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Organizing for High Reliability: Processes of Collective Mindfulness

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High reliability organizations (HROs) are harbingers of adaptive organizational forms for an increasingly complex environment. It is this possibility that warrants an effort to move HROs more centrally into the mainstream of organizational theory and remedy the puzzling state of affairs identified by Scott in the epigraph. Stated summarily, HROs warrant closer attention because they embody processes of mindfulness that suppress tendencies toward inertia. The fact that HROs are seldom portrayed this way or used more widely as templates for organizational design is due partly to their seeming exoticness and partly to uncertainty about how they might generalize to organizations that operate under less trying conditions. We will argue that HROs are important because they provide a window on a distinctive set of processes that foster effectiveness under trying conditions.

The processes found in the best HROs provide the cognitive infrastructure that enables simultaneous adaptive learning and reliable performance. A focus on these processes represents a theoretical enrichment of previous discussions on the origin and context of organizational accidents (e.g., Perrow, 1984) which have been framed in a largely macro-level, technology-driven structural perspective. The enrichment arises from the fact that, by explicating a set of cognitive processes that continuously reaccomplish reliability, we supply a mechanism by which reliable structures are enacted. This mechanism is often underdeveloped in non-HROs where people tend to focus on success rather than failure and efficiency rather than reliability. We suspect that failures in process improvement programs built around reliability (e.g., Total Quality Management) often occur because the cognitive infrastructure is underdeveloped.

We will construct the argument that processes as well as consequences distinguish HROs in the following manner. First, we sample the existing literature on HROs to establish the eclectic nature of the data base, the limited range of concepts imposed so far on these data, and the reasons why this literature has not had more impact on mainstream organizational theory. Given this background, we then take a closer look at bridges between HROs and traditional organizational theory afforded by the concepts of reliability and mindfulness. We then move to the heart of the analysis and argue that organizing for high reliability in the more effective HROs, is characterized by a preoccupation with failure, reluctance to simplify interpretations, sensitivity to operations, commitment to resilience, and underspecified structuring. These processes reduce the inertial blind spots that allow failures to cumulate and produce catastrophic outcomes. The analysis concludes with a discussion of the implications for organization theory and practice.

Conceptual Background

The Concept of High Reliability

When people refer to HROs they usually have in mind organizations such as nuclear power-generation plants (e.g., Marcus, 1995; Bourrier, 1996), naval aircraft carriers (e.g., Rochlin, LaPorte, & Roberts, 1987), air traffic control systems (e.g., LaPorte, 1988), and space shuttles (Vaughan, 1996), to list some examples. When we describe processes used in effective HROs, we have in mind cognitive processes found in better nuclear power plants, nuclear aircraft carriers, and the air traffic control system. These three settings constitute our "default" referent when specific studies are not available to illustrate the precise contrast we are making between effective and ineffective practice. Diverse as HROs may seem, we lump them together because they all operate in an unforgiving social and political environment, an environment rich with the potential for error, where the scale of consequences precludes learning through experimentation, and where to avoid failures in the face of shifting sources of vulnerability, complex processes are used to manage complex technology (Rochlin, 1993). There is considerable variation among high hazard organizations in these qualities as is evident in the fact that many of them are known by their failures to remain reliable (e.g., Bhopal, Chernobyl, *Exxon Valdez*). However, we intend to focus on commonalities in the better ones rather than variation to highlight a distinctive perspective on reliability that these organizations share in theory, if not always in practice.

The literature on HROs that behave "under very trying conditions" (LaPorte and Rochlin, 1994, p. 221), thus the data base available to us for analysis, consists of an eclectic mix of case studies involving effective action (e.g., Diablo Canyon in Schulman, 1993b), limited failure (e.g., Hinsdale telephone switching center fire in Pauchant, Thierry, Mitroff, Weldon, & Ventolo, 1991), near catastrophes (e.g., Three Mile Island cited by LaPorte, 1982), catastrophic failures (e.g., Tenerife disaster in Weick, 1990b), and successes that should have been failures (e.g., nuclear weapons management in Sagan, 1993). Existing analyses of these cases tend to emphasize structure and technology rather than process; activities involving anticipation and avoidance rather than activities involving resilience and containment; more focus on interorganizational macro levels of analysis than on micro group levels of analysis; more concern with fatalities than with lasting damage in other domains such as reputation, legitimacy, and survival of the social entity; and more implied comparisons with traditional trial and error organizations than with other high reliability organizations where the first error is the last trial.

At least two streams of work have addressed organizing around high hazard technologies within organizations – Normal Accidents Theory (NAT) and High Reliability Theory (HRT). NAT is based on Perrow's (1984) attempt to translate his understanding of the disaster at Three Mile Island (TMI) into a more general formulation. What stood out about TMI was that its technology was tightly coupled due to time-dependent processes, invariant sequences, and limited slack. The events that spread through this technology were invisible concatenations that were impossible to anticipate and that cascaded in an interactively complex manner. Perrow hypothesized that any system in which elements were tightly coupled and interactively complex would have accidents in the normal course of

operations precisely because of this combination of lack of control and inability to comprehend what was happening. These systems include aircraft, chemical plants, and nuclear power plants. He argued that a change in either dimension – from tight to loose coupling, or from an interactively complex to linear transformation system – would reduce the incidence of catastrophic error.

HRT also considers high-risk technologies but focuses on a subset of high-risk organizations, high reliability organizations, that take a variety of extraordinary steps in pursuit of error-free performance (e.g., Weick, 1987; Roberts, 1990; Rochlin, 1993; Schulman, 1993a, 1993b; LaPorte, 1994). Some of the necessary but not sufficient conditions that HRT emphasizes are a strategic prioritization of safety, careful attention to design and procedures, a limited degree of trial-and-error learning, redundancy, decentralized decision-making, continuous training often through simulation, and strong cultures that create a broad vigilance for and responsiveness to potential accidents (LaPorte & Consolini, 1991; LaPorte, 1994).

Because HRT is relatively new, some of the basic assumptions included in this body of work continue to evolve. Early characterizations of HROs emphasized the total elimination of error and the absence of trial-and-error learning (Weick, 1987) while later characterizations appear to allow for the inevitability of errors and the importance of a limited degree of trial-and-error learning based on those errors (LaPorte & Consolini, 1991). Early high reliability theory stressed the closed system nature of high reliability organizations (Weick, 1987; Weick & Roberts, 1993) by suggesting that these organizations tend to be more buffered from environmental influences and work actively to develop and maintain those buffers (LaPorte & Consolini, 1991). Later versions of high reliability theory (Rochlin, 1993; LaPorte & Rochlin, 1994) recognize the active influence of exogenous influences like regulations and public perception. Similarly, earlier versions of high reliability theory appear to stress the singular focus of HROs on safety where more recent work recognizes how HROs actively pursue multiple objectives (e.g., safety AND service) (Rochlin, 1993; LaPorte & Rochlin, 1994).

Each stream of work has registered serious concerns about fundamental premises contained in the other's theorizing. Normal accident theorists (principally Perrow and Sagan) criticize high reliability theorists' for neglecting complex environmental influences that compromise the alleged single-minded pursuit of safe operations. They point to the complex political and social forces that often corrupt the capacity to honestly report and learn from shortcomings. Specifically, ambiguous cause and effect relationships and politically motivated cover-ups of accidents compromise trial and error learning (Sagan, 1994). Moreover, they argue that competing interests seldom align behind safety. Rijpma (1997) has argued that NAT theorists believe that reliability-enhancing strategies actually increase the likelihood of normal accidents. Thus, redundancy can make the system more complex by making it more opaque, centralized decision premises can induce blind spots, conceptual slack can "shatter" a common perspective and spread confusion, and learning may anticipate complexity but fail to stop it from escalating.

Conversely, high reliability theorists have criticized normal accident theorists for their disregard of the conditions under which a tightly coupled interactively complex system will not fail. Assertions such as, "no matter how hard we might try, the characteristics of complexly interactive and tightly coupled systems will cause a major failure, eventually" (Perrow, 1994a, p. 216) raise the question, how long does a system need to avoid disaster for that avoidance to count as evidence against

the hypothesis of vulnerability to normal accidents. Also, most organizations are not frozen into one of the four combinations that are possible in Perrow's 2 × 2 of loose/tight coupling and linear/complex interaction. Instead, whole organizations change character in response to changed demands, some portions of any organization fit all four combinations, and all organizations, because of interconnected technologies and interconnected resource demands, are moving toward an interactively complex tightly coupled state (Weick, 1990a, pp. 29–34). Rijpma (1997) also weighs in with the suggestion that interactive complexity and tight coupling may actually increase overall reliability. Complexity and tight coupling motivate designers to create more redundancy in a system, inspire operators to customize centralized decision premises, favor the development of multiple theories of system functioning, and encourage learning and discourage complacency.

If we return to Scott's question of why HROs are not linked to the mainstream, one answer is that there is insufficient coherence to generalize. Perrin (1995, p. 157) draws a similar conclusion and cites the Royal Society's observation that the research map on the topic of organizational risk looks "a bit like the population map of Australia, with almost everything clustered round the edges and hardly anything in the central conceptual areas." Other plausible answers to Scott's question are that the existing work is more descriptive than theoretical; the literature itself is treated more as if it is about accidents than about organizations; the meaning of the idea of reliability is treated as obvious; simplistic binary distinctions contrast HROs with all other organizations; and there is limited development of Scott's themes of effectiveness (see Creed, Stout, and Roberts, 1993 for an exception) and learning (see Turner & Pidgeon, 1997, pp. 191–195 for an exception).

Our review of the HRO literature suggests that there is an additional reason that a more robust connection has not been made, namely, key HRO processes have remained unarticulated. Processes in HROs are distinctive, though not unique, because they focus on failure rather than success, inertia as well as change, tactics rather than strategy, the present moment rather than the future, and resilience as well as anticipation. We will argue later that HROs strive for reliability through processes of cognition as much as processes of production. As a result tendencies toward inertia are suppressed. It is mindlessness coupled with thoughtless action that makes it difficult to cope with a continuous open-ended stream of surprises and non-routine events. HRO processes that counteract inertia are potentially important because most theorists who discuss organizational learning and adaptation overlook them. We elaborate these ideas below.

The Concept of Reliability

While the phrase "high reliability" has been annexed by some theorists to convey the idea that high risk and high effectiveness can coexist, these same theorists have been somewhat circumspect in their attention to just what they mean by reliability, where it is localized, and how it is accomplished. This oversight is not trivial since reliability itself has been seen as an important competency made possible by organization. Commonly defined as the "unusual capacity to produce collective outcomes of a certain minimum quality repeatedly" (Hannan & Freeman, 1984, p. 153), reliability depends on the "lack of unwanted, unanticipated, and

unexplainable variance in performance" (Hollnagel, 1993, p. 51). Organizational reliability is thought to be achieved through the development of highly standardized routines (Hannan and Freeman, 1984, p. 154). In fact, the notion of repeatability or reproducibility of actions or patterns of activity is fundamental to traditional definitions of reliability. And, over time, routines and reliability have become synonymous with one another and also have become linked as an antecedent of inertial tendencies that are presumed to reduce adaptive capabilities (Hannan & Freeman, 1984). Unfortunately, this taken-for-granted definition (grounded in an engineering perspective), while useful for theorizing on more macro levels (e.g., population level), is misleading and restrictive at a more micro level.

The singular focus on repeatability as the primary defining quality of reliability in traditional definitions, fails to deal with the reality that reliable systems often must perform the same way even though their working conditions fluctuate and are not always known in advance. For a system to remain reliable, it must somehow handle unforeseen situations in ways that forestall unintended consequences. This is where previous definitions of reliability are misleading. They equate reliability with a lack of variance in performance. The problem is, unvarying procedures can't handle what they didn't anticipate. The idea that routines are the source of reliability conflates variation and stability and makes it more difficult to understand the mechanism of reliable performance under trying conditions.

What seems to happen in HROs is that there is variation in activity, but there is stability in the cognitive processes that make sense of this activity. This pattern is found in Schulman's (1993b: 369) analysis of Diablo Canyon: "The proposition that emerges from analyzing Diablo Canyon is that reliability is not the outcome of organizational invariance, but, quite the contrary, results from a continuous *management of fluctuations* both in job performance and in overall department interaction" (emphasis in original). To see how this works, consider Woods' (1988, p. 132) description of cognition in complex systems cited in Perrin (1995, p. 156). "[To be] opportunistic and flexible in order to detect and to adapt to events which require revision of situation assessment and plans...problem solvers need to revise their understanding of the situation, their evidence collection and evaluation tactics, or their response strategy when new events are detected and evaluated. Failures to revise in any of these ways produce what are seen as fixation failures." By separating the variation and stability folded into routines and assigning the variation to routines and the stability to processes of cognition, we stop treating stable patterns of activity as the source of reliable outcomes. Instead, reliable outcomes now become the result of stable processes of cognition directed at varying processes of production that uncover and correct unintended consequences.

Unexpected events require revisions of assessments, plans, and tactics but this revision is possible only because processes of "understanding," "evidence collection," "detection," "evaluation," and "revising" themselves remain stable in the face of new events. These stable cognitive processes do the "detecting," the variable patterns of activity do the "adapting to events which require revision." The contrasting case is organizations that focus on efficiency. Efficient organizations often enact the opposite split, namely, stable activity patterns and variable cognitive processes (Starbuck, Greve, & Hedberg, 1978, pp. 114–119). For example, Hynes and Prasad (1997) show that prior to the Westray mine explosion on May 9, 1992, which killed 26 miners, production routines kept "rolling" while monitoring of methane

buildups, spilled fuel, and enforcement of limestone dusting to neutralize coal dust, were done only sporadically. Efficient organizations often experience errors when they do the same things in the face of changing events, these changes going undetected because people are rushed, distracted, careless, or ignorant. Variable cognition falls to detect faults in machinery, substandard materials, or declining compliance, and these oversights lead to unintended consequences. Thus, to understand how organizations organize for high reliability, we need to specify what is done repeatedly – in our case this is cognitive processes – and what varies – in our case this is routinized activity manifest in performance.

Our point is simply that each time a routine is re-enacted, it unfolds in a slightly different way, a point also made by March and Olsen (1989, p. 38), Feldman (1989, p. 130), and Nelson and Winter (1982). In an unknowable, unpredictable world, ongoing mutual re-adjustment is a constant, and it is this adaptive activity that generates potential information about capability, vulnerability, and the environment (e.g., Landau & Chisholm, 1995, p. 70). That information is lost unless there is continuous mindful awareness of these variations. By this line of argument, unreliable outcomes occur when cognitive processes vary (e.g., are not stable) and no longer stay focused on failures, simplifications, recoveries, situations, and structuring, or when patterns of activity fail to vary and unexpected events are normalized (Vaughan, 1996). This conceptualization of reliability is more grounded in adaptive human cognition and action (Hollnagel, 1993) than is the engineering definition that equates reliable outcomes with repetitive cognition and action. Furthermore, our conceptualization highlights reliability as an overall goal of the system and whether the system, in the global sense, works appropriately; not only individual components or sub systems. This distinguishes it from definitions that focus on the repeatability or reproducibility of single observable actions.

The Concept of Mindfulness

To grasp the distinctiveness of HROs, one needs to look more closely at the ways in which diverse but stable cognitive processes interrelate in the service of the discovery and correction of errors. There has been ample recognition in the literature that diverse cognitive processes are associated with high reliability organizations. Westrum (1992, 1997), for example, alludes to a "generative" organization in which information is actively sought, failures cause inquiry, and new ideas are welcomed, a pattern which he refers to as a "license to think" (1992, p. 405), acting with "utter probity" (1992, p. 402), and a "protective envelope of human thought" (1997, p. 237). Evocative as those images are, their mechanisms remain largely unelaborated. The same holds for Klimoski and Mohammed's (1994) thoughtful survey of team cognition, Thordsen and Klein's (1989) discussion of team mind, and Hutchins' (1990) use of connectionism to interpret crew interaction in ship navigation.

While there has been some recognition that cognitive processes are important in high reliability functioning, what has been missing from these accounts is a clear specification of ways in which these diverse processes interrelate to produce effective error detection. When people in HROs focus on failures, tendencies to simplify, current operations, capabilities for resilience, and temptations to overstructure the system, these concerns cover a broader range of unexpected events. As shown in Figure 1, these separate concerns are tied together by their joint

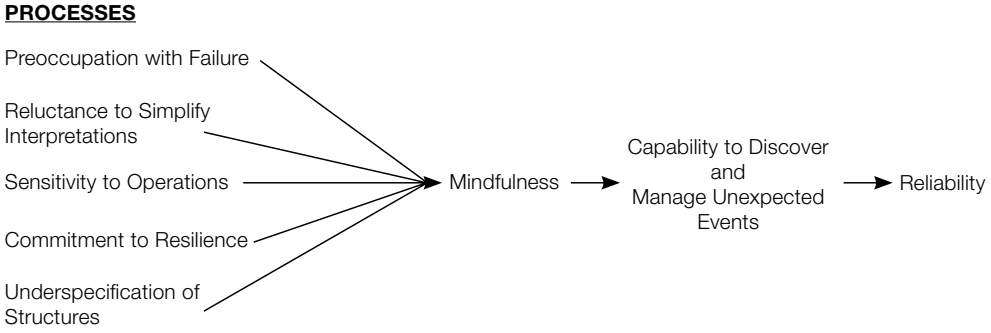

Figure 1: A mindful infrastructure for high reliability

capability to induce a rich awareness of discriminatory detail and a capacity for action. We label this capability mindfulness, following Langer (1989, 1997). It is this enriched awareness, induced by the distinctive concerns of HROs with potentials for catastrophe, that facilitates the construction, discovery, and correction of unexpected events capable of escalation (Rochlin, 1989, pp. 164–165). In Langer's model, the rich awareness associated with a mindful state is expressed at the individual level in at least three ways: active differentiation and refinement of existing categories and distinctions (Langer, 1989, p. 138); creation of new discontinuous categories out of the continuous streams of events that flow through activities (Langer, 1989, p. 157); and a more nuanced appreciation of context and of alternative ways to deal with it (Langer, 1989, p. 159). In our extension of this model to the group level, we assume that awareness is expressed in at least these same three ways as byproducts of the five cognitive processes we discuss later.

To grasp the role of collective mindfulness in HROs, it is important to recognize that awareness is more than simply an issue of "the way in which scarce attention is allocated" (March, 1994, p. 10). Mindfulness is as much about the quality of attention as it is about the conservation of attention. It is as much about what people do with what they notice as it is about the activity of noticing itself. Mindfulness involves interpretive work directed at weak signals (Vaughan, 1986, chap. 4), differentiation of received wisdom, and reframing, all of which can enlarge what is known about what was noticed. It is the enlarged set of possibilities that suggests unexpected deviation that needs to be corrected and new sources of ignorance that become new imperatives for noticing.

Mindfulness in HROs is distinctive because it is closely related to the repertoire of action capabilities (Westrum, 1988, p. 8). The close relationship between mindfulness and the action repertoire in HROs is a key to their effectiveness. The central idea is found in Westrum's (1988) discussion of "the ecology of thought." Westrum argues that organizations that are willing to act on specific hazards are also organizations that are willing to see those hazards and think about them. Thus, when people bring new variables under their control and enlarge their ability to act on them, they also enlarge the range of issues they can notice in a mindful manner. Conversely, if people are blocked from acting on hazards, it is not long before their "useless" observations of those hazards are also ignored or denied, and errors cumulate unnoticed. Thus, the richness of a state of mindfulness is determined by the richness of the action repertoire. The richness of that action repertoire, in turn, is determined partly by the extent to which the cognitive

processes are stable and continue to develop and partly by the extent to which the repertoire of variable routines that uncover and manage unexpected events continues to expand. HROs that are less effective (e.g., Osborn & Jackson, 1988) have a more limited range of action repertoires, use fewer of the cognitive processes associated with effective failure-avoidance, and update and enlarge their action repertoires less often.

When fewer cognitive processes are activated less often, the resulting state is one of mindlessness characterized by reliance on past categories, acting on "automatic pilot," and fixation on a single perspective without awareness that things could be otherwise. As we move away from the better HROs and their preoccupation with failure, we find more organizations that are preoccupied with success. While people can be mindful about success, the irony is that this preoccupation tends to encourage simplification and exploitation of existing performance routines, adherence to institutionalized categories, and compliance with inherited job descriptions, all of which represent acts that are largely mindless (Miller, 1993). If artifacts of mindlessness dominate, mindfulness occurs less frequently which means that small errors with potentially large consequences go undetected. This state of affairs is what HROs try to forestall.

To say that an organization is drifting toward mindlessness is simply another way of saying that the organization is drifting toward inertia without consideration that things could be different. Whether the condition is labeled inertia or mindlessness, the important point for organizational theory is that HROs actively strive to suppress it, which means they are important sources of insight about the conditions under which inertia is not indigenous to organization. Thus, HROs with their ongoing mindful renegotiation of routines, provide valuable information about ways in which organizations in general might forestall their own drift toward inertia by more effectively managing surprises that challenge adaptability.

Processes of Mindful Organizing

Our examination of the literature on HROs suggests that the combination of stable cognitive processes and variations in action patterns enables the more successful HROs to manage unexpected events effectively. These outcomes appear to be mediated by a way of being that is fostered by an apparent ongoing focus on failure, simplification, current operations, resilience, and underspecified structures, a way of being that we refer to as mindfulness. Mindfulness is less about decision making, a traditional focus of organizational theory and accident prevention, and more about inquiry and interpretation grounded in capabilities for action. Furthermore, mindfulness in HROs is not activated solely by novelty, but rather is a persistent mindset that admits the possibility that any "familiar" event is known imperfectly and is capable of novelty. This ongoing wariness is expressed in active, continuous revisiting and revision of assumptions, rather than in hesitant action.

A state of mindfulness appears to be created by at least five processes that we have induced from accounts of effective practice in HROs and from accident investigations:

1. Preoccupation with failure
2. Reluctance to simplify interpretations

3. Sensitivity to operations
4. Commitment to resilience
5. Underspecification of structures

Preoccupation with Failure

A chronic worry in HROs is that analytic error is embedded in ongoing activities and that unexpected failure modes and limitations of foresight may amplify those analytic errors. In their study of a nuclear submarine, Bierly and Spender (1995, p. 644) found "collective bonds among suspicious individuals," LaPorte in his study of air traffic systems (1996, p. 65) observed "prideful wariness," while Rochlin (1993, p. 14) describes "suspicion of quiet periods." Schulman in his study of Diablo Canyon (1993b, p. 364) describes the chronic worries this way: there is "widespread recognition that all of the potential failure modes into which the highly complex technical systems could resolve themselves have yet to be experienced. Nor have they been exhaustively deduced. In this respect the technology is still capable of surprises. In the face of this potential for surprise, there is a fundamental reluctance among higher management to put decision or action frameworks in place that are not sensitive to the possibilities of analytic error."

Worries about failure are what give HROs much of their distinctive quality. The distinctiveness arises from the simple fact that failures are a rare occurrence. This means that HROs are preoccupied with something they seldom see. Their ways of working around this shortfall and the cues they use as substitutes for failure, suggest modes of organizational learning that go beyond the simple duality of explore versus exploit (March, 1996). If we view failure as an important precondition for learning (e.g., Sitkin, 1992), then safe HROs should find it tough to learn since they have so few data points of failure. To be preoccupied with failure, therefore, is to make do with these less than ideal learning conditions and convert them into grounds for improvement. Effective HROs do this in at least three ways: by treating any and all failures as windows on the health of the system, by a thorough analysis of near failures, and by focusing on the liabilities of success.

If serious failures are rare, one means to get more data points for learning is to broaden the number and variety of failures that are given close attention. Effective HROs both encourage the reporting of errors (Tamuz, 1994) and make the most of any failure that is reported. They remedy a paucity of data with richer analysis of the data they do gather (Bierly and Spender, 1995, p. 644). Schulman (1993a, p. 34) argued that the more effective nuclear power plants use reliability as a proxy for organizational health. We interpret this to mean that any failure, regardless of its location, is treated as a window on the reliability of the system as a whole. One lapse could be a weak signal that other portions of the system are vulnerable. While most organizations tend to localize failure, effective HROs tend to generalize it. Carroll (1997) made a similar point when he observed that many nuclear power plants attend to small incidents in the belief that the accumulation of such incidents increases the probability of a major problem. They act as if there is no such thing as a localized failure and suspect, instead, that causal chains that produced the failure are long and wind deep inside the system.

One byproduct of this increased attentiveness to all failures is that in contrast to their inconsequential role in traditional organizations, maintenance departments

in HROs become central locations for organizational learning (Kmetz, 1984; Marcus, Nichols, & McAvoy, 1993, p. 352; Bourrier, 1996). Maintenance people come into contact with the largest numbers of failures, at earlier stages of development, and have an ongoing sense of vulnerabilities in the technology, sloppiness in the operations, gaps in the procedures, and sequences by which one error triggers another. These observations enlarge the database for learning and are given detailed attention.

To increase the data points available for learning, effective HROs also encourage and reward the reporting of errors. Rochlin (1993, p. 27) argues that HROs are unique because they "self-organize to encourage and reward the self-reporting of errors...on the explicit recognition that the value to the organization of remaining fully informed and aware of the potentiality for the modality of error far outweighs whatever internal or external satisfaction that might be gained from identifying and punishing an individual and/or manufacturing a scapegoat to deflect internal or external criticism." Westrum (1992, pp. 405–406) emphasized the important lesson conveyed when Wernher Von Braun sent a bottle of champagne to an engineer who, when a Redstone missile went out of control, reported that he may have caused a short-circuit during pre-launch testing. Checking revealed that this had caused the accident, which meant that an expensive redesign was avoided. As Westrum (1988, p. 14) observed, "Note here that the engineer took two risks: he was not sure what had caused the problem so he was advancing a guess; and if he had, he could face sanctions. In most organizations, such an admission would have received a very different response." Landau and Chisholm (1995, p. 77) describe a seaman on the nuclear carrier Carl Vinson who loses a tool on the deck, reports it, all aircraft aloft are redirected to land bases until the tool is found, and the seaman is commended for his actions the next day at a formal deck ceremony. Edmondson (1996) found, contrary to her hypotheses, that the highest performing nursing units led by skilled and supportive managers, had higher detected error rates for adverse drug events than did units that were lower on these dimensions. She interprets these results to mean, not that more errors were made in the high performing units, but that a climate of openness had been created that made people more willing to report and discuss errors and to work toward correcting them. Supplementary analysis and observational data were found to be consistent with this interpretation. The general point is that, one means to learn even though trial and error is limited, is by broadening the set of errors that are available from which to learn and by instituting practices that encourage people to report all of those errors that are detected.

To broaden the variety of data points available for learning close attention is paid to analyzing near misses. Using as an example a near collision in aviation, the issue in a near miss is that "Every time a pilot avoids a collision, the event provides evidence both for the threat and for its irrelevance. It is not clear whether the learning should emphasize how close the organization came to disaster, thus the reality of danger in the guise of safety, or the fact that disaster was avoided, thus the reality of safety in the guise of danger" (March, Sproull, & Tamuz, 1991, p. 10). Attending to failure in more effective HROs takes the form of seeing the reality of danger in a near miss, whereas in less effective HROs it takes the form of seeing the reality of safety.

A third means to learn in the face of limited trial and error is to define as failures any dysfunctional response to success. HROs after all are highly successful in the

sense that failures are rare. What is distinctive is that it is this very success and the temptations that arise from it that define a new form of failure from which HROs can learn. These failures that arise as consequences of success include restricted search, reduced attention, complacency/inertia, risk aversion, and homogeneity (Sitkin, 1992, pp. 234–236). All of these outcomes arise because people expect success to repeat itself. Thus, these outcomes represent dangerous expectations and the better systems treat them as proxies for failure.

Starbuck and Milliken's (1988, pp. 329–330) analysis of the *Challenger* disaster points to the liabilities of success. "Success breeds confidence and fantasy. When an organization succeeds, its managers usually attribute success to themselves or at least to their organization, rather than to luck. The organization's members grow more confident of their own abilities, of their manager's skills, and of their organization's existing programs and procedures. They trust the procedures to keep them appraised of developing problems, in the belief that these procedures focus on the most important events and ignore the least significant ones." Under the assumption that success demonstrates competence, people drift into complacency, inattention, and habituated routines, which they often justify with the argument that they are eliminating unnecessary effort and redundancy. What they fail to see is that this pattern increases the likelihood of human errors, and that each of the liabilities of success must be detected and opposed. In the more effective HROs, complacency is interpreted as a failure of striving, inattention is interpreted as a failure of vigilance, and habituation is interpreted as a failure of continuous adjustment. Attending to potential failures implicit in success is equivalent to acting on the assumption that any current success makes future success less probable.

Reluctance to Simplify Interpretations

Members of all organizations handle complex tasks by simplifying the manner in which the current situation is interpreted. These simplifications, variously referred to as worldviews, frameworks, or mindsets, basically allow members to ignore data and keep going. This is a common property of all organizing (Turner, 1978). However, simplifications are potentially dangerous for HROs because they limit both the precautions people take and the number of undesired consequences they envision. Simplifications increase the likelihood of eventual surprise. They allow anomalies to accumulate, intuitions to be disregarded, and undesired consequences to grow more serious.

The issue in simplification is "whether the simplified diagnosis of the present and likely future situation is accurate enough to enable the organizational goals to be achieved without encountering unexpected difficulties that lead on to catastrophe. The central difficulty, therefore, lies in discovering which aspects of the current set of problems facing an organization are prudent to ignore and which should be attended to, and how an acceptable level of safety can be established as a criterion in carrying out this exercise" (Turner, 1976, p. 379). Thus, front the perspective of work on HROs, perhaps the most crucial fact about organizations of all kinds is that they "achieve a minimal level of coordination by persuading their decision-makers to agree that they will all neglect the same kind of consideration when they make decisions" (Turner, 1978, p. 166). Organizations are defined by

what they ignore, which means they are also defined by what can surprise them. Traditional organizations tend to overlook the question of what they ignore (e.g., Pearson & Mitroff, 1992, p. 55) whereas effective HROs respect this question and know more about what they don't know.

Since precautions are designed to fit a simplified view of the world, HROs tend to restrict their simplifications (Roth, 1997) in order to enlarge the number of precautions they enact. Thus, while all organizations make assumptions and socialize people to ignore the same things, HROs are distinctive because they make fewer assumptions and socialize people to notice more (Xiao, Milgram, & Doyle, 1997). Many have argued that what sets HROs apart is the effort they make to match internal complexity with external complexity (e.g., Meshkati, 1989; Perrin, 1995, p. 165). To restrain temptations to simplify, HROs cultivate requisite variety and assume that it takes a complex system to sense a complex environment. These efforts take such forms as diverse checks and balances embedded in a proliferation of committees and meetings, frequent adversarial reviews, selecting new employees with non-typical prior experience, frequent job rotation, and re-training.

Simplification is also curbed through negotiated complexity (Schulman, 1993b, p. 361). In HRO's, "not only are a wide range of informal interorganizational agreements observable, their negotiation and continual renewal are recognized and embraced *formally* in the organization as an integral foundation of its safe and reliable operation" (Schulman, 1993b, p. 362, emphasis in original). In this way, procedures become increasingly complex rather than simple. This process of renewal, revision, or rejection means that "each procedure encapsulates new experience (often won the hard way through error)" (Schulman, 1993b, p. 362). The process of constantly tending to procedures mitigates complacency and rigidity.

Schulman (1993b) defines requisite variety as "conceptual slack" by which he means "a divergence in analytical perspectives among members of an organization over theories, models, or causal assumptions pertaining to its technology or production processes" (Schulman, 1993b, p. 364). This divergence of perspectives is not about what the organization is doing, but rather about how it is going about it. Divergent perspectives provide the organization with a broader set of assumptions that sensitize it to a greater variety of inputs. The price of this expansion is that it can increase the incidence of disagreement and conflict when it comes time to act. HROs are distinguished not just by their diverse views, but also by the mechanisms they institutionalize to manage disagreements among those who hold these diverse views. Bourrier, in her observation of nuclear power plants (1996, p. 105), puts it this way: "Cooperation is constantly elaborated through the mutual adjustments of the strategies of individuals who continually re-negotiate their participation inside the organization, trying to get control of what is relevant for their tasks." We emphasize the point about the centrality of negotiation because it is missed so often, even among scholars of HROs. What they miss is that when people convert divergent perceptions into action, they may focus only on those perceptions that are held in common among the divergent thinkers (Sutcliffe, 1994). Even though diverse groups have more information available than more homogeneous groups, communication patterns and cognitive limitations lead to a situation where unique information does not get shared (e.g., see Larson et al., 1996). And it is the divergence not the commonalities, that holds the key to detecting anomalies. Thus, there is a premium on interpersonal skills (e.g., Schulman, 1993a;

Weick and Roberts, 1993), mutual respect (Weick, 1993a), norms that curb bull-headedness, hubris, headstrong acts, and self-importance (Schulman, 1993a, p. 45), continuous negotiation (Perrin, 1995), reaccomplishment of trust, and simultaneous cultivation of credibility and deference (Bierly & Spender, 1995).

To preserve awareness of simplifications, HROs often implement a novel form of redundancy. Normally, redundancy in any system means that there is duplication and backups (Landau, 1969; Lerner, 1986; Husted, 1993). This is true of high reliability systems. But redundancy in HROs also takes the form of skepticism and is one of the reasons that trust has a problematic stature in this literature (Bierly and Spender, 1995, p. 644). When a report is met with skepticism and the skeptic makes an independent effort to confirm the report, there are now two observations where there was originally one. The second set of observations duplicates and backs up the first set and may itself be double-checked by still another skeptic. This skepticism may counteract the potential complacency that redundant systems may foster. Redundancy involves cross checks, doubts that precautions are sufficient, and wariness about claimed levels of competence. Conceptual slack is also a form of skepticism since it represents concern that when others see what they believe, both their seeing and believing miss a lot. Concomitant with trust is the belief that all humans are fallible, and that skeptics improve reliability.

Sensitivity to Operations

Sensitivity to operations in HROs is often described by a phrase borrowed from the Navy, "having the bubble" (Roberts & Rousseau, 1989). Rochlin (1997, p. 109) describes the phenomenon this way: "Those who man the combat operations centers of US Navy ships use the term 'having the bubble' to indicate that they have been able to construct and maintain the cognitive map that allows them to integrate such diverse inputs as combat status, information sensors and remote observation, and the real-time status and performance of the various weapons and systems into a single picture of the ship's overall situation and operational status." The notion of "having the bubble is similar to the notion of "situational awareness" (Endsley, 1997, p. 270) defined as "the perception of the elements in the environment within a volume of time and space. The comprehension of their meaning and the projection of their status in the near future." Both phrases refer to the integrated big picture of operations in the moment, an accomplishment that is difficult to maintain. Whereas situational awareness refers generically to the big picture that any operator forms, having the bubble refers to an effortful achievement of a high level of situational awareness. LaPorte (1988, p. 224) puts it this way: in HROs "the effort and intensity of purpose required to build what we sometimes characterize as the 'bubble', the state of cognitive integration and collective mind that allows the integration of tightly-coupled interactive complexity as a dynamic operational process, is enormous."

If someone has the bubble at all times in HROs, then catastrophic failures are forestalled by large numbers of ongoing small adjustments that prevent errors from cumulating (Wildavsky, 1991, p. 26). To forestall cumulation is to reduce the likelihood that any one error will become aligned with others and interact in ways not previously seen. Furthermore, maintaining the bubble is another way to describe what it means to act thinkingly in HROs. When people have the bubble,

ongoing action occurs simultaneous with attention, and people act thinkingly with wisdom and heed (Meacham, 1983; Weick, 1993a, 1998).

The importance of sensitivity to current operations is reflected in much of the terminology associated with HROs. Descriptive words such as struggle for alertness, misinterpretation, overload, decoys, distraction, mixed signals, surprise, vigilance, near misses, warnings, anomalies, lookouts, clues, and neglect, all portray the concern to catch errors in the moment. Dangers inherent in the loss of this sensitivity can be illustrated by a totally new class of problems called "automation surprises" (Miller & Woods, 1997, p. 143). These surprises occur, for example, in automated cockpits when pilots command the aircraft to do one thing, and it does something else because on-board computers are integrating a different set of inputs in a different way. The crew finds itself in the unfamiliar position of asking "now what is it doing? what will it do next?" and losing valuable time and separation among aircraft while seeking an answer. Situational awareness and sensitivity to operations reduce the incidence of automation surprises and shorten the period of inaction.

One obstacle to the maintenance of broad operational awareness is the danger of production pressure and overload. For example, the grounding of the carrier *Enterprise* on Bishop Rock (Roberts and Leuschner, in press) was attributed in part to saturation of the captain by multiple demands which led him to misinterpret a red light that warned of shoal waters and to see that light instead as a white light warning of a fishing net buoy. More effective HROs tend to be more self conscious in dealing with pressures of overload and to "exhibit extraordinary sensitivity to the incipient overloading of any one of its members" (Reason, 1990, p. 483) as when air traffic controllers gather around a person working a very high amount of traffic and look for danger points. The issue of awareness of production pressure and its effects on judgment and performance is crucial, because many organizations have raised production pressure and overload through downsizing.

Endsley (1995) suggests that situation awareness emerges from the perception of elements in the environment, the synthesis of discrete elements in order to achieve comprehension of the current situation, and the projection into the future to envision possible future states of the situation. Because HROs involve complex technologies operating in complex environments, each of these situation awareness dimensions depends on the sharing of information and interpretations between individuals. The expression "having the bubble" may actually mislead to the extent that it suggests that an individual possesses the one correct representation of a complex environment. The limited cognitive resources of the individual prevent the development of a cognitive map that accurately registers the entirety of an HRO and its operating environment. Even sophisticated cognitive maps will have limited range and incorporate a potentially high level of generalization or simplification. Having the bubble, when achieved, is typically a shared accomplishment and bubbles of varying focus and range may coexist in a high-functioning HRO.

Roth's (1997) studies of operator decision making in simulated nuclear power plant emergencies illustrate the ways in which effective HROs retain sensitivity to operations. Sensitivity to operations is achieved through a combination of shared mental representations, collective story building, multiple bubbles of varying size, situation assessing with continual updates, knowledge of physical interconnections and parameters of plant systems, and active diagnosis of the limitations of

preplanned procedures. The value of her work lies in the articulation of the ways in which higher-level cognitive activities, social construction of coherent explanations, and knowledge of the physical plant, all produce mindfulness in the moment.

Roth's picture of effective operational HRO functioning, reveals important details that are not tapped by the simplified processes implied by the seductive phrase, "situation awareness." It is clear, for example, that operators "actively generate situational assessments" (plural) (Roth, 1997, p. 178) for the symptoms they notice, revising each assessment when they fail to observe symptoms expected on the basis of that assessment. They were not simply "aware" of the situation but searched for a "coherent explanation that minimized the number of separate faults that need to be postulated" (p. 178). These coherent explanations often consist of "story building" (p. 177) and monitoring to see "whether actions indicated in procedure steps made sense in the context of the particular event" (p. 180). Operators used knowledge of the assumptions and logic that underlie preplanned procedures to deal with situations not fully covered by the procedure (p. 181). There was an ongoing effort "to determine whether observed plant behavior was the result of known influences on the plant, such as manual and automatic actions and known malfunctions, or was unexpected and signaled an unidentified plant malfunction" (p. 179). This emphasis on actual operations and plant characteristics is noteworthy across effective HROs and is the reason why we chose the label "sensitivity to operations" to capture this process. Roth describes knowledge of plant characteristics this way: "crews needed to utilize mental models of physical plant systems and to reason qualitatively about expected effects of different factors influencing plant state in order to localize plant faults and identify actions to mitigate them" (p. 181). Finally, Roth also observed that efforts to improve the accuracy of representations were social and interactive: "[W]e saw repeated cases where operators stopped to discuss as a group whether the procedure path they were following would eventually lead them to take the actions they recognized to be important for safe recovery of the plant" (p. 180).

What becomes clear in Roth's work is that images such as "the bubble" and "situation awareness" are overly static and are neither deep enough nor dynamic enough to capture continuous formulating, monitoring, story building, and acting. Although our phrase "sensitivity to operations" highlights only the first of Endsley's (1995) three phases of situation awareness – perception – the above description underscores the importance of integration and extrapolation as well. Further, it appears to us that integration and extrapolation are actually products of the mindfulness created by all five processes, rather than activities tied specifically to operations. It is collective knowledge of failures, details, potentials for recovery, and relevant past experience, gathered into mindful processing, that provides the context within which present operations either make sense or are reconstructed to make sense.

Commitment to Resilience

The maritime industry is renowned for its low reliability organizations (e.g., Perrow, 1984, chap. 6). For example, in the case of tanker ship oil spills Nalder (1994, p. 260) expressed skepticism that requiring double hulls on these ships would do much to prevent environmental damage: "Double hulls will not solve

the problem if ships carry the maximum amount of oil with the minimum amount of steel and people; if vessel-traffic systems exist in only a few waterways of the world; if standards for crew training do not change; if regulators are fragmented and weak; and if the profit margin squeezes out safety. History show that things return quickly to business as usual in this tanker trade." While the "maritime business is one huge accident waiting to happen all the time" (Nalder, 1994, p. 118), in one regard mariners are exemplary. They are accustomed to resilience. They have no choice but to rely on their own coping skills when most of their operations consist of "blue-water" cruising away from land and rescuers and spare parts and expert diagnoses. (See Danton, 1991, for discussion of how to cope with such conditions as collision damage, heavy weather damage, loss of rudder, stranding, handling disabled vessels.) If a rudder breaks, if power goes off, the crew is dependent on its own resourcefulness to do something right now, even if it is only to drop anchor and buy time to figure out the problem. Most HROs engage in their own form of blue-water operations when they stumble onto problems far from informed rescuers, uncommitted resources, and expertise, and have no choice but to respond to the unexpected in real-time.

Earlier, we noted that reliable performance in the face of unexpected events was achieved at Diablo Canyon through "continuous management of fluctuations." In that earlier discussion we focused on the word "fluctuations" and argued that variation rather than invariance in reliability-enhancing activities was necessary to cope with the unexpected. Here we want to focus on the equally important word "management" because it makes clear that people deal with surprises, not only by anticipation that weeds them out in advance, but also by resilience that responds to them as they occur. Furthermore, to manage a surprise is to contain it rather than eliminate it (Schulman, 1993b, p. 369). In the case of Diablo Canyon, both resilient containment and reactive responsiveness are made possible by continuous reinforcement of three "perishable" values: credibility, trust, attentiveness (Schulman, 1993b, pp. 365–368).

Effective HROs tend to develop both anticipation and resilience in the sense defined by Wildavsky (1991, p. 77). Anticipation refers to the "prediction and prevention of potential dangers before damage is done," whereas resilience refers to the "capacity to cope with unanticipated dangers after they have become manifest, learning to bounce back." Unlike effective HROs, traditional organizations tend to lean heavily toward one or the other of the two, typically toward anticipation of expected surprises, risk aversion, and planned defenses against foreseeable risks.

While it is to be expected that HROs would devote enormous attention to anticipating possible failure modes (Wildavsky in fact uses nuclear power plants to epitomize over-reliance on anticipation, 1991, p. 147), it may be less obvious that HROs develop capacities for resilience. Resilience is not only about bouncing back from errors, it is also about coping with surprises in the moment. It is important to retain both connotations of resilience to avoid the idea that resilience is simply the capability to absorb change and still persist. To be resilient also means to utilize the change that is absorbed. The best HROs don't wait for an error to strike before responding to it. Rather, they prepare for inevitable surprises "by expanding general knowledge and technical facility, and generalized command over resources" (Wildavsky, 1991, p. 221). Even though a central tension in the HRO literature is the possibility that once a mistake starts to amplify in a system, that error may be the system's last trial, it is clear that HROs accept the inevitability

of error. HROs acknowledge the reality of fallible humans, murky technology (Vaughan, 1996, p. 200), and narrow specialties. To cope with this reality they pay attention both to error-prevention and to error-containment.

An example of a commitment to resilience is the capability on aircraft carriers to contain emerging crises through informal "epistemic networks" (Rochlin, 1989, pp. 161–168). This form of resilience materializes when events get outside of normal operational boundaries and knowledgeable people self organize into ad hoc networks to provide expert problem solving. These networks, which have no formal status, dissolve as soon as normalcy returns. Bourier (1996, p. 105) describes these structures as "informal latent networks activated only in the face of uncertainties and rapidly developing contingencies as a supplement to the normal patterns of formal hierarchy and compliance with strict roles." The value of these networks is that they allow for rapid pooling of cognitive knowledge to handle events that were impossible to anticipate. Thus epistemic networks represent a strategy for flexible crisis intervention that enables systems to deal with irreducible uncertainty and imperfect knowledge. They are also an ideal example of the generalized, uncommitted resources that are necessary if one is to cope in a resilient manner with the unexpected (Wildavsky, 1991, p. 85).

The commitment to resilience in HROs is also visible in their formal support for improvisation (see Bourier, 1996, p. 109). To understand the counterintuitive idea that improvisation co-exists with potentials for catastrophe, recall the argument made earlier (p. 90) that organizations that are able to act on hazards are also able to see those hazards and think about them. In the earlier discussion we implied that the addition of specific actions enabled people to recognize new issues in a mindful manner. Here, we want to make the additional observation that effective HROs also have the capability to recombine actions already in their repertoire into novel combinations. And the possibility of recombination enlarges the size of the action repertoire just as surely as does the addition of specific actions. With an extended range of action goes an extended range of perception of new threats (Jervis, 1976; Weick, 1988). Theoretically, a system with a well-developed capability for improvisation should be able to see the threatening details in even the most complex environment, because, whatever they discover, will be something they can do something about. The range of possible action, and, by implication, the range of possible things that can then be noticed, are both extended if HROs develop competence at recombination and bricolage (Levi-Strauss, 1966; Harper, 1987; Weick, 1993b, pp. 351–353). As Wildavsky makes clear, this is the ultimate form of resilience: "Improvement in overall capability, i.e., a generalized capacity to investigate, to learn, and to act, without knowing in advance what one will be called to act upon, is a vital protection against unexpected hazards" (Wildavsky, 1991, p. 70).

Finally, resilience also takes the form of ambivalence toward the applicability of past practice. HROs, unlike most organizations, are able simultaneously both to believe and doubt their past experience (Weick, 1969, pp. 86–96; 1979, pp. 217–224). Simultaneous belief and doubt is important for adaptive action when a hazard is encountered, as Ryle (1979, p. 129) makes clear: "(T)o be thinking what he is here and now up against, he must both be trying to adjust himself to just this present once-only situation and in doing this to be applying lessons already learned. There must be in his response a union of some Ad Hockery with some know-how. If he is not at once improvising and improvising warily, he is

not engaging his somewhat trained wits in a partly fresh situation. It is the pitting of an acquired competence or skill against unprogrammed opportunity, obstacle or hazard."

Underspecification of Structures

In our analysis of high reliability organizing we confronted the paradox that the adoption of orderly procedures to reduce error often spreads errors around, an observation made earlier by Turner (1978, p. 180). Turner (1978) described a manufacturing firm, Evans Medical that made sterile fluids for hospitals that were distributed through an efficient distribution network. When in 1971 Evans made a batch of dextrose infusion fluid that was not sterilized adequately, and information about the low preparation temperature was ignored, that same efficient distribution network sent the contaminated fluids to several British hospitals where "untoward reactions" (Turner, 1978, p. 108) were immediately observed. The reliable system insured that the contaminated fluids got to the hospitals swiftly with their contamination intact. Vaughan (1996, p. 65) also highlights this paradox in her description of how the orderly routines put in place at NASA (e.g., the five step process to handle deviations) allowed the erosion of O-rings to continue across more launches and be accepted as normal by more units than if NASA's procedures had been less orderly. In both cases, an early error was amplified by an orderly system.

We interpret these data to mean that effective HROs are sometimes failure-free in spite of their orderliness, not because of it. Any orderly hierarchy can amplify errors, especially when those miscues occur near the top (Turner, 1978, p. 187). Higher level errors tend to pick up and combine with, lower level errors, which makes the resulting combination harder to comprehend and more interactively complex. It is the very reliability that HROs cultivate, that makes it possible for small errors to spread, cumulate, interact, and trigger serious consequences.

In the face of such dangers, HROs gain flexibility by enacting moments of organized anarchy (Rasmussen & Batstone, 1989; Perrow, 1994b, p. 216; Vaughan, 1996, pp. 200, 203). Changes are made that move the organizations in the direction of a garbage can structure (Cohen, March, & Olsen, 1972). In a garbage can, problems, solutions, decision makers and choice opportunities are independent streams flowing through a system. These streams become linked by their arrival and departure times and by any structural constraints that affect which problems, solutions, and decision makers have access to which opportunities. In an absolute garbage can there are no structural constraints, so solutions become linked to problems and decision makers become linked to choices, primarily by their joint presence in the same moment (March & Olsen, 1986, p. 17). This emphasis on temporality contrasts with a more common organizational emphasis on consequences. In a system held together by close attention to consequences, "wanting something leads to doing something connected to the want, and doing something leads to consequences related to the intention" (March & Olsen, 1986, p. 17). In garbage cans, coexistence in time, as opposed to rational intention or hierarchical position tends to determine problem solving processes.

Effective HROs achieve flexibility simultaneously with orderliness by enacting partial garbage cans. They do so by opening the access to what is normally a hierarchical authority and decision structure. In a closed hierarchical structure,

important choices are made by important decision makers, and important decision makers can participate in many choices. What is distinctive about effective HROs is that they loosen the designation of who is the "important" decision maker in order to allow decision making to migrate along with problems. When HROs move in the direction of a more garbage can like structure, people loosen the filters on who gains access to what with the result that hierarchical rank is subordinated to expertise and experience. When problems and decision rights are both allowed to migrate, this increases the likelihood that new capabilities will be matched with new problems. As a result, a wider range of capabilities and solutions gain access to a wider range of problems. Expertise at the bottom of the pyramid may rise temporarily to the top when the filter of formal position is loosened. This depiction of how HROs enact flexibility is supported by field research. With respect to aircraft carriers Roberts observed: "[D]ecisions are pushed down to the lowest levels in the carriers as a result of the need for quick decision making. Men who can immediately sense the potential problem can indeed make a quick decision to alleviate the problem or effectively decouple some of the technology, reducing the consequences of errors in decision making. The ability of any man on the deck to call it foul, thereby enabling some of the extreme time pressure to be reduced and decisions to be made quickly is an example of the behavior in these organizations....[M]any events in [HROs] are unique. Uniqueness coupled with the need for accurate decisions leads to decisions which 'search' for the expert and migrate around the organization. The decisions migrate around these organizations in search of a person who has specific knowledge of the event. This person may be someone who has a longer tenure on the carrier or in the specific job" (Roberts, Stout, & Halpern, 1994, p. 622). Similarly, in nuclear power plants Bourrier (1996, p. 109) "found that the most important characteristic [during a planned outage] is the formal delegation of power to craft personnel supported by a nearly complete availability of top-management at all times. By being a very flexible and adaptive organization, any problem can rapidly receive the attention it requires at all levels of the organization."

This enactment of more anarchic modes of functioning by the loosening of hierarchical constraints is facilitated by the mindful system in place in HROs. As discussed, when effective HROs' focus on failure they treat every signal as if it were novel. This generates the attentiveness necessary to link expertise with problems, solutions, and decisions in the moment. Because they are mindful of failure, this also preserves awareness of consequences. Mindfulness, then, is attuned to timing as well as to consequences, which means that a mindful system counteracts the typical flaws in garbage can decision making of decisions made by flight and oversight.

The shift to anarchy is part of the ongoing project of mindful action. When people examine an anomaly, they turn to others in an effort to understand what the anomaly means. This turn is a subtle loosening of hierarchy in favor of expertise. The "agency" that triggers this loosening is not an edict from the top, but rather a collective, cultural belief that the necessary capabilities lie somewhere in the system and that migrating problems will find them. In a mindful system, structure is a variable and activity of structuring is a constant. This is just another way of saying that routines and designs are fluid. Invariant mindfulness grasps both anomalous events and structural constraints that make it difficult to comprehend

the meaning of those anomalies. To grasp these limits mindfully is to counteract them with consultation that is less hierarchical. To loosen the filter of hierarchy is to spread the troublesome cues around and to expose them to a more varied set of capabilities. When filters are loosened, people also pay more attention to inputs in the moment, they are more sensitive to their time of arrival, and processes are more influenced by temporal connections. This heightened sensitivity to temporal sorting decouples problems from high ranking decision makers, allows problems to migrate, and allows a wider variety of people to make sense of novel cues and determine whether they signify a problem or a transient event.

Discussion

We started with the observation that HROs are important because they are harbingers of adaptive organizational forms for an increasingly complex environment. They provide a window on a distinctive set of processes directed toward fostering effectiveness that can unfold in all organizations. It is important to reiterate that our goal is not to minimize what is distinctive about HROs. Instead, we want to use that distinctiveness as the occasion to see all organizations in a different manner and to suggest a different set of processes that influence their effectiveness. HROs remain the anchor of this exercise in generalization, but we believe that everyday organizations increasingly display some of the character of HROs. Therefore, we need to revise our theories of organization so that they are more sensitive to the themes outlined here. The need to do so is driven by the fact that longer term environmental conditions such as increased competition, higher customer expectations, and reduced cycle time create unforgiving conditions with high performance standards and little tolerance for errors. These conditions are likely to continue, as environments become more competitive, uncertain, turbulent, and complex (D'Aveni, 1994). Many organizational settings contain a million accidents waiting to happen, but most organizations don't see things that way. As organizations are driven to squeeze slack out of their operations through downsizing or mergers or resource constraints, or through complex distributed computer technologies (Shin and Sung, 1995; Rochlin, 1997), they come to exhibit the tightly-coupled, interactively complex profile of many HROs (Weick, 1990a). The important question is are those transformations accompanied by increased capability for mindfulness?

There are a number of continuties between HROs and non-HROs. For example, failures that occur in HROs and non-HROs alike are similar in the sense that some event disrupts prevailing cultural assumptions about the efficacy of current precautions. These failures can be called failures of foresight, since it is likely that some forewarning was available and some avoiding action was possible (Turner, 1976, p. 380). Because the incident was potentially foreseeable and avoidable, this suggests that the precautions were not as adequate as they were thought to be. When failure is defined as "an event, concentrated in time and space, which threatens a group with unwanted consequences as a result of the collapse of precautions which had hitherto been culturally accepted as adequate" (Turner, 1976, p. 380), the common features across both HROs and non-HROs are blind spots induced by cultural presumptions, the collapse of precautions, concentrated triggering of a visible disruption, and unwanted consequences.

Further continuities are implicit in the fact that the five processes we discuss can counter the dreaded combination of interactive complexity and tight coupling associated with normal accidents (Perrow, 1984). Mindfulness both increases the comprehension of complexity and loosens tight coupling. People preoccupied with failure comprehend more of the potential complex interactions in a system and create alternative paths for task performance that loosen couplings. People who simplify reluctantly pay close attention to the details of complexity rather than abstract them away and see more components that can be rearranged in more ways to avoid tight invariant sequences. People who maintain sensitivity to operations see more interconnections and comprehend more complexity in the moment which enables them to make adjustments that loosen time-dependencies, introduce redundancy, and in general, loosen tight coupling. People who develop capabilities for resilience stay attuned to unfolding events for longer time intervals which increases the likelihood that they will be able to comprehend puzzling interaction. Resilient systems also create slack resources and alternative means to a goal, both of which loosen couplings. And people who loosen hierarchical access structures increase the comprehension of complexity by marrying problems more closely and more quickly to experience and expertise, and reduce the likelihood of tightened coupling by isolating problems earlier in their development before they spread and constrain other system properties.

When we propose these five ways in which mindfulness counters normal accidents, we differ from other analysts such as Perrow and Sagan because we do not treat technology as a given that dominates organizational life through its own imperatives. Instead we treat technology as an equivoque (Weick, 1990a), as a sequence of events that can be understood more fully, and as a sequence of events that can also be interrupted, redirected, isolated, loosened, slowed, patched, halted, accelerated, etc. We see technology less as an intractable technological imperative and more as a controllable option if it is engaged by effortful, continuous collective mindfulness enacted by smart, trusting, trustworthy, self-respecting (Campbell, 1990) people willing and able to negotiate the differences among their diverse views under intense time pressure. We realize how big that "if" is. We are mindful that engaged collective mindfulness is a complex and rare mix of human alertness, experience, skill, deference, communication, negotiation, paradoxical action, boldness, and caution. Which is why infallibility is so hard to achieve. But we are also mindful that effective HROs do exist and that they are distinguished by the form of their fallibility. Effective HROs are known by their capability to contain and recover from the errors they do make and by their capability to have foresight into errors they might make. Both capabilities serve to illuminate complex interactions, loosen tight couplings, and insure that complex, tightly coupled technologies do not automatically dominate outcomes.

There are also continuities between HROs and non-HROs in consequences, an observation that may be less obvious. HROs with their consequences on a catastrophic scale may seem irrelevant to organizations in which people shuffle papers and lose a few, attend meetings and solve nothing, catch airplanes and miss connections, conduct briefings and persuade no one, evaluate proposals and miss the winners, and meet deadlines for projects on which the plug has been pulled. We have argued throughout that the magnitude of consequences is not as crucial

in conceptualizing HROs as is the nature of their cognitive processes and the likelihood that those processes induce a state of mindfulness.

This is not to dismiss consequences as a defining feature of high reliability, since it was their inclusion originally that set these systems apart. But those consequences varied enormously in the range of their severity (Three Mile Island killed no one while Bhopal killed thousands and *Challenger* killed seven). If people wish to remain attentive to consequences in their conceptualization of reliability, then they should put those consequences on the same scale as the activities being observed. To halt an assembly line is not an absolute catastrophe, but it is a catastrophe relative to what the foreman expects not to fail and for which she or he takes precautions. The failure of those precautions can cause reputational harm and end careers. A visit from Mike Wallace to a CEO's office is not an absolute catastrophe in the sense of producing fatalities, but it can affect markets, share price, legitimacy, and liability, all of which the CEO counted on not to fail given the precautions that were envisioned. To put catastrophes on the same scale as one's tasks is to see the potential for big trouble arising from small moments when intentions fail, when a surprise occurs, or when a near miss and good luck reveal unexpected danger. Small though those moments may be, they recapitulate on their own scale what happens in larger HROs on a larger scale. And small moments on any scale can cumulate, enlarge, and have disproportionately large consequences as complexity theorists keep telling us.

Theory Refinements

Among the many issues raised earlier that need further conceptual development and empirical research, we would single out four for their centrality to organization theory: effectiveness, learning, meaningful levels of analysis, and requisite variety.

Effectiveness

HROs are important to mainstream organizational theory because they are "nonnormal organizational performance situations" (Whetten & Cameron, 1994, p. 136) that enrich our conceptualization of organizational effectiveness. At first, HROs seem to be simply one more ideal type of organization whose effectiveness is measured by a single universalistic criterion. Thus, the ideal HRO that maximizes reliability takes its place alongside the ideal bureaucracy that maximizes efficiency, the ideal cooperative system that maximizes need satisfaction, or the ideal natural system that maximizes resource acquisition. The problem of course is that a universalistic criterion of effectiveness is insensitive to the diverse environmental conditions and the diverse preferences of strategically critical constituencies with which any organization contends (Cameron, 1995, p. 393). Furthermore, reliability is not the full story of effectiveness in either HROs or organizations in general. "[T]o the extent that some researchers persist in claiming that HROs are unique, they fail to recognize that reliability is really one of many concepts that fall under the rubric of organizational effectiveness. HROs seek to operate effectively using their own distinctive criteria much as McDonald's makes good food and clean bathrooms its endeavor" (Creed, Stout, & Roberts, 1993, pp. 56–57).

Sensitivity to simultaneous conflicting definitions of effectiveness is regained when observers pay closer attention to the paradoxical logic of effective organizational performance. And it is here where HROs aid articulation. Paradoxical logic is necessary to capture "the inherently paradoxical nature of organizational life. Administrators must not only make tradeoffs between day-to-day competing demands on the organization's resources, but more importantly, they must balance competing expectations regarding the core identity of the organization as an institution. From this point of view, effective organizations are both short-term and long-term focused, flexible and rigid, centralized and decentralized, goal and resource control oriented, concerned about the needs of members and the demands of customers" (Whetten & Cameron, 1994, p. 141). Cameron (1986) found that the presence of simultaneous opposites created the highest level of effectiveness in recovering institutions of higher education, organizations that are loosely coupled and interactively complex in Perrow's (1984, p. 97) matrix of the "organizational world." HROs suggest that the acceptance of paradox continues to create high effectiveness when systems become more tightly coupled and more interactively complex. As we have seen, HROs pursue simultaneous opposites such as rigidity and flexibility, confidence and wariness, compliance and discretion, anticipation and resilience, expertise and ignorance, and balance them rather than try to resolve them.

Rochlin (1993, p. 24) neatly summarizes some of the paradoxes of effectiveness in HROs: HROs "seek an ideal of perfection but never expect to achieve it. They demand complete safety but never expect it. They dread surprise but always anticipate it. They deliver reliability but never take it for granted. They live by the book but are unwilling to die by it. If these beliefs seem wonderfully contradictory, those who express them are under no particular pressure to rationalize their paradoxes, indeed, they seem actively to resist such rationalization....This lack of goal rationalization extends to the organizational as well as the individual level. The observed deliberate, and often self-conscious, effort to create and maintain multiple modes of decision making and duplicative error searching regimes, and to hold differing perspectives and rank-ordering of preferences by different groups is a manifestation of collective organizational response rather than individual behavior. Such representational ambiguity is implicitly (and sometimes explicitly) acknowledged and accepted by the organization, not just as part of the cost of maintaining performance levels, but as an active contributor to problem solving."

HROs, however, provide more than just a comparative window on the role of paradox in effectiveness. They also depict an important sense in which effectiveness is defined by conditions to be avoided rather than conditions to be sought. As Roberts and Creed (1993, p. 254) put it, "reliability-enhancing organizations identify sets of outcomes they continually work never to experience." Effectiveness defined in terms of avoidance necessitates much more mindfulness, capability, and alertness than does effectiveness defined in terms of approach. The complexities inherent in effective avoidance affect culture as well as perception in HROs. In the case of culture, "Reliability, as a cultural value [in HROs], is oriented against ineffectiveness rather than toward effectiveness. If this is true, it may be that these organizations – existing as they do in an era of continuous technological change – can enjoy no equilibrium state and are characterized by continually changing cultures striving to avoid a non-goal" (Roberts & Creed, 1993, p. 252). In the case

of perception, Schulman (personal communication, 6/25/97, p. 2) has distilled his research on Diablo Canyon into these two propositions: "(1) The major determinant of reliability in an organization is not how greatly it values reliability or safety per se over other organizational values, but rather how greatly it *disvalues* the mis-specification, mis-estimation, and misunderstanding of things; (2) All else being equal, the more things that more members of an organization care about mis-specifying, mis-estimating and misunderstanding, the higher the level of reliability that organization can hope to attain."

If HROs strive to reduce mis-specification, then they need structural and cognitive mechanisms that encourage the sensing and organization of detail. These mechanisms need to be complex in order to register complexity. But they also need to keep that complexity *un*integrated to preserve its detail. Efficiency and simplification encourage integration and discourage unintegrated complexity. To pursue unintegrated complexity, however, is to run the risk of appearing disorderly, messy, and unsafe, which could jeopardize legitimacy. The safest organizations may look the most dangerous. And vice versa. There may be a fine line between messes that promote requisite variety and messes that undermine it. Effective HROs manage this tension artfully. More importantly, effective organizations in general may be those that are wise enough to accept the reality of paradox in organizational life and bold enough to define their effectiveness in terms of its preservation.

Learning

HROs are distinguished by the fact that their modes of learning do not fall neatly into the currently popular distinction between exploitation and exploration (March, 1996). Exploitation involves the use and development of things already known, exploration involves the pursuit of new knowledge. The prevailing high reliability literature, however, cautions against exploration where trials can ramify in unexpected, dangerous ways. Exploitation, however, is also difficult because systems are understood imperfectly and all possible failure modes have not yet occurred.

High reliability organizations seem to cope with these limits on exploitation and exploration in part through exploration of meaningful analogues. In the early debates over the lessons of Three Mile Island, LaPorte (1982, p. 189) called attention to the "need for analogous, less risky phenomena from which to learn" and suggested that nuclear power plants might learn analogically from petrochemical plants. Effective HROs, faced with infrequent failures, learn from the failures of others. What is unusual is that they are sensitive to the ways in which these "outside" failures are better or worse analogues of what they might experience. Thus, accidents on submarines and aircraft carriers are potentially more instructive to nuclear power plants than are accidents in petrochemical plants, since most contemporary submarines and carriers are nuclear powered. Failures within wildland firefighting crews (e.g., Weick, 1995) may be more instructive to aircraft crews than failures in nuclear power plant control room crews, since firefighting crews and cockpits crews have continuous rotation of personnel and control rooms do not. The intent in using these analogues as modes of exploration is to uncover assumptions people take for granted, trace out new implications of old assumptions, and identify latent organizational flaws.

But what is perhaps even more striking in our analysis is that high reliability is not totally dependent on conventional learning processes. We concur with those who argue that learning is stored in routines; but we also emphasize that assumptions store much of what an organization learns. Attention to failure and situational awareness seem to create many of the adaptive changes that would ordinarily be attributed to learning. Since surprise is the primary non-repetitive input that threatens reliable operations, other than strengthening the processes that heighten mindfulness, it is not obvious what can be learned from surprises that may happen only once and which may never happen again. It is as if, the more fully a system maintains a state of mindfulness, the less that remains to be explained by concepts of organizational learning. Said differently, when people in HROs concentrate on situational awareness, resilience, and containment, they deal with what is in front of them through operations that have an emergent quality similar to the activity of bricolage (Weick, 1993b). People combine fragments of old routines with novel actions into a unique response to deal with a unique input. To portray this rich mixture of perception, surprise, bricolage, and experience as mere learning would seem to conceal the fine-grain of complex adaptation that HROs actually accomplish.

Levels of Analysis

A further implication of our analysis is that there is nothing sacred about the organizational level of analysis when processes become the focus. Instead, to pursue reliability in a meaningful fashion is to pay closer attentions to systems (Carroll, 1997, pp. 24–27), positions (Vaughan, 1996), or programs (Perrin, 1995, p. 162).

Consider "systems," for example. Perrow (1984) argues that the concern in normal accident theory is with system accidents rather than component failures, although he tends to draw systems somewhat narrowly (Vaughan, 1996). Woods, Johannesen, Cook, and Sorter (1993, p. 36) similarly argue for more attention to systems: "Erroneous actions that lead to bad consequences involve multiple people embedded in larger systems. It is this operational *system* that fails. When this system fails, there is a breakdown in cognitive activities, cognitive activities which are distributed across multiple agents and influenced by the artifacts used by those agents" (emphasis in original). It is also possible to move away from large systems to much smaller ones and argue that in HROs the operating crew enacts the organization. It is the risk handlers who embody the organization and its reputation in their manual, interpretive, experience-based work (Perrin, 1995, p. 158) and not the risk-analysts or others who espouse safety. As the Captain of the tanker *Arco Anchorage* put it, "The boat people can take the corporation down in one move" (Nalder, 1994, p. 223). The organization is the crew in the same sense that the organization *is* the meetings it convenes (Schwartzman, 1987, p. 288). The organization is realized and comes into being in its meetings and in the working of its crews.

Concerns with a shift in level of analysis is consistent with Wiley's (1988) suggestion that "organization" is not a meaningful level of analysis in social science. He argued, instead, that the sui generis breaks in the evolution of the social animal occur at the levels of the individual, the intersubjective (synthesis of two communicating selves), the generic subjective (self as filler of roles and follower

of rules), and the extrasubjective (pure meanings without a knowing subject as in culture). In the previous discussion, key issues were framed intersubjectively and dyadically (e.g., Van Braun rewards an engineer who volunteers that he may have caused a launch failure), generic subjectively (e.g., supervisors help overloaded air traffic controllers), and extrasubjectively (e.g., medication errors are reported when the culture is friendly to errors). It is conceivable that HROs have languished outside the mainstream of organizational theory precisely because they did not fit traditional definitions of organization. The lesson, however, may be that almost nothing looks like a conventional organization any more when we see forms shaped uniquely for high velocity environments (Eisenhardt, 1993), knowledge-intensive practice (Starbuck, 1993), hyperturbulence (D'Aveni, 1994), and virtual existence (Sotto, 1993).

Given this rethinking of the appropriate level of analysis for conceptualizing HROs, it becomes less surprising that Vaughan (1996, pp. 413–415), in her analysis of the *Challenger* disaster, is able to move seamlessly between intimate dyads and NASA systems. She argues that turning points in intimate dyadic relationships occur when one partner begins to pull away from the other. These turning points show the very same pattern of normalization of signals of danger that she observed in the far more complex decision-making that led up to the *Challenger* disaster. In both cases, the focal object displays discontent/malfunctioning through weak, mixed signals that soon become treated mindlessly as they are embedded among other signals that have taken-for-granted meanings. In both cases, those mixed, embedded signals are seen to form a clear ominous pattern only when an exiting partner or an exploding space shuttle trigger retrospective sensemaking.

The reason Vaughan is able to juxtapose images of such diverse complexity and size is that she maintains a consistent focus on process. She argued that intimate relationships are small organizations that exhibit organizing. "When we marry or live with another person, we develop a division of labor, share some goals, compete for scarce resources, and socialize new members. We come and go regularly, making decisions daily, creating precedents, decision streams, culture, and history. Like their larger and more formal counterparts, these small organizations are also subject to failures with human consequences." Thus, the feedstock for studies of reliable organizing is much closer at hand than a nuclear power plant, aircraft carrier, or chemical plant. The fundamental processes involved in reliable performance are processes indigenous to all relationships that matter.

Requisite Variety

Finally, the concept of requisite variety has been central in previous discussions of HROs and it remains central in our analysis. However, when pushed, this concept raises other questions, one of which is when does requisite variety help and when does it hamper the pursuit of reliability? We noted earlier Schulman's redefinition of requisite variety as conceptual slack: "a divergence in analytical perspectives among members of an organization over theories, models, or causal assumptions pertaining to its technology or production processes" (Schulman, 1993b, p. 364). This definition resembles Turner's description of the variable disjunction of information. Variable disjunction refers "to a complex situation in which a number of parties handling a problem are unable to obtain precisely the

same information about the problem so that many differing interpretations of the problem exist" (Turner, 1978, p. 50). Our focus is on the similarity between Schulman's "divergence in analytical perspectives" and Turner's "many different interpretations of the problem."

Early work by Reeves and Turner (1972, p. 91) elaborated the idea of variable disjunction this way. "It is variable because the state is not one in which no information can be exchanged or amplified to remove discrepancies: such exchanges are constantly being made, so that the content of the sets of information which are disjoined is always varying. However, no single agreed-upon description of the situation exists. People who have to operate in a situation in which there is disjunction of information are unlikely to reach complete consensus about the information which describes the total situation, simply because of the problem of convincing others of the status of their own set of information and thus of the validity of their analysis of the situation and their suggestions for action." What is jarring when we juxtapose Schulman and Turner is that conceptual slack supposedly reduces the incidence of disasters whereas variable disjunction increases the incidence. Are diverse perspectives dangerous or an investment in safety?

We suspect that important boundary conditions for requisite variety are implicit in the answer. Divergent perspectives may reduce the incidence of disaster when they occur within an organization (Schulman speaks of members of *an* organization) or when tasks are not decomposable, but increase the likelihood of incidence when they cross boundaries and connect multiple organizations or when tasks are decomposable. Turner's data show that it is commonplace for disasters to happen "when a large complex problem, the limits of which were difficult to specify, was being dealt with by a number of groups and individuals usually operating in separate organizations" (Turner, 1976, p. 384). This suggests that reliability will be an emerging concern as organizations increasingly participate in interorganizational networks because interorganizational coordination is so difficult to achieve and because the system becomes more complex and harder to comprehend.

Our analysis updates thinking on requisite variety, but it also raises a number of other issues. For example, if we focus on key phrases in Reeves and Turner (1972), then additional boundary conditions become clearer. Requisite variety may have the potential to increase disasters when corporate cultures emphasize,

(1) accuracy rather than plausibility: A culture that values accuracy may influence people to withhold judgments and communication until they have "precisely the same information" and can demonstrate "the validity of their analysis." Since accuracy is difficult to demonstrate in a dynamic partially understood environment, norms that favor accuracy may silence the reporting of imprecise hunches about anomalies that could cumulate into crises.

(2) advocacy rather than active listening: If people define their job as "convincing others of the validity of their own set of information" rather than listening to others to determine the validity of their own information, then advocacy replaces analysis and synthesis. As a result, subtle cues that are ordinarily registered when requisite variety is high, go unacknowledged and the errors they point to are left unattended and remain available for cumulation.

(3) constant rather than periodic exchange of information: A culture in which information "exchanges are constantly being made," may make it harder to detect small changes than one in which exchanges are periodic. With periodic exchanges,

contrasts between past and present become more clear-cut than is the case when exchange is continuous. With more frequent reporting, there is less change to report and more of a tendency to assimilate a current report to an earlier report (Hutchins, 1991). Errors that begin to cumulate in a single direction go unnoticed when exchange is continuous. This suggests that there may be an optimal frequency or periodicity for information exchange that varies from organization to organization. But it also suggests that continual talk is problematic as a blanket formula for increased reliability.

(4) complete consensus rather than partial "working" consensus: A culture that encourages people to seek a "single agreed-upon description" and to "reach complete consensus" ignores the reality of diversity in experiences and the impossibility of anything more than general agreement. Pressure for consensus is dangerous because it stifles the reporting of anomalies and because it takes time to attain it, time during which conditions can worsen and origins become harder to uncover.

Thus, high requisite variety may not improve reliable performance unless it is developed intra-organizationally as part of a context that encourages plausible judgment, active listening, periodic information exchange, and a working consensus. Departures from any of these potential boundary conditions may turn a system that uses variety to destroy variety into one in which variety amplifies variety.

Practice Refinements

Perhaps the key question for practice is, does it make sense for mainstream organizations to invest time, energy, and human resources in processes of high reliability in order to prevent mistakes of relatively minor consequence? The answer is more straightforward for HROs driven by failure-avoidance and the prospect of catastrophe than it is for traditional efficiency-oriented organizations driven by success and the prospect of a weak bottom line. Although that is a gross simplification, it does reach the point that safety costs money (Wildavsky, 1991, p. 214). And when safety boils down to the non-occurrence of bad outcomes, there is strong temptation to use that non-occurrence as proof that an investment in safety is no longer necessary (Starbuck & Milliken, 1988).

The piece that is missing in this tidy picture is that it is not just safety that costs money. Learning does too. And this is where the pragmatics of reliability and efficiency begin to blend. If we view safety as a process of search and learning (Wildavsky, 1991, p. 207), then the costs of building an infrastructure that induces mindfulness, can be viewed as an investment in both learning and safety. Investments in safety are defined as investments in mindfulness that mean greater familiarity with the system, an enlarged response repertoire, and clearer accountability, all of which can create competitive advantage (Thompson, 1995). To invest in mindfulness is to assign a high priority to the probability of error and to the importance of responsibility for mistakes, internal criticism, and the removal of self-serving defensive postures (Landau & Chisholm, 1995, p. 77). Furthermore, to encourage mindfulness is to tap into intrinsic motivation and increase performance-enhancing perceptions of efficacy and control (Langer, 1997; Pfeffer, 1997, pp. 67–71). But whether a high reliability approach leads to sufficient returns in the form of avoided disasters or enhanced performance to justify its implementation, remains an empirical question, difficult to assess and

perhaps ultimately unknowable. The choice by mainstream organizations to pursue high reliability organizing in the absence of obvious threats may ultimately be an issue of identity and appropriateness (who do we want to be and how do we want to go about our business), rather than an issue of reality and consequentiality (March & Olsen, 1989, pp. 21–52).

An additional question for practice is, what is new here in our analysis of mindful organizing in HROs? That question arises in part because many of the recommendations that flow from HROs sound like what Perrow (1987) calls "motherhood items." He argues that few managers would question the value of intense effort, group trust, complete knowledge of how everything works, no mistakes by anyone, buffers to contain failure, clear specifications of jobs, thoughtful plans, ample resources, redundancy, conforming to rules, complex skills for complex work, constant alertness, continuous learning, open and frequent communication, and effective leadership. It is lists like this that lead some observers to equate good management with safe management (e.g., Allinson, 1993).

Part of what's missing from any list of motherhood items are contingent propositions, propositions such as high requisite variety promotes reliability in non decomposable tasks but hinders reliability in decomposable tasks. But one is also tempted to say, what's missing here are "good mothers." If these are motherhood items, then a case can be made that in a downsized, outsourced, acquisitive, divesting, reorganizing, insecure, competitive world, a good mother is hard to find. Managers aren't managing because, with too few resources, they don't have the time to. Absorption in details normally handled by subordinates keeps managers from coordinating, building overviews, increasing the capacity for resilience, and anticipating much farther than the next week, let alone the next quarter. Managers faced with these pressures are not just overworked. They are dangerous because of the potential to make high level errors that disperse and cumulate. And that's where a thorough understanding of HROs begins to produce a different set of insights into organizing.

The lessons to be learned from HROs are not just lessons of motherhood, although successful implementation of even those lessons could be the source of competitive advantage. In fact, many organizations are already capable of serious failure that can create serious harm, but are unable to see these possibilities (Roberts & Libuser, 1993; Rochlin, 1997) and may benefit from the lessons outlined here. Additional lessons *implicit* in the preceding analysis include,

1. The expectation of surprise is an organizational resource because it promotes real-time attentiveness and discovery (Schulman, 1993b, p. 368).
2. Anomalous events should be treated as outcomes rather than accidents, to encourage search for sources and causes (Edmondson, 1996).
3. Errors should be made as conspicuous as possible to undermine self-deception and concealment (Tamuz, 1994).
4. Reliability requires diversity, duplication, overlap, and a varied response repertoire, whereas efficiency requires homogeneity, specialization, non-redundancy, and standardization (Landau & Chisholm, 1995, p. 68).
5. Interpersonal skills are just as important in HROs as are technical skills (Westrum, 1997).

Lessons such as these have direct implications for practice issues such as those that focus on quality and decentralization to name two examples described below.

There is some overlap between practices that improve quality and practices that induce mindful error detection and correction. Our hunch is that the greater the overlap, the higher the incidence of sustained quality improvement. There are obvious parallels even when the overlap is modest. The core concern in quality programs with the elimination of defects and reducing variability has obvious links with goals in HROs. Recall that Deming (1982) emphasized defining quality efforts in terms of a sustained and broad-based organizational vigilance for finding and addressing problems over and above those found through standard statistical process control methods. Moreover, if high reliability organizing is understood in part as a strategy to deploy attention, quality practices could be viewed as devices to direct and channel that attention. A process orientation in quality programs focuses attention on issues such as the interrelation of units or individuals, origins of errors, and the consequences of different process changes (Winter, 1994). Customer focus directs attention beyond an internal focus toward consideration of a larger set of consequences. And systematic and continual attention to fact-based analysis heightens awareness of potential and existing errors.

All of these processes intended to improve quality have their counterparts in HRO processes that deal with failure, resilience, and operations. Interestingly, however, quality programs seem to overlook HRO processes that reduce simplification and loosen structures. These two oversights may explain why some total quality efforts fail. When quality programs preserve simplification and tight structure they ignore complex, emergent problems (Sitkin, Sutcliffe, and Scchroeder, 1994). We interpret this preservation as a clear case of stable routines and variable cognitive process, a combination that may be dysfunctional.

There are limits, however, in the extent to which a move toward total quality represents a move toward high reliability. Organizations may adopt total quality programs as much for institutional reasons as for reasons of enhanced performance (Westphal, Gulati, & Shortell, 1997). The pursuit of legitimacy through adoption of formal quality programs neutralizes the mindful pursuit of reliability. Similar neutralization of mindfulness occurs if quality programs are adopted as part of a fad (Abrahamson, 1996). Finally, the very quality practices designed to encourage mindfulness may themselves become routinized and mindless in the interest of efficiency. In each of these cases improvements in quality processes bypass several features of the cognitive infrastructure associated with HROs.

HROs have implications for decentralization, as well as quality. As systems increase in complexity, centralized organizations lose the ability to respond at local levels (Lustick, 1980). In these cases they must delegate authority to create a more elaborate sensing mechanism capable of detecting possible dangers on a local level. This delegated capacity for local detection must be held simultaneously with a centralized capacity that maintains the organization's larger awareness of its vulnerability and serves to coordinate responses and learning that occur at the local level. In high reliability organizations decentralization and centralization are held in critical balance (Weick, 1987), often by means of tight social coupling around a handful of core cultural values, and looser coupling around the means by which these values are realized. In ordinary organizations where reliability is

becoming increasingly important, excess centralization may weaken local containment and resolution of problems, while excess decentralization may weaken the comprehension of wider threats and of the capacity to coordinate responses.

Consider the practice of outsourcing. Many organizations confront external conditions that are tightly coupled and interactively complex (e.g., increased competition and reduced slack). To control costs more organizations resort to practices such as outsourcing. Outsourcing sacrifices many of the reliability-enhancing qualities of decentralization such as more fine-grained local understanding of complex environments and swift detection, isolation, and resolution of problems. For example, when Valujet outsourced maintenance to Sabre-Tech, this reduced the complexity of Valujet but it did not reduce the complexity of the system within which it operated. That system became more interactively complex and harder to comprehend. Thus, when Valujet outsourced it made itself less complex at the very moment that its interdependencies became more interactively complex. In our terminology Valujet lost requisite variety right when they needed to increase it. Outsourcing appears to be one of a growing number of devices for cost-saving that also leave firms with less variety to cope. Outsourcing of maintenance is also a good example of removing an antecedent of mindfulness (preoccupation with failure), thereby reducing the capability for error detecting. When maintenance is outsourced, the supplier, not the buyer, now must become preoccupied with failure, which means that the buyer becomes more mindless. That may be unimportant if the buyer faces only predictable forms of failure that are easy to anticipate. But if novel forms of failure are possible, then the loss of a preoccupation with failure to an outsider could make the buyer less mindful and more vulnerable.

Conclusion

Effective HROs organize socially around failure rather than success in ways that induce an ongoing state of mindfulness. Mindfulness, in turn, facilitates the discovery and correction of anomalies that could cumulate with other anomalies and grow into a catastrophe. Mindfulness, with its rich awareness of discriminatory detail, enables people to manage juxtapositions of events they have never seen before. But the ways in which they do this are still not fully understood. Our analysis represents an effort to further this understanding.

Effective HROs represent complex adaptive systems that combine orderly processes of cognition with variations in routine activities in order to sense and manage complex ill-structured contingencies. In a dynamic, unknowable, unpredictable world one might presume that organizing in a manner analogous to HROs would be in the best interest of most organizations. Hints of such moves are evident when traditional organizations graft TQM cultures onto a pre-existing preoccupation with efficiency, and aspire to the relatively error-free performance found in HROs. But many of these attempted changes fail because traditional organizations demonstrate little awareness of just what kind of infrastructure it takes to support reliable performance. Unfortunately, mainstream organizational theory isn't much help in developing this awareness.

The purpose of our analysis has been to consolidate conceptually a body of work that begins to articulate the social infrastructure of reliability. The language

of a near miss, having the bubble, migrating decisions, conceptual slack, resilience, normal accidents, redundancy, variable disjunction, struggle for alertness, performance pressure, situational awareness, interactive complexity, and prideful wariness, describes how people organize around failures in ways that induce mindful awareness. That mindfulness, in turn, reveals unexpected threats to well being that can escalate out of control. And that, in our estimation, is a central theme for mainstream organizational theory.

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