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Quality Enhancement: Surprises in Nuclear  
Power Plant Operations**

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**Regulatory Compliance and the Ethos of Quality Enhancement:  
Surprises in Nuclear Power Plant Operations<sup>1</sup>**

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**Abstract:** The relationship of regulatees to regulators is expected to be characterized predominately by either efforts to coopt, to resist, or to comply minimally. The object of regulatees, it is assumed, is to reduce the strictures of regulatory constraints. This paper 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 propose the conditions that sustain these processes are noted, and a typology of regulatory responsiveness.

Introduction

The nuclear generation of electrical power is a very 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 institution which was operating well and had a strong sense of self-confidence.<sup>2</sup>

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<sup>1</sup> Revision of a paper delivered at the annual meeting, American Political Science Association, San Francisco, CA, August 31, 1990.

<sup>2</sup> 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 100 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

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 which operate beneficial, highly hazardous technical systems at high capacity with very low risk, i.e., 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.<sup>3</sup> The challenge for these organizations is to provide full capacity at any time and to do it very 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.<sup>4</sup> 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

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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, 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 primary point of contact with the plant, and to Charles Perrow, Harold Wilensky, and David Leonard for their comments on earlier drafts.

<sup>3</sup> 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, i.e., very hazardous systems that fail frequently. High hazard, frequently failing (or high risk) systems are self-liquidating.

<sup>4</sup> 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 Roberts (1989) for descriptions of the project, and Lascher and La Porte (1990), Roberts (1990), Roberts, Rousseau, La Porte, (1991), and Rochlin, La Porte and Roberts (1987),..... for provisional findings.

-- 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. It is not intended as a representative case.

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/typically held in low methodological esteem within the social science/ "scientific community" because findings from one case can not be easily generalized to other cases within a known population, we agree with Yim's (1984:39) proposition that analysts should generalize their cases to theory, to not 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 exceeds 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 current exit in various industries and to suggest some hypotheses regarding the factors which drive such behavior.<sup>5</sup>

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 end 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 very costly aspects of operating a nuclear power plant is assuring 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 why nuclear facilities draw so much public attention. "Radiation protection" means

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<sup>5</sup> See Barzelay (1993) and Ecktein (1975) for a constructive discussion of the potential contributions of single case studies to social science theory.

developing 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.<sup>6</sup>

Overseeing radiation safety during the regularly scheduled re-fuelling 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 exposures of hundreds of workers through the collection and checking of individual radiation sensitive badges. Dosages are cumulative and, without great care, workers can be exposed relatively quickly to the point where their radiation dose exceeds NRC limits, and their risk of long-term radiation effects is increased. When these exposures exceed regulatory safety standards, technicians are disqualified from working in radiation sensitive areas or jobs for the rest of a re-fuelling period (up to three months) or possibly for a year.<sup>7</sup>

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 re-fuelling activities until the problem is resolved and written up. If the NRC discovers a violation, the plant could be heavily fined, 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 complexly integrated work processes, in a radiation sensitive environment, may mean a considerable delay in 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 operations at DCPD was \$2.4 million per day or about \$100,000

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<sup>6</sup> 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 exposures to workers over the past ten years, with no recorded deaths or acute radiation illnesses from operations in the industry.

<sup>7</sup> Title 10, Code of Federal Regulations Part 20.

per hour. "(Bringing things to a halt) is sometimes pretty sticky!" noted one Rad Protection person. It is plausible that operators could 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 re-fuelling teams would be under a dangerous level.

A senior Rad Protection manager at DCPD described the importance of estimating the possible exposure to workers that might accompany technical procedures involved in repairing parts of the reactor when it is opened up for re-fueling, devising special temporary shielding barriers, and 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 'gold fish 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 costs 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 costs of compliance, the firm may either 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 upon, identify with, and protect the industry whose behavior they once sought to alter.<sup>8</sup> More recent studies (Gormley, 1983; Mitnick,

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<sup>8</sup> 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).

1980; Weaver, 1978) have argued that capture -- if it, in fact, has ever occurred -- is more likely with the older, single-industry agencies, e.g., 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 will more likely identify with the regulatees, and are likely to develop a symbiotic relationship characterized by industry control of shared information, professional rewards, and possibly career opportunities (Gormley, 1983; Mitnick, 1980)).<sup>9</sup> Conversely, the newer agencies charged with implementing social regulation, e.g., OSHA, and the EPA, should be less prone to capture because they regulate many different industries and even more individual firms. Moreover, newer agencies are often dominated by professionals with pro-protectionist values (Kelman, 1981). These values probably increase the propensity of the regulator to exercise whatever compliance means are at his 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, i.e., 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).<sup>10</sup> The standard stereotypes notwithstanding, there are a number of cases in the regulation literature where compliance is largely 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 of the regulatory responsibilities normally handled by inspectors, such as conducting inspections and investigating complaints (Rees, 1988).<sup>11</sup> Rees argues that, in

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<sup>9</sup> Evidence supporting the popular "revolving door" hypothesis, therefore, is weak. Though individuals indeed make career moves between firms and regulatory agencies, those these moves are not closely linked to an individual's policy preferences regarding either regulation or compliance. (Quirk, 1981; Gormley, 1983).

<sup>10</sup> 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.

<sup>11</sup> 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.



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 costs of compliance were true, there may be instances in which the act of complying itself is the firm's cost-minimizing strategy (Sigler and Murphy, 1998:69). This was the case in Virginia, for example, where compliance with state pollution control laws was achieved -- even when the costs of non-compliance and the probability of detection were low. Downing and Kimball (1982) argued 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 which 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 no indication in the literature that conditions might exist in which a firm would go beyond formal compliance standards to set even higher standards for itself in order further to reduce pollution or increase worker safety. Firms might occasionally anticipate government demands in order to situate themselves strategically in a competitive market (Sigler and Murphy, 1988:53), 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.<sup>12</sup> Despite the diverse array of social legislation which has been passed 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

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<sup>12</sup> We follow the standard distinction in the regulatory literature between economic and social harms. Health, safety and environmental damage 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, etc., all intended to protect consumers by regulating business practices.

result of both the availability or quantitative data the widely-perceived difficulties in implementing and enforcing worker-safety and pollution-control legislation. While deepening our understanding, this literature may also have biased our views of enforcement experiences more generally. That is, one might come to expect other industries, such as nuclear power, to exhibit similar behavior patterns, i.e., efforts to coopt, resist, or minimally comply.

Nuclear utility/NRC relationships have received relatively little attention at the micro level. Most studies of the NRC have focused on macro issues, i.e., the politics of regulation and regulatory reform, rather than 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.<sup>13</sup> Though it is a so-called independent commission, regulating a single industry, it nevertheless regulates social, i.e., safety, rather than economic concerns. Thus, according to capture theories, the NRC should be more vulnerable to cooptation than other social regulation agencies because of its intense working relationships with relatively few plants. We would, therefore, expect to find evidence of the utility coopting 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, pro-environmental enforcement professionals who check cooptation 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 vs. stringent, adversarial enforcement of rules and standards.<sup>14</sup> 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 indicating 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

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<sup>13</sup> Gene I. Rochlin was particularly helpful on this point.

<sup>14</sup> 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).

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 thinly spread over numerous industries. They are typically unable to monitor any one operation closely, and are thus 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 based on little information.

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 themselves (Downing and Kimball, 1982; Hawkins, 1983).<sup>15</sup> 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 in dealing 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 much more closely watched by regulating agencies than others. Nuclear power is perhaps the most closely watched of U.S. industries.<sup>16</sup> NRC inspectors are housed on-site at nuclear

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<sup>15</sup> Country comparisons indicate the U.S. approach is generally more adversarial than either Sweden's (Kelman, 1981) or Britain's (Vogel, 1986), in part due to an historical lack of trust of industry in the U.S. 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.

<sup>16</sup> 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

power plants, and are frequently supplemented by specialist NRC inspection teams. Nuclear power is unusual in this respect since most industries are only subject to self-reporting requirements and/or relatively infrequent site visits by inspectors.<sup>17</sup>

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 2 or 3 resident NRC inspectors with these local residents augmented by up to 20 specialists on annual inspection team visits.

Relatively few studies touch upon 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), 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

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California Public Utility Commission (CPUC), the Office of Emergency Services (OES), Occupational 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 Operators (INPO), and Nuclear Utilities Management Review Council (NUMRC). The instruments for this watchfulness include: annual inspections, annual and bi-annual 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.

<sup>17</sup> 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, focussing primarily on organizations setting private-sector standards.

nuclear power industry -- rather than potential insights into our findings at an operating nuclear power station like DCP. 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 upon 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 upon 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 1000 NRC inspections of 17 plants over three years. In doing so, however, he made questionable assumptions regarding the goals of plant managers, e.g., that plant managers "desire to conceal violations, whether these violations are intentional or arise spontaneously because of insufficient oversight..." (1989:122). 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 ..." (1989:117). 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 what is the U.S.'s most scrutinized industry? Specifically, what has one nuclear powered electrical generating organization become as it 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 200 miles south of PG&E's General Offices in San Francisco. It looms up round 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 500 cars. Its two nuclear power reactors are each larger than any other single power generating unit in PG&E.<sup>18</sup> Each of these units 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 16,000 miles of transmission and distribution lines in a service area about the size of the New England states and composed of 13 distinct ecological zones. The company has consistently over the past ten years 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 their history, the utility was enabled to vary their rate of return, by achieving and then exceeding certain high levels of power production.<sup>19</sup> In addition, the

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<sup>18</sup> For comparative and system description purposes the study included the fossil fuelled Pittsburg Power Plant (PPP), (central) Power Control, Transmission and Sub-stations of the East Bay Region, and the Diablo Division of the Distribution Business Unit. PPP's largest of seven units generates about 730 MW.

<sup>19</sup> In contrast to the traditional method of 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% of capacity, the industry's average, the utility can charge an agreed

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 had also recently set an industry record of nearly 400 days of continuous operations of the Unit 1 reactor, and has now 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 DCP's record. At the same time, they wondered at their own achievement and were apprehensive about their ability to sustain it.

Field work 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 bi-annual event, the activation of the utility and county wide emergency response exercise. Members of the seven person team were placed in nearly all of the strategic locations for the day long affair that involved some 600 plant and community participants.<sup>20</sup>

Shortly after the emergency exercise, the plant began one of its periodic, critical processes of replacing a major portion of the

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amount of past investment to the rate payers and keep the revenues generated beyond the 58% level. If they do 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.

<sup>20</sup> These simulations are based on a closely reasoned and "secret" scenario developed by NPG staff which 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 the 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.)

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 very significantly from about 90 days to almost 70 days (thus increasing their annual revenue by some \$40 million.) This goal was accomplished with great effort. We ended most of our field work mid-way through a second scheduled outage on Unit 2 which was trying to achieve an even shorter outage time, 62 days --and actually made it in 58.

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.<sup>21</sup> These produced intense responses for they often resulted 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 sub-unit mandated by the NRC to emphasize regulatory relations. The team was given nearly free run of the DCPD facilities to do systematic interviewing of some 100 key managers, supervisors, experienced operators, and bargaining unit (union) representatives, and observations of operations and typical work and coordination activities and management meetings. Nearly 30 of these were directly related to the quality enhancement process. (See the Technical Appendix for more details.)

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### Findings In Context.

In some respects, the DCPD's regulatory environment is similar to other regulated organizations. There are general environmental and health worries calling for OSHA, EPA, and state water and air quality regulation.<sup>22</sup> But the attention paid to safety requirements

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<sup>21</sup> 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.

<sup>22</sup> "Normal" environmental and health concerns within the plant are overseen by the 21 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 IRMA's



is heightened by the superordinate concern with the hazards of radioactive materials. For our purposes here, we emphasize DCP's response mainly to concerns about this nuclear hazard.

In brief, we found an unexpected type of regulator/regulated 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 who 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 peculiar dynamics of the relationships of senior technical managers with the NRC resident.

DCPP operations are "marbled" with many more formal groups and activities than are strictly required. This is formally visible via the NRC required Regulatory Compliance group,<sup>23</sup> and the stipulated review and evaluation processes that form the accountability interface between the 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 1). This unit provides experienced liaison with 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 the NRC Washington, after a review by the NPG San Francisco office.

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.

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(Industrial Related Major Accidents). S&SE is also involved in substantial medical first aid and "fitness for duty" (drug abuse) programs.

<sup>23</sup> 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.

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Box 1

"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;
  - \* Non-Compliance Reports (NCRs), that identify problems which are not "in conformance" with plant programs and procedures;
  - \* These official notifications of rule violations are reviewed by the Plant (senior) Staff Review Committee (PSRC), about one third of which result in;
  - \* Licence Event Reports (LERs) -- formal NRC "rule violations"; and finally, the less frequent
  - \* Justifications to Operate (JOs).
-

Timely delivery of accurate, well formed documents, communicated fully, unambiguously and quickly, is believed to signal the NRC that acute analysis is going on. As one manager put it, "Better to discover a problem first and report it, than for the NRC to discover it on its own!" (else 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 groups that take up particular "quality enhancement" tasks. There was a far more extensive and differentiated array of units than in the fossil fuel powered plant or the other organizations in our study:<sup>24</sup> for example, Quality Assurance, Quality Control, and the Off-Site Review Group, and Documents Control.<sup>25</sup> 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 was comprised of 8 units on-site with 5 more hierarchically related oversight groups in NPG's San Francisco office. Table 1 lists these units with brief descriptions of the on-site units' closely complementary functions. For this paper, we emphasize those that are formally chartered by the NRS and the

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<sup>24</sup> 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 wider 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 of very high explosive ordinance in quite 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 had evolved among people who had worked together often for many years, and had 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.

<sup>25</sup> Of course, there are also environmental and OSHA requirements; but we emphasize the nuclear safety related units in this paper.

company to engage in inspection, oversight, verification, and assurance functions.<sup>26</sup>

Several things about the formal structure 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 Table 1), e.g., 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 DCP, and cost the company an estimated \$100,000 per position.<sup>27</sup>

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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. Figure 1 schematically portrays something of the complex formal structure, division of labor, and the key relationships of DCP's QE and regulatory compliance structure.<sup>28</sup> 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.

Table 1 about here

Figure 1 about here

QE units are quite differentiated, with a finely grained division of labor. Although many people in the plant outside the QE groups themselves had difficulty distinguishing between specific QE functions, each group has a reasonably clear sense of the boundaries around its activities. And each group has decision rules that assist it in knowing "what was theirs," "what was someone else's," and when to cooperate. The groups are staffed with very skilled

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<sup>26</sup> 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 paper. Contact the senior author if there is interest in such detail.

<sup>27</sup> In contrast, the fossil fuelled power plant we also studied HHP DeskJet/DeskJet Plus to consider HPD

<sup>28</sup> During a discussion of the interactions of these groups with senior DCP 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!"

inspectors and analysts who command a wide range of technical knowledge. Varying in size from 5-25, the groups developed their own brand of technical professionalism, and competed with each other in demonstrating technical, analytical prowess.

For our purposes, the key on-site units are (listed in increasing order of formal status):

- a) the rigorous Radiation Protection Group (from which we drew our opening vignette) reporting to the Operations Assistant Plant Manager (APM); and
- b) 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 the Nuclear Power Generation (NPG) located at the General Office (GO) in San Francisco. They are:

Table 1

Regulatory/Quality Assurance/Safety-Emergency Units: On-site and at General Office [~150]**		FTE
<u>Plant's Units</u>		
125		
* Radiation Protection & (police function ~15/63)	Establishes radiation protection procedures in order to meet regulatory safety standards, and ensures enforcement.	15
* Quality Control (QC)	Formal inspections of all "reportable" action requests (AR's) and sampling of other less critical AR's.	36
* Chemistry Testing (police function ~ 5/63)	Test for the environmental quality of water and 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
	sub-total	80
<u>NPG's units (on-site)</u>		
* Quality Assurance (QA - 19 PGE + 6 Consult.)	Reviews adequacy of procedures and audits the quality of QC other safety functions in the plant.	25
* On-site Safety Review Group (OSRG)	Independent reviews of ARs, Technical Review Group (TRG) meetings, and other activities to maintain quality.	9
* Regulatory Compliance	Administers formally processes of review, investigation, reporting to the NRC.	11
	sub total 45	
<u>Nuclear Power Generation (NPG): San Francisco General Office</u>		
	22	
	Nuclear Safety	
2	Quality Support (QA)	
6	Quality Control	
4		

Radiological Support

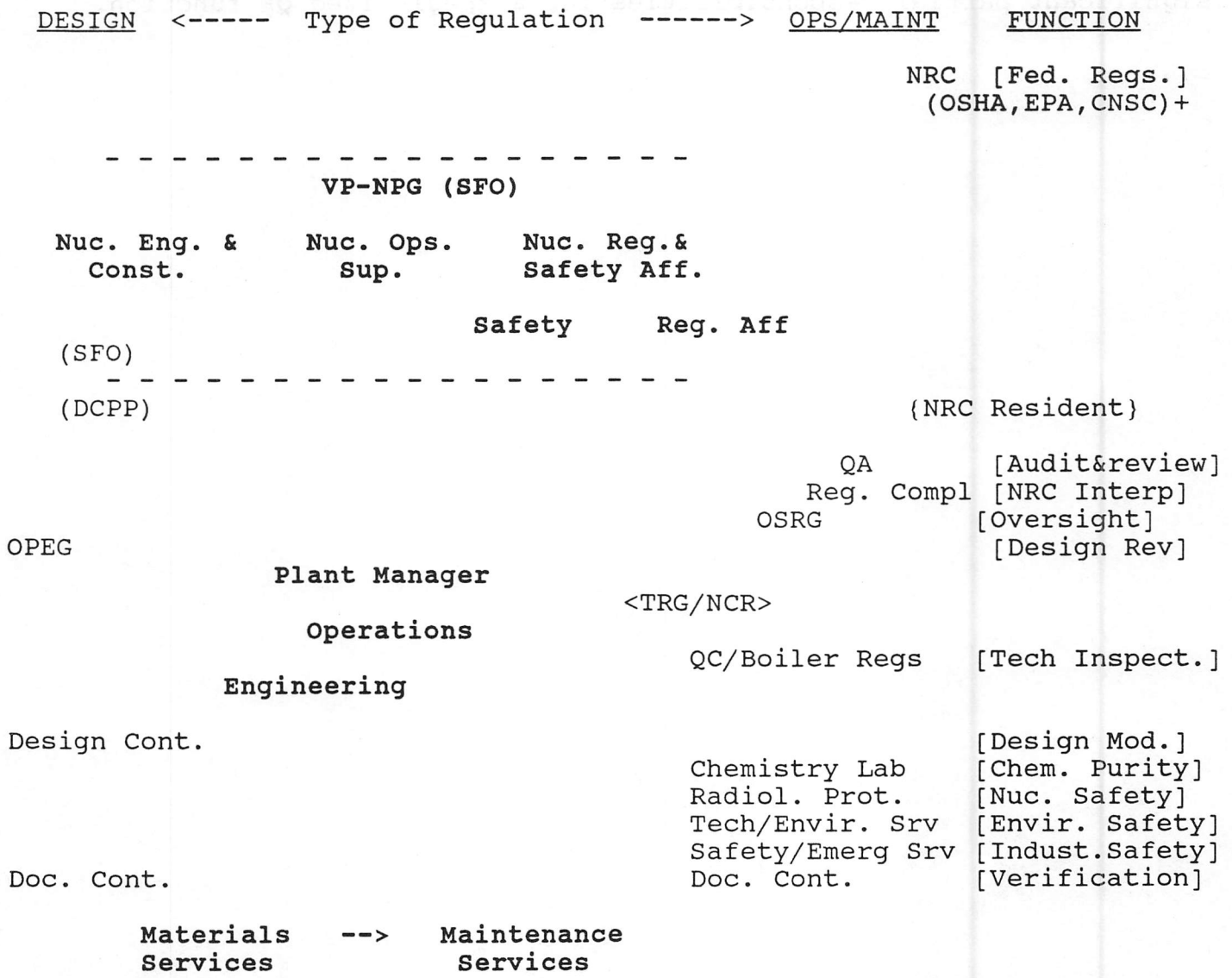
6

Emergency Planning

4

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\*\* At least two or more people from each on-site QE group were interviewed, for a total of 30 people employed full time or with significant partial responsibilities for a specialized QE function.

Figure 1.  
 Nuclear Power Generation  
 and  
 Diablo Power Plant  
 Regulatory/Quality Enhancement Schema



- 
- o o o o    QC inspections
  - o-o-o-    TRG/NCR initiating/involved
  - .-.-.    Documents Verification
  - - - -    Service Relationship



c) the On-Site Safety Review Group (OSRG), independently reviewing any activities or documents it deems necessary to maintain quality of safety performance; and

d) Regulatory Compliance, each reporting to the Nuclear Safety Affairs and Regulatory Affairs offices (NSARA); and

e) 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 procedures, design modifications, economic policies and organizational issues that may directly or indirectly 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 over whom they have oversight responsibility. Typically each group has mild suspicions that superordinates are less operationally acute, and that they are probably slightly more technically competent than other group.

The second pattern suggested by Figure 1 is an intriguing 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: a) to the Operations Assistant Plant Manager (AMP), b) to the Plant Manager (PM), c) to those on-site but reporting to superiors in the Nuclear Power Generating department located at the General Office (GO) in San Francisco 200 miles away, and d) to the NPG review units in the San Francisco offices.

This structure and accountability requirements seem to have produced an internal system in which each of the groups at each level confront QE "tasked" groups who may also be rewarded i) formally for discovering lapses in performance of groups of lesser formal status reporting to management in "lines" other than their own, and ii) 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 a competition among some groups to beat the others in the discovery of significant error or a 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 of external watchers that information is accurate and complete.

Incorporation of Regulatory Requirements into an Ethos of "Quality Enhancement".

DCPP operates a very complex, highly technical production system.<sup>29</sup> 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 them, NRC's stipulations are seen as a fixed reality. Regulations are received as part of the organizational environment, not so much to be resisted or embraced as to be observed rigorously. They are taken as "part of nature:" to take into account, not judged to be good or bad. "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..."

A crucial aspect of technical professionalism is to honor excellence in technical operations and to demonstrate 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 them at peak technical efficiency while maintaining the machinery to enable it to 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 good deal. And if in fact, over the past decade, resources have rarely 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

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<sup>29</sup> It is a system Perrow (1984) characterizes as complex and tightly coupled. This is the case both for its internal functional, physical properties (the types Perrow implicitly addresses) and the organizational system developed to animate and operate the technology (La Porte, 1984).

industry!" While this may have been apocryphal, the story crisply symbolizes a commonly held view.

Of course, there have been budget constraints, but until very 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 results in a Non-Compliance 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, e.g., 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 emphases 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 extraordinary effort devoted to processes of discovering the "root causes" of errors -- the reasons why things fail. It is an intense, multi-faceted 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 in TRGs, etc. The emphasis is on the discovery of technical flaws in either physical operation or procedural protocol. Nothing seems out of bounds, nor too "deep" to be exempt. Technical prowess is stressed and rewarded. There appears to be no stopping rule 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, specifying everything to its nth degree. Know everything and there will be no failure (cf. Landau and Stout, 1979). This seems very much to be a dominant objective; and they seem well on the way. At present, the running census of plant and NPG of administrative and technical procedure stands at over 4500 and growing at some 10 percent per 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 becoming more brittle and hemmed in by procedures that it may harbor unpleasant surprises?<sup>30</sup> Perhaps not. At the same time they are seeking elegant, fully articulated procedures, and 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 (at least this analyst generation) understand the difficulties of crafting omni-competent procedures for the range of circumstances they know the plant confronts.

The Dynamics of the "Regulatory Hammer".

Do regulators play a role in the process? When asked about the NRC's presence, staff at all levels would grudgingly say, "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 sense of symbiotic relations grows as a function of the technical respect they have for particular NRC residents, and inspection teams. The more technically skilled these teams, the more respect.<sup>31</sup>

A special word is necessary about the role of the on-site "NRC Residents" and their relationship with the management of the plant. 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 U.S. It represents a qualitative difference in the regulatee/regulator relationship we have found described in the literature.

The Resident NRC office at DCPD 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.<sup>32</sup> The tone is one

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<sup>30</sup> These is a literature alerting us to the problem of dependence on procedures especially when there is insufficient opportunity to change faulty procedures which have become the basis for control by managerial or regulatory superordinates of operator behavior (get cf refer. from Mathilde).

<sup>31</sup> The industry has its own parallel regulator, Institute of Nuclear Power Operators [INPO] (Rees, 1994). This body was set up and financed by the industry after the Three Mile Island accident to improve self-regulation and 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.

<sup>32</sup> Since the time of our field work, the NRC resident staff has turned over and now only one resident is in place, a testament, it is thought, to the positive safety and regulatory record of the plant in recent times.

of slightly awkward, earnest watchfulness and mild, continuous social discomfort.

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 have the capacity to be the sole discoverers of violations. As one NRC professional put it, "It's 2 against 2000." (The 2000 is the peak number of plant, construction and contract personnel who periodically are simultaneously involved in DCPD activities.) This has prompted the senior Resident to insist that DCPD officials carry on self-reporting, i.e., identify and report problems to NRC rather than wait for the Residents or NRC inspection teams to find them first.

The dynamic of plant disclosure vs. NRC discovery has two levels. If a problem is discovered by plant personnel or by an NRC inspection team, 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.<sup>33</sup> Depending on the type of problem, the NRC may fine the plant, or merely review its plans for implementing the solution.

But the degree of sanction may increase dramatically if the NRC discovers a problem itself without assistance from the plant. If this occurs the Resident or the Regional Office believes it reveals a flaw in the self-reporting system. An example is an incident where 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 that a review of all engineering drawings be carried out in a search for any other lapses in fidelity between these drawings and what was actually out in the plant.<sup>34</sup> This represented a major engineering review effort 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

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<sup>33</sup> Problems vary in severity from those that may be deferred until a slack time; others, however, may require analysis and solution within 72 hours or NRC will shut the plant down.

<sup>34</sup> 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, diagnosis, the prescription of remedy, and responding to emergencies when there is potential radioactive damage.

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. When revenues are that much, any unnecessary interruption is to be avoided. The Resident has the authority to cause costly delay sometimes for days and weeks: by inhibiting the completion of a critical replacement of design change task, by refusing to authorize a re-start, 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.<sup>35</sup> Therefore, when confronted with a Resident murmuring, "I'd hope for . . .," or an "I'll feel more comfortable with. . .," plant engineering and senior managers will think hard before they will challenge the "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."

There are rare instances where the plant has 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.

But we do not want to dwell overly on the coercive potential of the the NRC Resident. While the potential is there, it is only very occasionally evoked. It seems to have become more of 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 well run, "quasi-self-regulated" facility. It is a vastly productive system. It is also an extraordinarily hazardous one. At present, it is rendered harmless on a daily basis by the devoted attention of a large number of very able people employed by the regulatee and the regulator. So far, this combination has performed in a way to win the nervous confidence of the public, and the state (and the investment community). It is an extraordinary price to

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<sup>35</sup> Part of the folklore of the nuclear power community is that every time an NRC Resident has taken a disliking 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.

pay, a cost 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 very substantial, and we do not know whether other nuclear power plants are succeeding in meeting them.

From our study thus far, we may tease out some of the conditions that support an unexpected development of the ethos of quality enhancement at DCP. 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 capacity. Second, through structure and process, there is a continuously reinforced emphasis on high technical quality in operator performance and training and engineering prowess, without a high emphasis on the costs of following technical professional judgments. 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.

Thus, the challenge before managers and regulators of well-managed hazardous systems, e.g., the high hazard/low risk HROs in our study, is not so much to discover important improvements, though this might conceivably happen, but somehow to maintain the conditions that reinforce something like the present pattern. Changes in their environments will and are occurring: technical "improvements" introduce sometimes surprising interactive disharmonies, and tightening budgets press managers to seek cost saving changes, changes that may have surprising rippling effects on the conditions that enable discovery and rigorous technical watchfulness. DCP is also nearing the wholesale change of work generations that learned their craft at the infancy of the industry. As the next generations implement new, complexifying technology in a era of relative scarcity, will they remember why it is so necessary to be watchful?

And as we observe the continued deployment of highly hazardous/benefit rich systems, we should also be wary of too quickly supposing that the existing literature gives a firm guide on how we might design regulatory relationships for such systems. We found few insights in the regulation literature which match our findings at Diablo Canyon Nuclear Power Plant. This should alert us to the problems of making inferences from that literature.<sup>36</sup> 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.

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<sup>36</sup> We found a similar absence of insight from the literature of organization theory (La Porte and Consolini, 1991).

Since individual firms themselves are seldom studied, their behavior is typically assumed (either explicitly or implicitly) to conform to the standard paradigms -- that is, they will either shirk, deceive, attempt to coopt, 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 which significantly exceed 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. DCPD may in fact be attempting to limit the costs and uncertainties of non-compliance by taking upon itself costly, strenuous efforts to avoid more costly violations. But we still see very little in the literature that provides a rationale for why an industry (or an organization within one) would desire to layer more requirements upon itself in addition to those of existing regulatory agencies. Nor does the literature assist much in identifying the conditions which re-enforce effective, credible regulations of organizations operating hazardous systems over long periods of time.<sup>37</sup>

Bardach and Kagan's (1982:95-102) multi-agency study of compliance behavior, however, suggest 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 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 are increasingly 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 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 DCPD 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. DCPD compliance managers and the perspective they represent importantly define corporate perspectives. Moreover, the "quality enhancement perspective" is equally fostered by corporate management as well.

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<sup>37</sup> See Brady and Bower (1982) for a discussion of factors which promote initial versus sustained compliance with air pollution regulations.



## 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 coopt 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, i.e., coopt, the regulator to alter regulations or construe them in a way that benefits the industry.

It is also conceivable that regulatees might believe their experience with the technology and understanding of the local situation gives them warrant to judge 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 being used to direct them to change their practices.

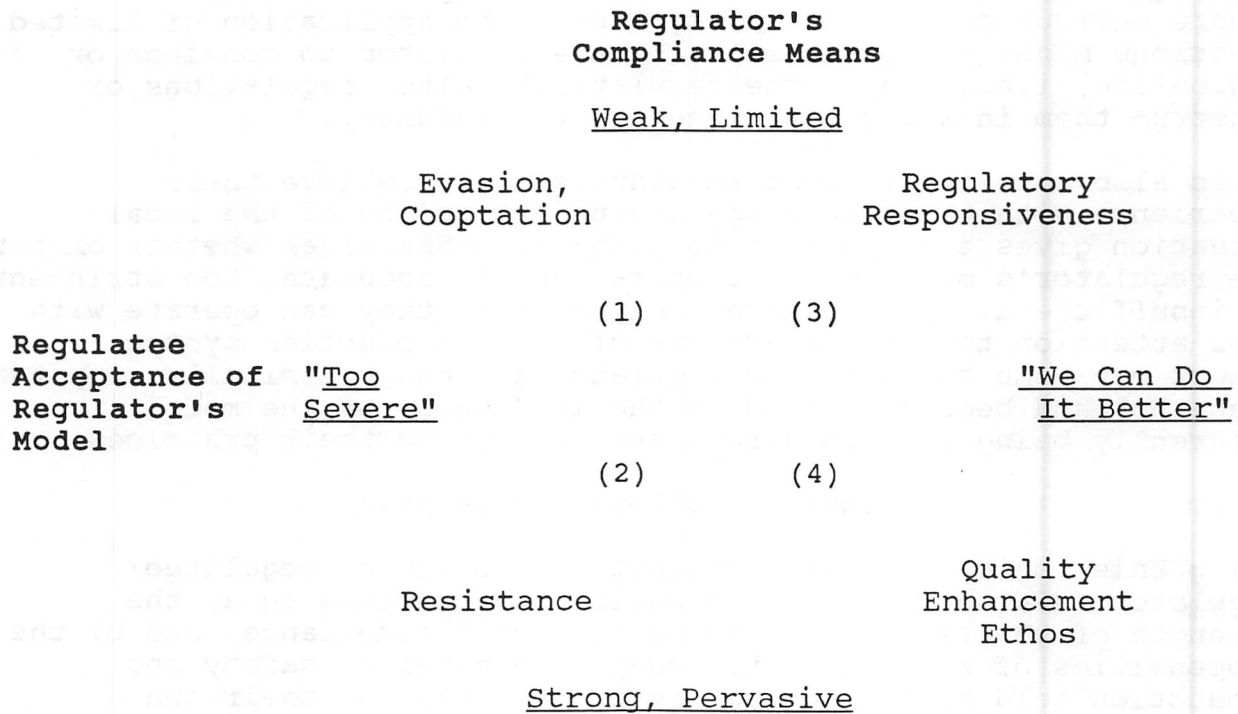
Figure 2 following this page

Using this logic, one can construct a typology of regulatee/regulator relationships on the basis of variations in a) the strength of the regulators' means to compel compliance, and b) 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 Figure 2) 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 upon the magnitude and scope of the regulatory stipulations and penalties; the regulatory presence, i.e., the number of inspectors per site and frequency of site visits; the safety ethos of enforcement officials, i.e., whether they are pro-safety 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 into an inclusive framework of more stringent, self-administered requirements. A key factor in this propensity would be the firm's judgment about what is actually needed to effect satisfactory levels of production and safety, i.e., their own model of safe operational requirements. These models may differ considerably from the models

FIGURE 2

TYPES OF REGULATEE COMPLIANCE BEHAVIOR



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 will also 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.

These two dimensions combine to form a typology of regulatee compliance behavior (Figure 2) based upon variations in the strength of compliance means, on the one hand, and the degree to which regulatees judge regulatory requirements as too severe or believe they can do it better.<sup>38</sup> 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 coopt (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, may steadfastly 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, they both agree substantially on the regulator's model of what is appropriate, and where the firm has the

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<sup>38</sup> 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 pre-empt government regulation and thus reduce market uncertainties (Abolafia, 1985).

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 may in fact 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).

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.<sup>39</sup> If there are strong regulatory compliance means in use, and the firm held 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.<sup>40</sup> {<-keep for now.}

### Conclusion.

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<sup>39</sup> 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 Figure 2 assumes that the professionalism of both regulator and regulatee is relatively high.

<sup>40</sup> There is a point of balance 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 and optimally effective in meeting regulatory objectives: any less effort in regulation and operational watchfulness would degrade the safety of the system, any more will 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 are all effective and obtained at least effort.

In concluding, we return to the basic premise about regulatee/regulator relations that informs much regulatory research, that firms will do whatever they can to minimize the costs of complying with regulations. We have described a case in which compliance cost must be seen in the very long term. Management behavior at DCPD suggests that there are conditions which 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 -- i.e., those operating high-hazard, high-risk technologies. The case we describe should thus 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.<sup>41</sup> 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 may not only desire to comply, they may even incorporate external regulations within a more rigorous encompassing framework of internally imposed regulations.

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<sup>41</sup> Formal game-theoretic models of compliance behavior are becoming increasingly complex, incorporating many of the dynamic processes found in case studies. While still relying upon the economic theory of self-interest to drive the models, researchers are expanding upon 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 upon 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 2 to 4 days on-site at the facility, about 200 miles south of our Berkeley home base.

There are, from time to time, a total of some 2000 employees on-site from all sources: about 1100 regular DCP members; 400 on-site with Nuclear Construction; and in times of Outages, another 400+ contract personnel come on-site. There are also some 400 NPG management and support personnel in the San Francisco General Office (GO).

The following data were collected mainly between 9/89 - 6/90.

A. Documents. Operating manuals, procedural materials, safety reports, daily status reports, plant newsletters, schematics of systems, Non-Compliance Reports (NCRs), etc.

B. Interviews. Over 100 different people were interviewed, some a number of times, at the DCP site and its superordinate office of Nuclear Power Generating (NPG) in the General Office (GO) sited 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 30 were directly involved, either full time or mainly, in one of the several specialized QE functions. In addition, 20 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, have also 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 & Shift changes  
Outage Control Center (OCC), esp., Outage Up-Date meetings.

Maintenance Work Planning meetings.

High Impact Teams (HIT team) meetings: Specially designed teams made up of specialists skilled in various functions needed to deal with problems during major re-fuelling 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.

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% of each groups' total employed. The overall return rate was about 80% DCPP employees.

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