Organizing Maintenance Work At Two American Nuclear Power Plants

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Organizational strategies used by operations and maintenance personnel at two US nuclear power plants are compared with those described by the Berkeley group in their extensive high reliability organization studies. Using the method of strategic analysis, we show that the two organizations use quite different strategies in their search for reliability and effectiveness. The focus on the coordination of workers and structuring of tasks reveals areas not completely dealt with in previous HRO-related studies. It is argued that adopting a complementary approach in which elements of both methods are selectively applied may lead to an analytic framework of greater theoretical and explanatory power.

Introduction

The work reported here is based on a series of extensive field studies of four nuclear power plants in France and the US over the past several years that focused specifically on the activities carried out during scheduled outages by those organizational units usually characterized as 'maintenance'. This paper deals specifically with comparisons of two US plants studied in 1992 and 1993, exploring the differences in the strategies adopted by the two different plants to ensure operational safety and reliability in the face of major challenges. It demonstrates that what have become known in the literature as 'high reliability organizations' (HRO) may seek to achieve their goals of a reliable workforce through quite different mechanisms.

First, there is a discussion of some of the literature that framed the field research, indicating how and where it was found to be lacking elements that would help us understand the details of organizational life at the worker level. It is argued that only by focusing closely on the structuring of tasks and the coordination of process can the actual functioning of these systems, in the face of a recurring set of specific problems, be understood. The organizational strategies uncovered by the Berkeley group and others who have contributed to the existing HRO literature are then compared with the author's efforts to see what the application of the theory of 'strategic analysis' (SA), as developed by Crozier and Friedberg (1977), contributes to the study of some of the unusual properties of these organizations. The empirical work focuses on the tangible problems that maintenance organizations have to face, contrasting the different strategies of the two plants.

The response of both plants to four major issues identified as key indicators for evaluating the various organizational strategies-of-work are compared: The interface between operations and maintenance personnel; the necessity of compliance with detailed written procedures; the intrinsic uncertainty of maintenance activities; and the organization of activities and mechanisms of control in the field. All are of comparable importance, and each requires a very high degree of involvement and attention from the whole system. Indeed, failure to deal with these issues would greatly impede the effort by both organizations to fulfill both their operational efficiency goals and public as well as worker safety requirements.

The paper argues that none of the existing literature can be brought directly to bear on what both groups found to be crucial in such systems, that is, the ways actors deal with the formalities, requirements and restrictions that surround them, and that adopting an approach in which elements of both are incorporated is likely to lead to a richer and more complete approach to the study of organizations which must maintain a high degree of reliability to be allowed to continue to operate.

Framing elements

Perrow's *Normal Accidents* (1984) opened up a rich field for organization theorists, advocating new conceptual approaches for studying high-hazardous industries. Disasters in such complex, tightly-coupled, high-technology systems as *Challenger* (Vaughan, 1990), Chernobyl (Ballard, 1988; Medvedev, 1991) and Bhopal (Shrivastava, 1987) have contributed to placing

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organizational aspects of complex socio-technical systems in the foreground of public concern (Reason, 1990). More recently, especially in France, the major and dramatic failure of the blood supply system and the inability to acknowledge the severity of the risk of HIV contamination has also "highlighted" the urgency of gaining a better understanding of the functioning of such potentially dangerous socio-technical systems (Setbon, 1993; Setbon and Thoenig, 1995).

As discussed by La Porte (1996), the Berkeley HRO group and colleagues specifically sought out a number of highly complex and safety-critical activities to understand how high performance could be achieved in organizations in which the 'normal accident' was always latent—even if only as a possibility. Taking as the key example flight deck operations on US Navy aircraft carriers, they identified as a key factor the existence of informal 'latent' networks, activated only in the face of uncertain and rapidly developing contingencies as a supplement to the normal pattern of formal hierarchy and compliance with strict rules (Rochlin, 1989). Although these informal networks are supported by the formal hierarchical organization, neither their structure nor their function was written down anywhere; yet, they were extensively rehearsed and widely acknowledged. These informal networks are a key element of what the HRO group has called a 'self-designing organization' (Weick, 1977; Rochlin, La Porte and Roberts, 1987). They differ greatly from the more permanent local arrangements among small groups that are the basis of the classic sociological literature on organizational informalities (Crozier and Friedberg, 1977; Friedberg, 1993).

La Porte and Consolini (1991) developed a closely related concept, the role of constant redundant oversight on the part of management, when explaining what they call 'high tempo mode' in air-traffic control. Related factors include the continuing and permanent process of training and retraining, which provides personnel with opportunities to continue to practice and rehearse alternative scenarios, better preparing them to deal with situations never faced before (Roberts, 1988). Weick (1987) noticed a 'story-telling effect', pointing out the contribution to good performance of the remarkable capacity to exchange information informally, as well as formally, through stories about things that went wrong (see also Schulman 1996). The authors also noted that the organizations under study showed, concomitantly, a very strong tendency toward centralization of organizational decision making co-existing with a means for legitimate delegation of authority when time pressure, or other circumstances, required it.[1]

The HRO research findings direct attention towards aspects of organizational behaviour and structure that have rarely been described, and the sharpness of the analysis contributes greatly to our understanding of such systems (Roberts, 1993; La Porte, 1994). Yet, in the author's previous work organizations have been studied that seemed to perform very reliably as well, although they did not display some of the HRO characteristics (Bourrier 1991; 1994; 1995). Conflicting goals and objectives, compartmentalization of groups (journeymen, engineers, management) and of services (operations, maintenance) sometimes led to the emergence of competing strategies, and means for informal local adjustments, and at other times to a rather formal process of negotiation and explicit adjustment.

At the first French plant studied, for example, there was little common socialization among various groups, or recognition of craft of lower ranking workers (Bourrier, 1991). In fact, worker skills were only tacitly acknowledged by management, for example by implicit gaps in procedures. For workers, on the other hand, filling in these procedural gaps as they performed their tasks was the only acceptable/reasonable strategy if they wanted to be seen as competent, and, therefore, worthy of retaining some measure of autonomy and power (Terssac, 1992). This set of relationships contrasts sharply with the structures observed by the HRO group. Yet, this organization could also be characterized as 'highly reliable' since it has demonstrated impressive records of safety while reporting a high degree of performance and productivity.

This work, undertaken specifically to discover and explain those factors that might be able to account for both the observed coordination strategies and their variation, was therefore extended for comparison with the HRO findings. Since cooperation is necessary for operation of these complex systems, we sought alternative explanations for collective action, using as a basis the general sociological framework developed in France by Crozier (1963), which sees the organization as a political system and takes power inside the organization as the key feature (Crozier and Friedberg, 1977). In this frame, organized collective action is never a given, but must always be explained as problematic behaviour. Cooperation is constantly elaborated through the mutual adjustments of the strategies of individuals who continually re-negotiate their participation inside the organization, trying to get control of what is relevant for their tasks and frequently appearing uncertain and unpredictable to their co-workers in order to gain or maintain some advantage over them.

The use and abuse of formal rules are of particular importance in this approach, leading some analysts to focus on this aspect as a major element of organizational life (Terssac, 1992; Friedberg, 1993). Formal rules and structures are never strictly obeyed, they are constantly turned to the benefit of some at the expense of others; they can never fully describe the reality actors have to face in their daily activities (Reynaud, 1989). It is impossible for organizational designers to anticipate all the conditions and situations that workers will have to cope with. Local adjustments to and re-arrangements of rules and, at times, even rule violations, are not only constant but necessary for organizations to effectively pursue their goals. It is therefore of interest to examine HROs to see whether such seemingly dysfunctional patterns functionally related to reliability are also present.

Four major problems of scheduled outages

Schulman (1993) describes scheduled outages as one of the most difficult exercises a nuclear power plant (NPP) has to go through: Safety, financial, technical and coordination challenges put tremendous stress on the human system and its actors. Major activities to be carried out during a scheduled outage include not only refueling, but also scheduled repairs, legally mandated testing of plant equipment and a wide range of modifications and upgrades required by technical improvements and/or regulatory changes. Hundreds of activities must be carried out safely and in a timely manner, while minimizing worker exposure to radiation. All activities are tightly and logically coordinated and adhere to a carefully designed schedule aimed at fitting into a specific plan. Mechanisms for coordination and means for mutual adjustments in this demanding environment are therefore crucial elements for the sociologist's attention.

We identified four major challenges that NPPs had to face and respond to if they wanted to 'successfully' manage their outages by following (or bettering) the schedule while limiting worker exposure and minimizing costs. Each of these present challenging, real-world problems for the workers and management of a NPP.

The need for efficient coordinating processes between maintenance and operations

Coordination between operations and maintenance crews is driven by two factors. Unlike other industries, nuclear power plants are never completely shut down; some cooling functions, for example, have to stay available at all times. Therefore, maintenance crews cannot work on the plant's equipment without following exactly the operator's instructions regarding the availability of operating equipment. In addition, all equipment work must be formally authorized by Operations Department Shift Supervisors, who have both the formal authority and the power to either accept or refuse work on the installation, depending on their knowledge of the plant's condition. They are also legally responsible for the correct release of materials to maintenance crews and, therefore, take seriously the requirement that they have to sign-off on all work orders, as well as issuing clearances to work on equipment and monitoring the proper hanging of 'clearance tags' inside the plant.

The dependence of maintenance crews on operators is a source of constant friction in every plant studied. The crews resent this constraint, arguing that since they have to perform the bulk of the 'real work', under very tight schedules, they should get more sympathetic assistance from operations. Operators, on the other hand, insist that maintenance personnel are not trained well enough to be given discretion. Indeed, any observer who has spent time in a control room during an outage will quickly note that operations personnel do not seem to like having maintenance personnel around.[2] Maintenance is always a disturbance; in an outage it means too many people working at once in too many places, including contractors who may not be familiar with the plant, and therefore there is a great deal of cross-checking to do.

> We have different missions, our job is to make the plant better than when we got there in the morning. In order to do so, our work involves changing things...We have to be out changing equipment each day. Ops, their goal is to run the plant safely from a nuclear safety point of view. their goal is not to change anything, every time we want to do something, it means a disturbance to them and they will fight us...there is a natural tendency on Ops part to do things carefully and slowly (Superintendent Maintenance A2 plant).

The need to work with very detailed and specific procedures

The organizational implications of requiring workers to comply with huge bodies of detailed, written procedures has rarely been studied. No body of written procedures can be exhaustive. The 'human factors' community — particularly those focusing on ergonomics — have demonstrated that achieving 'perfect' (complete) procedures is a dream that will never be fulfilled (Faverge, 1970; 1980; Chabaud and Terssac, 1987; Amalberti 1988; Hoc, 1991). Yet very little is known about how these systems manage to adapt to the use of procedures that can never be complete, while at the same time being formally required to comply with them as if they were. How to comply? Following the procedures blindly is to be avoided since they may contain mistakes, but not following them closely enough is risky, not only from the regulatory standpoint, but also because they are the best guide to the performance of tricky or unusual tasks.

The need to cope with unplanned situations

Maintenance activities are not only thoroughly prepared, but tightly-coupled, because utilities are striving for short outages in order to minimize the impact on plant availability and revenue stream as well as radiation exposures. Yet unplanned situations and fortuitous repairs are not uncommon, no matter how detailed the preparation has been. Therefore, the organization must design the outage to allow some flexibility in dealing with uncertainty and contingency. The two plants under study also displayed considerable differences in their response to this problem.

Ensuring the proper execution and quality of the work

Because of the potentially dangerous and adverse consequences of a repair not being properly performed, many administrative and technical strategies have been developed to ensure what each plant hopes is proper control of task execution. Designing an adequate system of control is not an easy thing to achieve. Many questions have to be asked: Who should control the work? What kind of control is needed? What is the role and power of the controller? Here, again, the two systems studied showed different responses and different organizational approaches.

Two American nuclear power plants: contrasting organizational responses

The critical problem areas discussed above are common to both the American NPPs discussed here. Yet, despite considerable technical, organizational, regulatory and cultural similarities, the organizational responses of the two plants differed significantly along all four of these dimensions.

Planning the outage

Because operations and maintenance crews must cooperate closely, bridges must be built between the two sub-organizations. Maintenance foremen hate to see jobs that were planned being cancelled or postponed by operations; they need to anticipate their work-load so that they will not end up with too many people hanging around the shops doing nothing. Operations shift-supervisors cautiously seek to avoid any disturbance on their shift and maintenance work as it always raises the risk of new problems and errors. If they feel that not enough time has been given to the preparation of maintenance work, they will not hesitate to postpone the task. The foreman can then be exposed to reproach from management for not making good use of expensive and highly-trained workers. Therefore, the interests of both groups converge around planning their work together and sticking to the schedule as closely as possible.

The first plant studied, A1, mediated the relationship between the two groups by establishing a permanent super-ordinating organizational unit, the Work Planning Centre (WPC). Composed of almost one hundred persons — planners and schedulers of all kinds — the WPC can draw on other organizational and technical resources to facilitate the work of both operations and maintenance. Moreover, these activities are pursued not only during outages but all year long.

The WPC is in charge of three main activities at the core of any maintenance: a) the writing and issuing of clearances, formally authorized by shift-supervisors, but not prepared by operations personnel; b) design and management of a 'matrix system' in which a single document with two categories is used to record and report both the preventive activities taken by maintenance and the periodic tests performed by operations; and c) the construction of a detailed schedule of maintenance activities to be performed. The first two ensure that the operational constraints of each sub-organization can be jointly monitored and increases both mutual and overall knowledge of the two sets of tasks. In addition, if a problem develops that eventually requires rapid action to be taken on any piece of equipment, management can decide whether to take immediate action or wait for periodic maintenance.

The WPC system ensures a high level of coordination throughout the year. The detailed schedule is established and up-dated daily by a special group, with input from the foremen responsible for the work. One or two daily schedulers help foremen within each specialty (I&C, Mechanical, Electrical) allocate resources and means efficiently, ensuring that they are fully prepared before the work begins.

These three main and on-going activities are of crucial importance during outages. The practice at A1 of having operations and maintenance crews work together all year long, with relationships constantly mediated and fostered by a Work Planning Centre, is quite remarkable. Cooperation between operations and maintenance is heavily structured by their mutual reliance on the WPC, whose goal is to anticipate, as well as react to, potential problems. As a result, we found very little friction between the two groups; subordination to a powerful planning centre effectively mediated and mitigated potential conflicts.

The response of the A2 plant to a nearly identical requirement for coordination was notably different. There is a Work Planning Service (WPS), but it employs only 37 persons, compared to the 100 in A1's WPC. The main task of the WPS is to establish a 'Plan Of the Day' (POD) for all daily activities performed at the plant — periodic tests as well as preventive and corrective maintenance. Although formally a third actor, as at A1, the WPS plays a less active role in seeking compromise and reducing conflict between the two groups.

Where A1's response to coordination requirements is the hierarchical and powerful WPC, A2's adopts two less structured organizational devices. The WPS provides an arena for discussion and argument between operations and management, while actual negotiation between the two sub-organizations is carried out directly with no intermediaries. The negotiation process is formally acknowledged and each group devotes time and energy to reaching agreements, despite difficulties. It is interesting to note that even when both groups report difficulties, they value the direct confrontation, which they see as a necessary 'evil', yet the only way to go.

Compliance and adaptability

The necessity of working in accordance with very detailed procedures while recognizing their incompleteness is acknowledged as a major burden by both plants. Because of the requirement for 'verbatim compliance' with written procedures, there must either be explicitly specified room for tolerance in the field or adequate resources for their rapid real-time modification. The two organizations have adapted to these demands through very different organizational strategies, mobilizing different resources and adopting different methods and structures.

A1 deploys considerable resources in the field in order to ensure 'verbatim compliance'. There are as many section engineers as foremen; during outages they work in the foremen's offices in order to be more responsive to workers' needs. A foreman cannot himself change a procedure; he in turn must depend upon a specific group of on-site section engineers formally authorized to change and up-date existing procedures in the field. And the workers themselves have no power at all to update maintenance procedures; they must go through their foreman if they realize they cannot perform what is expected of them with the procedure currently in use.

We observed a close and supportive relationship between task foremen and section engineers. Both groups have to sign-off changes in a procedure, and this sign-off process in itself enhances the coordination between the two groups. Because the section engineers' availability during outages is almost total, it usually takes very little time for field crews to get a request for change in a procedure acted upon. And although they therefore require frequent assistance from section engineers, they do not resent this dependence since it largely echoes the union position that union personnel should take no initiative outside their defined scope of work.

The system at A2 was completely different. The plant allows for updating and modification of procedures in the field; coherence and responsibility are assured through the oversight of management. Task foremen have the initiative. It is they who decide that a change in maintenance procedures is required and their responsibility to write the modification in close coordination with their crew. If the modification has to be performed on equipment that is 'Important For Safety', the change must first be approved by a managers' committee, composed of the top plant managers (engineering, operations, maintenance, planning and scheduling, nuclear safety, licensing, quality assurance — with the noticeable exception of the plant manager himself), which also reviews all other procedural changes. It normally meets each morning, but a meeting can be called at any time if circumstances demand it. The idea is to get approval as fast as possible in order to reduce the delay in the field and therefore avoid any possible counter-strategies that workers might adopt if they expect that delays in approval of procedural changes could jeopardize their schedules.[3]

Instead of the formal restrictions of A1, field personnel at A2 are formally in charge of modifying, completing, adding or redesigning of procedures whenever they find it difficult to work within them. A2 combines an explicit delegation of power to the persons directly confronted with the problem, namely task foremen and their crews, with permanent control through management oversight in order to ensure that the right changes have been decided upon.[4]

Outage preparation

Unpredictable situations are unavoidable in maintenance activity. The many revisions and tests often uncover unexpected maintenance to be done or new problems that must be solved, with the risk of significantly expanding the scope of the work. Some repairs can be postponed to the next scheduled outage, allowing time for their preparation, but others have to be rapidly included in the current outage schedule. Maintenance organizations can either strive to reduce to a minimum the number of fortuitous repairs by performing preventive maintenance all year long (which facilitates the anticipation and preparation of repairs), or they can accept as a given having to face unanticipated problems and seek adaptive solutions based on the actors' innovation and initiative (Weick and Roberts, 1993; Weick, 1995). In each plant, the strategy must also take into account that outage managers are reluctant to add anything to an already tight schedule and may therefore tend to argue for deferring unexpected maintenance until the next (scheduled) outage.

The A1 plant relies heavily on eighteen months of detailed preparation for outages, supported by the creation of High Impact Teams (HIT) devoted specifically to the anticipation of any problem that could prevent the schedule from being carried out smoothly. Each HIT is given a window and a series of activities to be performed in a fixed timetable. The participants have no say over the duration of the window, which is decided by the outage manager. Their role is to make sure that resources and means will be allocated adequately to ensure a proper execution of the work inside the given time boundaries. Twenty to thirty persons work on each HIT, from the task foreman who will be in charge of the work to engineers, planners, schedulers and spare parts personnel. Once every detail has been planned (and sometimes rehearsed) the outage planning is completely frozen four months prior to the outage. The impact of the outage schedule on the daily life at the plant is quite remarkable. The schedule is considered to be inviolable. Nothing can drift from the plan, which is quite literally 'enforced' by the outage management team as if it were a law.

The strength of A1 relies almost entirely on its obsessive, minute preparation, the careful study of alternate scenarios and the redundancy of personnel and plans. Even when actors identify potential improvements during the outage, they are strongly discouraged from putting them forward. A1 management believes that last minute ideas, even good ones, can jeopardize the whole planning exercise, which is seen not just as a game plan but a negotiated social contract between sections, departments, disciplines and teams. After many months of debate and argument, participants arrived at various compromises in a single plant that they agreed to follow; accepting or encouraging any change of plan could put this valued and hard-bargained social contract at risk. This leaves very little room for flexibility in dealing with unplanned situations.

The strategy adopted at A2 is almost entirely opposite. There is no detailed long-term planning for the outage, apart from an overall plan prepared by a small team. No special structure has been designed to deal with or manage the outage; each person will only work two hours more per day (10 hours a day) and one more day per week (6 days a week). For A2's management, 'the outage is business as usual'. The question then becomes: how does this organization manage to organize an outage under these conditions while A1 is devoting such large resources to prepare its own? What kind of strategies allow A2 to do it so differently?

It was found that the most important characteristic is the formal delegation of power to craft personnel, supported by a nearly complete availability of top-management at all times. By being a very flexible and adaptive organization, any problem can rapidly receive the attention it requires at all levels of the organization. A2 can be called a 'self-correcting organization' (Landau, 1973), since any drift can be almost immediately either taken into account or corrected. Or a 'managerial' one in contrast to A1's 'controlling' behaviour (Landau and Stout, 1979). Although both possess the central HRO property of recognizing that safety and not schedule is primary, A2 seems more closely to possess those qualities that the HRO group characterized as a paradoxically simultaneous mix of decentralization and centralization within the same organizational structure.

Quality control

The final challenge that A1 and A2 have to face concerns the control of the actual performance of the work. How to ensure oversight and screening to detect any flaw or error that might take place during the execution of each task? Who or which group should be the controller? What kind of control should be practised? This is an area where the rules and regulations of the Nuclear Regulatory Commission (NRC) should apply equally to both of the plants. Yet, we found that each had its own system and design.

The major difference concerns who is in charge of assuring quality-control (QC) of maintainers in the field. At A1, a quality-control inspector is usually an outside contractor, certified in a specific field (I&C, electrical, mechanical). His role is twofold: Inspecting jobs and rapidly judging their quality. At the same time, he must be a devoted advisor if, and when, he is asked to assist a crew that encounters some difficulty with a procedural step. Since control and assistance are both facets of a quality inspector's job, he is usually accepted as a colleague by workers in the field.

At A2, quality-control inspectors are insider journeymen. At the beginning of each week, each foreman asks a technician to volunteer to become the QC inspector for this week. Specific QC training is provided by an industry group, the Institute of Nuclear Power Operations (INPO), to most of the A2's workers as part of a program agreed upon with NRC.[5] In order to ensure proper independence of judgement, the technician, once he has accepted, immediately shifts from reporting to his regular foreman to reporting to the QC chief on-site.

It may seem that having insiders control the work of their fellow workers is risky, since peer pressure and the strong social bonding that is typical of HROs could make it difficult for technicians to exercise proper and thorough control of work in the field. This was not the case at A2. The craft personnel insisted that they had a significant advantage over outsiders because 'no bad work could be hidden from them' given their knowledge of plant and process; they also mentioned that this approach significantly reduced the delay in the field, since they were more knowledgeable on the plant's orientation and could rapidly find where jobs had to be inspected. That journeymen are able to practice QC inspections in addition to being relied upon for taking initiative each time they realize that improvements can be made at their level is also a characteristic typical of the HRO; their empowerment is connected to their deep involvement in the success and performance of the organization as a whole, not just in their specific crew, section or division.

Contrasting approaches

The empowerment of workers at A2 is in seeming contrast with A1, where initiative is discouraged in order to maximize control over task execution. Yet, the power of craftworkers at A2 remains continuously bounded by arbitrages made at the top by plant's managers. The morning managers' committee is a lively social forum in which A2's centralization is regularly re-enacted. A1 substitutes for direct empowerment support for workers in every detail of their working life. Section engineers, planners, schedulers and QC inspectors are almost entirely devoted to the needs of workers in the plant. Powers and responsibilities are disseminated, shared and constantly balanced. The WPC is not just a forum, but an active buffer between operations and maintenance.

A1 depends on control and guidance of its work-force and eighteen months of detailed outage preparation to anticipate and prepare for contingencies. In order to avoid adverse occurrences, it combines the use of well-known bureaucratic mechanisms — detailed division of labor and partitioning of tasks, extreme proceduralization, long and detailed preparation — and achieves the flexibility required of HROs through the devotion and assistance given to workers in the field by many others on-site and on call. Without this assistance, A1's bureaucratic resistance to on-line flexibility could put the whole outage at risk.

In contrast, A2's management is willing to delegate considerable power and authority to task teams and foremen because they see them as key players in ensuring a proper level of safety. By allowing and encouraging craftworkers to formally participate in the daily negotiations over work issues and schedules, they encourage them to share responsibility. Where A1 seeks to keep its workers compliant, but loyal to management, A2 seeks to encourage them to actually 'buy in' to the system as if they themselves were managers.

Both systems seem to work effectively, despite their differences. A1 workers are satisfied because union and management both discourage them from being actively involved, and because they are provided with ample support. A2 workers are satisfied because they are strongly involved in the process, even helping to design and modify procedures to accommodate their needs. Two quotes chosen from dozen of interviews we had on-site illustrate our point in the words of the workers themselves:

> Here is the responsibility of the technician, if he ever observes any problem like a leak, then he has to contact the foreman and they discuss it. The foreman takes the appropriate measure. . .usually you write an Action Request to document. The technician is an instrument for the discovery, the rest is beyond his scope of work. . .in this country, you can't do a job unless it's an emergency that is beyond your scope of work. But if there is a stream, he will shut the valve of course. For normal work if there is a need to deviate from the work-order, they must get approval and besides many of the systems are too complex for them. The technician may not have the whole picture. The foreman will then speak with engineering, the planner and the technician, it's a team effort (Instrumentations Foreman, A1).

> See, we have a procedure and we are expected for everything to follow it exactly. It's easy to come to a point where it doesn't work. But we have to follow, if you fail to follow it you're in big trouble, so most of the time we need to change it . . . We at the craft level, we have to study companies policies, the foremen they seem to be responsible for everything, to me...it's their responsibility for making sure that the correct procedure is used, the acquisition of special tool, everything is up to the foreman...So we try to help him to cover all the ground. We want to help our foreman (Mechanic, A2).

Each of these plants demonstrates *some* of the properties identified by the HRO group in their previous research as important elements for socializing workers into adopting the overall goals of the organization, but neither displays them all.

Conclusion

There is some correspondence between the author's observations at the two American plants and some of those made by the HRO group in their work; for example, aspects of both centralization and decentralization (especially at A2), and compliant behaviour and remarkable organizational goal-sharing (at both). Yet, greater degrees of difference were found when detailed empirical studies of worker behaviour with a systematic Strategic Analysis of social interactions were carried out. SA seems to give us better clues towards understanding cooperative work in these complex and demanding systems, both in terms of the impact of organizational structures on actors strategies and in terms of actors' use of these structures to promote their own interest, than the grounded, semi-structured approaches (augmented by culture surveys) of the Berkeley group.

Our approach is *complementary* to theirs because it focuses on aspects they tend to understudy, that is, the actual making/emergence of 'HRO' behaviour at the workers' level. That A1 is almost rigidly compliant with rules is an important observation, but both this and the more flexible approach used at A2 must be explained as the result of detailed study of relationships at the level of task and worker as well as by 'external' circumstances. Strategic analysis provides us with a useful framework for exploring such issues, since it focuses on local adjustments and helps to identify the strategies of actors and of groups as they are displayed and readjusted in the course of work.

How and why do different strategies for compliance emerge given the constraints and the many uncertainties maintainers had to face daily in an outage? What alternatives are there for an organization that seeks to be reliable and effective as well as compliant? Such questions may require a blend of the strategic analysis methodology, which is strongest in terms of its focus on actors' relationships and behaviours, with less formally grounded observations of organizational performance.

Despite the theoretical predictions of strategic analysis, workers at both plants were able to comply with the rules: despite the observations of the HRO group, variations between the plants were significant. On the one hand, the HRO literature does not fully deal with actors' strategies and behaviour inside the organization. On the other hand, the SA literature has far too restrictive an idea of what collective action should be about (always inhabited by tacit and informal sub-games) to be of help when confronted by systems that actually seek to extirpate informal local adjustments and implicit demands.

These two bodies of literature can offer useful guidance when one wants to study large, complex, potentially hazardous systems, such as nuclear power plants. But neither provides a fully satisfactory explanation of what is actually happening in NPPs. They lack a sufficiently precise description of the structuring of the system and its impact on the attitudes and behaviour of individual actors.

We find that it is possible to be an HRO (and A1 and A2 both seem to fit that description very well) through self-consciously different organizational designs, using different structures and tactics to achieve what are generally the same set of behavioural and functional objectives. The differentiation seen in this work suggests that there is still much to be done in understanding the internal social dynamics of HROs, both in comparison with other HROs and in contrast to other kinds of organizations.

Notes

1. On the Navy aircraft carrier, for example, every deck hand, regardless of rank or function has the power to stop everything if he feels the ship or the personnel are at risk (Rochlin, 1989). Even in case of a false alert, he will not be blamed but rather praised by his superiors. This behaviour is held to be an essential characteristic of HROs (La Porte, 1994 ; 1996).
2. See, for example, Rochlin and Von Meier (1994) who report very similar observations in their comparative observations of NPPs in five different countries.
3. This strategy was used by French workers at French plant 1 (Bourrier, 1991).
4. Our field observations of the content of exchanges in this committee show that managers are not all that concerned with every detail of technical aspects of the changes. But they do pay a lot of attention to the methodology used by the foreman and crew by which they determine that a change in the procedure is necessary.
5. For a discussion of INPO and its growing role in American nuclear power operations, see Rees (1994).

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