Abstract

This paper examines the problem of risk mitigation in virtual organizations (VO's). We begin by discussing risk propensity in virtual organizations, and draw on a variety of research to suggest processes important in obtaining high levels of reliable performance.
in VO's. From this research we identify four processes we think are important: organizational structuring and design, communication, culture, and trust. Based on existing research done in conventional and high reliability organizations, we suggest how these processes may enhance reliability in VO's. We discuss how thoughtful management of these attributes can mitigate risk, and conclude with a theoretical and research agenda for future work.

Introduction

A growing number of researchers are interested in organizations in which the probability of error is low but the consequences are high (e.g. Morone and Woodhouse, 1986; Wildavsky, 1988; Sagan, 1993; Tenner, 1996; Vaughan, 1996), and in risk mitigation processes in these organizations (e.g. Roberts, 1990; Rochlin, La Porte & Roberts, 1987; Schulman, 1993; Weick, 1987). In this paper, we address the problem of risk mitigation in virtual organizations (VO's)--organizations comprised of multiple, distributed members, temporarily linked together for competitive advantage, that share common value chains and business processes supported by distributed information technology (Davidow and Malone, 1992; Business Week, 1993). Examples of VO's in which risk mitigation processes are critical include health maintenance systems of doctors in widely dispersed managed care environments, medical societies, and electronically-linked members of Physicians On-Line (Virtual Enterprises, 1997; Physicians On-Line, 1998); fire and emergency medical services units providing support in large-scale disasters (Weick, 1993; 1996); oil spill response teams responding to oil spills of national significance (Harrald, Cohn, & Wallace, 1992; Grabowski, Harrald & Roberts, 1997); aerospace conglomerates jointly developing mission- and safety-critical applications (Augustine, 1997; SmartBridge, 1997; Spotts & Castellano, 1997); international oil exploration consortia investigating oil fields in the Caspian Sea (Chevron, 1997), and global telecommunication alliances providing 99% of the world's inter-bank financial transactions (SWIFT, 1996; 1998).

Risk in systems can exist because one or more components in the system are risky, or it can result from components that are themselves relatively safe, but interact in ways that increase risk. Perrow (1984) discusses such risk propensities at length, but generally for smaller systems than those that can be imagined as VO's. Here we use the commonly used engineering definition of a risky event as one that is low probability but high consequence (e.g. Wenk, 1982).

VO's and systems of organizations have been little studied by organizational researchers. In fact, Perrow reported in 1979 and again in 1986 that only one study had specifically examined systems of organizations (1979, 1986). The literature on inter-organizational alliances comes the closest to offering us a fairly well developed paradigm for studying organizational systems (Barrett & Konsynski, 1982; Cash & Konsynski, 1985; Johnston & Vitale, 1988; Hagedoorn, 1993; Benasou & Venkatraman, 1995), as does the literature on network organizations (Powell, 1990; Miles & Snow, 1992; Nahria & Eccles, 1992). More recently, some organizational researchers have begun to examine systems of organizations (e.g. Uzzi, 1997; Eisenhardt & Schoonhaven, 1996), and risk propensities in large-scale systems have received empirical attention (Perrow, 1984; Pauchant & Mitroff, 1992; Sagan, 1993; Vaughan, 1996; Grabowski & Roberts, 1996; 1997).
In this paper, we draw on research on high reliability organizations (HRO's) (LaPorte, 1982; Roberts, 1990), risk and safety research (Shrivastava, 1986; Wildavsky, 1988; Sagan, 1993; Vaughan, 1996), research on network organizations (Powell, 1990; Nohria & Eccles, 1992; Jarillo, 1988; Thorelli, 1986) and inter-organizational systems (Barrett & Konsynski, 1982; Johnston & Vitale, 1988; Konsynski & McFarlan, 1990), and recent discussions of VO's (Davidow and Malone, 1992; Goldman, Nagel & Preiss, 1995; Preiss, Goldman and Nagel, 1996) to explore important risk mitigation processes in VO's. We begin by discussing risk propensity in VO's, and examine in detail characteristics of VO's important to mitigating risk. We discuss how thoughtful management of these attributes can mitigate risk, and conclude with a theoretical and research agenda for future work.

**Risk Propensity in Virtual Organizations**

The major distinction between virtual and other organizations is that the former are networked (usually electronically) organizations that transcend conventional organizational boundaries (e.g. Barner, 1996; Berger, 1996; Rogers, 1996). The bonds among members of VO's are temporary, and VO's are noted for forming and dissolving relationships with other members of the VO (e.g. Palmer, Friedland & Singh, 1986; Bleeker, 1994; Byrne, 1993; Nohria & Berkley, 1994; Coyle & Schnarr, 1995). The traditional advantages attributed to VO's include adaptability, flexibility, and the ability to respond quickly to market changes.

Although members of VO's may occasionally meet face-to-face as well as electronically, members are not co-located, and VO success hinges on shared, interdependent business processes that are designed to achieve shared business objectives. Virtuality thus has two features: the creation of a common value chain among the distinct entities of the VO (Benjamin & Wigand, 1995; Rayport & Sviokla, 1995), and business processes supported by distributed information technology (Palmer & Speier, 1997). VO's are distinguished from traditional network organizations by the temporary linkages that tie together the distinct organizations, and by the members' shared business processes and common value chains supported by distributed information technology. Network organizations, in contrast, generally establish more permanent linkages between members, and generally do not create shared value chains and interdependent business processes between members, as VO's do.

Research shows that risk propensity in traditional organizations has its roots in a number of factors (Wenk, 1982; Perrow, 1984, National Research Council, 1996; Grabowski & Roberts, 1996; Tenner, 1996; Vaughan, 1996). One cause of risk is that the activities performed in the system are inherently risky (e.g. mining, manufacturing, airline transportation); another is that the technology is inherently risky, or exacerbates risks in the system (e.g. heavy equipment, locomotives, and cables). Yet a third cause is that the individuals and organizations executing tasks, using technology, or coordinating both can propagate human and organizational errors. In addition, organizational structures may encourage risky practices or encourage workers to pursue risky courses of action (e.g. lack of formal safety reporting systems or departments in organizations, or organizational standards that are impossible to meet without some amount of risk taking). Finally, organizational cultures may support risk taking, or fail to sufficiently encourage risk aversion (e.g. cultures that nurture the development of “cowboys” who succeed by taking risks, or of management practices that encourage new generations of risk takers).

VO's are characterized by several of the same factors that determine a traditional
organization's risk propensity. Tasks executed by the VO, although distributed, may still be inherently risky (e.g., oil exploration, fire fighting, eye surgery), as in traditional organizations. Technology used to execute the VO's tasks may also be inherently risky (e.g., drilling equipment, interacting chemicals, lasers, or infrared equipment). Human and organizational error can continue to propagate in VO's as long as humans and organizations are a part of them. Organizational structures in VO's may make risk mitigation difficult (e.g., virtual management structures can reduce physical oversight and contact, and organizational relationships presumably based on shared commitments to safety may not be equally shared among members of a VO). Finally, organizational cultures may send confusing or contradictory messages to members about risk tolerance in the VO (e.g., safety bulletins that celebrate the number of accident free days while the virtual organization simultaneously rewards workers for flaunting safety practices and "living on the edge").

However, risk propensity in VO's has some interesting differences. Because VO's are distributed, networked organizations with fluid and shared business processes, risk in the VO can migrate between organizational members, making risk identification and mitigation difficult (Grabowski & Roberts, 1997). Because VO's are comprised of members with their own individual goals, policies, and cultures, and because the members are bound in temporary alliances that reflect changing marketplace opportunities, developing a shared culture of reliability and shared commitments to reliability goals is difficult, as the presence of simultaneous interdependence and autonomy creates an inherent tension in the VO (Grabowski & Roberts, 1997). Finally, because VO's are large scale organizations with complex interactions between their members, precipitating incidents and accidents may have long incubation periods, making identification of a leading error chain difficult (Grabowski & Roberts, 1997). These risk propensities can provide important clues about effective risk mitigation in VO's.

HRO research can also suggest issues that merit attention in risk mitigating VO's. In HRO's, small errors can propagate into grave consequences, and risk mitigation processes are critical to the organization's survival (Roberts, 1990; LaPorte and Consolini, 1991; Sagan, 1993; Weick, 1987; 1993). Typical examples of HRO's include flight operations aboard aircraft carriers, command and control organizations in battle management operations, the U.S. air traffic control system, and operations of some U.S. commercial nuclear power plants (Rochlin, LaPorte, & Roberts, 1987; LaPorte, 1988; Roberts, 1990; La Porte & Consolini, 1991).

Four findings from the high reliability research seem appropriate to VO's seeking to mitigate risk. HRO's are characterized by prioritization of safety and reliability as goals, as such practices enhance a milieu of safe operations. HRO's clearly define what they mean by safety goals and establish safety standards against which they assess themselves. For instance, at the Navy Aviation School in Monterey, California, aviation accidents are detailed on a large board adjacent to a chart showing the Navy's aviation safety record since the early 1950's. Operationalizing safety and reliability goals in HRO's often takes the form of redundancy in personnel and technology. Pilots and co-pilots on commercial airliners can both fly the airplane, and both pilots and co-pilots are required aboard before commercial airliners will fly. HRO's are also noted for developing a high reliability culture that is decentralized and constantly reinforced, often by continuing practice and through training. For instance, nuclear power plants that run well build in high reliability cultures for regular employees, and try to build them in for additional employees who are brought in for scheduled outages. The building process involves continuing practice, continual training, and reinforcement through incentives and reward systems. Finally, HRO's continually attend the development of interpersonal...
trust. Incident command systems (ICS) in fire authorities, for instance, routinely publicize information about who in local, state and federal fire authorities can be trusted. Trust is then further developed in the ICS fire authorities by training and encouraging firefighters to get to know each other.

These characteristics of HRO's are critical to reliable performance in complex, changing environments. However, transferring these practices from the HRO world to the VO world is difficult. Insuring everyone in a distributed VO has the same safety and reliability goals is difficult at best. While sheer numbers of persons and job functions in VO's assures some redundancy, without careful attention to design, it is not clear the redundancies are of the form required to assure reliability. Geographical dispersion of VO's constrains their ability to develop a shared, reinforced culture of reliability, and the lack of a shared culture inhibits the development of interpersonal trust in VO's.

Mitigating risk in VO's thus requires attention to and knowledge of risk mitigation research and processes in conventional and high reliability organizations, as well as an understanding the nature and behavior of VO's. With attention to these requirements, we propose that risk mitigation in VO's focuses on four characteristics we think are related to both previous findings and the nature of VO's. The geographical distribution of VO’s and the necessity for reliability enhancing organizations to prioritize safety goals, engage in redundancy, and develop a decentralized culture suggest the necessity of paying attention to organizational structuring and design in the interests of risk mitigation. Because interfaces are a key aspect of virtuosity and because trust and culture are important for obtaining reliability, communication processes must be a point of focus. We suggest that risk mitigation processes in VO's should focus on communication at the interfaces of the VO. Because creating a common, reliable value chain is of primary interest to VO’s seeking to mitigate risk, we suggest that such VO's develop a shared organizational culture of reliability across all members of the VO, utilizing effective communication at the organization’s interfaces. A final non-variant process inherent in reliable operations is trust. We suggest that the development of trust among members of VO's is also critical to risk mitigation processes in the organization. In the next sections, we examine each of these characteristics to understand how thoughtful management of them can enhance reliability in VO's.

**Organizational Structuring and Design**

Structuring is the organizational process for solving two fundamental problems: "the division of labor into various tasks to be solved and the coordination of these tasks to accomplish the activity" (Lucas & Barudi, 1994, p.9). Redundant organizational structures that provide operational slack and the assurance of task performance in dynamic environments are linked to risk mitigation in HRO's (LaPorte & Consolini, 1991). Because a number of organizations comprise a VO, some amount of redundancy in them is inevitable (Davidow & Malone, 1992; Goldman, Nagel & Preiss, 1995). However, redundancy in VO's can cause difficulties if duplicate tasks are executed in geographically dispersed operational settings by organizational members who do not share each others' values, or understand each others' roles and responsibilities. For example, redundancy in federal, state, and local oil spill response team VO's can permit enough slack to allow different response groups in each organization the latitude to conduct similar tasks during the response. However, determining the point at which the different groups should cease parallel activities and begin joint clean up is challenging in geographically and culturally diverse settings, particularly if members of the VO do not understand how the response process works, or who is in charge (Harrald, Cohn & Wallace, 1992). The challenge for VO's, therefore, is to harness whatever redundancy
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exists to leverage needed slack, and manage the processes so that distributed groups can work together in support of their shared mission.

Because distributed VO's must synchronize their goals and respond quickly in the face of changing requirements, we suggest that risk mitigation in VO's is primarily linked to fluidity in organizational structures, rather than to redundancy. Fluidity in organizational structures can allow disparate organizations the flexibility to respond in different ways to varied conditions and situations, which is critical for VO's faced with frequent changes in requirements, their environments, and in resources. VO's that can vary their organizational structures in response to such changes can also create opportunities to dampen the risks of miscommunication, disjointed decision making, misunderstanding, or disparate organizational goals by providing multiple paths through which structuring and communications can occur (Weick, 1993; 1996).

For instance, in VO's such as fire and emergency services responding to large-scale disasters such as the Laguna Beach fires in 1993, fluidity in organizational structuring is essential. Large scale disaster response organizations are comprised of various local, state, and federal emergency response teams tied together by common information technology, each working on different geographic and topical parts of the same disaster. In large scale disaster response, the responders have seldom met before the disaster, have often never worked together, but are united by a common technological link (radios, cellular phones, personal computers and/or local area networks) and the common need to resolve and respond to the disaster--the disaster manager's equivalent of a common value chain. Moreover, even though the responders are unknown to each other, their success is highly dependent on their ability to interact and cooperate effectively with each other. The success of the response is the result of highly interdependent activities carried out by geographically and culturally diverse "stranger groups" (Drabek, 1986; Tuler, 1988; Grabowski, Harrald & Roberts, 1997).

Organizational fluidity in large scale disaster response is formalized to some extent in the United States with the use of Incident Command System (ICS), which provides cooperative inter-agency (federal, state, and local) organizational structures for all types of emergency response that center on five functional areas: command, operations, planning, logistics, and finance (Fire Protection Publications, 1983). Disaster response teams in most U.S. federal, state, and local agencies, as well as in many international oil and chemical companies, have adopted ICS-based organizational structures, and the U.S. Coast Guard and Environmental Protection Agency have directed that ICS organizational structures be incorporated into the U.S. National Contingency Plan for response to large scale environmental disasters (Grabowski, Harrald, & Roberts, 1997).

Virtual fire and emergency response teams utilizing the ICS in large scale disasters require different organizational structures at different stages of the disaster response (Brouillette & Quarantelli, 1971; Drabek, 1986; Tuler, 1988). These stages are often referred to as initiation, integration, and production, and each is distinct from the other in intensity, tasks, and structure (Grabowski, Harrald, & Roberts, 1997). ICS tasks for the initiation phase of large scale emergency response focus on birthing the response organization; identifying the requisite parties, resources, and initial response strategies; and developing an initial set of internal and external expectations for the response effort. Organizational structures in the first hours of disaster response, however, are loose and chaotic for the arriving waves of first responders, which can result in truly dangerous situations. The Mary Pang warehouse fire in Seattle in 1994, which was characterized in the first hours of the response by confusion about response roles and responsibilities, illustrates such a situation. The warehouse was built into the side of a hill, and one set of firefighters, confused about response organizational structures and responsibilities,
rushed into the second floor, presuming it to be the first floor. The second floor collapsed, killing the response team of four firefighters (U.S. Fire Administration, 1995). Such situations illustrate the dangerous nature of loose and chaotic organizational structures in the early hours of emergency response.

In contrast, the middle phase of emergency response (the integration phase) is much less chaotic: response teams arrive, and settle into pre-ordained organizational structures formalized by the ICS that are designed to allow response teams to perform threat assessments, develop a formalized response strategy which can be promptly and effectively executed, and make adjustments to the initial response team resource allocation to correspond with the response strategy. Finally, in the latter stages of response (the production stage), dwindling organizational units execute and pursue a daily work plan and clean up operations. At this point, the response organization has stabilized and is able to operate in a routine fashion, and the task environment and information flows have been well established.

Disaster managers responding to catastrophic events must therefore grow effective, functioning response organizations, comprised of multiple stranger groups, in a period of less than 24 hours, and then adjust the organizational structures to the needs of the response (Tuler, 1988, p. 128):

Time constraints may impose unacceptable burdens on personnel, both in information flows and delays. The transition from normal to crisis operating modes affects...response systems by changing information flows and characteristics, objectives, and personnel assignments. Hierarchical structures that are effective during normal operations of technological systems may be inadequate to cope with emergency situations (Carley, 1986; Perrow, 1984). For example, inefficiencies result because organizations first attempt to maintain familiar tasks and roles within established frameworks. Then they attempt to adapt tasks or structures to the new environment (Brouillette & Quarantelli, 1971). Only as a last resort do they adopt new structures and tasks (Stallings, 1978).

The ability to provide varied organizational structures in response to environmental demands is thus critical to the success of fire and emergency VO's, much in the same way as HRO aircraft carrier organizational structures vary from low to high tempo operations as environmental conditions change (Roberts, 1990). Distributed information technology which connects the VO responders provides the technological glue that ties the members of the organization together, and fluid organizational structures allow the VO to grow, expand, contract, and respond to changes in a dynamic, high tempo environment.

Fluid organizational structures have been achieved in a number of ways. Network forms of organizations, based on network exchange (Cook, 1977; 1982; Yamagishi, Gillmore & Cook, 1988; Bienenstock & Bonacich, 1992; 1997; Cook & Whitmeyer, 1992; Cook & Yamagishi, 1992; Markovsky, Skvoretz & Willer, 1993) and resource dependency theories (Pfeffer & Salancik, 1978), are collections of organizations and the linkages that tie them together (Monge & Contractor, 1998). Resource dependency theory, which suggests that organizations structure to buffer themselves from their environments, also suggests that fluid organizational structures can be achieved by network extension (by increasing the number of organizations they are connected with) or by network consolidation (by decreasing the number of organizations other organizations are connected with, and/or by forming coalitions with other organizations) (Monge & Contractor, 1998). Both network extension and network consolidation can permit VO's
to expand or contract in response to their environments, or to perceived threats. Network organizations have existed for a number of years (Powell, 1990):

Network research, which positions organizations as technology, centers around describing the characteristics of networks and their linkages, including their strength or intensity, symmetricality, reciprocity, and multiplexity. The strength or intensity of a linkage is a reflection of the amount of information, affect, or resources flowing through the system. Symmetricality refers to the degree to which both people enter the same kind of relationship with one another. Reciprocity refers to the degree that two people supposedly in a relationship report the relationship. Multiplexity refers to the degree to which the same people are involved in different networks in an organization (Roberts and Grabowski, 1996, p.416).

In HRO's, the intensity, symmetricality and reciprocity of linkages among members are very strong, leading to the development of trust, fine-grained information transfer, and joint problem solving as effective means of risk mitigation (Schulman, 1993; Uzzi, 1997). Weick and Roberts (1993) and Roberts, Stout, and Halpern (1994) describe the presence of these characteristics during flight operations aboard aircraft carriers, where weather and battle conditions change rapidly, requiring rapid, intense decision making and negotiation. Vaughan (1996) notes the striking absence of these processes in the Challenger accident.

However, the intensity, symmetricality, and reciprocity of linkages in VO's are different than those of HRO's, as VO's are populated with varying and changing organizational members in physically distributed locations, with varying degrees of shared goals. Achieving symmetricality and reciprocity among members of VO's may be very difficult, as VO's seem inherently devised to work against the development of the kinds of organizational "fabric" characteristics (trust, fine-grained information, and joint problem solving) that can mitigate risk. In fact, VO's often presume and exploit inequalities in linkages among members (Davidow & Malone, 1992; Goldman, Nagel & Preiss, 1995), which suggests that although fluidity is desirable in VO's, the intensity, symmetricality, and reciprocity of linkages in them may be different than in traditional network organizations.

As an example, the VO's led by Nike (Chowdhury & Paul, 1997), Sun (Chesbrough & Teece, 1996), or the Ambra alliance (Goldman, Nagel & Preiss, 1995) are led by dominant organizations with strong design, marketing, service, and support capabilities. In such organizations, the alliance is a network, but the face projected to the outside world is that of the leader: thus, we have 'Nike' sneakers and 'Sun' workstations. These VO's may resemble integrated corporations (Chesbrough & Teece, 1996) or dynamic networks (Miles & Snow, 1986), as the dominant player in the VO subsumes the roles of broker, designer, and sometimes distributor, with other members of the VO taking the roles of suppliers and producers. In such VO's, the concepts of linkage symmetricality and reciprocity are at odds with the dominant player models of VO's, and risk mitigation processes would need to attend to the differences (Goldman, Nagel, & Preiss, 1995).

Lateral organizational forms have also been used to foster fluid coordination among organizational units by "utiliz[ing] structures that range from simple direct contact relationships and liaison roles, through group-based forms utilizing teams and task forces, to formal lateral structures, such as project management and matrix structures" (Joyce, McGee, & Slocum, 1997). Following contingency theory approaches to organizational structures, which suggest that an organization should structure itself in a manner that maximizes its ability to decrease uncertainty in its environment, a number
of authors suggest that organizations establish lateral integrative mechanisms to increase their capacity to handle high information requirements and reduce uncertainty in turbulent environments (e.g. Galbraith, 1994; Burns, 1989; Davis & Lawrence, 1977). The benefits of such structuring can be improved lateral management, empowerment of lower level managers, interdepartmental cooperation and decision-making, and improved communications. However, such organizational structures can also incur a number of costs: low functional excellence, low technical expertise, losses in organizational commitment and team performance, high stress and other personal costs (Joyce, McGee & Slocum, 1997).

Lateral organizational forms that empower managers, foster cooperation among distinct entities, and improve communication, may offer significant advantages to VO's seeking to mitigate risk. Such organizational structures may provide the flexibility needed to handle the high information requirements of the VO's diverse activities. However, careful attention must be paid to the costs of such lateral forms. Reduction of functional excellence and technical expertise are particularly worrisome in VO's. Stress is known to negatively influence cognition and communication, and good cognition and communication are major requirements in reliability enhancing organizations. Breakdowns in these processes have been key contributors to several major human-made catastrophes (e.g. Turner, 1978; Shrivastava, 1986; Medvedev, 1990). Poor performance can be fatal in HRO's, as exemplified by commercial and military aviation accidents (Foushee & Helmreich, 1988; Diehl, 1989; O'Hare & Roscoe, 1990). Thus, the benefits offered by fluid lateral organizational forms in VO’s could be tempered by their costs.

Ciborra's perspective of organizations as platforms provides a third view of fluid organizational structures:

From a structural point of view, the platform is the resilient outcome manufactured from the ingenious reconciliation of existing organizational mechanisms and forms, picked by management according to subjective and situated plans and interpretations. As a result, it looks fragmented and intertwined; still, it may be the only form capable of surviving in a high-tech industry where a monolithic rigid business identity would not seem as able to cope with the frantic pace of technological change (Ciborra, 1996, p.104).

Platform organizations are best suited to products, markets, and technologies that rapidly change--the type of market conditions VO’s are designed to address. In platform models, surprises determine organizational structures, the outcomes of artful recombinations of what is at hand under a set of specific circumstances:

The platform differs from the network because it functions at two distinct levels: the structural one of routines and transactions (similar to the network corporation) and the one of the higher order context where re-architecturing of structures is frequently carried out... It makes sense to rely on process capabilities, which serve a general purpose and are flexible, generic, and relatively stable. Thus, the resulting model of the dynamically stable organization contains two levels: one of the products (frequently changing) and one of the processes (which change more slowly)... Bahrami (1992) comes closest to the platform idea in her study of high-tech firms in Silicon Valley, organizations described as "structured yet chaotic." These firms have developed "dualistic organizational systems," made up of "bedrock" and temporary arrangements (Ciborra, 1996, p.113)
The platform is much more elusive than formal structure, resembling a bundle of trajectories when studied longitudinally (Ciborra, 1996). Managers in such organizations are improvisers and "bricoleurs" (Weick, 1993) who are creative in the face of uncertainty because they are accustomed to operating in chaotic situations. "In this perspective, the platform works as a meta organizational context that creates simultaneous dependencies and belongings" (Ciborra, 1996, p.115). While managers may operate within two or more organizational forms at the same time, the platform is the culture bed of the organization.

Platform notions of organizational structure have some applicability to VO's seeking to mitigate risk. For example, in their quest for optimum operations, modern militaries often regroup, depending on the kind of enemy they think they will face. Thus, a different organizational mix will engage a war at sea problem than will engage a search and rescue problem. The organizational forms are not only new, they are temporary, and they are virtual. HRO's also restructure in the face of surprises. While Weick and Roberts (1993) illustrate this aboard aircraft carriers, Medvedev (1990) and Read (1993) provide illustrations of the disastrous consequences associated with failures to restructure at Chernobyl. Managers in HRO's often operate in two or more structures simultaneously (e.g. La Porte & Consolini, 1991), and the delicate balance of interactions in HRO's reflects a richness of managerial actions (Weick and Roberts, 1993).

Often organizations that should be reliability enhancing fail to restructure in the face of change because the cognitive frameworks of their managers fail to change to meet changing situations. One reason many lives were lost in Waco, Texas, was that decision makers in the U.S. Federal Bureau of Alcohol, Tobacco, and Fire Arms, and the Federal Bureau of Investigation acted as though they had a common criminal on their hands, which was not the case.

As numerous National Transportation Safety Board investigations show, a large percentage of aircraft accidents happen when flight crews lose situational awareness (Sarter & Woods, 1991; National Transportation Safety Board, 1996; Gilson, Garland, & Koonce, 1996; Orasanu, 1997). Timely response to change and surprise is required in HRO's, as well as in VO's seeking to mitigate risk. VO's particularly need to address the necessity for adaptability to change and surprise, and continually reassess those needs across distributed organizations that lack face to face contact.

In summary, VO's seeking to mitigate risk need to be able to restructure quickly, to adapt to change and surprise, and to structure their organizational structures in a way consistent with the needs of a changing environment. Although the intensity, symmetricality and reciprocity of the linkages among members of the VO may be different, distributed organizations bound together by temporary ties and distributed information technology need fluid organizational structures to allow their dispersed member organizations to respond quickly and appropriately in dynamic environments. The flexibility provided by lateral or platform organizational forms might be essential for members with high and diverse information requirements, such as fire and emergency services responding to large-scale disasters. As interorganizational systems, VO's are continually faced with surprises; a rapid succession of technological discontinuities; the necessity to change cognitive frames as new information, requirements, or missions appear; changing structural routines and transactions; and simultaneous dependencies and belongings. We suggest that fluidity in organizational structures can mitigate risk in VO's by providing the flexibility needed to restructure and respond to rapid changes in the environment (Zaheer & Zaheer, 1997), as well as organizational surprises (Weick, 1996; 1998). Attention to the costs of fluid
organizational forms may be warranted, however, as low organizational commitment, poor performance and high stress can exacerbate, rather than mitigate, risk.

**Communication**

Uncertainty reduction theory suggests that people communicate to reduce uncertainty, thereby making their environments more predictable (Berger & Bradac, 1982; Berger, 1987; Weick, 1979). One of the hallmarks of HRO's is the use of effective and varied communications as one means of reducing uncertainty and mitigating risk (La Porte & Consolini, 1991; Weick, 1990; 1996). VO's have similar needs for many and varied communications to mitigate risk, to reduce uncertainty, and for sense making (Weick, 1993). Communication about member responsibilities and relationships in a VO can help make clear the links and roles different members assume, making explicit and more understandable the differing levels of autonomy and interdependence present in distributed organizations (Grabowski & Roberts, 1997).

However, communication processes in VO's that mitigate risk are different than those in traditional organizations, reflecting the VO's varied and changing organizational structures. The communication processes in virtual fire and emergency response organizations reflect changes in organizational structure experienced by their members: the communications are rich for some periods of the response effort (i.e., in the initiation and integration stages, when the VO is establishing its goals, objectives, responsibilities, and measures of effectiveness), and more austere in others (i.e., in the production stage, when skeletal logistical information is communicated to the few clean up teams remaining) (Grabowski, Harrald & Roberts, 1997), reflecting operationalization of the law of requisite variety (Weick, 1993). Just as organizational structures change in the VO, so too do communication patterns within and among those structures.

Communication in distributed VO's can clarify the goals, relationships among, and responsibilities of their members. It can also provide opportunities for members to discuss improvements, including explicit discussion of risk mitigation strategies and approaches, as well as what the probable impact of different risk mitigation measures might be. For geographically dispersed, networked alliances of workers, communication can also serve social support needs, which can reduce individual and organizational stress (Lin & Ensel, 1989, Kadushin, 1983; O'Reilly, 1988; Walker, Wasserman, & Wellman, 1994). Such communication can contribute to the development of a shared culture of safety and can mitigate risk (Weick, 1987; 1993), which is especially important in organizations that cannot presume the same set of shared values, or the development of heedful interrelating (Weick, 1998) that conventional or HRO's with physical proximity and face-to-face contact have.

One example of the importance of communications in VO's seeking to mitigate risk is the Chevron Caspian Sea oil exploration consortium comprised of Chevron, the State Oil Company of the Azerbaijan Republic (SOCAR), and Tengizchevroil (a joint venture company which operates the Tengiz oil field in Kazakhstan). Distributed information technology provides the vehicle through which much consortia communication is passed, including critical drilling and safety information (Chevron, 1997; Matzke, 1997). Members are encouraged to communicate through electronic mail that connects organizational members on different sides of the globe to surface concerns, findings, hypotheses, and difficulties to other consortia members. These communications among organizational members offer opportunities to challenge assumptions, identify errors, voice issues, and reinforce the VO's norms; they are also clearly opportunities for dispersed organizational members to grow and learn together. The safety culture of the
consortium is primarily developed through the consortium's communication structures, which are critical to the development of a shared culture of reliability among consortium members, as well as shared mental models of reliability (Staggers & Norcio, 1993).

Although not all members of the consortium speak the same language or come from the same background, they share two things: an excitement about the prospect of exploring huge untapped oil reserves, and a commitment to the primacy of safety on the project (Matzke, 1997). Achieving a balance between enthusiasm and safety has required special attention to communications at the interfaces of the organizations, as that is where the values, norms, and tacit assumptions are communicated. Communication at the interfaces not only define the members to each other and to the outside world; it also provides the vehicle through which culture is transmitted. If these communications do not reflect shared values, assumptions, expectations, or perceptions that enhance reliability, the organization may be destined to fail (Weick, 1990). Managing the communication processes among members of the VO is thus critical to the development of highly reliable safety cultures.

Developing trust in VO's requires constant, continual communication among members to build relationships that provide the foundation for trust. In geographically dispersed VO's, such interactions and communications are most often electronic (Hart & Saunders, 1997), yet still important to the development of trust (Fukuyama, 1996). Those interactions not only offer the opportunity for members of the VO to communicate their thoughts, expectations, assumptions, and values, but also the opportunity to change the nature of their members' underlying relationships with the parent organization:

When laborers become assets, the underlying contract with the organization has to change. Trust inevitably requires some sense of mutuality, of reciprocal loyalty. Virtual organizations, which feed on information, ideas, and intelligence (which in turn are vested in the hands and hearts of people), cannot escape the dilemma. One answer is to turn laborers into members; that is, to turn the instrumental contract into a membership contract for the smaller core. People who think of themselves as members have more of an interest in the future of the business and its growth than those who are only its hired help (Handy, 1995, p.48).

Thus, communication in VO's plays an important risk mitigation role. It provides opportunities for clarification, for sense making, for organizational growth, and opportunities for people to discuss improvements to the organization and the impacts of different risk mitigation strategies. It serves social support needs for geographically dispersed but technologically linked groups, and it can contribute to the development of a shared culture of safety and reliability. Communication at the interfaces of the VO is particularly important to risk mitigation, as that is where the VO defines itself to its members, and to the outside world; it is also where the culture of the VO is transmitted. We follow this thread, and explore the importance of organizational culture to risk mitigation in VO's, in the following section.

**Organizational Culture**

Schein (1992; 1996) defines culture as a set of basic tacit assumptions about how the world is and ought to be that a group of people share; it determines their perceptions, thoughts, feelings, and to some degree, their overt behavior. Culture manifests itself at
three levels: the level of deep tacit assumptions that are the essence of the culture; the level of espoused values that often reflect what a group wishes ideally to be and the way it wants to present itself publicly; and the day to day behavior that represents complex compromise among the espoused values, the deeper assumptions, and the immediate requirements of the situation (Schein, 1996). Overt behaviors cannot be used alone to decipher culture because situational contingencies often make us behave in a manner that is inconsistent with our deeper values and assumptions (Schein, 1992; 1996).

In conventional organizations, shared assumptions typically form around the functional units of the organization, and are often based on members’ similar educational backgrounds or experiences. HRO’s are characterized by strong cultures and norms that reinforce the organization's mission and goals, and focus attention on procedures, policies, and reward structures consistent with the organization's mission and safety (LaPorte & Consolini, 1991). Risk is mitigated in HRO's with cultures attentive to errors; in cultures where closely held ideas about the organization, its mission, and member roles in reliability enhancement are articulated; in cultures that encourage learning; and in cultures where safe areas -- for decision making, communication, and the like -- are created as buffers (Weick, 1993). Constructs such as oversight and checks and balances reinforce the strong cultural norms of the HRO.

Developing strong organizational cultures in VO’s is difficult because they are often comprised of several cultures. Thus, developing a single culture of reliability from these many cultures can prove challenging. The existence of shared deep tacit assumptions and values across all members of the VO, or of similar educational backgrounds or experience, is unlikely in such organizations, particularly if the VO crosses cultural lines (Chesbrough & Teece, 1996). The various cultures represented in the different members of VO’s will almost surely introduce dysfunctions and miscommunications, as communication and functionality in VO's takes place across organizations that do not share common values, assumptions, or perceptions (Porter, 1993; Stephenson, 1995; King, 1994; 1996).

However, assuring that errors are caught; that closely held ideas about the VO, its goals, and member roles and responsibilities are articulated; that appropriate organizational norms are developed and reinforced; and that the system improves or learns over time are essential goals for VO's. Chevron's Caspian Sea consortium provides one example of a VO that has addressed, but not conquered, the difficulty of developing a shared culture of reliability (Matzke, 1997). Safety-critical operations such as oil exploration require a shared understanding of and commitment to the consortium's safety goals and mission. To develop this understanding and commitment, lessons learned and best practices are promulgated across member entities of the VO, and when safety events occur, root causes analyses attempt to determine the deeper assumptions that may have produced unsafe conditions (Weick, 1996).

However, despite the VO's efforts to develop a shared culture of reliability, problems of disparate assumptions, perceptions and values pervade the Caspian Sea consortium (Energy Information Administration, 1997). Considerable international controversy surrounds oil exploration plans and alternative strategies in the Caspian Sea region, and some members of the Chevron Caspian Sea consortium are also partners in competing alliances with other organizations for pipelines and vessel traffic system alternatives. These competing alliances create a tension in the VO: while Chevron Caspian Sea consortium members share a common commitment to safety and reliability in the drilling consortium, some members of the VO also share business interests with competing organizations and alliances which could prosper in the event of drilling safety or reliability problems. These tensions are illustrative of the difficulties faced by VO's
seeking to mitigate risk and to develop shared cultures of reliability.

Risk mitigation in VO's requires melding the varied cultures that comprise the system into a cohesive whole in which the deep assumptions and espoused values in each of the member organizations can be built around the need for reliability. This is extremely difficult in distributed, multicultural systems aligned by temporary linkages that may dissolve as business opportunities and requirements change. VO's may also be plagued by vulnerabilities that make the development of a melded culture of reliability very difficult: a proliferation of different languages and cultures; communication between units and members of comparable stature, but non-comparable experience and training; rivalry between VO members; a reluctance to listen and ask questions; an eagerness to "get the job done;" and ethnocentrism, a tendency to discredit members or individuals not of the same background or experience. These characteristics are present in traditional and HRO's, but are exacerbated in VO's because of the distributed interdependence and amorphous nature of VO's. As Schein (1996) emphasizes, too often behavior is unwittingly in place that is dysfunctional to the system:

For example, many organizations -- virtual and otherwise -- espouse "teamwork" and "cooperation," but the behavior that the incentive and control systems of the organization reward and encourage is based more on a shared tacit assumption that only individuals can be accountable and that the best results come from a system of individual competition and rewards. If the external situation truly demands teamwork, the group will develop some behavior that looks, on the surface, like teamwork by conducting meetings and seeking consensus, but members will continue to share the belief that they can get ahead by individual effort and will act accordingly when rewards are given out (p.13).

Thus, risk mitigation in VO's requires attention to the difficult task of melding the varied cultures of the member organizations into a cohesive whole, and also examination of underlying incentive and control systems, as such systems have much to do with promoting organizational behavior aligned with the VO's goals and culture. Attention to incentive and control systems can help prevent situations where shared cultures of deep and espoused values are required for success, but are undermined by the individual members' reward and control systems, or by competing business opportunities. Establishing slack and safe areas in the VO to discuss incentive and control system issues can be a first step in creating an environment and conditions conducive to resolution of these sensitive inter- and intra-organizational issues, and to dampen risk overall in the VO.

Trust

Trust has long been of interest to a variety of researchers (Bonoma, 1976; Lewis & Weigert, 1985; Ring & Van de Ven, 1994; Hosmer, 1995; Mayer, Davis & Schoorman, 1995; Kramer & Tyler, 1995). Mayer, Davis & Schoorman (1995) define trust as "the willingness of a party to be vulnerable to the actions of another party based on the expectation that the other will perform a particular action important to the trustor, irrespective of the ability to monitor or control that other party (p. 712)." Trust among organizational members is critical for VO's. Without trust, commitment to the goals of the organization can waver, as members perceive the alliance as weak or disintegrating, fractured by misunderstanding or mistrust (McAllister, 1995; Handy, 1995; Zaheer, McEvily & Perrone, forthcoming). Trust is particularly important in VO's that require constant and close attention to shared commitments to safety and reliability, as well as a
shared willingness to learn and adapt (Davidow & Malone, 1992; Coyle & Schnarr, 1995). We suggest that trust permits a VO to focus on its mission, unfettered by doubts about other members' roles, responsibilities and resources, and that with trust, synergistic efforts in interorganizational missions are possible.

Developing trust in VO’s is a complex task. It requires fairly constant, small group activities among members, because it is difficult to trust people you do not know well, who you have not observed in action over time, and who are not committed to the same goals (Frey & Schlosser, 1993; Handy, 1995). Trust plays an important synthesis role because with trust, VO’s with fluid organizational structures can leverage the ability and willingness to learn (Senge, 1990; Coyle & Schnarr, 1995), thereby enhancing performance and attention to reliability over time. VO's with high levels of trust among their members can effectively utilize interactions and communication processes at their interfaces so members can learn together, and can develop shared mental models of reliability and a shared culture of safety. Finally, high levels of trust also contribute to strengthening linkages among member organizations. If anonymous, geographically dispersed organizations are truly to dampen their risk propensities, the relationships among their members and the organizational structures discussed earlier must more closely resemble alliances of collective responsibilities than hierarchies of reporting relationships. Trust among organizational members is an important prerequisite to changing those linkages to alliances, thus mitigating risk, as organizations are reluctant to adopt alliance-like organizational structures that make them vulnerable to the uncertainties of the environment, and to impacts from other organizations, without some assurances of shared vulnerability (Handy, 1995; McAllister, 1995).

Aerospace conglomerates jointly developing mission- and safety-critical systems, comprised of defense contractors, research universities, agencies of the federal government, and other private organizations (Augustine, 1997), are good examples of the need for such trust in a VO. In these organizations, members have different backgrounds, experiences, goals, objectives, and understandings, but belong to the conglomerate to pursue shared development of mission- and safety-critical aerospace systems. One example is the SmartBridge project, an alliance among Lockheed Martin, Rensselaer Polytechnic Institute, Chevron Shipping Company and the National Oceanographic and Atmospheric Administration. This group worked together for two years on a Defense Advanced Research Projects Agency (DARPA)-funded project, not bound by contractual relationships, but by consortium agreements that governed what each member would provide and contribute (Spotts & Castellano, 1997; SmartBridge, 1997). Conglomerate members, including the first author, all understood the safety criticality of their responsibilities, and the necessity of joint system development that leveraged each member's core competencies. These understandings were documented in jointly developed mission statements reviewed at quarterly program review meetings (SmartBridge, 1997). For effective joint development to take place, however, members needed to trust in the other members' talents, capacities, willingness to work, and interests in the alliance’s larger goals (Augustine, 1997; SmartBridge, 1997). Without such trust, members could duplicate other members' efforts; could subvert the mission and goals of the conglomerate by providing private information about conglomerate members to the members' competitors; and could introduce inefficiencies and costs pathological to the VO's goals.

Although they were rarely physically co-located, members of the SmartBridge project effected joint system development using distributed information technology in geographically dispersed settings. Members were only physically co-located immediately preceding installation of the system aboard its host, a Chevron oil tanker in San Francisco Bay. Distributed system development and integration with other
organizations was a novel concept for all members of the VO, particularly Lockheed Martin (Augustine, 1997). In this VO, trust provided the initial attraction that tied members together, as well as the background music that allowed the members, and the safety- and mission-critical systems they developed, to dance together effectively.

Trust on the SmartBridge project, however, had a temporal quality. Initially, when VO members were excited about the opportunities joint software development and integration posed, much proprietary product and planning information, as well as member-confidential development and integration strategies were exchanged. Over time, however, as the VO matured, and the strength of the linkages between some members faded, the initial trust between some members faded. Some members, although partners on paper, were excluded from planning and integration discussions late in the project, and less proprietary information overall was exchanged as the project matured. The introduction of new project management by one VO member led to routine questions about the wisdom of joint software development, and the utility of proprietary information exchanges. Thus, as this VO matured, trust among some members of the VO waned, suggesting that management of trust in VO's requires at least as much effort and interest as management of the organization and its linkages.

How Virtual Organizations Might Mitigate Risk

The characteristics discussed previously — variations in organizational structures and communications patterns, challenges to developing strong cultures and barriers to trust — present particular challenges in mitigating risk in VO's. In this section, we synthesize our observations of how VO's might mitigate risk.

VO's are characterized by multiple organizational structures. With careful attention to design, these structures can be rendered sufficiently malleable so they provide flexibility and functionality in simple as well as complex modes, depending on the simplicity or complexity of the environment (Weick, 1990; 1993). Both high reliability and VO's require such fluid organizational structures. For example, in waging wars at sea or over land, the U.S. Navy uses a structuring process called composite warfare command. Assets such as cruisers, submarines, and destroyers needed to fight a particular kind of battle are brought together around the centerpiece weapons platform, the aircraft carrier. The number and kinds of weapons platforms depend on the complexity of the warfare environment. When the battle is completed and the environment is simpler, the various weapons platforms disengage one another (Grabowski & Roberts, 1996). VO's require just such an ability to restructure and regroup to respond to changes in their environments.

By their nature, VO's are more diffuse than are traditional reliability enhancing organizations, which may contribute to the existence of overlapping roles across the whole of the VO. For example, in a VO comprised of a hospital, a pharmacy tied to a nursing care center, and an outpatient mammogram center, all geographically dispersed, individuals in several units may be concerned simultaneously or sequentially with drug prescriptions, radiation technology, or patient after care. If this dispersion is managed appropriately, participants can understand other participants' operations, constraints, goals, and contributions, as well as the role each plays in the organization's shared mission. Flexibility in structure not only permits organizations to adapt their structures to variances in tempo and complexity, but also provides opportunities for members with overlapping roles to clarify those roles and responsibilities so everyone knows what to do as events unfold.
The communications that accompany these structural changes are critical to the success of the VO, as they provide opportunities for members to understand roles and responsibilities as the organization changes, and to learn the utility of various organizational structures in different environmental conditions. Fluid organizational structures, and the communication processes that facilitate them, have much to do with risk mitigation in VO's.

The use of multiple organizational structures--tight and loose coupling (Weick, 1976)--enhances reliability in VO's. Organizational theorists suggest that when organizations are tightly coupled, and consequently fairly centralized, they become brittle and are unable to respond to changing environments (Daft & Weick, 1984; Perrow, 1984). Loose coupling is often called for so the organization exhibits flexibility and can respond to changing requirements and conditions. However, both tight and loose coupling have been observed in reliability enhancing organizations that failed (e.g. Medvedev, 1990; Vaughan, 1996). The simultaneous existence of tight and loose coupling may be seen more often in VO's than in other organizations simply because they are composites of organizations, each with their own coupling characteristics. In bringing organizations into virtualness, managers must explicitly decide what needs to be tightly and loosely coupled, and design organizational structures with appropriate levels of flexibility and fluidity.

Shared cultures are essential to the success of a VO. However, simply espousing common values does not result in shared values, assumptions, or understandings. Rather, careful attention to communication processes at the interfaces of the VO can permit the development of such shared values by creating opportunities for members to interact, to understand one another, and to develop shared mental models of high reliability. For instance, in the response efforts following the Exxon Valdez oil spill, many examples were given of disjoint values, assumptions, communications and understandings (Harrald, Cohn, & Wallace, 1990; Davidson, 1990; Keeble, 1991). Consequently, subsequent response efforts for oil or chemical spills of national significance now focus on use of the Incident Command System (Fire Prevention Publications, 1983; Grabowski, Harrald & Roberts, 1997), which promotes focused, effective, consistent communication of the spill response team's goals, objectives, values, and assumptions. Such communications foster the development of shared commitments by members of the virtual response organization, the development of a culture of safety, and an effective response. Large spill response efforts utilizing the ICS have been noted for greater cohesion, unity, effectiveness, and esprit de corps (Hunter, 1993; National Research Council, 1993).

Risk mitigation is also dependent on effective communication processes at organizational interfaces, where the VO and its members are defined to each other and to the outside world. Such communications transmit the organization's culture, and are particularly important when organizations are distributed across geographical areas. In traditional organizations, the focus of communication is on effective talk among individuals within an organization. In distributed, linked organizations, the focus shifts to communications across system interfaces. This is underscored in distributed systems with risk mitigation mandates.

Risk mitigation in VO's requires special attention to their peculiar characteristics. Because of the pervasiveness of distributed information technology, and the shared processes that underlie the organization, interactions and interdependencies among its members define the organization. Those interdependencies are also related to risk mitigation processes. For instance, fluid organizational structures alone may or may not dampen risk in VO's; however, organizational structures that provide flexibility in
response options as well as communication opportunities for organizational members have much to do with risk mitigation (Weick, 1993). Similarly, communication processes at the interfaces that work to develop a shared culture of reliability and trust also have much to do with risk mitigation. The challenge for VO's is to harness the shared business processes and distributed information technology in a way that permits effective utilization of flexible organizational structures, that permits effective communication of a shared culture across the VO's interfaces, and that promotes the development of trust among members. The interfaces of the VO, and the interactions among the risk factors discussed in this paper, define where attention must be focused. In the next section, we discuss practical advice for managers faced with risk mitigation challenges in VO's.

**What Management Can Do**

In VO's in which risk mitigation is as important an outcome as is productivity, top management needs to develop a cohesive management team that can maintain the "big picture." This team needs to be accepted by all players in the VO. Such teams have parallels at the individual level, not unlike the incident commander in any incident command system. The team has to be trained in how change at one interface of the organization can have unexpected consequences at other interfaces. The team composition requisite variety should mirror the requisite variety in the VO and in its environment.

One person on the team should be appointed as the czar of structural fluidity. That person's job is to assess and manipulate the lines of communication and resource transfer that maintain high degrees of fluidity. This person needs to think about the various ways we've indicated organizations achieve structural fluidity (network, platform or lateral forms). This czar also needs to be sensitive to appropriate usages of loose and tight coupling. He or she needs to ask questions about the functions of one over the other, perhaps protecting the VO's core with tight coupling.

A second czar can attend the related problems of communication, culture, and trust. In organizational parlance, it is rare to see any one of these processes discussed in the absence of the other two. This czar might wish to start by assessing the various cultures likely to be found in various parts of the VO. A major task may well be trying to work with different participants to figure out key cultural constructs that must be similar across them. One obvious candidate is the development of an appreciation for safety and constant attention to developing risk mitigation strategies. Another task might be to obtain information from each unit about the kind of culture it expects or desires in itself and in other units. That may be a first step to developing an amalgamated, agreed-upon culture.

These activities will also elucidate for the czar the kinds of communication taking place within and across units. Does communication clarify goals and relationships among participants? Are they opportunities for people to develop new risk mitigation strategies and improve old ones? Does communication serve to buttress the social support system? If the answers to these questions are no, efforts must be taken to open up communication along with the structural fluidity across the partners.

Properties of the third leg of the communication-culture-trust stool should become apparent as the first two legs are given attention. As we said, developing trust is a complex and time-consuming task. It needs to be done first at the small group level. One way to do this is through training. One can easily imagine an incident command system
fighting a large urban wildfire bringing in widely geographically distributed fire teams. To enter dangerous places and do its job, each team must have faith that all its members and all members of other teams are well trained. Another mechanism for obtaining trust is through fluid communication. The VO’s attention to organizational fluidity and open communication should also increase trust.

Organizations often fail to attend these issues because of the perception that the high cost of developing social adhesive exceeds the costs of errors that may ramify through systems. We have very good evidence from high profile accidents that this isn’t true (Davidson, 1990; Weick, 1993; Harrald, Cohn & Wallace, 1992; Read, 1993; Vaughan, 1996). The kind of internal team we propose here is only one mechanism for dealing with these nebulous issues. Another mechanism is to bring in outsiders who can see social processes with fresh eyes. Again, a team of outsiders is probably warranted if the requisite variety of the VO is to be matched with the requisite variety of the problem solvers. These suggestions provide some ideas of practical steps managers faced with risk mitigation challenges in VO's might take. In the next section, we discuss a theoretical and research agenda associated with risk mitigation processes in VO's.

Theoretical and Research Agenda

A general drawback to all behavioral science research on VO's is their inherent "temporariness." In addition, there are a hodge podge of descriptions of them. Researchers need to push for definitional clarity, as well as to investigate many different types of network and VO's (Monge & Contractor, 1998; Palmer & Speier, 1997). At the same time, a host of research issues associated with VO's suggest themselves. We suggest a series of research assertions related to the issues discussed in this paper that should be tested.

Structuring

We propose that VO's will structure themselves to obtain maximum flexibility and adaptability. Researchers may want to adopt some of the rich structural metaphors currently being discussed in developing propositions about organizational structuring in VO's (e.g. Fulk & De Sanctis, 1995; Senge, 1990; Volberda, 1996; Orlikowski, 1996). We offer here three approaches to organizational form that have the potential to maximize flexibility and may influence reliability enhancement. We need to examine the extent to which one or another form best describes the unfolding of a VO and how these forms change over time. With regard to risk mitigation, one might investigate such assertions as:

- Risk mitigating VO's develop recognizable mechanisms that increase internal structure fluidity.
- VO's change their structuring as they move from normal to crisis modes of operation. They also change their structuring as they move from crisis to normal modes of operation.
- VO's engage in network extension to meet increased environmental requisite variety, as those demands present them with situations requiring risk mitigation.
• Multiplexity, reciprocity, and symmetricality are more likely to occur in VO's with long histories of risk mitigation, rather than in VO's that have experienced reliability problems.

• The use of lateral organizational forms in VO's enhances sensitivity to risk propensity and the development of risk reduction strategies because these activities are more apt to occur in situations in which there are strong lateral liaisons.

• Platform organizational forms are best suited to reliability enhancing organizations that provide a product (as Ciborra’s organization does), while network forms are best suited to those organizations providing a service (fire services, for example).

• VO's involved in long-term strategies to mitigate risk are more apt to adopt platform types of structuring than are VO's involved in short-term risk mitigation strategies because platform organizations are relatively permanent.

• The cognitive frameworks of managers in successful risk mitigation VO's are relatively more "nimble" than are the cognitive frameworks of managers in less successful VO's because of the necessity for flexibility in obtaining restructuring.

A major discussion in the organizational structure literature concerns the inappropriateness of tight coupling for reliability enhancement. We observe that loosely coupled or entirely disconnected systems can cause accidents as readily as can tight coupling. From these observations, the following assertions might be tested:

• Tight and loose coupling are both appropriate in different parts of VO's. Core functions of these organizations must be tightly coupled. Environmental sensing functions must be loosely coupled.

• Loose coupling of inter-unit interactions contributes to reliability enhancement.

Studies of network dynamics and evolutions (Stokman & Doreian, 1996) provide some descriptions of change in networks, as well as of mechanisms that determine change. New, more specific theories of network and emerging organizations are needed that describe both characteristics of VO's and processes that give rise to their evolution (Brass, 1995; Salancik, 1995; Monge & Eisenberg, 1987).

Communication

Studies of communication in large-scale systems often focus on the impact of technology on communications (e.g. Steeb & Johnston, 1981; Gallupe, De Sanctis, & Dickson, 1988; Clemons & Row, 1992; Hart & Saunders, 1997), or on the relationships between communication and participation (e.g. Gallupe, et al., 1988; Steeb & Johnston, 1981). Few studies address system-wide communication, its collective impact on a system, or the impacts of communication on system performance. We suggest the
following possibilities:

• Risk mitigating VO's are characterized by communication that clarifies their goals, relationships, and responsibilities.

• Communication in risk mitigating VO's is characterized by large amounts of content addressing safety issues.

• In VO's with good risk mitigation histories, redundancy is built into communication lines.

• In VO's with good risk mitigation histories, the degree of communication richness reflects the requisite variety of the environment, not of any particular point in time.

Although the amount of research on social support networks has increased substantially in the past few years, few studies have examined networks of social support in organizational contexts, even though several scholars have underscored the need for research in this area (e.g. Bass & Stein, 1997). As virtual and network organizations become increasingly common, and individual workers are distanced from institutional support structures of traditional organizations, increasing needs for such research will be felt (Monge & Contractor, 1998).

Future communication research associated with mitigating risk in network and VO's needs to respond to calls for conceptual delineation between uncertainty reduction and equivocality reduction (Weick, 1979), a potentially useful but as yet untapped area of inquiry (Monge & Contractor, 1998). Further, past network research based on uncertainty reduction theory has not distinguished between uncertainty reduction and uncertainty avoidance (March & Weissinger-Baylon, 1986). Resolution of these open questions will be important to future communication research in VO's.

Culture

Organizational culture studies typically focus on one organization or on a network of organizations. A myriad of issues suggests themselves here. Recently, some research attention has been devoted to understanding how organizations learn (e.g. Attwell, 1992; March, Sproul, & Tamuz, 1991; Schein, 1992; Wishart, Elam, & Robey, 1996). How organizations learn certainly influences the cultures they develop. A major challenge in VO's is to identify where the system cultures must be strong and unified and where "a thousand flowers" can be allowed to bloom. A related challenge is to develop ways to insure that an appropriate culture adhesive is in place in those parts of the system in which it is needed. This suggests the following assertions might be tested:

• Strong cultures are required at the interfaces of VO's to ensure reliability enhancement.

• Risk mitigating VO's develop strategies for oversight as well as checks and balances in their cultural fabrics.

• Member goals, roles, and responsibilities are more carefully
articulated in risk mitigating VO's than in other types of VO's.

- Clarification of roles, responsibilities, and interdependencies with others by system members will pinpoint those places in need of strong cultures in VO's.

- Content analysis of electronic mail in risk mitigating VO's should disclose more messages about concerns, findings, hypotheses, and goals than in other VO's.

- A diversity of cultures is desired in engineering units concerned with things like rocket ship launches and units dealing with weather characteristics for these launches (because the whole is more likely to uncover all potential risk than is either part).

- A desirable diversity of cultures will be supported only under conditions of high trust and open communication.

- Incentives and control systems in risk mitigating VO's should directly address behaviors desired to obtain low risk operations.

**Trust**

While trust has long been a major issue in the organizational literature, there is little systematic research on its place in VO's. Our previous discussion suggests assertions like the following might be examined:

- Risk mitigating VO's devote significant numbers and types of activities to building trust. These activities might take the form of training, encouraging interpersonal interaction, and increasing interorganizational linkages.

- Risk mitigating VO's engage in activities that encourage shared commitment as one element of building trust.

- In VO's in which risk mitigation is high, group meetings using lateral organization forms are used to further the development of trust.

- The organizational form best suited to risk mitigation in VO's is the platform because trust enhancement is higher in platforms than in the network form.

- In VO's with good risk mitigation histories, interpersonal trust is higher than in VO's with poor risk mitigation histories.

We have identified several general areas for research in VO's seeking to mitigate risk. Some of these areas of research are applicable to all VO's. Some are more critical to VO's in which error reduction is a major factor. What makes their exploration critical is the paucity of empirical or theoretical work done in VO's, at the same time that there are increasing demands for higher levels of safety and performance in them.
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