RESEARCH MONOGRAPH

Regulatory Compliance and the Ethos of Quality Enhancement: Surprises in Nuclear Power Plant Operations[1]

Todd R. La Porte and Craig W. Thomas
University of California-Berkeley

The relationship of regulatees to regulators is expected to be characterized predominantly by either efforts to co-opt, to resist, or to comply minimally. The object of regulatees, it is assumed, is to reduce the strictures of regulatory constraints. This research monograph reports an unexpected relationship in which regulatory constraints have become incorporated within a broader ethos of quality enhancement and regulatee self-imposed processes of endless analysis, watchfulness, and search for root cause of errors. We outline the salient features of this situation and the conditions that sustain these processes, and we propose a typology of regulatory responsiveness.

INTRODUCTION

The nuclear generation of electical power is a hazardous, potentially lethal activity for plant operators and citizens in the surrounding communities. It is also a source of considerable economic benefit and great financial and political risk. And it is judged too dangerous and valuable to be left to the mercies of the market as the main control mechanism. But what type of relationship has evolved between regulated plants and their regulators? We had an opportunity to see—in a nuclear power plant which was operating well and in which the operators had a strong sense of self-confidence.[2]

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[1]This research monograph is the revision of a paper delivered at the annual meeting, American Political Science Association, San Francisco, August 31, 1990.

[2]In early fall, 1989, our team of social scientists was allowed nearly complete access to the operational and management activities of Diablo Canyon Power Plant. Over the next six months, the team spent over one hundred person-days, at all hours, observing operations and management coordination and evaluation processes and interviewing control operators, supervisors, engineers, maintenance and support personnel, quality control specialists, regulatory officers, and middle and senior level management.

In addition to the senior author, other researchers involved in the field research for this project were Karlene Roberts, Gene I. Rochlin, Paul Schulman, and Alexandra Suchard. A Brookhaven National Laboratories research team, Sonja Haber and Daniel Metlay, also participated with a parallel study of methodological techniques of data collection in electric power-generating facilities. La Porte concentrated on the organization's response to its regulatory environment. Craig Thomas, a doctoral candidate, is a research assistant with the project. The research was supported by Brookhaven National Laboratories (contract no. 459427) and the National Science Foundation, (Grant No. SES-8911105). We acknowledge the candor of the many managers, operators, and staff of the plant who talked with us. Special thanks to Mitchell States, our of contact with the plant, and to Charles Perrow, Harold Wilensky, and David Leonard for their comments on earlier drafts.

The research reported here emerged from a more sweeping program that had different objectives—to enlighten a general set of questions about the dynamics of high reliability organizations (HROs). These are organizations that operate beneficial, highly hazardous technical systems at high capacity with very low risk, for instance, the effective management of physically (and often socially) very hazardous production processes with very low incidents of operational failure—in effect, high hazard, low risk systems.[3] The challenge for these organizations is to provide full capacity at any time and to do it safely lest an accident or failure destroy the capability to continue providing full capacity—securing simultaneously both reliable high production and assured continuity. We have studied three such organizations in order to understand more fully the consequences of striving for failure-free performance in operating beneficial, costly, technically powerful systems.[4] One is the electric utility industry's largest, highly diversified, and profitable investor-owned utility, the Pacific Gas and Electric Company (PG&E). Among its some 180 electrical power-generating facilities is the large, well-run nuclear power station—Diablo Canyon Power Plant (DCPP). It is also the utility's largest, most economically and politically visible facility within its wide-spread, diverse operations in central and northern California.

We did not intend to address regulatory matters, but as we began to learn of the plant's internal dynamics, the plant's compliance behavior was too arresting to ignore. Notably, this is not a study of organizational pathology, nor is it a study of the industry. The findings reported here are from only one of some 70 utilities that operate the nation's 110 nuclear power reactors.

Since we have not studied other nuclear power plants, we do not claim that DCPP is representative of the industry and thus do not make any generalizations to other plants. While single case studies are often held in low methodological esteem within the scientific community because findings from one case can not be easily generalized to other cases within a known population, we agree with Yin's (1984, 39) proposition that analysts should generalize their cases to theory, not to other cases. In this vein, we present our findings at DCPP as a theoretically surprising case in which a regulated firm not only complies with externally imposed regulations but systematically sets and meets standards for its own performance that exceed those of its regulators. DCPP's internal regulatory behavior thus challenges some well-accepted theoretical generalizations in the regulatory literature, leading us to think more broadly about the types of compliance behavior which may exist currently in various industries and to suggest some hypotheses regarding the factors that drive such behavior.[5]

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[3]The demand is for *no* risky operations at all. Recall that *riskiness,* in the strict engineering sense, is a product of the intrinsic hazard of the technical process (i.e., the harm caused as a consequence of failure, and the probability that failure will occur). In HROs, quality management and operations reduces the incidence of failure and in that sense reduces risk, not hazard. Strictly speaking, there are very few risky systems or organizations, that is, very hazardous systems that fail frequently. High hazard, frequently failing (or high risk) systems are self-liquidating.

[4]In addition to units of Pacific Gas and Electric Company (PG&E), we have studied the Federal Aviation Administration's (FAA) air traffic control systems and the two aircraft carriers of Carrier Air Group 3, USS Carl Vinson and USS Enterprise. See La Porte and Consolini (1991) and K. Roberts (1989) for descriptions of the project. See Lascher and La Porte (1990); K. Roberts (1990); K. Roberts, Rousseau, and La Porte (1991); and Rochlin, La Porte, and K. Roberts (1987) for provisional findings.

[5]See Barzelay (1993) and Eckstein (1975) for a constructive discussion of the potential contributions of single case studies to social science theory.

After a bit of organizational context, we summarize what the literature on regulatory relationships would lead us to expect from studies of the enforcement practices of social, as contrasted to economic, regulation, including the compliance behavior of closely watched hazardous systems. Then we turn to what was found on the basis of intensive field research at one plant, and we conclude by proposing a typology of regulatee compliance behavior based upon variations in the compliance means of regulators and the regulatee's acceptance of the regulator's model of the requisites for safe operations.

Demand and Response

One of the most sensitive and potentially most costly aspects of operating a nuclear power plant is ensuring that no one in the plant or outside it is exposed to unacceptable levels of radiation. The principle long-term health risk from occupational radiation exposure is an increase in the likelihood of contracting cancer. This hazard is the primary reason nuclear facilities draw so much public attention. "Radiation protection" means the developing of work processes and safety measures that stringently limit the amount of radiation employees receive on the job and assure that no one off site will be exposed to plant-related radiation. This function is of keen interest to inspectors of the Nuclear Regulatory Commission (NRC), the nuclear industry's chief federal regulator.[6]

Overseeing radiation safety during the regularly scheduled refueling of the nuclear core is especially trying. It is a highly technical, complex process in which there is a substantially increased chance of exposure to high levels of radiation. Assuring worker safety requires rigorous observation of work sites and processes and constant watchfulness for inadvertent situations that may expose workers needlessly to radiation. It also includes daily monitoring of the potential exposure of hundreds of workers through the collection and checking of individual radiation-sensitive badges. Dosages are cumulative, and without great care workers quickly can be exposed to the point where their radiation dose exceeds NRC limits, increasing their risks of long-term radiation effects. When these exposures exceed regulatory safety standards, technicians are disqualified from working in radiation-sensitive areas or jobs for the rest of a refueling period (up to three months) or possibly for a year.[7]

A plant's radiation protection unit is charged with developing and enforcing procedures that meet regulatory safety standards. If a "rad protection" person spots a dangerous practice or violation of NRC procedures, he/she can—in fact should—call a halt to refueling activities until the problem is resolved and written up. If the NRC discovers a violation, the plant can be fined heavily or even shut down until the problem is remedied.

This watchfulness and policing function, if carried out properly, can result in the abrupt halt of work at crucial times, without recourse to appeal. Putting a stop to the flow of complex, integrated work processes in a radiation-sensitive environment can mean a considerable delay in

[6]For reference, NRC's acceptable radiation limit for employees is 5 REMs per person per year. Title 10, Code of Federal Regulations, part 20. The efforts of the NRC and the nuclear industry have resulted in very limited cumulative radiation exposure to workers over the past ten years, with no recorded deaths or acute radiation illnesses from operations in the industry.

[7]Title 10, Code of Federal Regulations, part 20.

getting on with very demanding, tension-inducing jobs that have potentially high opportunity costs. As a reference, the revenue value of each of the two nuclear reactors in full operation at DCPP was $2.4 million per day, or about $100,000 per hour. "[Bringing things to a halt] is sometimes pretty sticky!" noted one rad protection person. It is plausible that operators can be under heavy pressure from management to fudge standards, and/or, in the midst of great overload during times of peak activity, lower their guard in potentially dangerous situations, hoping that the number of person rems accumulated by the refueling teams would be under a dangerous level.

A senior rad protection manager at DCPP described the importance of estimating the possible exposure to workers as a result of their repairing parts of the reactor when it is opened up for refueling, of devising special temporary shielding barriers, and of carefully tracking the dosage people might receive under different conditions. He noted that "we can be hammered by the NRC if they think we're losing control of this business." When asked: What's it like being in a regulatory 'goldfish bowl' all the time, with so many people coming 'round to check-up on you? he sat back with a quizzical little smile. "They [NRC inspectors] seem to think we invariably cover-up. They come in here with that idea. When they come in [to inspect], this is what I do." Pulling out a pad and a pen, he leaned forward and began to write. "I say, to 'em, 'Here's a list of our four or five most serious problems,' and hand it to 'em. 'Go see if we aren't right. And let me know if our solutions aren't working.' They don't expect this. And they go away and look. We try to be better than they are at finding and fixing problems."

REGULATORY RESPONSES

This was an unexpected exchange. The strategy of full disclosure may be sensible, but it is not obvious, nor is it what academics have come to associate with regulated industries. The stereotype of regulatee response to regulation is predicated on the assumption that a firm will do whatever it can to minimize the cost of complying with regulations. This assumption underlies the "capture" theories of both economists (Stigler 1971; Peltzman 1976) and political scientists (Bernstein 1955; Sabatier 1975). To reduce the cost of compliance, the firm either may resist complying or persuade the regulator to alter rules and/or be lenient in enforcing them. Proponents of capture theories argue that such industry influence is ubiquitous and pervasive.

Bernstein, for example, claimed that regulatory agencies move through life cycles in which they gradually lose their political support and staff expertise and eventually come to rely on, identify with, and protect the industry whose behavior they once sought to alter.[8] More recent studies (Gormley 1983; Mitnick 1980; Weaver 1978) have argued that capture—if it in fact has ever occurred—is more likely with the older, single-industry agencies such as the ICC, CAB, and FCC. These so-called independent commissions regulate relatively few individuals, all of whom are engaged in the same type of economic activity. Therefore, it is argued, the regulators more likely will identify with the regulatees and are likely to develop a symbiotic relationship characterized by industry control of information, professional rewards, and possibly career opportunities

[8]The theory seemed attractive and has persisted, even though Bernstein noted later (1961) that it had yet to be supported by empirical evidence: "Studies in depth of the impact of regulated interests upon the regulatory agency and program have rarely been published." See Sabatier's treatment (1975).

(Gormley 1983; Mitnick 1980).[9] Conversely, the newer agencies charged with implementing social regulation, for example, OSHA or the EPA, should be less prone to capture because they regulate many different industries and even more individual firms. Moreover, newer agencies often are dominated by professionals with pro-protectionist values (Kelman 1981). These values probably increase the propensity of regulators to exercise whatever compliance means are at their disposal and decrease the likelihood of capture.

Recent studies of enforcement suggest that the range of industry efforts to comply is quite broad. Enforcement officers report everything from negligence and intransigence to minimal formal compliance, such as meeting but not routinely exceeding government standards. Between these extremes, there exists a considerable diversity of behavior, including good-faith efforts that are hampered by a firm's limited resources and/or incomplete knowledge of rules and alternative means for compliance (Bardach and Kagan 1982; Richardson et al. 1982).[10] The standard stereotypes notwithstanding, in a number of cases in the regulation literature compliance largely is achieved and maintained with little or no enforcement effort. OSHA, for example, has had since 1982 a voluntary program in which companies with exemplary safety records may assume many regulatory responsibilities normally handled by inspectors, such as conducting inspections and investigating complaints (Rees 1988).[11] Rees argues that in addition to reducing overloaded inspection schedules the public purpose of such mandated self-regulation programs is "to build into the social structure of the regulated enterprise a sustained and effective commitment to insecure or precarious values, such as environmental protection, affirmative action, and occupational safety" (1988, 604).

Moreover, even if the assumption that all firms attempt to reduce the cost of compliance were true, there may be instances in which the act of complying is itself the firm's cost-minimizing strategy (Sigler and Murphy 1988, 69). This was the case in Virginia, for example, where compliance with state pollution control laws was achieved—even when the cost of non-compliance and the probability of detection were low. Downing and Kimball (1982) argue that this resulted from the combined effects of government subsidies on capital investment in pollution-control equipment, desires to improve corporate image, and a general aversion to risking violations that lead firms to conclude that "compliance actions . . . [are] the least costly alternative" (1982, 62). In this situation, minimal formal compliance can be seen as an economically rational strategy.

Yet such cases of cooperative behavior seem not to be carried out in what might be termed a *spirit of regulation*. In other words, though a given firm may choose to meet a regulator's minimal compliance standards with little or no resistance, we found almost no indication in the literature that conditions might exist in which a firm would go *beyond* formal compliance standards to

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[9]Evidence supporting the popular revolving door hypothesis is weak, however. Though individuals indeed make career moves beween firms and regulatory agencies, these moves are not linked closely to an individual's policy preferences regarding either regulation or compliance (Quirk 1981; Gormley 1983).

[10]A variation of this theme argues that compliance is more difficult to achieve with public agencies than with private firms because public agencies are more autonomous from sister government bodies (Wilson and Rachal 1977; Durant 1984; Durant et al. 1986). Empirical work focuses on TVA compliance behavior with EPA requirements.

[11]Similar programs exist within the EPA and in the FAA's airplane worthiness division, which certifies the quality of air frames. See Sigler and Murphy (1988) for a discussion of why government agencies should promote compliance programs within corporations rather than simply regulate and enforce.

set even higher standards for itself in order further to reduce pollution or increase worker safety. Firms might anticipate government demands in order to situate themselves strategically in a competitive market (Sigler and Murphy 1988, 53) and/or to avoid more costly retooling in the future (DiMento 1986, 31; Roberts and Bluhm 1981, 356), but we should not expect them to routinely and systematically outregulate the regulator.

Moreover, we found few insights into what we might expect in a nuclear power station from the literature on the dynamics of social—as distinguished from economic—regulation.[12] Despite the diverse array of social legislation over the last three decades—from consumer-product and worker safety to pollution control, food and drug laws, and access for the handicapped—the case-study literature dealing with the implementation of social regulation and the relationship between regulator and regulatee deals mainly with two policy areas: worker safety and pollution control. This topical clustering is probably a result both of the availability of quantitative data and of the widely perceived difficulties in implementing and enforcing worker-safety and pollution-control legislation. While it has deepened our understanding, this literature also may have biased our views of enforcement experiences more generally. That is, one might come to expect other industries, such as the nuclear power industry, to exhibit similar behavior patterns—efforts to co-opt, resist, or minimally comply.

Nuclear utility/NRC relationships have received little attention at the microlevel.[13] Most studies of the NRC have focused on macro issues such as the politics of regulation and regulatory reform rather than on case studies of the working relationships between plants and NRC inspectors. Moreover, Three Mile Island—a case study of operational failure—dominates our perception of what is typical in nuclear power operations.

On a theoretical level, the NRC also does not fit neatly into the standard dichotomy of economic versus social regulation.[14] Though it is a so-called independent commission, regulating a single industry, it nevertheless regulates social—safety—rather than economic concerns. Thus according to capture theories, the NRC should be more vulnerable to co-optation than other social regulation agencies because of its intense working relationship with relatively few plants. We would, therefore, expect to find evidence of the utility co-opting the regulator, winning its sympathy, and thereby gaining leniency in the stringency, specificity, and enforcement of regulatory requirements. On the other hand, the NRC is a relatively new agency with many pro-protectionist, proenvironmental enforcement professionals who check co-optation tendencies. In this sense, we should see nuclear utilities resisting or, if pressed, carrying out minimal compliance programs. We return to these points below.

With regard to the means of effecting and maintaining desired regulatory changes, the regulation literature consistently draws a distinction between strategies of cooperation and stringent,

[12]We follow the standard distinction in the regulatory literature between economic and social harms. Health, safety, and environmental damages are included under *social*. In this section we emphasize social harm. The literature on economic regulation is extensive and distinct, focusing on rate-making, barriers to entry, promoting competition, regulating natural monopolies, and so forth, all intended to protect consumers by regulating business practices.

[13]Roberts and Bluhm (1981) is an important exception.

[14]Gene I. Rochlin was particularly helpful on this point.

adversarial enforcement of rules and standards.[15] That is, officials must decide whether or not the regulatory target is making good-faith efforts to comply but is constrained in so doing by time, limited resources, and/or incomplete understanding of applicable rules. Despite the popular image of combativeness and research findings that indicate the newer agencies are generally less cooperative than the older agencies, many of these agencies do rely on cooperative strategies such as persuasion, education, and even compassion in the face of "unreasonable" regulations (Bardach and Kagan, 1982). Key factors in employing one or the other, or a mix of strategies, are the number of agency inspectors available, the skill of inspectors and their personal attitudes toward regulatory targets, and the sweep and stringency of enforcement sanctions.

Enforcement officers at agencies such as OSHA and the EPA are spread thinly over numerous industries. They typically are unable to monitor any one operation closely and thus are unable easily to distinguish between good-faith efforts and resistance, making the choice of enforcement technique difficult (Diver 1980). Scholz (1984b, 211) argues that "the large jurisdictions of the newer agencies hamper cooperation by increasing uncertainty in the firm-agency relationship." Such agencies must rely on game-playing techniques for gaining compliance, with individual enforcers often forced to make assumptions about the behavior of individual firms, although they have little information to base the assumption on.

Agency inspectors typically begin either with a strategy of stringent enforcement which may later be tempered as they learn that many firms are willing to comply (Scholz 1984b), or they follow a series of sequential steps to gain compliance, beginning with such cooperative strategies as education and coaxing (appealing to norms of social responsibility), and only later advancing to threats of sanctions and—as a last resort—the use of sanctions (Downing and Kimball 1982; Hawkins 1983).[16] Though an inspector may never have to resort to sanctions, the threat of coercion and the perceived ability of inspectors to apply sanctions are important determinants of the success of cooperative strategies (Scholz 1984b; Frank and Lombness 1988). Sometimes organizational factors, however, impede an inspector's ability to employ coercion, thus also limiting their ability to bluff. Frank and Lombness (1988) found that Wisconsin dairy inspectors were undermined when they dealt with uncooperative violators because of inadequate training (thus reducing their confidence and credibility); incentives to increase the quantity versus the quality of site visits; and norms discouraging assertiveness and "rocking the boat."

Regulatory Responses in Closely Watched Highly Hazardous Processes

Some industries are watched much more closely by regulating agencies than are others. Nuclear power is perhaps the most closely watched of U.S. industries.[17] NRC inspectors are

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[15]For elaboration of this distinction and recent efforts to conceptualize typologies of regulatory enforcement styles, see Hawkins and Thomas (1984); Reiss (1984); Kagan (1989); Smith and Stalans (1991); and Braithwaite, Walker, and Grabosky (1987).

[16]Country comparisons indicate the approach in the United States is generally more adversarial than either Sweden's (Kelman 1981) or Britain's (Vogel 1986), due in part to an historical lack of trust of industry in the United States. Britain has been referred to as "a haven for self-regulation" (Baggott 1989, 442) in policy areas as diverse as financial services, consumer protection, and worker safety.

[17]For reference, nuclear power plants have a strong battery of formal governmental watchers: the Nuclear Regulatory Commission, the Federal Emergency Management Administration (FEMA), the Environmental Protection Agency (EPA) and, in California, the California Public Utility Commission (CPUC), the Office of Emergency Services (OES), Occupa-

housed on site at nuclear power plants and frequently are supplemented by specialist NRC inspection teams. Nuclear power is unusual in this respect since most industries are subject only to self-reporting requirements and/or relatively infrequent site visits by inspectors.[18]

If nuclear power is an example of a closely watched industry, then most of the social regulation literature focuses on industries in which individual sites receive little scrutiny. Though OSHA has written voluminous regulations, its inspections of any one site are relatively few, far-between, and often cursory. Estimates of the number of sites for which each OSHA inspector is responsible range from approximately 1500:1 (Bardach and Kagan 1982, 160) to 1700:1 (Rees 1988, 605).

In contrast to the cases described in the social regulation literature, the NRC/nuclear utility relationship is one of the regulator overseeing a relatively small number of homogeneous facilities, with an unusually large number of inspectors per facility who have open access to operator production and safety data. Each nuclear plant is assigned two or three resident NRC inspectors with these local residents augmented by up to twenty specialists on annual inspection team visits.

Relatively few studies touch on the regulatory compliance dynamics of highly hazardous, closely watched industries such as nuclear power. Moreover, those articles that deal with nuclear power have little to say about site-specific interactions between plant operators/managers and NRC inspectors. Rather, they focus either on the politics of regulation and regulatory reform after Three Mile Island (Temples 1982), on the enforcement practices of NRC inspectors (Nelkin 1981), or on industry-wide data in attempts to establish the factors associated with noncompliance (Feinstein 1989) and innovation (Marcus 1988). These studies tend to evince vestiges of older paradigms—and perhaps an older way of doing business in the nuclear power industry—rather than on potential insights into our findings at an operating nuclear power station like DCPP. For instance, Nelkin (1981, 137) states that "government has become a partner in the nuclear field, developing through its contracts and subsidies a stake in the promotion of nuclear power. This partnership reduces the ability of government to exercise independent regulation and control." Though Nelkin's article focuses primarily on the NRC's failures to evaluate the operating practices of plants and to review minor accidents, it provides no indication about how plant managers run operations.

More recent work based on statistical analyses of NRC data and individual plant characteristics suggests that nuclear power plants are quite diverse in management style and are sometimes proactive in complying with NRC regulations. Marcus (1988) found that some plants anticipate and even implement new safety concepts before they are required to do so. However, his study analyzed industry response only to *one* new regulation, thus limiting our ability to generalize about a given plant's response to regulations per se. Feinstein (1989), conversely, analyzed data from more than one thousand NRC inspections of seventeen plants over three years. In doing so, however, he made questionable assumptions regarding the goals of plant managers—that plant

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tional Health and Safety Agency (CAL/OSHA), and the state Nuclear Safety Review Group (NSRG). These are joined by two industry bodies: the Institute of Nuclear Power Operations (INPO) and Nuclear Utilities Management Review Council (NUMRC). The instruments for this watchfulness include: annual inspections, annual and biannual emergency simulations, license reviews, personnel reviews, and fitness for duty tests (random testing for drug abuse). There is a strong informal presence as well, with high visibility in the local and regional press, local governments, and grass roots citizen groups.

[18]Self-reporting refers to reporting violations of standards imposed on the regulatee. Self-regulation refers to situations in which regulatory standards are made by those to whom they apply. See Cheit (1990) for an extensive study of industry self-regulation, focusing primarily on organizations setting private-sector standards.

managers "desire to conceal violations, whether these violations are intentional or arise spontaneously because of insufficient oversight . . ." (p. 122). This assumption, presumably derived from historical stereotypes of firm behavior, appears inconsistent, however, with his statistical finding that "overall management style and idiosyncratic technology . . . appear to be important determinants of noncompliance . . ." (p. 117). Thus, while his data suggest that some plants may in fact strive to comply, his basic assumption regarding management behavior leads him to frame his entire analysis in terms of each plant's "estimated propensity to noncomply."

Based on the literature of regulatory response, we would expect to find something like the following in organizations operating hazardous systems such as nuclear power stations.

On the one hand, the utility is unlikely either to have coopted (captured) the NRC, or to have been successful in altering the rules or coaxing inspectors to be lenient in enforcing them because the agency has inspectors with pro-protectionist values. On the other hand, the NRC has close working relationships with relatively few plants. Thus, the on-site inspectors might have developed symbiotic relationships with the plant, such as a reliance on plant officials for information or professional rewards and respect. Because of this close relationship, inspectors would have an accurate sense of whether the plant was making good faith efforts or was trying to evade regulations and thus they would be pursuing a relatively stable pattern of enforcement procedures whenever the plant failed to meet compliance standards. The plant would comply whenever the threat of sanctions exceeded the financial costs of compliance. We would not expect the plant to exceed compliance standards.

RESEARCH QUESTIONS, CONTEXT AND PROCESS

What can be said about the responses to regulatory demands in operating a very demanding technical system in the United States' most scrutinized industry? Specifically, what has one nuclear-powered electrical generating organization become as it has faced a close regulatory presence and stringent enforcement processes?

The organizational location for this field study is unusual in placement, system scale, and effectiveness. The Diablo Canyon Power Plant (DCPP) is some two hundred miles south of PG&E's general offices in San Francisco. It looms up around a bend at the end of a seven-mile road along a beautiful, deserted, and mountainous sea coast. Rising up from the rural surroundings, its two great containment domes seem anchored to the rocky bluffs by a broad-shouldered, glass-windowed, five-story administration facility in the midst of a bevy of lesser training and support buildings and a split-level car park for some five hundred cars. Its two nuclear power reactors are each larger than any other single power generating unit in PG&E.[19] Each unit generates about 1100 MW at full power producing a daily revenue stream of $2.4 million.

Diablo's power-generating capacity joins 12,900 MW produced by 180 large and small PG&E generating facilities (and 6800 MW available from external sources). This is delivered to four million customers over sixteen thousand miles of transmission and distribution lines in a

[19]For comparative and system description purposes the study included the fossil-fueled Pittsburg Power Plant (PPP), (central) power control, transmission and substations of the East Bay region, and the Diablo Division of the distribution business unit. PPP's largest of seven units generates about 730 MW.

service area about the size of the New England states and composed of thirteen distinct ecological zones. The company consistently over the past ten years has made electric power available 99.97 percent of the time. (That is, the average customer lost power for only 180 minutes per year.)

When our study at DCPP began, the plant's managers were digesting several important changes in their operating environment and corporate status based on an unusual new agreement with the state PUC. For the first time in its history the utility was allowed to vary its rate of return, by achieving and then exceeding certain high levels of power production.[20] In addition, the management of the nuclear power generating (NPG) department was anticipating increased financial and administrative autonomy (now gained) by achieving the status of a corporate business unit within the PG&E system rather than a subordinate unit within the existing power generation business unit.

The plant also recently had set an industry record of nearly 400 days of continuous operations of the unit 1 reactor and now has broken all records for light water reactor operation of over 490 days on unit 2. Thus, after a very rocky first decade of controversy prior to start-up, it has achieved in its five years of operation a reputation in the industry and in the Nuclear Regulatory Commission as one of the most productive and well-run nuclear power plants in the country. The utility and plant management and plant work force were proud of DCPP's record. At the same time, they wondered at their own achievement and were apprehensive about their ability to sustain it.

Fieldwork was carried out during several major activities and events that highlighted the plant's intense dynamics and the processes that have evolved to cope with a variety of situations. At the plant's suggestion, research team visits began during an important biannual event, the activation of the utility and county-wide emergency response exercise. Members of the seven-person team were placed in nearly all strategic locations for the day-long affair that involved some six hundred plant and community participants.[21]

Shortly after the emergency exercise, the plant began one of its periodic, critical processes of replacing a major portion of the spent fuel in unit 1. This scheduled outage had a higher than usual intensity, for the plant was attempting to reduce the necessary down time significantly from about ninety days to about seventy days (thus increasing their annual revenue by some $40 million.) This goal was accomplished with great effort. We ended most of our field work midway

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[20]In contrast to the traditional method for establishing rates of return based on capital investments and allowing about a 10 percent profit, the new California PUC agreement stipulates that if the plant operates at an annual available rate of at least 58 percent of capacity, the industry's average, the utility can charge an agreed-amount of past investment to the ratepayers *and* keep revenues generated above the 58 percent level. If it does not achieve that level, however, very little past indebtedness can be so charged. For the past two years, the plant's capacity factor has averaged about 90 percent for the two units.

[21]These simulations are based on a closely reasoned and secret scenario developed by NPG staff that guides the exercise directors and operators (and their umpires) through a series of events, situations, and equipment failures that would result in a significant amount of radiation escaping via steam from the plant and drifting in a particular path toward a portion of the surrounding community. (In order to make the scenario realistic in reaching a point where containment would be breached and radioactive materials released into the atmosphere, the early part of the sequence had to be highly improbable, to the disgust of the plant operators who were constrained from "solving problems too early.") Emergency monitoring and plant and county command facilities were activated early in the day with all key players in attendance. Evaluators from the utility, the NRC, FEMA, and the state Office of Emergency Services observed the processes. (See also Metlay and Haber 1990.)

through a second scheduled outage on unit 2, which was trying to achieve an even shorter outage time, sixty-two days—and actually made it in fifty-eight.

But scheduled projects and regular power production were not the only stimulus to intense activity. During our six months on site, unit 2 experienced one unscheduled *trip,* and unit 1 experienced two.[22] These produce intense responses for they often result in reactor shut downs that take several days to restart and come to full power—at a potential revenue loss of almost $100,000 per hour.

The research team examined the functional relationships of the production/operations units, maintenance, technical support services (mainly engineering and technical analysis), and "regulatory compliance," the subunit mandated by the NRC to emphasize regulatory relations. The team was given nearly free run of the DCPP facilities to interview some one hundred key managers, supervisors, experienced operators, and bargaining unit (union) representatives, and to observe operations, typical work and coordination activities, and management meetings. Nearly thirty of these meetings were related directly to the quality enhancement process. (See the technical appendix for more details.)

FINDINGS IN CONTEXT

In some respects, the DCPP's regulatory environment is similar to other regulated organizations. General environmental and health worries call for OSHA, EPA, and state water and air quality regulation.[23] But the attention paid to safety requirements is heightened by the superordinate concern with the hazards of radioactive materials. For our purposes here, we emphasize DCPP's response mainly to concerns about this nuclear hazard.

In brief, we found an unexpected type of regulator/regulatee relationship: the incorporation and extension of regulatory measures within a pervasive, uncompromising ethos of operational rigor and quality enhancement. Its most vivid expression is in a series of formalized processes and groups that search endlessly for both obvious and subtle error-producing situations in an atmosphere of discovery and urgency to improve codified procedures (see also Schulman 1993). The plant's quality enhancement functions were characterized by an elaboration of formal quality enhancement (QE) organizational structure; a keen sense of technical professionalism and pervasiveness of QE activities; processes of discovery and analysis; and the dynamics of the relationships of senior technical managers with the NRC resident.

[22]Unscheduled *shut downs* and *trips* of a reactor occur when the reactor's operations are curtailed, sometimes turned off, due either to an automatically triggered system after instrument and computer sensing of a dangerous situation or, more usually, by a control operator, due to what is seen as a potentially unsafe situation on the unit in a safety related process in the reactor, steam generating unit, or off site, e.g., a malfunction of a critical transmission line.

[23]Normal environmental and health concerns within the plant are overseen by the twenty-one people of safety and emergency services (S&SE), who cover a range of demanding, more or less traditional industrial safety and fire prevention and fighting functions. The plant is an intrinsically dangerous place and S&SE emphasizes increasing awareness as much as responding to injuries and accidents. They encourage reporting of even minor IRMAs (industrial related major accidents). S&SE also is involved in substantial first aid and fitness for duty (drug abuse) programs.

DCPP operations are marbled with many more formal groups and activities than strictly are required. This is formally visible via the NRC-required regulatory compliance group[24] and the stipulated review and evaluation processes that form the accountability interface between the company's nuclear power generation business unit (NPG) and the regulator. "Reg compliance's" function is not—as we first thought—simply to see that compliance is secured. Rather it is to facilitate and administer the formal NRC review and evaluation processes (see box). This unit provides experienced liaison with the NRC, knowing its bureaucratic mores, sensitivities,and pet peeves. Reg Compliance staff assures the required composition of investigation groups and proper form and content for these reports, which are then forwarded to NRC headquarters office in Washington, D.C., after a review by the NPG San Francisco office.

"Reg compliance" is a key role player in the on-going processes of NRC required investigations and justifications (listed by increasing degree of regulatory importance):

- event investigations teams (EITs);
- technical review groups (TRGs), convened to consider design or operations flaws that could result in worrisome
- noncompliance reports (NCRs), that identify problems not "in conformance" with plant programs and procedures;
- official notifications of rule violations, reviewed by the plant (senior) staff review committee (PSRC), about one third of which result in
- license event reports (LERs)—formal NRC rule violations; and finally, the less frequent
- justifications to operate (JOs).

The unit's objective is to assure efficient, unambiguous transactions in relations with the federal regulators on site, at the regional office in northern California, and in Washington, D.C.

Timely delivery of accurate, well-formed documents, communicated fully, unambiguously, and quickly, is believed to signal acute analysis to the NRC. As one manager put it, "Better to discover a problem first and report it than for the NRC to discover it on its own!" (And therefore draw harsher penalties.) This mode of self-reporting is akin to the perspective in "rad protection" described above.

But "reg compliance" does not act alone; rather, it plays an important coordinating role in facilitating the work of a number of other goups that take up particular quality enhancement tasks. There was a far more extensive and differentiated array of units than in the fossil-fuel-powered

[24]Regulatory compliance is one of several stipulated formal organizational requirements demanded by the NRC of all nuclear power plants. See NUREG 0800, ch. 13 for NRC guidance on organizational structure and properties.

plant or the other organizations in our study[25]—for example, quality assurance, quality control, and the off-site review group, and documents control.[26] Much of what we found went well beyond the formal requirements of the NRC and its local residents.

ELABORATION OF THE FORMAL STRUCTURE OF QUALITY ENHANCEMENT

The formal structure of quality enhancement covered a wide range of functions and comprised eight units on site with five more hierarchically related oversight groups in NPG's San Francisco office. Exhibit 1 lists these units with brief descriptions of the on-site units' closely complementary functions. For this article, we emphasize those that are formally chartered by the NRC and the company to engage in inspection, oversight, verification, and assurance functions.[27]

Several things about the formal structure of quality enhancement are intriguing: it is relatively large scale, quite varied, and exhibits an intriguing pattern of authority. QE activities are carried on by a notably large number of people at considerable cost (see exhibit 1), for instance, quality control's (QC) function of visual inspections of critical jobs is staffed (36) to inspect the hundreds of maintenance action requests (ARs)—work orders—carried out each month. The total of 140-150 QE related positions for NPG, covering the range of specific functions, is unusually high. The some 125 positions on site represent over 10 percent of the 1100-person production force at DCPP and cost the company an estimated $100,000 per position.[28]

The plant's safety, regulatory, and quality enhancement functions are distributed throughout the operations, maintenance, and support divisions rather like a lymphatic network of small connected nodes of watchfulness. Exhibit 2 schematially portrays the complex formal structure, division of labor, and key relationships of DCPP's QE and regulatory compliance structure.[29] It also shows authority checks which encourage rather than inhibit disclosure and the speeding of negative information "upward." The design of reporting relationships attempts to assure the highest level of objectivity.

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[25]DCPP represents the most intense and concentrated high reliability activities of our several organizations, followed closely by the aircraft carriers (CVNs). Flight operations at sea involve a wide range of hazardous activities: operating nuclear powered engines and high performance aircraft, intense deck handling and aircraft recovery operations, demanding management of the navigation bridge, and sometimes handling very high explosive ordinance in confined spaces. These activities, in contrast to those characterizing this nuclear power plant's operations, are carried out by people who have had relatively little time together as team members. Their behaviors are based on well-understood and relatively more stable and simpler rules and standard operating procedures. The behaviors in the power plant evolved among people who worked together often for many years and incorporated subtle relationships among workers and managers that have accommodated to special competencies and personal styles. DCPP is more formally regulated than air traffic control (ATC) and exhibits more numerous and subtle forms of interpersonal and procedural relationships than either the CVNs or ATC.

[26]Of course there are also environmental and OSHA requirements, but we emphasize the nuclear safety related units in this article.

[27]The duties of each group are varied and quite detailed. A careful functional description, while perhaps interesting in general, would take us beyond the bounds of this article. Contact the senior author if there is interest in such detail.

[28]In contrast, the fossil fueled power plant we also studied produces about as much energy from its seven units as DCPP, with a total work force of about 280, four of whom occupy quality enhancement and safety-related positions.

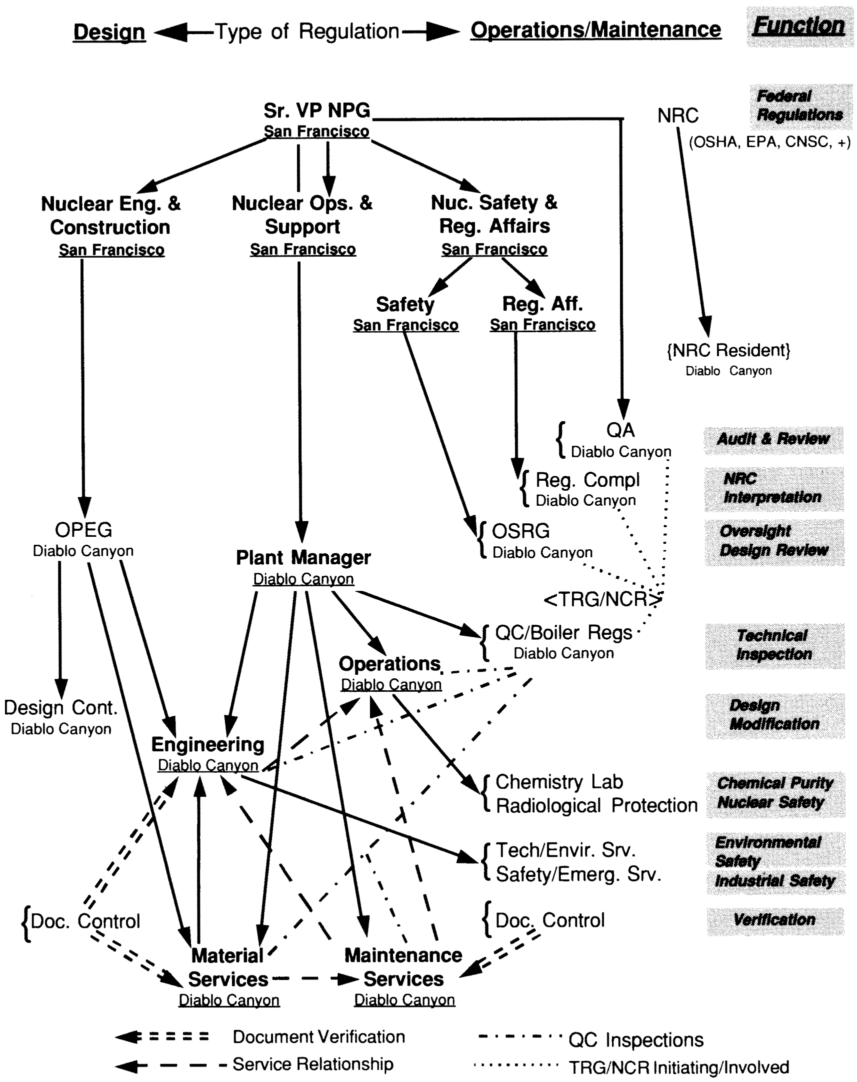
[29]During a discussion of the interactions of these groups with senior DCPP managers, noting the simplistic skein of lines on this figure, one observed, "If you put in all the relationships, there would be a big black blob on the chart!"

Exhibit 1
Regulatory/Quality Assurance/Safety-Emergency Units:
On-site and at General Office [~150]*

PLANT'S UNITS		FTE
Radiation Protection & (police function ~15/63) Establish radiation protection procedures in order to meet regulatory safety standards, and ensure enforcement.		15
Quality Control (QC) Formal inspection of all reportable action requests (ARs) and sampling of other less critical ARs.		36
Chemistry Testing (police function ~5/63) Test for the environmental quality of water/chemical processes.		5
Documents Control Assure the accuracy of documents describing procedures and plant machinery, especially nuclear safety elements.		19
Safety (est) Industrial safety inspection and education		5
	Subtotal	80
NPG'S UNITS (on site)		
Quality Assurance (QA - 19 PGE + 6 consult.) Review adequacy of procedures and audit the quality of QC and other safety functions in the plant.		25
On-site Safety Review Group (OSRG) Independent review of ARs, Technical Review Group (TRG) meetings, and other activities to maintain quality.		9
Regulatory Compliance Administer formally processes of review, investigation, reporting to the NRC.		11
	Subtotal	45
	Total on site	125
NUCLEAR POWER GENERATION (NPG): San Francisco general office		
Nuclear Safety		2
Quality Support (QA)		6
Quality Control		4
Radiological Support		6
Emergency Planning		4
	Subtotal	22
	Grand total	147

*At least two or more people from each on-site QE group were interviewed, for a total of thirty people employed full time or with significant partial responsibilities for a specialized QE function.

Exhibit 2
Nuclear Power Generation and Diablo Power Plant Regulatory/Quality Enhancement Schema



QE units are highly differentiated, with a finely grained division of labor. Although many people in the plant outside the QE groups themselves have difficulty distinguishing between specific QE functions, each group has a clear sense of the boundaries around its activities. And each group has decision rules that assist it in knowing what is theirs, what is someone else's, and when to cooperate. The groups are staffed with skilled inspectors and analysts who command a wide range of technical knowledge. Varying in size from five to twenty-five members, the groups developed their own brand of technical professionalism and competed with each other in demonstrating technical and analytical prowess.

Listed in increasing order of corporate formal status, the key on-site units are:

- the *radiation protection group* (from which we drew our opening vignette) reporting to the operations assistant plant manager (APM); and
- the *quality control (QC) branch,* ensuring that work is done in accordance with technical (and regulatory) specifications, accountable directly to the plant manager (PM).

Three other groups with strong on-site presence report *off site* to different superordinate levels of nuclear power generation (NPG) located at the general office (GO) in San Francisco. They are:

- the *on-site safety review group (OSRG),* independently reviewing any activities or documents it deems necessary to maintain quality of safety performance, reporting to the nuclear safety affairs and regulatory affairs offices (NSARA);
- *regulatory compliance,* also reporting to (NSARA); and
- *quality assurance (QA),* reporting directly to the senior vice president for nuclear power generation.

QA has a wide-ranging mandate which includes reviewing the adequacy of prodecures, design modifications, economic policies, and organizational issues that directly or indirectly may affect the operational (and nuclear) safety of the plant. In addition to the audit function, they also carry out three major processes: safety systems modification investigations, the readiness for restart (of cold reactors) program, and the operational quality enhancement assistance program.

Each of these groups has a strong sense of its mission and is held closely accountable by plant and NPG division management for its shortcomings and achievements. And each group emphasizes the need to be both inspector and consultant to those for whom it has oversight responsibility. Typically each group has mild suspicions that superordinate groups are less operationally acute and that they are probably more technically competent than other groups.

The second pattern suggested by exhibit 2 is an unexpected allocation of reporting relationships among QE functions. From the schematic and the summary of reporting relationships noted above, there is an evident concern that any tendency to withhold information from higher authorities be resisted. Quality enhancement, inspection, and review activities are distributed among at least four different hierarchical levels, on and off site: the operations assistant plant manager (AMP); the plant manager (PM); those on site but reporting to superiors in the nuclear power generating department located at the general office (GO) in San Francisco, two hundred miles away; and the NPG review units in the San Francisco offices.

These structure and accountability requirements have produced an internal system in which each group at each level confronts QE "tasked" groups who also may be rewarded formally for discovering lapses in performance of groups of less formal status reporting to management in "lines" other than their own, and/or informally through better relations and access for assisting the improvement of the performance of "their reviewed groups" through helping, consultative service. In combination, this structure, and its parallel reward system, results in competition among some groups to beat the others in the discovery of significant errors or weakness in basic procedures.

The distribution of reporting and mission responsibilities, especially the on-site/off-site hierarchical levels, also highlights management's emphasis on safety and QE functions and assures more rapid transfer of credible information upward. And it bolsters a sense of confidence and credibility among external watchers that information is accurate and complete.

INCORPORATING REGULATORY REQUIREMENTS INTO AN ETHOS OF QUALITY ENHANCEMENT

DCPP operates a complex, highly technical production system.[30] Engineers and technical operators strongly define its culture. They have responded to the range of externally imposed regulations in the manner of disciplined technical professionals. While they do not necessarily like the regulations, NRC's stipulations are seen as a fixed reality. Regulations are understood to be part of the organizational environment, not so much to be resisted or embraced as to be observed rigorously. They are "part of nature": to be taken into account. "We live in a hazardous environment," one engineer said. "Care is important. If we are required to follow NRC and EPA regulations, let's do it well and right!" Over and over one hears, "Safety is very important! We really pay attention to this. We are better at this than the NRC . . ."

Crucial aspects of technical professionalism are honoring excellence in technical operations and demonstrating technical analytical ability. At DCPP, there is a primary emphasis on the technical engineering and/or operations aspects of understanding and manipulating the machines. The goal is to operate the machinery at peak technical efficiency while maintaining it so that it will keep delivering maximum capacity as long as the system is able. Two things follow: Invest in advanced systems in the interest of operational control and technical (not economic) efficiency, and employ the highest analytical skills in every aspect of the system to ensure its safe, continuous operation.

Following this pattern is likely to cost a great deal. And in fact, over the past decade resources rarely have been a hinderance at DCPP to improving the analytical or sensing capacity of control systems or the quality of the technical system itself. Senior executives want the best technical operation in the industry—the "Cadillac of the industry" in every respect. "If an engineer discovered a better, more reliable way to do something, say an improved computer analytical technique, we could get the money to do it." To illustrate the point, managers at all levels often told the same story. A senior VP for nuclear power generation was conducting a periodic walk-round of the working area of power plant operators. He noticed pretty scruffy "johns" in the operators' ready room. "Get this changed, I want the best [operators'] johns in the industry!" While this may have been apocryphal, the story crisply symbolizes a commonly held view among plant personnel.

Of course, there have been budget constraints, but until recently these were limited to the cases for which a good technical rationale could not be fashioned. The technical professional approach has been allowed to reach full flower with only limited resource constraints. Skilled technical analysis, as well as competent technical operations, has high prestige, even if it is employed in the elaboration of procedures that constrict operators or maintenance staff and/or

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[30]It is a system Perrow (1984) characterizes as complex and tightly coupled. This is the case for both its internal functional, physical properties (the types Perrow implicitly addresses) and the organizational system developed to animate and operate the technology (La Porte 1984).

results in a noncompliance report to the NRC. This professionalism is expressed in the processes and ethos of quality enhancement.

This ethos nurtures the efforts of specialized groups charged with specific aspects of the quality enhancement processes we discussed above. Their work is integrated in a number of formal processes of collective analysis and review, for instance, the some 130 technical review groups (TRGs) convened each year to consider the causes of problems that are discovered in the application of inspection standards and/or in the repair of equipment. These analytical gatherings constitute a complex, highly active process of inspection; review; analyses of technical process and operating and maintenance procedures; further review; and emphasis on discovery, anticipation, and codification in procedures. Within these processes, quality enhancement is as much a goal as merely complying with the NRC's or others' regulations.

PROCESSES OF DISCOVERY AND CENTRALITY OF PROCEDURES

We were struck by the intense effort devoted to processes of discovering the root causes of errors—the reasons things fail. It is an intense, multifaceted process, involving representatives from all sectors of the plant according to the technical parameters of the problem. There are particular processes carried on within each QE group which are then pooled, as in technical review groups (TRGs). The emphasis is on the discovery of technical flaws in either physical operation or procedural protocol. Nothing is out of bounds or too subtle to be exempt. Technical prowess is stressed and rewarded. There are no stopping rules for what will be analyzed. This suggests a system in which a "technical mentality" of precision, and then control, is given full reign. Its dicta: Engage in detailed analysis, codify this knowledge in required procedures, specify everything to its nth degree. Know everything and there will be no failure (cf. Landau and Stout 1979). At present, the running census of plant and NPG of administrative and technical procedures stands at over 4500 and growing at about 10 percent a year (Schulman 1993). "We are about 80 percent of the way toward totally proceduralizing this system," one senior engineer estimated.

Are we seeing a system that is becoming more brittle and so hemmed in by procedures that it may harbor unpleasant surprises?[31] It does not seem so. At the same time engineers seek elegant, fully articulated procedures, they harbor a fundamental suspicion of the discovery process per se. Every procedure has a potential flaw. Complacency is the enemy: "If it seems right, we get nervous." Thus in the process of analysis, they understand the difficulties of crafting omnicompetent procedures for the range of circumstances they know the plant confronts.

THE DYNAMICS OF THE "REGULATORY HAMMER"

The NRC resident office, on site at each nuclear power plant, is, with the possible exception of GAO facilities auditors, the most intensive overseeing and reviewing regulator in the United States.[32] It represents a qualitative difference in the regulatee/regulator relationship described in

[31]There is a literature alerting us to the problem of dependence on procedures (Landau and Stout 1979; Perrow 1984), especially when there is insufficient opportunity to change faulty procedures which have become the basis for control by managerial or regulatory superordinantes of operator behavior.

[32]The industry has its own parallel regulator, the Institute of Nuclear Power Operators [INPO] (Rees forthcoming). This body was set up and financed by the industry after the Three Mile Island accident to improve self-regulation and

the literature. The resident NRC office at DCPP occupies a small part of one corner in the main administration building on the floor close to the meeting rooms often used for incident discussions, senior plant staff review meetings (PSRC), and management conferences. It is staffed with two professionals and two clerks. The key factor driving the relationship of the NRC office to the plant is the recognition that the on-site NRC people are not in sufficient numbers to be the sole discoverers of violations. As one NRC professional put it, "It's two against two thousand." (Two thousand is the peak number of plant, construction, and contract personnel who periodically are involved simultaneously in DCPP activities.) This has prompted the senior resident to insist that DCPP officials carry on self-reporting: identifying and reporting problems to the NRC rather than waiting for the residents or NRC inspection teams to find them first.[33]

The dynamic of plant disclosure vs. NRC discovery has two levels. If plant personnel or NRC inspection teams discover a problem, the plant must demonstrate, sometimes with breathless speed, that it has analyzed the problem and developed a solution. The solution is reviewed by the NRC and, if approved, then carried out.[34] Depending on the type of problem, the NRC may fine the plant or merely review its plans for implementing the solution.

The degree of sanction may increase dramatically if the NRC discovers a problem without assistance from the plant. If this occurs the resident or the NRC regional office believes it has revealed a flaw in the self-reporting system. For example, an error was discovered in an appendix to an engineering drawing seven years after it had been filed in permanent storage. While the mistake was quite small, the NRC fined the plant a substantial sum and insisted on a review of all engineering drawings to search for any other lapses in fidelity between these drawings and what was actually in the plant.[35] This represented a major engineering review and an embarrassment for the plant's engineering group. If there is an unrecognized divergence between the drawings and actual plant material, grave errors can occur (cf. Weick 1989 on errors of renditions). Remedies to problems based on these drawings can create problems even as the engineers and maintenance personnel suppose they are doing the right thing. Engineering documentation verification is an exceedingly complex and crucial task, and the discovery of an error years after it was made casts suspicion on the integrity of the whole body of drawings.

The NRC Resident has significant formal and substantial informal coercive power: sufficient informal power possibly to explain a good deal of the utility's compliant behavior. Again, recall that the revenue stream for each of the two reactor units is "$2.4 million per day," a phrase we heard over and over. The resident has the authority to cause costly delay sometimes for days and

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operator training and raise standards across the industry. It conducts periodic, intensive plant inspections, certifies operator training programs, and has considerable power to sanction its member utilities.

[33]When asked about the NRC's presence, DCPP staff at all levels say a bit grudgingly, "Well, they do serve a function. They are a pain . . . but we do things that we might not if they weren't here. They keep us on our toes." This symbiotic relationship grows as a function of the technical respect they have for particular NRC residents and inspection teams.

[34]Problems vary in severity from those that may be deferred until a slack time to those that require analysis and solution within seventy-two hours or the NRC will shut the plant down.

[35]The plant's engineering group has the prime responsibility to assure that the engineering drawings of the physical layout and machinery of the plant are exactly faithful to what is actually out in the plant. These drawings, monitored by documents control, often computerized, become the key representations of the system for planning, diagnosing, prescribing remedy, and responding to emergencies when there is potential radioactive damage.

weeks: by inhibiting the completion of a critical replacement of design change task, by refusing to authorize a restart, by discovering an unreported error and forcing a shut down or curtailed level of power production. Each hour of unplanned, unnecessary interruption or outage is seen as very costly—in dollars and in loss of the resident's confidence in plant management and operations.[36] Therefore, when confronted with a Resident murmuring, "I'd hope for . . ." or "I'll feel more comfortable with . . ." plant engineers and senior managers will think hard before they will challenge that hope even if they think it is unnecessary on technical or safety grounds. "Better be compliant than right. If compliance is only merely costly . . . not dangerous."

In rare instances the plant's personnel have engaged in sustained resistance and technical challenge, but only if they believe their design change enhances safety or the NRC-demanded change erodes it. Very rarely do they challenge on economic grounds, for the trade-off boils down to the costs of the change versus the loss of a day's revenue—changes can cost a great deal before they come close to the costs of interruptions or outages.

We do not want to dwell on the coercive potential of the the NRC Resident. While the potential is there, it is only occasionally evoked. It seems to have become more a background possibility than an everyday motivation to be watchful. Too much emphasis on the "hammer" masks the depth of professionalization of the QE process that is actually present.

SUSTAINING CONDITIONS AND IMPLICATIONS

We have tried to suggest something of the complexity and dynamism of this facility. It is a vastly productive system. It is also extraordinarily hazardous. At present, it is rendered low risk on a daily basis by the constant attention of a large number of professionals and able people employed by the regulatee and the regulator. It is an extraordinary price to pay, a cost that succeeding work generations will have to bear as a condition of the benefits of this technology. While defeating "Murphy" in a continuously operating system is exhilarating for a time, we should be wary of designs that require it. The challenges are substantial, and we do not know whether other nuclear power plants are succeeding in meeting them.

From our study, we may tease out some conditions that support the unexpected development of the ethos of quality enhancement at DCPP. First, there is a clear understanding that the technical systems are both very beneficial and hazardous. Everyone agrees with the goals of maximum safety and maximum on-line capacity. Second, through structure and process, there is a continuously reenforced emphasis on high technical quality in operator performance and training and on engineering prowess, with little emphasis on the costs of following technical professional judgments.[37] Third, the state public utility commission, and especially the NRC through its resident office, provides a pull from outside to match the push from the internal operators and technical professionals to enable a sustained emphasis on quality of performance and the continual search for changes that will enhance the quality of the system.

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[36]Part of the folklore of the nuclear power community is that every time an NRC Resident has taken a dislike to the plant manager and/or lost confidence in him, he has lasted less than a year. It is a powerful myth even if it is not 100 percent true.

[37]One intriguing aspect of the novel state PUC agreement noted earlier is that DCPP no longer has to justify its expenditure to the PUC. The plant thus can spend as much as it wants on quality enhancement, taking these funds from what might be designated as profit. (Q: And pass those on to the ratepayers and investors?)

Thus, the challenge to managers and regulators of well-managed hazardous systems—the high hazard/low risk high reliability organizations in our study—is not so much to discover important improvements, though this conceivably might happen, but somehow to maintain the conditions that reenforce something like the present pattern. Changes in their environments are occurring: Technical improvements introduce sometimes surprising interactive disharmonies, and tightening budgets press managers to seek cost-saving changes, changes that may have surprising ripple effects on the conditions that enable discovery and rigorous technical watchfulness. DCPP also is nearing the wholesale change of work generations who learned their craft during the infancy of the industry. As future generations implement new, complexifying technology in an era of relative scarcity, will they remember why previous generations were so watchful?

As we observe the continued deployment of highly hazardous/benefit-rich systems, we also should be wary of too quickly supposing that the existing literature on regulatory compliance gives firm guidance about how we might design regulatory relationships for such systems. We found few insights in the literature that match our findings at Diablo Canyon Nuclear Power Plant. This should alert us to the problems of making inferences from that literature.[38] First, the social regulation literature dealing with compliance is clumped around regulation of pollution and worker safety rather than high-hazard, highly technical processes. Moreover, most case studies of social regulation focus specifically on the perceptions and behavior patterns of the *enforcer* rather than the target of regulation. Since individual firms themselves are seldom studied, their behavior typically is assumed (either explicitly or implicitly) to conform to the standard paradigms—that is, they will either shirk, deceive, attempt to co-opt, or comply minimally. Though many enforcers report good-faith efforts to comply—often in the face of financial constraints or incomplete understanding of the regulations—none report self-regulatory efforts that exceed significantly the stringent standards of the regulating agency itself.

Although these findings were unexpected, given the general stereotypes of industry behavior in the regulation literature, they do not necessarily contradict some of its assumptions. DCPP in fact may be attempting to limit the costs and uncertainties of noncompliance by taking upon itself costly, strenuous efforts to avoid more costly violations. But we still see little in the literature that provides a rationale for why an industry (or an organization within one) would want to layer more requirements on itself, in addition to those of existing regulatory agencies. Nor does the literature assist much in identifying the conditions that reinforce effective, credible regulations of organizations operating hazardous systems over long periods of time.[39]

Bardach and Kagan's (1982, 95-102) multiagency study of compliance behavior, however, suggests that tough enforcement strategies seem to bring about significant long-term changes in corporate management. That is, when faced with more enforcement actions and higher sanctions, larger firms will hire experts to keep up with regulations and to devise programs to "keep the company out of trouble." As these compliance managers gradually assume greater authority within the corporation, they increasingly are able to influence the attitudes of other managers, sometimes explicitly referring to the threat of tougher enforcement to support their requests for such things as expensive pollution-abatement equipment. Once these changes have occurred, legalistic

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[38]We found a similar absence of insight from the literature of organization theory (La Porte and Consolini 1991).

[39]See Brady and Bower (1982) for a discussion of factors that promote initial versus sustained compliance with air pollution regulations.

enforcement practices may be self-defeating, particularly if the new compliance managers believe the regulators are indifferent to their insights and attitudes.

Bardach and Kagan (1982, 99) claim that the most important effects of the newer-style, tougher regulation may be indirect: "The benefits flow less from concrete directives by government enforcement officials, than from a broad range of anticipatory actions taken by regulated enterprises because of the generalized threat of tough enforcement." Our DCPP experience is consistent with this insight. In this case, however, the organization's quality enhancement/ regulatory compliance behavior has advanced well beyond the stage of compliance managers gradually assuming greater authority. DCPP compliance managers and the perspective they represent importantly define corporate perspectives. Moreover, the "quality enhancement perspective" is equally fostered by corporate management.

AN ORGANIZING PERSPECTIVE

Recall that the regulatee's behavior was expected to be influenced by the means regulators have to monitor a firm's behavior and, if found wanting, to employ harsh sanctions. The weaker such means, the more likely the regulated entity would attempt to evade or co-opt the regulator. At the extreme, we could expect the regulatee to ignore onerous constraints altogether. The application of limited sanctions might prompt attempts by the regulatee to convince or manipulate—coopt—the regulator to alter regulations or construe them in a way that would benefit the industry.

It is also conceivable that regulatees might believe their experience with the technology and understanding of the local situation warrants their judging for themselves whether or not the regulator's model of safe operations is accurate, too stringent, or insufficient. Some managers may believe they can operate with less attention to certain aspects of their production system. Others may come to judge the regulator as less technically competent than they and become alarmed at the inadequacy of the model apparently used to direct them to change their practices.

Using this logic, one can construct a typology of regulatee/regulator relationships on the basis of variations in the strength of the regulators' means to compel compliance and the propensities of regulatees to accept the model of safety and production held by the regulators or to insist on their own potentially conflicting perspective (see exhibit 3). *Regulators' compliance means* (cf. Etzioni 1961) may vary from only a few means which are limited in scope and effectiveness, to many different means which could be combined to exert strong coercive force. This force would vary depending on the magnitude and scope of the regulatory stipulations and penalties; the regulatory presence—the number of inspectors per site and frequency of site visits; the safety ethos of enforcement officials—whether they are prosafety or seek to assist industry; the political support for the regulatory agency; and the degree to which enforcement officials are independent of the industry for future employment opportunities, information, and/or professional rewards. We expect that the higher the intensities of each of these conditions, the more likely the regulatee will comply with regulatory demands.

Similarly, the *regulatee's propensity to accept the regulator's model and related demands* may vary from a strong reluctance to comply, to a preemptive incorporation of external regulatory demands, to an inclusive framework of more stringent, self-administered, requirements. A key factor in this propensity would be the firm's judgment about what actually is needed to effect satisfactory levels of production and safety, such as their own model of safe operational requirements. These models may differ considerably from the models used by regulators. For example, operators might emphasize output or production measures as indications of safe operations contrasted with regulators' preferences for measures of equipment reliability, maintenance inspections and audits, and close monitoring of operator and/or management behavior. Or there might be a high degree of agreement between the regulator and regulatee about the importance, content, and specificity of formalized technical procedures. Clearly, the degree to which operators and engineers accede to or disagree with the operating and safety model of regulators also will affect their sense of the appropriate cost and benefits of compliance. Moreover, it is possible that regulated firms could come to see their own operating perspectives as both more rigorous and more essential for safety and effective operations than those held by the regulators. This could prompt such firms to enfold externally imposed regulations within a potentially more pervasive and exacting self-administered or self-imposed regulatory regime than expected by the regulators.[40]

Combining these two dimensions, then, forms a typology of regulatee compliance behavior (exhibit 3) based upon variations in the strength of compliance means and the degree to which regulatees judge regulatory requirements as too severe or believe they can do it better.[41] Some of these combinations are reported in the literature. When regulators' compliance means are limited and firms are reluctant to accept regulatory stipulations, we see attempts to evade or co-opt (cell 1). As compliance means are strengthened and applied more vigorously, such firms may become resisters (cell 2).

While cells 1 and 2 represent the historical stereotypes of compliance behavior, cells 3 and 4 describe firms that exhibit a reasonably high propensity to apply regulatory measures in the spirit of the regulatory impetus, emphasizing safety as well as economic efficiency. Firms that have incorporated a sustained and effective commitment to regulatory objectives, such as environmental protection and occupational safety, steadfastly may implement regulatory standards and processes even in the relative absence of regulatory enforcement measures (cell 3). Regulatory responsiveness occurs in cases where both the regulator and the firm have strong commitments to safety values, where they both agree substantially on the regulator's model of what is appropriate, and where the firm has the willingness and economic means to implement that model. Thus the firm chooses to comply with the regulations even though the regulator's compliance means are weak. Though economic analysis leads one to assume that firms are amoral calculators, and may simply choose to comply when confronted by weak regulators because they are boundedly rational and/or averse to risk, it is possible that some firms in fact may be good citizens, inclined to follow the rule of law, provided that the regulations do not appear arbitrary or unreasonable (Kagan and Scholz 1984). Organizational decisions to comply are likely to be complex, and thus single factors such as the economic self-interest of managers seldom explain business response to regulations (DiMento 1989; Roberts and Bluhm 1981).

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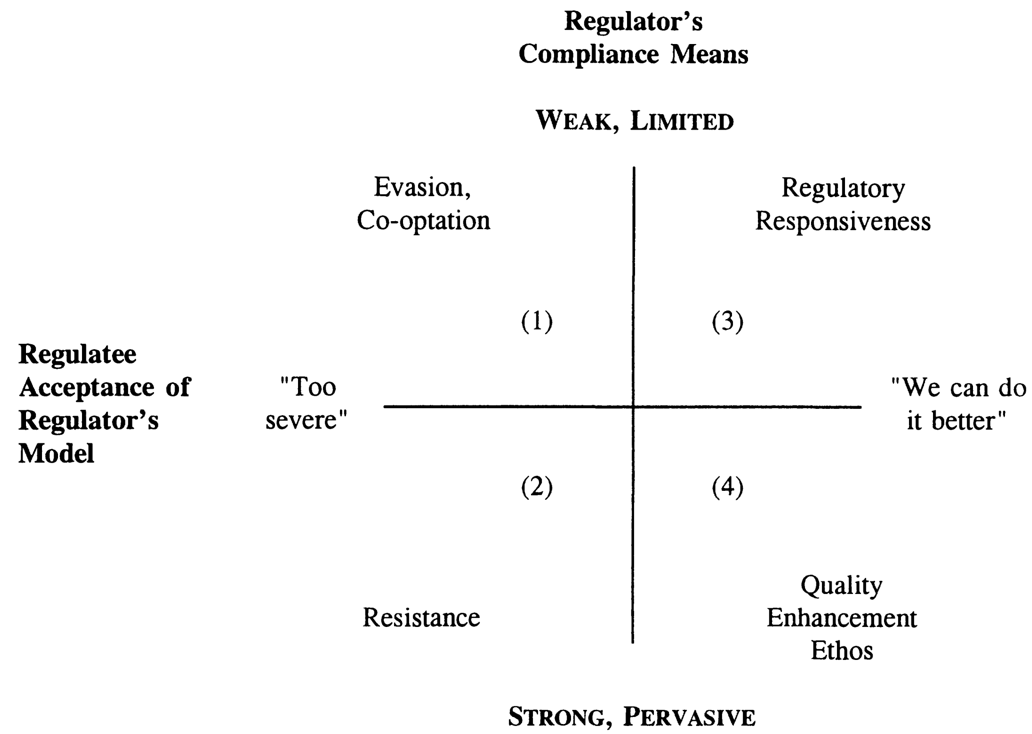
[40]M. Roberts and Bluhm (1981) are the only researchers we found who acknowledge that such behavior not only exists but is neither anomalous nor irrational. Even though they focus on utilities, their book was one of the last citations we reviewed because it has been systematically overlooked within the compliance literature. As far as we could tell, only DiMento (1986 and 1989) cites and discusses the implication of their work.

[41]Our emphasis is on situations in which there is a formal, politically legitimated regulator. Therefore, we do not draw on literature dealing with pure self-regulation (Rees 1988; Cheit 1990). It has been argued that self-regulation is likely to be more effective than government regulation because self-established standards enable regulation in the spirit rather than the letter of the law, while maintaining flexibility to deal with problems and new developments (Baggott 1989). Firms are not likely, however, to engage in self-regulation for altruistic reasons; rather, they will do it in order to preempt government regulation and thus reduce market uncertainties (Abolafia 1985).

Exhibit 3
Types of Regulatee Compliance Behavior



It is also plausible that some firms could come to believe that their views of safe and prudent operations are more accurate and effective than the regulator's model (cell 4). In this case, firms could either object strenuously to what they believe are flawed aspects of that model, or if they are unable to persuade the regulator to alter its view, firms could invest in their own technical expertise both as a means to ensure effective, safe operations and to fend off potentially costly regulatory measures they believe could result in less safety than their own technical expertise indicated.[42] If there are strong regulatory compliance means in use, and the firm holds that its views are sounder than the regulator's, we could expect the development of a quality-enhancing perspective that incorporates the formal regulatory stipulations within a more rigorous, pervasive framework.[43]

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[42]We note here the importance of professionalism in both the application of regulatory tools AND the regulatee's confidence in its own models of safe operations. While the level of professionalism may vary, the typology in exhibit 3 assumes that the professionalism of both regulator and regulatee is relatively high.

[43]A point of balance is implied by the typology, at the mid- and crossing-points of each dimension: where there is moderate play of compliance means and considered adoption of regulatory models of safety and production. Conceptually, this is where regulations would be minimally and optimally applicable and where regulatee responses would be minimally

CONCLUSION

In concluding, we return to the basic premise about regulatee/regulator relations that informs much regulatory research: Firms will do whatever they can to minimize the costs of complying with regulations. We have described a case in which compliance costs must be seen in the very long term. Management behavior at DCPP suggests that there are conditions that produce unexpected long-term commitment of resources and organizational energies in cooperative tension with externally imposed regulatory intervention.

While such examples may be relatively rare in terms of the total number of regulated firms in the country, it is conceivable that they occur with greater frequency within those types of firms we desire most to regulate—those operating high-hazard, high-risk technologies.[44] The case we describe thus should not be considered an anomaly, particularly if Kagan and Scholz (1984) are correct in arguing that enforcement styles based on erroneous assumptions of firm behavior may be counterproductive. While formal models of compliance behavior are becoming increasingly sophisticated, and may provide us with new insights regarding the contingent outcomes of regulator/regulatee interactions, it is important that such models are not predicated upon overly generalized assumptions about firm behavior.[45] Our case suggests that firm behavior is not obvious and that it may vary in surprising ways between industries and organizational conditions. That is, under certain conditions firms not only may desire to comply, they even may incorporate external regulations within a more rigorous encompassing framework of internally imposed regulations.

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and optimally effective in meeting regulatory objectives: any less effort in regulation and operational watchfulness would degrade the safety of the system, any more would exact needless costs in equipment, procedures, inspections, litigation, and enforcement. This suggests a rough optimum balance between regulatee and regulator where efforts in specifying regulation, expenditures of compliance means, and regulatee behavior all are effective and obtained with the least effort.

[44]This hypothesis is supported by Rees's forthcoming study of the Institute of Nuclear Power Operations (INPO), which focuses on the collective effort within the nuclear power industry since the Three Mile Island accident to ratchet up self-regulatory safety standards in advance of and in addition to those of the NRC.

[45]Formal game-theoretic models of compliance behavior are becoming increasingly complex, incorporating many dynamic processes found in case studies. While still relying on the economic theory of self-interest to drive the models, researchers are expanding on the simpler tit-for-tat models, which demonstrated that repeated interactions between enforcer and firm could produce cooperative compliance in the long run if incentives are structured in such a way that each side abstains from temptations to maximize short-run gains (Scholz 1984b). More recent models include the ability of firms to plea bargain if caught (Langbein and Kerwin 1985), the ability of regulators to select their enforcement strategy based on their knowledge of firm strategies (Tsebelis 1991), and the possibility that interest groups and legislators may not allow enforcement officials to use such discretion (Scholz 1991).

TECHNICAL APPENDIX

The research field team included four senior and one junior researchers. The division of labor included: La Porte, administration and regulatory response; Roberts, surveys of organizational culture and commitment; Rochlin (and Suchard), operations and reactor operators; Schulman, maintenance and outage organization. Senior researchers went through the training and testing to be cleared for unescorted access to the secure areas of the plant. Field visits usually consisted of two or three team members spending from two to four days on site at the facility, about two hundred miles south of our Berkeley home base.

There are from time to time a total of some two thousand employees on site from all sources: about 1100 regular DCPP members; four hundred on site with nuclear construction; and in times of outages, another four hundred-plus contract personnel come on site. There are also some four hundred NPG management and support personnel in the San Francisco general office (GO).

The following data were collected between September 1989 and June 1990.

A. *Documents.* Operating manuals, procedural materials, safety reports, daily status reports, plant newsletters, schematics of systems, noncompliance reports (NCRs), and so forth.

B. *Interviews.* Over one hundred people were interviewed, some a number of times, at the DCPP site and its superordinate office of nuclear power generating (NPG) at the general office (GO) in San Francisco. Initially semi-structured guides were used. Interviewees were from most areas of the plant, excluding security; these included: operations and control room crews; materials; mechanical, electrical, and instrument and control maintenance; administration; and human resources. Some thirty were involved directly, either full-time or nearly full-time, in one of the several specialized QE functions. In addition, twenty exit interviews about plant relationships were conducted with key senior plant and supervisory personnel. A dozen people in the regulatory affairs and safety affairs branches, NPG/GO, also have been interviewed.

C. *Unobtrusive observations* were conducted in a number of work, supervisory and managerial meetings and situations. These included:

- regular Friday morning plant manager's (PM) staff meeting;
- periodic Wednesday morning meetings with the VP for nuclear power;
- technical review group (TRG): key review meetings on possible NRC violation;
- plant staff review committee (PSRC): convened as an investigative review group after a serious malfunction;
- safety systems outage maintenance investigation (SSOMI): carried out as part of the quality assurance function.
- operator control room: morning shift meetings and shift changes;
- outage control center (OCC), especially outage update meetings;
- maintenance work planning meetings;
- high impact teams (HIT teams) meetings: specially designed teams made up of specialists skilled in various functions needed to deal with problems during major refueling Outages, e.g., valves;
- ad hoc APM's survey guided development: feedback session among PM and APMs regarding the meaning of data from an in-house sponsored organizational survey taken in mid-1989; and
- Nuclear Regulatory Commission and INPO Inspectors "exit," or "end of exercise" briefing by NRC/INPO staff.

D. High proportion sample survey of organizational culture, safety, and commitment.

Paper and pencil *survey* of large samples of operations, maintenance, engineering, support services. Sample of +550 of the 1100 employed at DCPP. The proportion of those sampled ranged from 100-50 percent of each groups' total employed. The overall return rate was about 80 percent DCPP employees.

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