Systems engineers may be one important location for responsibility over systems, if they are given budget authority. Job enrichment and rotation can overcome boredom, maintain vigilance, and provide training. However, job rotation should not take away experienced people with training who have finally gained competence and become indispensable to a function. There is need for additional operators on shift so they can be out in the plant touring, observing, inspecting, and talking with others on roving watch. Such a resource commitment would be one example of management's proactive attitude.

9) Safety vs. Cost -- There are conflicts between safety and cost (including the external forces of NRC pushing safety while PUCs keep costs down). What incentives work during outages to meet schedules? Are these the right ones to enhance safety? How can we achieve both schedule and safety goals? Some plants have bonus systems that extend to all employees, involving sets of

performance and safety goals that are negotiated with each group. The goals from which bonuses are computed may differ from group to group, but come from a single pool of bonus money for the plant.

10) Proactivity vs. Reactivity -- Reacting to problems gives a sense of accomplishment and problem-solving, and is also exciting. This behavior fits the stereotype of operators as enjoying crises. Proactivity is thinking rather than doing; it feels like creating problems rather than solving them. Thus, despite broad agreement about the importance of being proactive, there are some emotional blocks (and manpower limitations) that inhibit these behaviors.

Prospects for Further Collaboration and Panel Activity

There was considerable formal and informal discussion of research opportunities that address the foregoing concerns and issues. Several plant representatives volunteered to invite us to conduct studies of their plants. For example, some plants have recently begun organizational changes; one plant is about to conduct a plant-wide self-assessment. These opportunities will be considered in the context of the overall research effort.

A variety of data sources was discussed -- information gathered by the plants on incidents, performance, worker suggestions and information requests, maintenance work requests, personnel, and so forth. Participants seemed willing to have MIT study such data within the constraints of confidentiality. The research team was also interested in the narrative of incidents

from which category coding is made for summary reports.

It was suggested that the Panel and MIT work toward more informative incident report categories. The Panel might create a pool of reports for us. Also, alternatives to traditional methods of corrective action and organizational change were of interest. The theme of "buy-in" resurfaced with interest in ways to get more commitment from upper management and workers.

The MIT team offered technical assistance for Panel members who might wish to conduct their own research in plants. For example, they might hold discussion sessions about incidents and recovery activities with supervisor-level workers. The MIT researchers also suggested that the Panel could send memos to MIT and to each other about topics or issues they find salient.

The Panel consensus was to continue to work and to meet again in nine to twelve months, in order to avoid conflict with workshops scheduled by INPO for HPES Coordinators. Other contacts via telephone, mail, and fax are likely.

Next Steps

The Panel first asked the MIT research team to issue a report or proceedings of the Panel meeting for general distribution, as rapidly as possible. To ensure accuracy and confidentiality of particular statements about plant incidents and performance, a preliminary version of the report is to be sent out for comment to all Panel participants before release as an MIT Center for Energy Policy Research report.

The MIT research team will also distribute a draft of a

questionnaire inquiring about the kinds of data relevant to the project that are already kept by plants. Panel members will provide brief descriptions and examples of this data (concealing personal and plant identities), as well as judgments of its usefulness and availability for research.

The MIT research team will identify the kinds of research sites most desirable for each of the studies planned for the coming months. Panel members may be contacted; specific negotiations for collaborative research will follow dissemination of the Meeting report to plants and utilities.

Panel members are encouraged to communicate any follow-up thoughts prompted by the meeting to the MIT team. Further expressions of interest in research or sponsorship of the MIT Program are welcome.

Attachment 1 - Program Sponsors

<u>Country</u>	<u>Organization</u>
Finland	Imatran Voima Oy Teolisuuden Voima Oy
Germany	Kraftwerk Union AG
Japan	Mitsui, Inc., Ltd. agent for: Chubu Electric Power Company, Inc. Japan Atomic Power Company Kansai Electric Power Company, Inc. Kyushu Electric Power Company, Inc. Tokyo Electric Power Company, Inc.
South Korea	Korea Electric Power Company
Switzerland	Swiss Nuclear Operators Group
Union of Soviet Socialist Republics	Institute of Nuclear Safety of the Soviet Academy of Sciences
United States	Boston Edison Company Commonwealth Edison Company Consumers Power Company Duke Power Company Florida Power and Light Company General Electric Company The John D. and Catherine T. MacArthur Foundation New York Power Authority The David and Lucile Packard Foundation Public Service Electric and Gas Company Stone and Webster Engineering Company Yankee Atomic Power Company
International	World Association of Nuclear Operators - Paris Center International Atomic Energy Agency - Division of Nuclear Safety

Attachment 2 - Advisory Panel Agenda

THURSDAY, OCTOBER 17

- 8:15 Coffee and rolls, Penthouse of 38 Memorial Drive (E56)
- 8:30 Introductions
- * Goals of the meeting
 - * Discussion of two-day agenda
 - * Brief overview of MIT research program
- 9:30 MIT collaborative research directions
- * Alfred Marcus, "Understanding Industry Improvement"
 - * Constance Perin, "Organizational Pathways Analyses"
 - * John Carroll, "Making Sense of Plant Incidents"
- 10:30 Break, beverages
- 11:00 Discussion
- * Panel concerns, issues
 - * Panel response to MIT research program
- 12:00 Lunch
- 1:15 Roundtable discussions (three of the following topics)
1. Outage planning and scheduling
 2. Coordinating operations and maintenance
 3. Corrective action tracking
 4. Procedure reliability
 5. Contractor training
 6. ALARA planning
 7. Fire prevention
- 3:00 Break, change rooms to E40-170, beverages
- 3:30 Roundtable reports and discussion
- 5:30 Cash bar at Faculty Club (6th floor of 50 Memorial Drive)
- 6:30 Dinner in the Penthouse at 38 Memorial Drive (E56)
- 7:30 After-dinner presentation and discussion
- Michael Golay, Professor of Nuclear Engineering
 - "Organizational and Managerial Issues in
 - Advanced Nuclear Power Plant Designs"

FRIDAY, OCTOBER 18

- 8:30 Coffee and rolls, Penthouse of 38 Memorial Drive (E56)
- 8:45 Presentation and discussion
- Thomas A. Kochan, George Maverick Bunker Professor of
 - Management, "Safety, Contractors, and Training
 - in the Petrochemical Industry"
- 10:30 Break, beverages
- 11:00 Discussion led by the MIT Research Team
- "Ways of Thinking About Organizations: The Social
 - and Cultural Logics of Nuclear Power Plants"
- 12:30 Wrap-up and action points
- 1:00 End of meeting (MIT team will stay as late as anyone wishes to continue discussion)

Attachment 3 - Panel Meeting Attendees

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October NPP Advisory Panel on Organizational Learning
"Understanding Industry Improvement"

Alfred A. Marcus
Research Plans and Rationale 1991-92

Understanding Performance Improvement

The research proposed here would concentrate on understanding improvement in nuclear power plant performance. Indeed, 1985-90 trends in the industry, based on published reports, were good. Plants operating at a high level generally maintained their high level of performance, and improvements were achieved at plants that previously had poor records (See Figures 1-2).

***What accounts for continued high level of performance at the "excellent" plants? What guarantees that these excellent plants will to continue to perform at the same level? What signs would indicate that they were headed for trouble?**

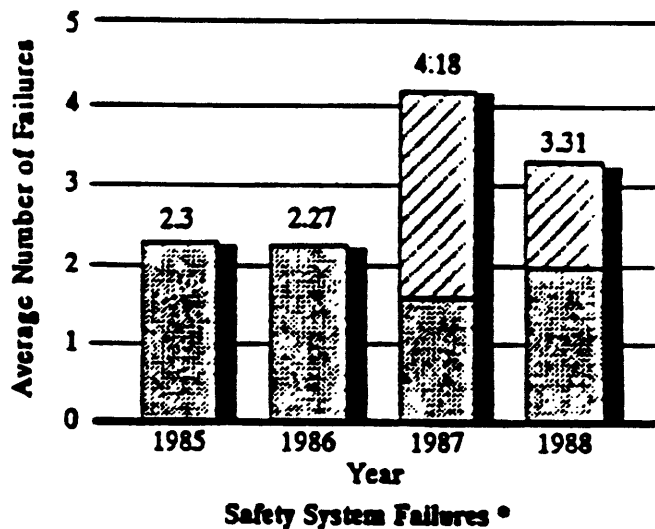
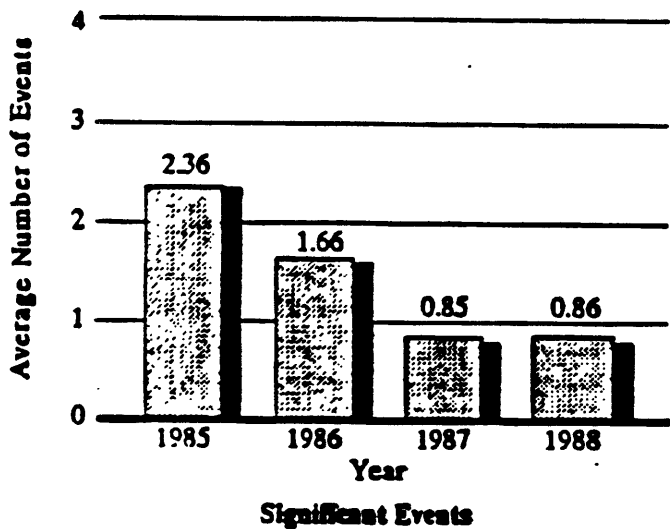
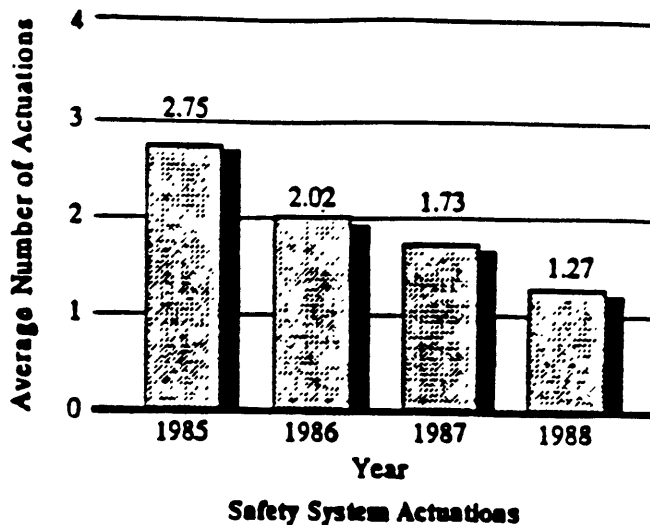
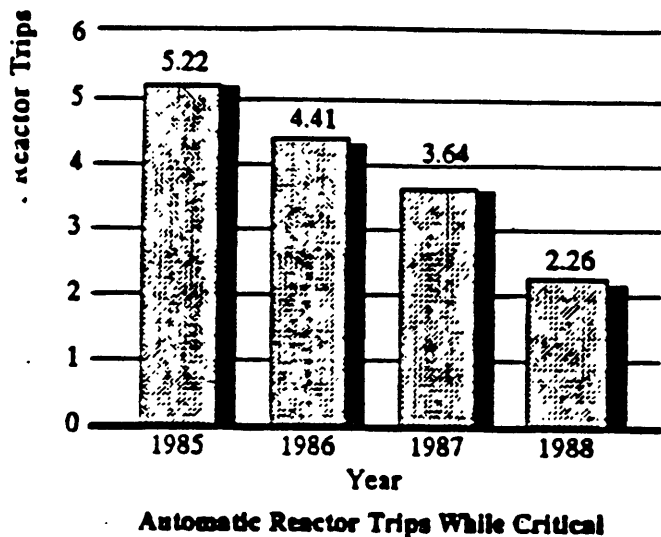
***How have some plants been able to make turnarounds in their performance? What accounts for their improved performance? How have the turnarounds been achieved?**

***What about plants that have tried to improve, but have not been able to accomplish as much as they hoped? What accounts for their inability to achieve what they want?**

Last Years Statistical Studies

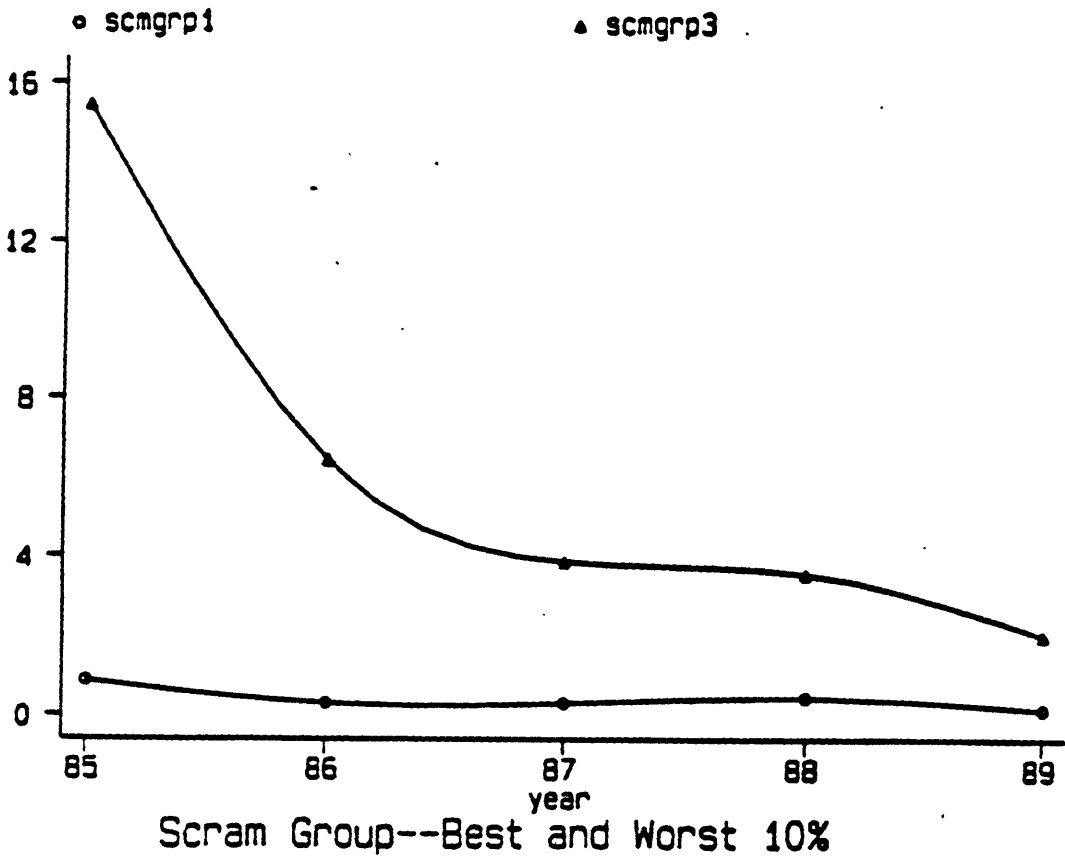
Last years statistical studies were based on a model of improvement at nuclear power plants (See Figure 3) which presumes that future performance on an indicator is best explained by past performance on that indicator. Improvement only occurs if problems are recognized, resources are available for problem solving, these resources are appropriately applied, and the utility's attention is focused on nuclear power and is not distracted by other strategic thrusts and initiatives. Alternative variables representing the

Figure 1



* The hatched area represents the additional data resulting from reclassifying safety system failures.

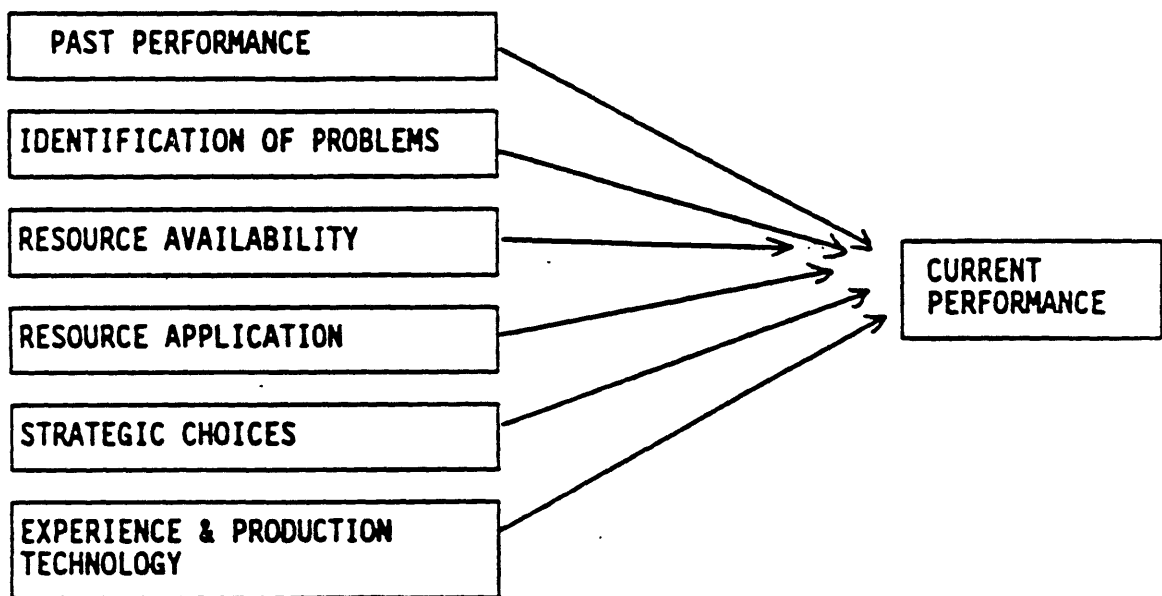
Figure 2



State

Figure 3

A Model of Improvement
Combining Economic and Behavioral Elements



concepts in the theory were used to validate the theory. Predictive models were developed using Poisson regression.

The central concepts of the theory appeared to be valid:

- *Past performance predicted future performance.

- *Plant performance was affected by utility-level factors, e.g.:

 - Spending on operations supervision and engineering predicted improvements in safety system failures and significant events.

 - Investment in other generating capacity predicted declines in safety system failure and significant event performance.

Research Plan

This years research plan would be as follows:

1. Continue Statistical Studies. Last years analyses would be wrapped up with attempts at publication, as new work is initiated. The data base will be expanded and leads pursued which were considered before, but for which there was no time to complete. For instance, work on measuring performance with PRA data could be undertaken, or new performance measures could be developed that take safety and productivity into account at the same time. A special focus may be the effects of PUC policies. What impact do they have on nuclear power plants?

2. Initiate Case Studies. The idea would be to devise careful case comparisons, for example to look at utilities that are similar in most respects but which have sets of plants performing at different levels. What accounts for the differences? Moreover, how have utilities attempted to transfer their competencies from plant to plant?

3. Begin to think about the broader implications of the work -- the distinct characteristics of nuclear power plant organization and management

and how it compares with other types of organization and management.

Significance of Work

This focus on performance raises many important questions:

1. The Meaning of performance. What exactly is meant by performance in the industry? Are the published statistics adequate? How do personnel on the spot know that they are doing OK? How do they know that their performance is getting better?

2. The Nature of Nuclear Power Plant Organization and Management: Does It Differ From Other Types of Organization and Management? People in the nuclear power industry, NRC, and elsewhere agree that management and organization contributes to the successful operation of nuclear power plants. However, the broad issue of what nuclear power organization and management is, and how it differs from managing other technologies has not been adequately settled.

*What are the special characteristics of organizing and managing a nuclear power plant that make it different, for example, from managing a bank, a university, a hospital, a chemical plant, a military brigade, or an automobile factory?

*Does nuclear power organization and management differ from organization and management generally?

These issues cannot be resolved without taking a fresh look at nuclear power plant organization and management based on careful observation of what managers do. Comparison with other technologies then is possible as is placing nuclear power organization and management in the framework of organization theory more generally.

Characteristics That Set Nuclear Power Plants Apart. Some of the

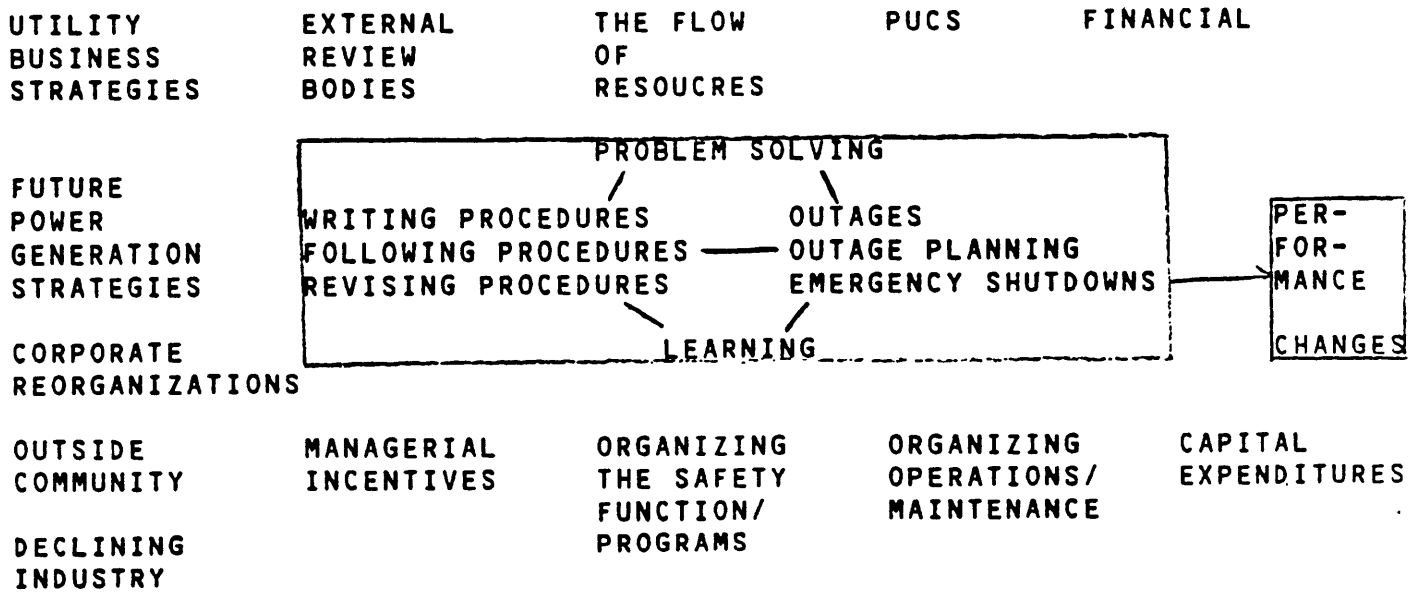
characteristics that seem to set nuclear power plants apart include (see Figure 4):

1. An extensive reliance on rules, externally imposed by the NRC, which are matched by a high degree of internal proceduralization.
2. Cycles of management attention and activity highlighted by the outage planning process.
3. The burden on personnel in nuclear power plants to be strong problem solvers.
4. The need to learn from errors and mistakes.

These activities are carried out in a context in which the factors in Figure 4 play an important role.

Figure 4

KEY PROCESSES AND
FACTORS INFLUENCING
CHANGES IN NUCLEAR POWER PLANT
PERFORMANCE



**MIT INTERNATIONAL PROGRAM FOR ENHANCED NUCLEAR
POWER PLANT SAFETY**

Research Plans and Rationale 1991-1992

Constance Perin

Organizational Pathways Analyses: Overview

Case studies comparing at least two plants will furnish information about how work gets done in several complex programs, from the plant floor to corporate offices. The programs to be studied are Outage Scheduling and Implementation, Fire Prevention, Procedure Revision, and Operations and Maintenance Coordination. These cases will map the organizational pathways in both directions between the actors in these complex programs, and, as possible, under different plant conditions (e.g., online and in outage). The maps will identify the paths travelled by human and technical resources of all kinds and specify the points at which actors discuss their options and constraints.

The cases will help us to learn how conflicts are negotiated and scarcity dealt with, how industry and regulator rules are helpful and restrictive, how influence and authority are exercised, and how these processes draw on the distributed knowledge of plant and corporate staff. The cases will provide a source of data with which we can begin to characterize the nature of organizational and managerial strategies and processes that enhance safe performance.

With these case studies in one kind of high reliability organization, we will begin to understand the operations of social and cultural authority systems as they intersect with complex technological systems. How are explicit, institutionalized authority systems both followed and challenged and how are less explicit but no less institutionalized normative and value systems followed and contested? Along this continuum of acquiescence and challenge are revealed processes of negotiation with both ends of the continuum.

These negotiating processes in practice form the backdrops to any of our attempts to leverage our findings into helpful concepts and tools for organizational learning. That is, how these processes play out form the dynamics that underlie each plant's organizational and managerial systems. How can we discover the properties of these processes and characterize them? Moreover, these processes are at the same time defining the contents of mental models of plant operations and how employees see their constraints and options during critical moments of diagnosis and recovery.

Organizational Pathways Analyses

Last year, we concentrated on comparing how plants integrate safety concerns into their operations by focusing on cross-functional relationships (e.g., maintenance work requests). This year, we're looking at several "programs," to learn how top management plans them and how they get implemented (e.g., outage planning, fire prevention). These studies will help us develop an understanding of how work gets defined and done, all the way from corporate offices to the plant floor. Last year, we were concerned with lateral relationships, this year, we'll deepen the picture by adding vertical relationships within the utility and, going even further, the institutional context that is so central to utilities' safety programs.

We conceptualize nuclear power plants as continuous learning and vigilance systems, drawing cautions and lessons from external and internal incidents and events. We assume that plants have permeable boundaries: Two-way communication with corporate headquarters, industry groups, regulator, vendors, contractors, local community, Congress. Within plants, we assume that much of the work consists of bridging the interstices between plant and corporate, between corporate and regulators, and between functions, levels, suppliers, and technical systems. This bridging work represents concretely the operational necessity for interdependence and cooperation. Especially when there are

incidents, the effectiveness of these bridging processes are called into question.

At the same time, responsibilities and accountabilities are assigned between corporate and plant and throughout the plant's organization. Some of these assignments are self-defined by utility leaders, some are required by the regulators. Organizational forms differ across nuclear power plants.

To develop data with which to understand these dynamics and differences better, we are planning case studies of programs for outage planning, fire prevention, and procedure reliability in two plants (we'd do more if we had more resources).

What we plan to do

Through interviews and observations, we will map the pathways in both directions between the main actors in such programs and document the various resources being sent and received along these organizational channels. These maps will show what blocks the paths, what facilitates movement along them in both directions, and how differences in priorities, in technical judgment, in experiences are negotiated. The "resources" travelling along these pathways consist of people, money, technology, information, rewards, sanctions, management "styles," and values. Our data will consist largely of the ways in which actors define

and discuss their options and constraints.

What we expect to learn

To manage resources and priorities requires at the same time managing differences in opinion, in experience, in interests. How these are negotiated and how scarcity is optimized adds up to "management style."

a) We will learn how management defines these resources, how they go about allocating them, and how these complex programs are implemented. We will learn how accountabilities are defined and delegated, how vetoes are exercised, how problem-ownership is handled, how distributed knowledge is drawn upon, how organizational slack is allocated, and how consensus is built.

b) We will learn how the institutional framework influences the shape and flow of resources. How do NRC regulations and reporting requirements facilitate or hinder them? How do public utility commissions influence management practices? How do SALP and INPO assessments enter into allocations and priorities? These are all significant parts of this story.

c) We will learn how new information is brought into these channels -- for example, industry experience and plant incident reviews. We will learn how the organization evaluates, adapts, and integrates new information -- that is, how it learns.

Why these questions are significant

These studies will develop information that will help us to develop tools for self-analysis and self-design for plants to consider using. The studies will provide a basis for characterizing the nature of organizational and managerial strategies and processes that enhance safe performance.

Plant organizations can consider how their situations compare.

More generally, these studies of nuclear power plants will add to new knowledge being developed about high reliability organizations and their differences from other kinds of large, complex organizations.

Similar issues arise in the petrochemical industry and on aircraft carriers, for example: How do social and cultural systems intersect with complex technological systems? How are explicit regulations followed and challenged? How are less explicit social conventions, traditions, and customs followed and contested? How are differences in knowledge, expertise, experience, and rank negotiated? Not only are these important processes for managing, but they also do much to define how employees up and down the chain of command see their constraints and options during critical moments of diagnosis and recovery.

These negotiating processes form the backdrops to any of our attempts to leverage our findings into helpful concepts and tools for learning in high reliability organizations. That is, how these processes play out form the dynamics that underlie organizational and managerial

systems. Any tools we develop specifically for nuclear power plants will have to acknowledge these processes, if plant managers are to find our suggestions credible.

Further, if we are to suggest organizational structures appropriate to high reliability organizations, we must also understand these dynamics in order to envision how such changes would affect them, for the better or for the worse. For nuclear power plants in particular, we assume that many of the current organizational structures are in place because of the nature of the production process.

Summary

Our studies suggest that the ways in which the complex programs we want to study are organized and managed, up and down the chain of responsibility and accountability, will provide a window into generic issues. We assume that how these are resolved will have some bearing on safe performance, directly or indirectly. We do not believe that there is a single ideal way for utilities to deal with these complex domains. We intend these case studies to lead instead to deeper understandings of operating and institutional dynamics as they align with organizational and managerial processes.

We will select programs such as outage planning not because they are error prone, but because they represent especially complex sets of

activities that carry a high burden for overall safe performance. Those we study put especially complicated demands on utility management to develop and implement policies that

- balance between efficiency and safety,

- balance between organizational stability and change,

- distribute responsibility and accountability,

- evaluate the relative importance of experience, judgment, and technical data, and

- maintain an effective learning curve.

They also are likely to be especially informative about ways that regulatory oversight, vendor relationships, and contractor support facilitate and hinder organizational and managerial strategies and choices for maximizing safe plant performance.

We will be interviewing executives, managers, supervisors, engineers, operators, craftspeople, and technicians at corporate, station, and plant levels. We will supplement these interviews with appropriate archival materials from individual utilities, industry groups and regulators as well as with the findings of other studies.

Ideally, we hope that these cases will allow us to develop alternative scenarios for organizing and managing. We ultimately would like to evaluate their effectiveness by conducting demonstration or pilot programs with cooperating utilities.

ATTACHMENT 6

October NPP Advisory Panel on Organizational Learning
"Making Sense of Plant Incidents"
John S. Carroll
Research Plans and Rationale for 1991-2

The nuclear power industry focuses extraordinary attention on safety-related incidents. Individuals and committees within plants and organizations in industry and government work very hard to gather and interpret information. Thus, the improvement of plant functioning and the enhancement of safe performance depend greatly upon the ability to interpret experience from within and outside the plant. And, this ability derives from knowledge and expertise, the "cognitive capital" distributed through the organization, and throughout the industry.

Causal Analysis

One major strategy for learning from experience is to identify the causes of safety-relevant incidents, in order to fix problems and learn more general lessons. Exemplary efforts to determine causes include plant committees formed to analyze events, HPES incident analysis reports, SALP reports, ASSET missions from the IAEA, and so forth.

For decades, the concern over the consequences of hazardous technologies was conceptualized primarily as a technical problem. When concern extended beyond the technical system to the human operators, maintainers, and designers who are essential to the safe functioning of the technical system, the convention was to examine the immediate interface of people and technology -- look for an incompetent or inattentive individual or a confusing set

of controls and indicators. These approaches have been demonstrably successful in improving safety and other aspects of effective performance.

What seems to be missing is to have as much detail about the managerial, social and cultural systems in organizations as we have about technical systems and individual human error (see Figure 1). Even sophisticated analyses that separate slips, lapses, mistakes, and violations lack categories other than individual intentions for understanding the sources of human error.

For example, TMI involved a stuck valve and operator misunderstanding, but also inadequate instrumentation, incorrect procedures and training, and failure to transmit information within the industry about this type of event. For each of these contributing causes, there were previous causes or conditions including design flaws, surveillance errors, outdated procedures and training, improper staffing for key domains of expertise, and so forth. Behind these conditions is the strategic direction and allocation of resources in utilities and the structure of the industry and regulators that inhibited the free flow of information.

In principle, such causal analysis can be endlessly extended, far beyond the point of being in the service of safe performance. As the head of the International Atomic Energy Agency Incident Reporting System writes, "the root cause must be a cause that we have the power to deal with and solutions can be

Figure 1

WHAT'S MISSING?

More detail about certain types of causes:

**communication, authority
social relationships
cultural meanings
conflicting goals/incentives
extra-plant institutions**

More understanding about causes:

**combinations of causes
dynamic relationships over time
redefining "root" cause**

More understanding of the analysis process:

**causes as the product of analysis
the importance of interpretive skills
social distribution of knowledge**

absurd if not limited" (Tolstykh, 1991). By limited, he means within our control and consistent with other objectives (e.g., produce energy economically).

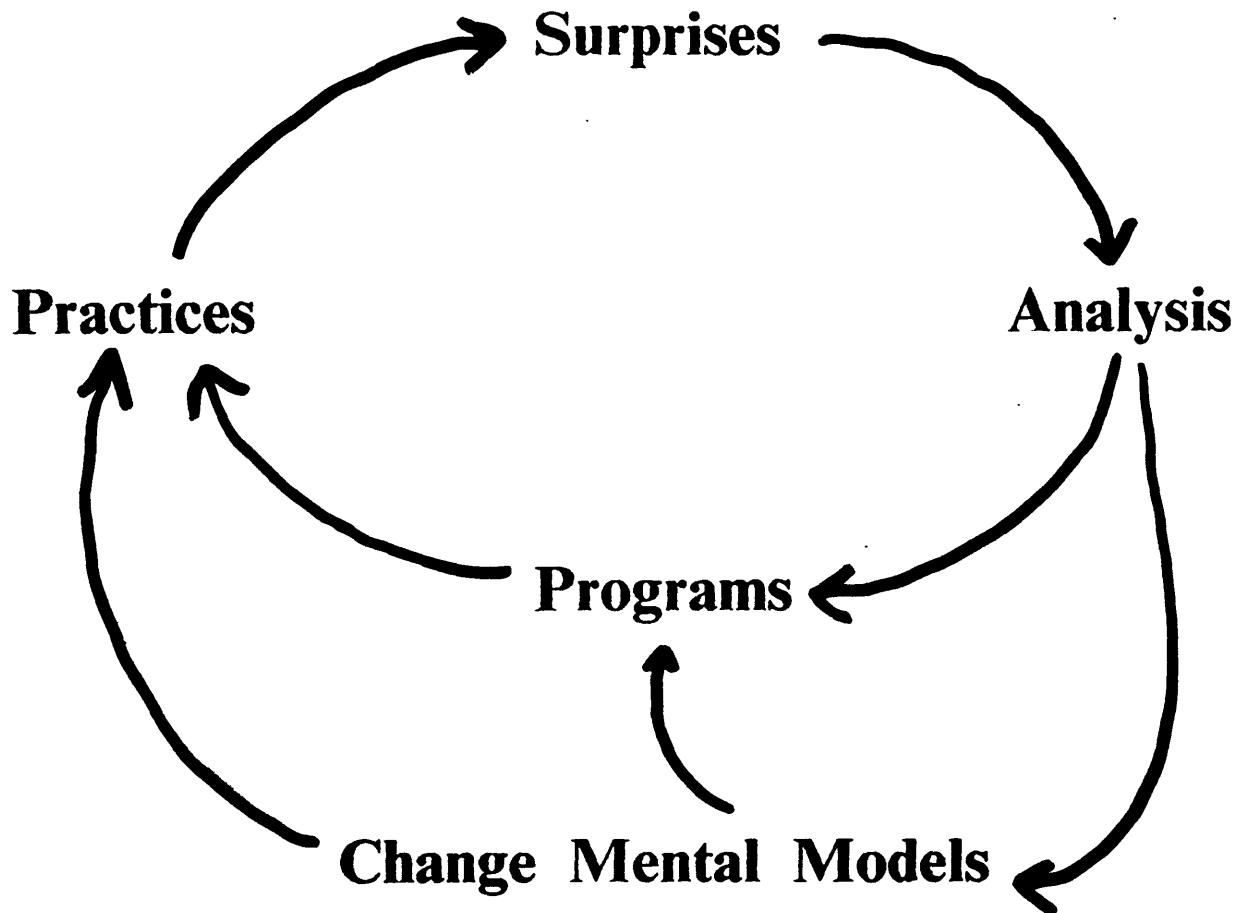
In contrast, HPES reports adopt the viewpoint that incidents are analyzed in order to promote discussion and understanding of the plant, not to find "the (single) root cause" of a problem. Issues are chosen for consideration because they are puzzling to an operational manager. The HPES analyses raise multiple points of attack to improve plant functioning, but the goal is to increase the ability of the plant to make effective changes, rather than to fix any one thing. Our approach to nuclear power plants as "learning organizations" shares this viewpoint.

Mental Models

In this spirit, we suggest that the underlying resource that is utilized in incident analyses, and is also the product of such analyses (considered as learning experiences), is plant employees' own understanding and interpretation of operational experience (see Figure 2). This is socially-distributed knowledge: no one person can know everything necessary about the plant. Due to differences in professional training and plant experience, different people will have different "mental models" of the plant. Effective interpretation and change management requires the marshalling of these distributed partial models of the plant. Therefore, it is reasonable to conclude that a feature of "good" plants will be mental models that individually and collectively diagnose problems effectively.

Figure 2

**ORGANIZATIONAL LEARNING
AND INCIDENT ANALYSIS**



For the most part, "mental models" of the plant are implicit. They are rarely discussed or formally presented. They emerge as the foundation of the interpretive work that occurs around problems, incidents, or issues that create surprise, concern, or a need to know more. In short, mental models are revealed as they are used. As people in the plant discuss and analyze such issues together, they are exposed to each others' mental models, and each person's own models becomes more general, more comprehensive, and more consistent and closely linked with others' models.

Research Proposal

We propose to develop a way to understand better these interpretive and learning processes. The overall approach would be to select some interesting examples or scenarios from actual situations in plants, and to present these to employees in different occupations, across a range of plants, for their reactions. In so doing, they would be exercising their "mental models."

One interesting sample scenario was sent to us by an HPES Coordinator. The Coordinator thought that the situation demanded more analysis than simply stating "the root cause is personnel error." This scenario is quite short:

During the inspection of [] Turbine Building ground floor, two caged maintenance storage areas in the northwest corner were found to contain significant housekeeping and fire hazard control deficiencies in violation of ACP 2.05B.

These deficiencies included: an unrestrained gas cylinder, improper storage of an oxy-acetylene unit, improper storage of flammable materials, improper disposal of combustible and inflammable materials, impeded access to fire system valve, storage of significant combustibles directly underneath cable trays, and general poor housekeeping.

We would ask for reactions to this situation using questions such as the following:

- (a) Please give as many implications as you can think of regarding the causes and conditions that underly this situation;
- (b) What would you do to find out more about this situation and its causes;
- (c) What, if anything, would happen in your plant following such a situation;
- (d) Give as many recommendations as you can for things to do in response to this situation.

Two reasonable hypotheses about the capacity of a plant to learn from experience readily emerge from our framework: First, the variety and depth of sophistication of the analyses produced by plant personnel should be important to learning. By "depth," the hypothesis refers to more system-based and temporally-complex causes rather than simple human error, poor training, etc.

Second, the overlap of analyses across functions and levels of plant personnel should be an indicator of the ability to communicate about incidents. The overlap is likely to index a

past history of shared problem-solving among a wide range of plant personnel. The need for variety and shared knowledge suggests that specialization of plant personnel into zones of expertise can be overdone, with an attendant difficulty in working together to address complex problems that cut across areas of specialization.

Throughout this research, we will maintain strict confidentiality regarding: (a) the plant location of the various materials, by removing all identifying information; and (b) the plant location and individual identities of the respondents.

Goals and Products

There are several practical purposes for conducting this research project, and the results will be usable in several ways. First, we will be able to characterize the kinds of understanding that plant personnel have regarding why things happen and how problems emerge and get solved. It is important to determine whether attention does get directed toward technical issues and individual human error, or whether there is widespread understanding of more systemic, social, and cultural processes. An understanding of the language and categories used to understand plant operations seems essential for characterizing what is or is not a "safety culture" and bridging the gaps between plants and researchers.

Second, we can examine the distribution of categories and language in these "mental models" across functional areas and hierarchical levels in plants (and utilities). Knowledge is

distributed within plants, but some plants are more highly specialized and compartmentalized than others. How different are plants in the ways that knowledge is distributed? What kinds of knowledge or viewpoints on the plant are held by different segments of the organization? Does a more widely-shared set of mental models suggest that communication across functional and hierarchical boundaries has been more effective?

Third, it is reasonable to assume that the long-term safe performance of plants, in particular the ability to learn and improve, is related to the capacity to analyze experience, as characterized in this study. We might expect that more volume and variety of analysis, and more attention to systemic, social, and cultural factors, will be associated with safe performance. Further, the overlaps across boundaries should reflect the ability to communicate and share expertise about plant incidents. This should lead to some suggestions regarding ways to enhance the learning capacity of nuclear power plants.

Finally, the study of incident analysis will help us better understand the nature of nuclear power plants as "self-designing organizations" (see Figure 3). In an environmental context of demands for safety and new technologies and regulations, nuclear power plants are continually challenged to adapt and innovate. In this context, "compliance" is not a sufficient concept to express the attitudes and values that lead to safe performance. Instead, there must be attention and resources given to the self-design process that depends on the involvement of a broad range

Figure 3

SELF-DESIGNING ORGANIZATIONS

Continual Adaptation and Innovation

- * **Equipment changes**
- * **Procedure rewrites**
- * **Task forces**

Compliance Isn't Enough

- * **Commitment and vigilance**
- * **Creativity**
- * **Can't get complacent**

Management Consulting Isn't Enough

- * **Beyond "best practices"**
- * **Organizations have the responsibility**
- * **Enhanced skills and "mental models"**

Strengthening the Self-Design Process

- * **Perception and diagnosis**
- * **Creativity and understanding**
- * **Implementation**

of employees.

Discussion Points

To carry out this project, we need advice from the Panel on the following issues:

1. Does our understanding of incident interpretations match up to your own ideas and experiences? How can we improve and deepen the way we conceptualize the problem?
2. How should we select issues and incidents to which plant personnel will respond? What dimensions should these have, such as interest, surprise, modest length, ability to be understood across different plants, etc.? We thought that we would ask the Panel to provide actual situations (without revealing plant identities), and then help us to select a small number that seem the best. We could also seek examples from Lifted Leads stories and INPO training materials.
3. How should we select respondents within a plant? We want to get a range of respondents from different functional areas and different hierarchical levels, yet we must keep the overall number of respondents manageable. How can we create a representative group of plant employees who will be asked to respond to the issues and incidents?
4. How do we design the materials to be clear and self-administering? In what form should we solicit replies - open-ended questions or rating scales/checklists? How do we ensure a high response rate? How much time will people be

willing to spend answering our questions? We would like to develop these materials in cooperation with the HPES Panel.

5. Which plants should we include in this study? There is some trade-off in the number of plants vs. the number of respondents within each plant. We are interested in both the differences that exist within plants, and the ways that different types of plants may have different types and distributions of "mental models."
6. Can the Panel participants help us to distribute materials and collect replies?

**ORGANIZATIONAL AND MANAGERIAL ISSUES IN
ADVANCED NUCLEAR POWER PLANT DESIGNS**

by

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presented at

Meeting of
Nuclear Power Plant Advisory Panel on Organizational Learning

PUBLIC ACCEPTANCE OF NUCLEAR POWER

SOME CAUSES OF LOST ACCEPTANCE

- **MAJOR REACTOR ACCIDENTS**
- **ABSENCE OF WASTE DISPOSAL SOLUTIONS**
- **A STEADY STREAM OF WELL-PUBLICIZED MISHAPS, COST OVERRUNS, MISMANAGEMENT EXAMPLES AND ENDURING CONTROVERSY**
- **THE LOSS, SINCE 1964, OF INFLUENCE OF AUTHORITY FIGURES IN VALIDATING NATIONAL POLICIES AND FORMING CONSENSUS**

SOME MEANS OF REGAINING ACCEPTANCE

- **SUSTAINED TROUBLE-FREE OPERATION OF THE EXISTING NUCLEAR POWER PLANTS IN THE U.S. AND WORLDWIDE**
- **DEVELOPMENT AND DEMONSTRATION OF SAFER, MORE ECONOMICAL NUCLEAR POWER CONCEPTS**
- **CONSOLIDATION OF A BROAD SENSE OF BENEFIT FROM NUCLEAR POWER (e.g., MITIGATING EFFECTS OF GLOBAL WARMING, AIR POLLUTION, COAL MINING AND TRANSPORTATION, DEPENDENCE UPON IMPORTED FUELS)**
- **OPENING REPOSITORIES FOR HIGH AND LOW LEVEL RADIOACTIVE WASTES**

GOALS OF NUCLEAR POWER TECHNOLOGY DEVELOPMENT

GLOBAL GOAL

- **Production of Safe, Economic Electric Power**

SUBORDINATE GOALS

- **Economic**
 - **Low capital costs**
 - **High reliability**
 - **Low operation and maintenance costs**
 - **Low fuel costs**
 - **Long life**
 - **Ease of control and diagnosis**
- **Safety**
 - **Stable operation**
 - **Reliable shutdown**
 - **Reliable reactor-cooling**
 - **Reliable containment of radioactive materials**

TABLE 2

SAFETY PERFORMANCE IMPROVEMENT

ESSENTIAL SAFETY FUNCTIONS

• STABLE OPERATION

- **Achieve High Mechanical Operational Reliability**
 - **Minimize number of system failure modes and inter-dependencies**
 - **Maximize component reliabilities**
- **Achieve High Human Operational Reliabilities**
 - **Provide extensive instrumentation and computer-aided information assessment to operators**
 - **Automate tasks difficult for humans**
 - **Design for easy operations, troubleshooting and response to unexpected events**

• RELIABLE SHUTDOWN

- **Design for Passive Negative Reactivity Feedback in Core**
- **Provide Diverse, Redundant, Passive Shutdown Systems**

• RELIABLE REACTOR COOLING

- **Use Natural Convection to Pump Coolant from the Reactor to a Heat Sink**
- **Conduct and Radiate Heat from the Reactor to a Heat Sink**

• RELIABLE CONTAINMENT OF RADIOACTIVE MATERIALS

- **Trap Materials in Filters, Pools, Sprays and On Exposed Surfaces**
- **Retain Materials Within Fuel, Reactor Coolant System and/or Containment Building**

IMPROVING ECONOMIC PERFORMANCE

CAPITAL COSTS

- **Maximum Power Level**
- **Reduce Hardware Inventory**
- **Shorten Construction Duration**
- **Modularize the Plant**
- **Factory Fabrication**
- **Standardize Design**
- **Achieve High Availability**
 - **High mechanical reliability**
 - **High human reliability**
- **Freeze Regulations and Designs Once Construction Starts**

OPERATION AND MAINTENANCE COSTS

- **Design Equipment and Plant for:**
 - **Easy replacement, maintenance, repair and inspection**
 - **Extensive automatic inspection monitoring and diagnosis**
 - **Substitution of humans by robots**

FACTORS OF SAFETY

FREQUENCY OF OPERATIONAL DISTURBANCES

Mechanically Originated

Human Originated

Operations

Maintenance

Organizational

RELIABILITY OF SAFETY FUNCTIONS

Mechanical

Human

Operations

Maintenance

Organizational

ACCIDENT MITIGATION

Mechanical

Human

Procedures

Improvisations

Organizational

WORLDWIDE PROGRAMS OF NUCLEAR POWER TECHNOLOGY DEVELOPMENT

PROGRAMS EMPHASIZING ECONOMIC PERFORMANCE

Europe

- Joint European Fast Reactor (France, Germany, United Kingdom)
- European (1400MWe?) PWR (Nuclear Power International: France, Germany)

Canada

- 450MWe HWR (CANDU 3) (AECL)
- 900MWe HWR (AECL & Ontario Hydro)

France

- 1400MWe PWR (N4 Project, Framatome, Electricite de France)
- 1200-1450MWe LMR (Superphenix-1 Project, Novatome, Electricité de France)

Federal Republic of Germany

- 500MWe HTGR (Successor to 300MWe THTR Project) (Dropped)
- 300MWe LMR (SNR 300 LMFBR Project) (Dropped)

Japan

- 1250MWe LWRs
 - ABWR (Tokyo Electric Power, General Electric, Toshiba, Hitachi)
 - APWR (Kansai Electric, Mitsubishi, Westinghouse)
- 714MWt LMR (Monju LMFBR Project)
- Successor to 148MWe FUGEN LWR/HWR Project

WORLDWIDE PROGRAMS OF NUCLEAR POWER TECHNOLOGY DEVELOPMENT

United Kingdom

- 1000-1400MWe PWR (Sizewell-B, Hinkley Point-C Projects)

United States

- LWR Requirements Document Project (Electric Power Research Institute)
- 1250MWe ABWR (General Electric)
- 1250MWe APWR (Westinghouse)
- System 80+ (ABB-Combustion Engineering)

Soviet Union

- Emphasis upon Passive Safety
 - 100MWe Modular HTGR (Dropped)
 - Chernobyl-Type RBMK Reactor Series Discontinued
- Emphasis upon Economic Performance
 - 950MWe PWR (VVER 1000)
 - 1250MWe LMR (LMFBR Type)

ABBREVIATIONS

BWR:	Boiling Water Reactor
CANDU:	Canadian Deuterium Uranium, Heavy Water Reactor
HTGR:	High Temperature Gas-Cooled Reactor
HWR:	Heavy Water Reactor
LMFBR:	Liquid Metal-Cooled Fast Breeder Reactor (version of LMR)
LMR:	Liquid Metal-Cooled Reactor
LWR:	Light Water Reactor
PIUS:	Process Inherent Ultimately Safe (version of LWR)
PRISM:	Power Reactor Inherent Safe Modular (version of LMR)
PWR:	Pressurized Water Reactor
SIR:	Safe Integral Reactor (version of LWR)

WORLDWIDE PROGRAMS OF NUCLEAR POWER TECHNOLOGY DEVELOPMENT

PROGRAMS EMPHASIZING PASSIVE SAFETY

Federal Republic of Germany

- 100MWe Modular HTGR (Siemens, Brown Boveri) (Dropped)

United Kingdom and United States

- 300MWe Modular PWR (SIR Concept) (Rolls Royce & ABB-Combustion Engineering)

United States

- 130MWe Modular HTGR (General Atomic)
- 130MWe Modular LMR (PRISM Concept, General Electric)
- 750MWe PIUS-BWR (Oak Ridge National Laboratory)
- 600MWe LWRs (Semi-Passive Safety)
 - SBWR (BWR, General Electric)
 - AP-600 (PWR, Westinghouse)

Sweden

- 500MWe PIUS-PWR (ASEA-Brown Boveri)

Strengths and Weaknesses of Different Reactor Concept Classes

<u>Reactor</u>	<u>Strengths</u>	<u>Weaknesses</u>
LWR	<ul style="list-style-type: none"> • Infrastructure exists 	<ul style="list-style-type: none"> • Vulnerable fuel High energy coolant
Evolutionary	<ul style="list-style-type: none"> • Proven success record Best understood Recently improved 	<ul style="list-style-type: none"> • Complex • Unforgiving
Passively safe	<ul style="list-style-type: none"> • More reliable safety functions 	<ul style="list-style-type: none"> • Economics
MHTGR	<ul style="list-style-type: none"> • Robust fuel • Longtime scales 	<ul style="list-style-type: none"> • Economics • No containment
LMR	<ul style="list-style-type: none"> • Breeding • High temperature coolant • Maybe waste-consuming 	<ul style="list-style-type: none"> • Economics • Spent fuel processing • Radioactive, chemical-coolant

FACTORS OF FISSION POWER SUCCESS OR FAILURE

NECESSARY CONDITIONS:

- **Economic Performance (Low Costs, Low Uncertainty)**

 - **Capital (construction costs)**

 - **Availability**

 - **Operations and Maintenance**

 - **Fuel**

- **Safety (Good Experience, Low Expected Risks and Low Safety Uncertainty)**

 - **Trouble-free operations**

 - **Demonstrable safety features**

 - **Comprehensive design refinement-based upon Probabilistic Risk Assessment to produce low accident probabilities and small expected consequences**

 - **Safety margin, defense-in-depth, containment**

- **Public Acceptance**

 - **Reasons for people to be interested in whether fission power can be done right (e.g., global warming, coal-related environmental effects, reduced reliance upon foreign fuels)**

 - **Successful safety and economic experience**

 - **Safety features which are either evident to the layman or endorsed by authority figures**

 - **Institutional restructuring to render global energy policies and definitive timely licensing decisions**

 - **A basis for trust that both the hardware and its users will be reliable**

Managing Workplace Safety and Health:
The Case of Contract Labor in the U.S. Petrochemical Industry

July 1991

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EXECUTIVE SUMMARY

Introduction

The purpose of this study is to examine the safety and health issues relating to the use of contract labor in the U.S. petrochemical industry. The study was commissioned by the Occupational Safety and Health Administration (OSHA) following the October 23, 1989, explosion and fire at the Phillips 66 Houston Chemical Complex in Pasadena, Texas. The explosion killed 23 workers and injured 232 others. This incident brought the long-standing debate over the use of contract workers in the petrochemical industry to the attention of national policymakers. This study was therefore designed to produce a better factual base from which policy and practice on the use of contract workers might be better informed.

OSHA directed that the study focus on the following issues:

- The prevalence of contractors in the petrochemical industry;
- The motivation for the industry's use of contract workers;
- The role of safety and health in the selection of contractors;
- The safety and health training experience of contract and direct-hire workers;
- The responsibility for and methods of safety oversight of contract employees; and,
- The injury/illness experiences of contract and direct-hire employees.

As the study progressed, the strong linkages among the issues involving the use of contract workers and safety on the one hand, and human resource and labor management relations in the industry on the other, became apparent. Therefore, a section of the report is devoted to an analysis of how these issues interrelate.

To aid in the design and conduct of the research, OSHA established a national Steering Committee composed of industry, labor, contractor, and third-party experts. The Steering Committee participated actively in all phases of the research project, including the validation of the focal questions OSHA had specified for the research, the choice of the industries to be included, the decision to expand the study to include surveys of employees and contractors, the choice of a sampling strategy, the efforts to obtain access to case study sites and to encourage individual plants to provide the data requested, the choice and wording of specific questions included in the surveys, and the review of various draft reports of the findings. OSHA and the Office of Policy, U.S. Department of Labor, and the Office of Management and Budget (OMB) also reviewed, modified, and approved each of the survey questionnaires prior to their administration. No effort was made, however, to produce a consensus with the Steering Committee or OSHA on the findings, conclusions, or recommendations reported here. Indeed, members of the Steering Committee do not concur in some of our conclusions and recommendations.

Therefore, the findings, conclusions, and recommendations remain the sole responsibility of the authors of this report.

It is important to note that this study was not designed to serve as a comprehensive examination of all the policy tools available to OSHA for monitoring or improving safety outcomes in this industry, nor did it investigate the specific causes of the major accidents that have occurred in the industry. In fact, the research team was specifically instructed not to study facilities that had recently experienced major accidents in order to avoid interfering with OSHA's investigations and any litigation that may involve the parties to these accidents. Instead, this study of the management systems which govern contract workers was designed to supplement standard development, enforcement, and education activities.

Research Design and Methodology

Data were collected from four different sources: (1) a national survey of plant managers; (2) nine plant-level case studies, (3) a survey of 600 direct-hire workers and a parallel survey of 600 contract workers, and (4) a survey of 300 contracting firms active in the industry. Each of these data sources has their individual strengths and limitations. For example, the plant manager survey provides representative data from which we can generalize about safety and health practices. However, because contractor injury statistics are not routinely kept on a site-specific basis, the plant manager survey did not produce the data needed for a reliable comparison of direct-hire and contractor injury experiences.

The case studies provide in-depth, qualitative data on how these issues are currently being addressed in a small number of plants and thereby provide the contextual detail that cannot be obtained through survey research. Yet, as in all case study research, one must be careful not to generalize solely from the cases to the entire industry. Instead, the case research provides examples, illustrations, and deeper understanding of the policies in actual practice and the views of different parties at the workplace on these issues.

The employee surveys provide upward feedback data from those closest to these issues at the workplace. The surveys provide data on the injury experiences of workers, their views on how policies and practices are implemented, a human resource profile of direct-hire and contract workers, and perceptions and views that influence worker behavior. Yet there is no means of randomly sampling either direct-hire or contract workers from the populations of workers employed in the industry. Thus, we again must be cautious in making generalizations to the overall industry from these data alone.

The contractor survey adds the suppliers' voice to the data base and thereby provides the best source on the expectations these firms see placed on them by the plants that employ them. But because there is no known population of contractor firms, we again cannot guarantee that the data gathered from those surveyed are fully representative of the distribution of practices of contractors in the industry. To the extent the samples drawn are biased, we believe they oversample those firms and employees that are covered by more comprehensive safety and health practices and possibly those firms with better than average safety performance records. The primary evidence for this view is that we have oversampled the larger plants and firms in the industry, and we consistently find that larger plants and firms have more comprehensive safety policies and lower injury rates than smaller organizations.

Despite these limitations, these data are the most comprehensive and complete body of information ever gathered on these issues in this industry and, taken together, serve as a rich body of information for policy-making purposes. Indeed, we observed a high degree of consistency in the responses and results generated from the different data sources. This consistency strengthens our confidence in the results, conclusions, and recommendations derived from this research.

Thus, the conclusions drawn from the research are based on the composite of information gathered from these four different data sources. We believe that, taken together, these are the broadest and most comprehensive data ever gathered from an industry for the purposes of analyzing this set of safety issues.

Guide to Different Reports

We encourage readers to review in more detail the separate reports that provide a detailed account of the methodology and results of the different components of the study. Separate reports are available from OSHA on the plant manager survey, the case studies, the direct-hire and contract worker surveys, and the contractor survey. This report integrates these data and provides the basis from which our conclusions and recommendations are drawn. Those who wish to go directly to a more detailed summary of the principal findings, conclusions and recommendations are directed to Chapter 11 of this final report.

Principal Findings

Lack of Adequate Injury and Incident Data. Current data reporting procedures do not capture the full range of injury and illness experiences in the industry because the injury statistics do not include the experiences of contract workers. Moreover, the existing injury reporting system does not provide an adequate data base for capturing those events that are most proximate to events that may lead to catastrophic accidents such as near misses, fires, and explosions that do not result in on-the-job injuries. Existing data are not adequate to support analyses of root causes of incidents at the plant level and, therefore, are of limited value for preventive or problem solving purposes.

Prevalence of Contract Workers. Contract workers account for a reported 32 percent of the workhours performed during non-turnaround periods and 54 percent of the workhours during turnaround periods. Seventy-three percent of the direct-hire workers and 61 percent of the contract workers indicate they have regular contact with each other in their workplaces. There is, however, wide variability in the use of contractors across plants and across work activities. In the case studies, for example, contract workers comprised from as low as 9 percent to as much as 44 percent of the workforce during non-turnaround periods. In the average plant, contract workers account for 50 percent of the workhours performed in major renovation activities, 37 percent of the work hours in turnarounds, 22 percent in maintenance and repair, 40 percent in specialty work, and 9 percent in operations.

Trends in Use of Contract Workers. The use of contract workers has increased in the past five years in four of the five work areas examined. According to the plant managers surveyed, the industry experienced a net increase in the use of contractors of

19 percent in renovation, 14 percent in turnarounds, 3 percent in maintenance, and 20 percent in specialty work. A seven percent net decrease was reported in the use of contractors for operations. Moreover, the case study evidence suggests that the five-year increase is part of a much longer trend toward a growing use of contract workers that dates back more than a decade.

Human Resource Profile of the Contract and Direct-Hire Workforces. Compared to the sample of direct-hire workers, contract workers are, on average, younger, less educated, less experienced in the petrochemical industry and with their employer, lower paid, and more likely to be of Hispanic origin. The case studies also found that contract workers are more likely to have English language or communications difficulties. Contract workers also receive less safety training than direct-hire workers, are less likely to be unionized or covered by a labor-management safety and health committee, and less likely to participate in safety discussions with others on their work site.

Role of Safety in Contractor Selection. There is wide variability in the extent to which safety issues are taken into consideration in selecting contractors. Plant managers report that 38 percent of employees in the industry work in plants that have no formal procedure for considering safety in the contractor selection process. In their survey, 34 percent of the contractors report submitting information on their safety and health programs as part of the selection process, 40 percent submitted OSHA injury statistics for either their overall company, and 63 percent submitted Workers' Compensation Experience Modification Rate (EMR) statistics. Contractors reported that the primary factor determining whether these data were submitted is whether the plant requires them as part of the bidding or qualification process. Larger plants and contractors bidding on larger projects were more likely to include these data in the selection process than smaller plants or bids on smaller projects. Two case study plants had extensive procedures for checking the validity of these data and examining in more detail the quality of the contractor safety programs prior to selecting contractors.

Safety Training of Contract Workers. The primary responsibility for safety training for contract workers lies with the contractor. The data from all the different sources indicated that, on average, contract workers receive less safety training than direct-hire workers. This finding applies to both pre-work or initial training received when contract workers come on a work site and ongoing annual safety training as measured by the annual hours reported in the plant manager and employee surveys. It is recognized that any general comparisons of the amount of training provided workers with different levels of risk exposure may be misleading. However, contract workers in general, and the contract workers in our sample, were found to be performing some of the more risky and hazardous work in these plants, such as major renovation, turnaround, and maintenance work. Moreover, after controlling for differences in the type of work performed, the data from the employee surveys indicate that the training contract workers receive is less effective in reducing the probability of injury than the training received by direct-hire workers. Thus, we conclude that both the amount and the quality of safety training provided contract workers are lower than the amount and quality of safety training provided direct-hire workers doing similar work.

General Management Oversight and Monitoring Systems. The method and extent of oversight used to monitor contract workers varies widely across the industry. For this reason we included in our analysis a list of different management procedures used to monitor and control contract workers. The list was developed from the practices suggested by the Business Roundtable's 1982 study of contract safety performance and from OSHA's requirements for participation in its Voluntary Protection Program. Our analysis found that the more of these practices plants follow, the lower their direct-hire worker injury rates. (The lack of reliable data on site specific contractor injury rates makes it impossible to adequately test for an association between use of these practices and contract worker injury rates). We interpret this as evidence that a comprehensive management approach – or one that develops a strong "safety culture" – produces better safety performance.

One factor that limits how much oversight plants provide is concern over the potential liabilities associated with co-employment. The majority of firms in the industry advise their plant managers to avoid responsibilities for training and supervising the contract labor force or for setting the conditions of their employment in order to avoid whatever legal and financial responsibilities would be incurred if the plant was found to be a co-employer of the contract workers. Concern over this issue results in creating what we conclude is an artificial and dysfunctional boundary between the more comprehensive safety management systems governing the average direct-hire worker and the less comprehensive systems governing the average contract worker.

Direct-Hire and Contract Worker Injury Comparisons. The data collected from plant managers proved to be inadequate to compare the injury experiences of direct-hire and contract workers. Less than half of the plant managers could supply injury rate data for contract workers and those data that were supplied were found to be unreliable, i.e., they were unrelated to any plant management practices and were not correlated with the injury rates of direct-hire workers in the plant.

Data collected from the employees did provide a basis for analyzing the probability of injuries of the two groups. From these data we concluded that contract workers are more likely to experience accidents than direct-hire workers. Some of this may be due to differences in the nature of the work performed since a higher proportion of contract workers are employed in maintenance and renovation work and those involved in these two work activities have higher probabilities of accidents than those working in other types of work activities in these facilities. Some of the difference in accident probabilities may also be due to differences in experience and the amount of training reported between the direct-hire and contract workers. That is, direct-hire workers have longer tenure with their employers and receive more safety training than contract workers. The accumulated training and experience has the effect of reducing accident probabilities for direct-hire workers but not for contract workers.

Labor-Management Relations. During the course of the study we observed that the overall labor-management relations climate in the industry and the human resource and labor relations practices at the plant level were closely intertwined with issues of safety management and the use of contract workers. In short, the highly adversarial and traditional nature of labor relations observed in this industry serves to limit the potential for constructive negotiations and problem solving on safety and health issues. Moreover, the traditions built into the U.S. labor relations system inhibit problem solving across the

boundary of the employer and employee organizations that represent direct-hire employees and contract workers in the union and non-union sectors.

At the plant level, the same separation of labor relations from safety and health issues impedes direct and open discussion of the decisions surrounding the use of contract workers and perpetuates a climate of uncertainty, distrust, and lack of communication particularly in unionized plants.

The traditional vehicle that has been used to provide an employee voice on safety issues has been the labor-management committee. Labor-management safety and health committees are widespread in the industry, numbering 85 percent among plant managers surveyed, but vary widely in their activity levels and effectiveness. We do find, however, that the presence of an active labor management committee that is integrated into an overall safety management system is associated with lower direct-hire injury rates. Moreover, employees rate labor-management safety committees as being more effective than unions *per se* in improving safety. These committees were also found in work sites where employees reported significantly higher levels of communication on safety issues and lower fear of reprisal for raising safety concerns. Contractors were more likely to provide data on their safety performance in the bidding process in plants where safety committees were active. Thus, the traditional, adversarial labor-management relations system in this industry does not contribute to improved safety outcomes. However, where labor and management work together in joint activities, more positive outcomes are achieved.

Direct Employee Involvement. Employee involvement on safety and health issues appears to be more common among direct-hire than contract workers, but is only in the early stages of development. Therefore, we cannot draw any firm conclusions from the effects of these innovations to date.

Emerging Innovations and Model Practices. Various firms and industry groups have recently (particularly following the Phillips accident and the commissioning of this research project) accelerated their efforts to develop stronger guidelines for training and monitoring contract workers. However, most of these are still in their formative stages of development. Moreover, few if any of these involve employees or their representatives in their design or development. Thus, the pattern of unilateral and separate managerial initiatives remains the norm.

Throughout the study we emphasize the range of variation in managerial practices with respect to contract workers. At one end of this continuum lies a number of plants that take a very active and comprehensive approach to the management of contract worker safety. In our case studies we refer to one such plant as a "model" since it sets the benchmarks for state-of-the-art practice in our sample and perhaps for the overall industry. We see the practices of this plant, and perhaps others that follow equally comprehensive practices that may lie outside of our case study and survey samples as serving a potentially useful role for organizational learning in the industry. However, to make this learning effective and to translate this learning into innovations that are appropriate in different settings and facilities, several barriers to diffusion of innovative practices need to be overcome.

Barriers to Diffusion of Innovations. Significant barriers to diffusion of benchmark or best practices and other innovations exist in the industry. These include

the lack of consensus among labor, management, and government over what constitutes best practices models; the adversarial nature of labor-management relations that limits joint approaches to these issues; the constraints of co-employment liabilities; and the lack of an adequate institutional infrastructure for learning from best practice models and diffusing these models, particularly from the larger, more innovative firms to the smaller firms that lack the professional and perhaps financial resources to innovate on their own.

Recommendations

Our recommendations are broadly aimed at accident prevention through the following three objectives: (1) to improve the data base needed for root cause analysis, problem solving and policy evaluation; (2) to diffuse innovations that are emerging in the industry more widely and thereby reduce the variability in practices and outcomes observed, (3) to break out of the cycle of separation of safety, human resource and labor issues by developing joint initiatives that involve all the primary stakeholders in the effort to improve safety and avoid risk of catastrophic accidents. The recommendations therefore call for action at the national level with OSHA and other relevant agencies of the federal government taking the lead, at the top levels of individual firms and union organizations that are necessary to break the cycle of declining human resources and deteriorating labor-management relations, at regional levels where new training and workforce preparedness activities are needed, and at the level of individual plants where the practices take place.

A complete discussion of our recommendations can be found in Chapter 11 of the final report. They are:

1. *The secretary of labor should convene a national task force of industry leadership – corporate and labor – to jointly address safety and health in the petrochemical industry.*
2. *OSHA should work with management and labor to create a collaborative, comprehensive, proactive data collection system.*
3. *OSHA should develop methods to identify and promote experimental and demonstration projects that test and diffuse best practice models across the industry ensuring the involvement of all legitimate stakeholders.*
4. *OSHA should establish and implement safety and health training standards for all petrochemical industry employees.*
5. *Management and labor representatives of the petrochemical and contractor industries should develop strategies to reverse the declining human resource profile in this industry.*
6. *OSHA should require plant management to assume responsibility for the safety and health of all workers – direct-hire and contract – at the work site.*

7. *OSHA should require the establishment of effective labor-management safety and health committees that include representatives of contract workers at each petrochemical work site and provide resources to train committee members in committee activities.*
8. *Plant managers should engage their workforce and labor representatives in open discussion of the contract decision-making process.*
9. *OSHA should review the criteria and management of the Voluntary Protection Program as it pertains to the management of contract employees.*
10. *The Congress should charge the General Accounting Office with responsibility for the review of the conduct, the findings, and the conclusions of this study.*
11. *OSHA should continue the research and evaluation process.*
12. *The Department of Labor and OSHA should determine the degree of increased appropriations necessary to respond to the recommendations of this study and should diligently seek such funding.*

Our report ends by sketching two possible future scenarios for the industry and its workforce. The first assumes the key parties involved in these issues – government, management, and labor – choose to reject or ignore the findings and recommendations and allow current conditions and recent trends to continue. The second scenario assumes the parties act on the information and recommendations provided here. We invite the readers to examine these two scenarios and decide which better serves the workers, firms, and communities affected by the risks inherent in the petrochemical industry and how they are managed.

Chapter 11

CONCLUSIONS AND POLICY RECOMMENDATIONS

Taken together, the case study, plant manager, direct-hire and contract worker, and contractor surveys strengthen our understanding of the implications of the use of contract labor for safety and health practices in the U.S. petrochemical industry. Each of the components of the study has strengths and weaknesses, but when combined they provide a comprehensive basis for formulating policies to improve safety and health practices in this industry. Moreover, the data collected from these different parties generally reveal a consistent pattern of results. Relatively few instances were found where the data reported are contradictory in direction, although some estimates of the magnitude of practices or problems differ somewhat among respondents to the surveys.

The surveys also reveal serious weaknesses in the existing data and information base available to those responsible for identifying and preventing safety problems. An important part of our recommendations will therefore focus on how to improve the collection and analysis of safety and health data in this industry.

This chapter will present a brief summary and review of the principal findings of this research and outline the policy recommendations we draw from this work. As we will note throughout this chapter, we believe that the data collected in this study should serve as the beginning of a continuous and collaborative effort to understand and act on the critical safety and health issues in this industry. These recommendations will have their greatest potential for reducing hazards in this industry if the government, management, and labor representatives who share responsibility for safety issues engage these data in a problem-solving fashion, and use them to design improvement strategies to which they are fully committed. As will become evident, we are recommending that all parties – government, management, and labor – adopt a more proactive, preventive, and collaborative approach to reducing the risks of accidents and injuries. We believe it essential that these three parties put aside their differing agendas to focus on the common interest of improved workplace safety and health in the petrochemical industry.

We should note one important feature of our results. All the survey and case study data reveal a wide diversity of safety and health practices and outcomes in this industry. This diversity has both benefits and costs. On the one hand, the variation allowed us to test and to affirm that a significant, positive relationship exists between the comprehensiveness of safety and health practices in a facility and safety performance, a correlation that others before us have also observed and reported (Business Roundtable, 1982). Moreover, close examination of the facilities with the most comprehensive and effective practices provided a clear picture of a current "state-of-the-art" or "best practice" model that can serve as a benchmark for the rest of the industry. On the other hand, the existence and persistence of wide variation in practices suggests there are significant barriers to the diffusion of state-of-the-art practices that need to be overcome if the

overall risk of accidents and injuries is to be reduced. Thus, we see the recognition of the severity of safety and health problems in this industry, the adoption of a best-practice model for the safety management of contract workers, and the diffusion of this best-practice or benchmark model as the key policy objectives for the parties. Our recommendations are designed to further these objectives.

By taking this approach we do not imply that a single "best way" to manage safety and health can or should be applied in all settings. Instead, we use the "best practice" model in the same way that organizations now use what is called in practice "competitive benchmarking" or in other circles "organizational learning" (Cohen and Sproull, 1991; Kochan and Useem, 1991). That is, we seek to encourage all the parties of interest to search out the information needed to compare their current practices to those judged to be the current "state of the art," to analyze the applicability of these practices to their own setting, to experiment with those practices believed to apply and to adopt others where appropriate to fit their unique conditions, and to evaluate the results. It is this type of learning and experimentation that fosters informed diffusion and innovation that, if widely communicated and shared among all the stakeholders in the industry, can foster continuous innovation and improvement. We believe that the data and analysis of practices presented in this report provide a starting point for this type of learning and diffusion process.