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MANAGING RAPIDLY DEVELOPING CRISES:
REAL-TIME PREVENTION OF SYSTEM ACCIDENTS

Robert G. Bea
Department of Civil & Environmental Engineering

Karlene H. Roberts
Haas School of Business

Marine Technology & Management Group
University of California
Berkeley, California

ABSTRACT

This report summarizes results from a study exploring how various communities of organizations manage rapidly developing crises and turn such crises into successes that are often referred to as 'near-misses.' The communities included in this research include commercial and military aviation, nuclear power, emergency medical services, fire fighting, law enforcement, oil refining, commercial shipping, and offshore oil and gas drilling and production. Here, we address strategies that can be used to better anticipate and manage rapidly developing crises that can develop into low probability-high consequence accidents involving marine systems such as ships and offshore platforms. We focus on crisis intervention: learning how to more frequently turn potentially catastrophic sequences of events into near-misses.

This paper defines crisis and discusses its effects. It then highlights our experiences with crises in the marine industry, and discusses how crises are usually studied and how they should be studied. Finally, it offers suggestions about how we can learn to improve crisis performance through improving the development and implementation of emergency action plans.

INTRODUCTION

During the past three years, the Berkeley *Marine Technology and Management Group* human and organizational error research has addressed strategies to better anticipate and manage rapidly developing crises that can result in low probability - high consequence accidents. Development of safety in marine systems has traditionally used two fundamental approaches: proactive and reactive (Rasmussen, 1996). The proactive approach is analytical, depends on the predictability of the system, and is focused on infrequent accidents. A major difficulty with most proactive approaches (e.g. probabilistic risk analyses) is that they can not adequately characterize and analyze complex future human and organizational interactions with systems. How can one develop an analytical model of what one can not characterize and predict? The reactive approach is fundamentally empirical, based on experience, focused on fixing the last accident, and primarily addresses frequently occurring accidents. Much of the field of worker and system safety has been built on the reactive approach.

We propose that there is a third approach to achieving safety in marine systems. This is real-time management as the accident unfolds. This is management based on OODA (Observe, Orient, Decide, and Act) 'loops' (recursive trials), migrating decision making, divide and conquer deployment, and requisite variety in problem identification and solving. We specifically focus on crisis intervention and learning how to more frequently march backward from the precipice of crisis to 'near misses.'

Experience with complex technological systems indicates that behind each major accident is something of the order of 10 to 100 near-misses, and perhaps 100 to 1000 hazardous acts or events (Groeneweg, 1994). It is obvious that people frequently interact with systems to produce safe operations. We want to increase the proportion of successful interventions, particularly as potentially high hazard or consequence events unfold.

The vast majority of high consequence - low probability accidents involving marine systems such as ships, fixed platforms, mobile offshore drilling units, and pipelines, are caused by human and organizational factors. The fundamental problem in most cases is not hardware but 'peopleware.' That most of these accidents could have been prevented even though they involve operator actions that contain fundamentally unpredictable combinations of events, is unsettling. Many of these accidents consist of rapidly unfolding sequences of events in which the pace of operations

is dramatically increased and the normal organization structure rendered ineffective.

Many marine accidents are fundamentally the result of human operators 'pushing the envelope,' and thereby breaching the safety defenses of an otherwise safe system (Bea, 1995; Bea, Roberts, 1995; Moore, Bea, 1995). Today, frequently these breaches develop under pressure to 'outsource' (contract crews), save money, time, and work (Bea, 1996). Many actions that cause breaches can be termed violations, doing what we know we should not be doing (Dougherty, 1995). Often they include degradation of defenses. For example, maintenance of safety systems is insufficient, complacency replaces vigilance, and accidents follow (Reason, 1990; Weick, 1995a; Pidgeon, O'Leary, 1995).

Recently, the developers of the ISM (International Safety Management) code have recognized the importance of crisis management and guidelines are being developed to better define what is needed to successfully manage crises onboard ships. The Intersessional Working Group on the Outcome of the 1995 STCW has issued "Special Training Requirements for Ro-Ro personnel (Conference Resolution 5)" that are proposed as an amendment to the STCW Code titled "Crisis Management and Human Behavior Training." The marine industries are recognizing the importance of real-time crisis management.

Our research indicates that many of the accidents that have and are plaguing the marine industries result from rapidly developing crises that are not appropriately recognized and managed. Most of these crises fundamentally are not predictable, and evolve so rapidly that optimum decisions and management are not possible (Nickerson, 1995).

This paper highlights results from our research on management of rapidly developing crises. This cross-community research is attempting to learn how organizations approach management of rapidly developing crises, how they maintain crisis readiness, and what they do in practice to turn potentially catastrophic crises into near-misses. This work is focused on preventative measures and real-time management. It involves organizations that have historically recognized they are faced daily with the threats and challenges of crises. The objective of this research is to learn from the laboratory of real world experience how the marine industries might best put measures in place to improve the safety of their systems, while preserving and improving profitability. The communities included in this research are law enforcement, municipal fire fighting, U. S. Navy aircraft carrier flight deck operations, commercial aviation (United Airlines, Boeing), air traffic control, nuclear power plant operations, emergency room and paramedic operations, commercial shipping, oil and chemical refining, and offshore drilling and production operations.

In performing this research we used five sources of information. Our first source was interviews with recognized experts in crisis management. We wanted to understand what they had learned in the crucible of experience about how to successfully manage crises, that in some cases occur on a daily basis (e.g., emergency rooms, law enforcement, commercial aviation). Our second source was direct observations and participation in the operations. We learned first hand about the 'ballet' and 'improvisation' (Weick, 1996) of crisis management operations. The third source was interviews with people who had been involved in accidents and near -misses. Many unique aspects of accidents and incidents were developed from these interviews. Interviews provided a richness and insight that could not be obtained from current accident and near-miss reports and databases. The fourth source was interviews with other researchers working in this or closely allied fields (e.g. military operations). Their insights and experience expanded the breadth and depth of our work. Our fifth source was to review the engineering, technical, management, and industrial psychology literature. These five sources of information provided a rich and coherent picture of crisis management 'best practices.'

CRISIS DEFINED

We define a crisis as a rapidly developing sequence of events in which the risks associated with the system rapidly increase to a hazardous state (Fig. 1). The crisis begins with a surprise warning of some type that the system is moving from a safe to an unsafe state. Crises involve potentially grave life and property threats.

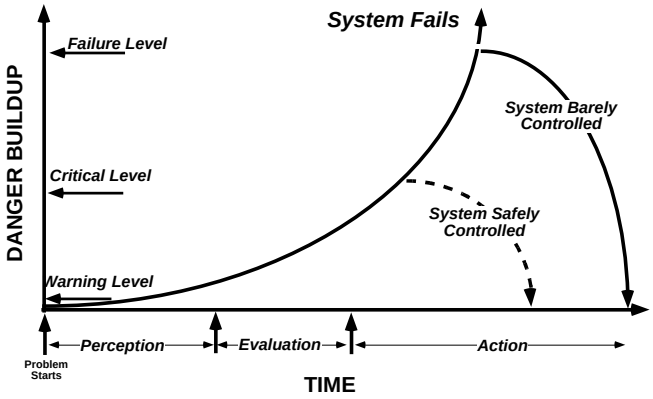

FIG. 1 - EVOLUTION OF A CRISIS

Lagadec (1993) describes crises as "events that do not play by the rules." These destabilizing breakdowns seem to feed on themselves and overwhelm normal problem solving resources. Crises are characterized by a threatening of normal values and goals, pressures to decide quickly, short times to act, unexpected events that shock, confusion, pressures to innovate in solving the crisis, development of limited options, developments in which inaction produces undesirable consequences, incomprehensible developments,

information overload, ambiguity and uncertainty, increased numbers of important demands, conflicts, limited resources, problems lumped together, exaggerated deviations, intense scrutiny, and loss of critical functions. Crises are traumatic affairs.

Lagadec further observes, "the ability to deal with a crisis situation is largely dependent on the structures ...developed before chaos arrives. The event can in some ways be considered as an abrupt and brutal audit: at a moment's notice, everything that was left unprepared becomes a complex problem, and every weakness comes rushing to the forefront. The past settles its accounts." Sarna (1996) characterizes crises as "...not the kind of incidents that occur on a regular enough basis to allow incident commanders to build a personal data base of experience."

In its simplest terms, a crisis can be divided into three general stages (Fig. 1): 1) perception, 2) evaluation, and 3) action. The first stage requires individuals to perceive and recognize warning signs of the evolving crisis. The second stage involves processing information to identify problems and causes, alternatives that might bring the system back into a safe state, consequences associated with each alternative, evaluation of alternatives, and the choice of alternative or alternatives to be implemented. The third stage involves implementing the alternative, and observing the results. If the observation indicates that the alternative is not working, the process must be repeated selecting a different alternative. If the system cannot be brought back to a safe state, an accident happens. If the system can be brought back to a safe state, a 'near-miss' or 'incident' occurs.

This characterization of crisis raises issues about strategies that can more frequently bring marine systems back to safe states and to understand how to have more 'near-misses' than 'direct hits' (accidents). To do this, we will explicate in greater detail what we have learned from the various communities how they have learned to successfully manage rapidly developing crises.

Rasmussen (1986) defined a crisis decision making model involving six steps: 1) monitoring and detecting, 2) interpreting the current state, 3) determining its implications, 4) developing a control plan, 5) implementing control actions, and 6) observing and obtaining feedback on the effectiveness of the control plan. This is a process that has been identified as OODA (Observe, Orient, Decide, Act) loops (Orr, 1983).

Fig. 2 summarizes the key steps in managing rapidly developing crises, based on Rasmussen and results from our research. Fig. 2 can be interpreted as a more detailed breakdown of Rasmussen's six steps and the three phases identified in Fig. 1. Fig. 2 details several additional important aspects of crisis management that are focused on the critical decision making and implementation aspects of developing a successful crisis management strategy. These include such activities as integrating information, establishing goals and priorities, reflecting and debriefing, etc. Weick (1995b) summarized this process as: "1) here is what I think we face, 2) here is what I think we should do, 3) here is why I think this, 4) here is what and why we should watch, and 5) now, talk to me!"

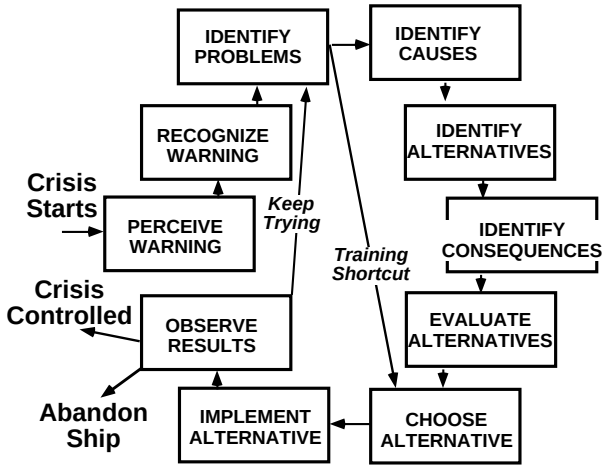

FIG. 2 - MANAGEMENT OF CRISIS

Note the potential effect of training in Fig. 5 (other 'short-cuts' are possible but not shown). Training can help eliminate much of the cognitive processing required to determine what should be done. This allows effective alternatives to be rapidly defined and implemented.

Also, note the importance of observations. Observations provide clues to determine if implementation is producing the desired results. If it is not, the processes of identification and evaluation need to be repeated to help arrest the crisis. If clues indicate the crisis is being arrested, the process must be continued until the emergency is over. The process should not be stopped until adequate safety has been achieved.

EXPERIENCE WITH MARINE SYSTEMS

Research on Human and Organization Errors (HOE) in design, construction, and operation of marine systems clearly indicates that the majority of high consequence, low probability accidents are due to HOE (exherent factors) (Moore, Bea, 1995) which are often identified as 'acts of man.' Inherent or environmental factors that represent residual or expected hazards account for only about 20% of these accidents which are often identified as 'acts of god.'

As might be expected, the majority of HOE induced accidents (approximately 80%) occur during the long-term operations phase of the life cycle of a marine system. These mal-operations frequently involve HOE in the maintenance that is not done or not done properly during the operations phase, resulting in long-term and observable systemic erosion of the system safety barriers. In many cases, accidents

that occur during the operations phase frequently have root causes in HOE that are developed during the design and/or construction phases.

Five critical elements are generally involved in failures of marine systems: 1) hardware (equipment, structure, facilities), 2) procedures (software), 3) environments (internal, external, social), 4) organizations, and 5) individuals (the people with their hands on the controls). A failure can be initiated and/or propagated by a failure of any one of these five elements or a combination of them. In addition, failures can develop at the interfaces between or among the five elements. When we refer to a marine system, we include each of these five components in the system.

The research has involved the study of a large number (more than 600) of well documented case histories of major accidents involving marine systems (Moore, Bea, 1995). It has identified three categories of HOE related events involved in the accidents: 1) initiating events, 2) contributing events, and 3) propagating events (Fig. 3).

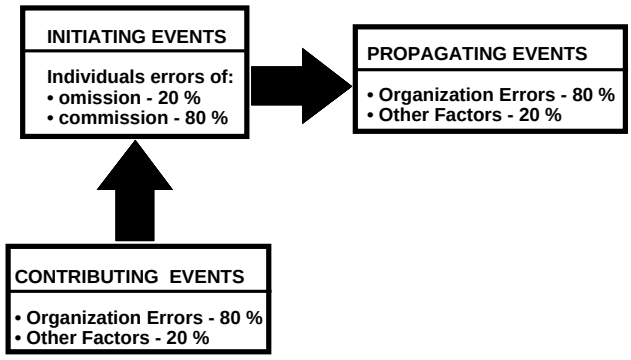

FIG. 3 - INITIATING, CONTRIBUTING, AND PROPAGATING EVENTS IN ACCIDENTS

Individual errors of commission dominate the initiating events while the dominant contributing and propagating events are related to organization errors (e.g. due to poor communications, lack of adequate planning and preparations, lack of resources, conflicting safety and production objectives, etc.).

This experience indicates that while efforts to reduce individual errors of commission are important, it is equally important to reduce the associated contributing and propagating organizational errors. Experience with accidents and near-misses indicates that it is through organizational aspects that we may have the greatest impact on interrupting potentially hazardous compounding of events and returning the system to a safe state.

In a detailed study of 100 accidents that involved ships at sea, Wagenaar and Groeneweg (1987), identified three general categories of causal factors (Fig. 4). The dominant category was cognitive (information processing, hypothesis development, etc.), while the second category was situational (environmental, physical, ergonomic). Social factors (roles, incentives, motivations, influences) did not play a dominant role in the accident causation. The cognitive and situational causes are further detailed in Fig. 5 and Fig. 6, respectively. Development of incorrect hypotheses and bad habits relative to safety are the dominant and leading cognitive causes followed by poor training, risk-taking personality traits, and incorrect information processing. Motivation and illusions play minor roles. The leading situational influence is poor ergonomics or man-machine / equipment interfaces. Environmental (storm seas, fog) and physical (fatigue, drug influences) causal rates are half to one-third those of the ergonomic influences.

This assessment indicates high priorities should be given to improvements that enhance operator cognitive skills and to improvements in the ergonomic aspects of their systems to both prevent accidents and permit operators to more frequently rescue their systems. Using the same database, Wagenaar and Groeneweg identified the numbers of people and the numbers of errors involved in causing accidents. Their results are summarized in Fig. 7. Accidents most frequently involve one person who makes three errors, closely followed by two people who make four errors. Extreme cases involve 3 to 4 people who make 6 to 10 errors before the accident happens.

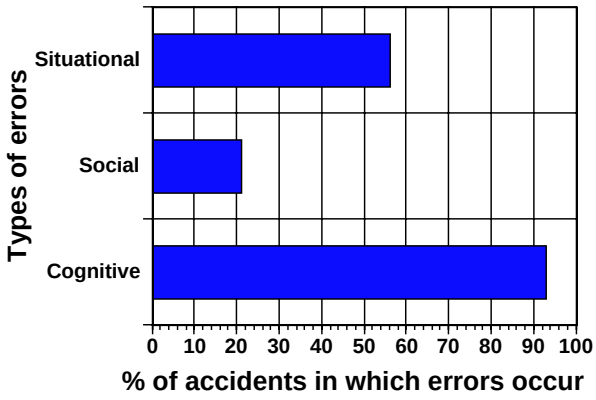

FIG. 4 - CAUSES OF 100 ACCIDENTS

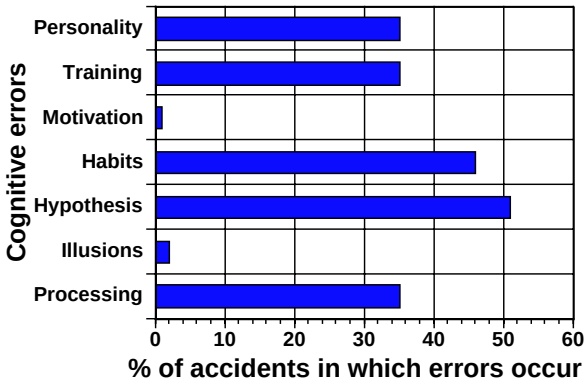

FIG. 5 - COGNITIVE CAUSES

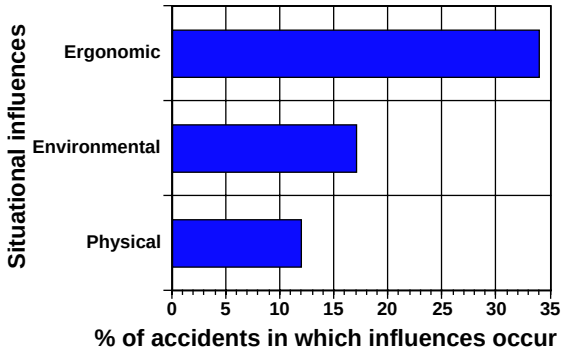

FIG. 6 - SITUATIONAL CAUSES

The number of errors indicates the potential opportunities to recognize the evolution of the accident (detection) and correct the evolution. The numbers of people involved indicate that this is not a large-numbers problem, but rather, individuals and small teams of 2 to 4 people. All of these findings are borne out by our research.

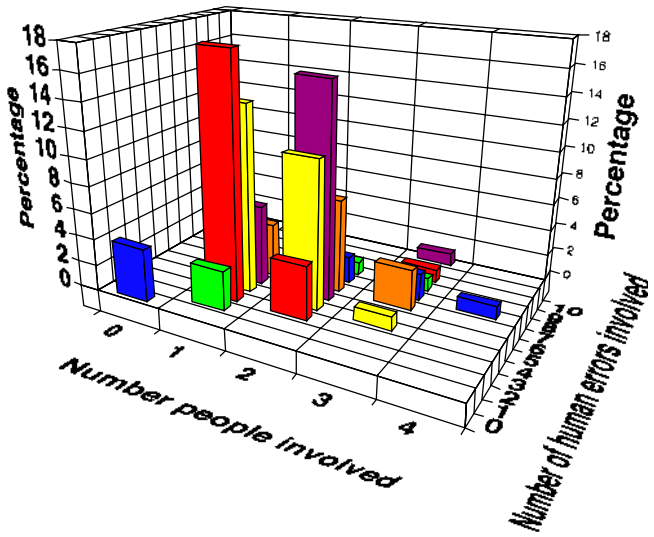

FIG. 7 - NUMBERS OF PEOPLE AND ERRORS INVOLVED IN ACCIDENTS

CRISIS RECOGNITION

Perhaps no stage in a crisis is as important as the first stage: recognition or perception. Because the crisis is just unfolding, if the situation can be quickly and correctly recognized, there will be more opportunity and time to bring it under control.

Humans seem to have a fundamental difficulty accepting the potential danger of a situation under development. In a study of crew and passenger reactions to accidents onboard passenger vessels or ferries (Harbst, Madsen, 1995), it was found that 60% of the people (passengers, crew) ignored or mis-judged the hazards, 30% investigated, and 10% accepted that hazards existed and initiated action. Once the hazard was recognized, something of the order of 10% to 25% panicked or went into shock (crisis paralysis), 50% to 75% behaved in confused helpless ways, and 10% to 30% made realistic evaluations and started positive corrective actions. These researchers observed that "people who have generally accepted the risks associated with an activity are not usually motivated to study or practice safety procedures or recognize early warning signs of a developing crisis." They have become 'risk habituated.'

Three classes of cognitive factors seem to govern how and how well people perceive a crisis (Cook, Woods, 1994):

1) knowledge - background that can be accessed when solving problems,
2) attention dynamics - control and management of mental workload, maintenance of situation awareness, and avoidance of fixations,
3) strategy development - successful trade-off between conflicting goals, dealing with uncertainty and ambiguity, avoidance of organizational double binds, and development of good priorities and decisions.

Feltovich, et al., (1989) identified a number of factors or biases that tend to suppress quick and accurate recognition of a crisis. These include:

- treating a dynamic situation as static,
- assuming that some general principle accounts for all of the observations,
- seeing different entities as more similar than they are,
- treating multidimensional phenomena as unidimensional,
- treating continuous parameters as discrete (uni-valued),
- treating the whole as the sum of its parts,
- treating highly interconnected elements as separable.

Other factors can be added to this list (Bea, 1994; 1996) including:

- failure to revise assessments based on new information,
- evaluation that the desired state or outcome is very likely when it is not likely (wishful thinking),
- over estimation of control over the developments and outcomes (supermen/women),
- over estimation of the predictability of the sequence of events, and
- 'garden path problems' in which strong 'signals' suggest plausible but incorrect answers; weaker signals that suggest plausible and correct answers are ignored or not detected.

Developing and maintaining an awareness of potentially hazardous situations involves a constant process of detecting anomalies; things that are not right or don't fit. This requires constant shifting of attention, a very limited resource, to modify a picture (mental model) of a system as a

whole. Building and maintaining the picture of the system requires cognitive effort, which when it breaks down is called 'loosing the bubble' (Roberts, 1994). It is here that team work can provide additional information, attention capacity, and requisite variety (Weick, 1995a) in insights and potential solutions and enable the team to recognize the early warning signs of the developing crisis and quickly implement effective control strategies.

HOW CRISES ARE USUALLY STUDIED AND HOW THEY SHOULD BE STUDIED

There are two common ways to develop safety practices in the marine industry. One is to develop statistical predictive models based on past incident data. The data come from accident data bases or from case studies. Our research includes study of a wide variety of accident databases on marine systems (Wagenaar, Groeneweg, 1987; Moore, Bea, 1993). We have not identified one database which adequately addresses initiating, contributing, and propagating factors, has incorporated an adequate HOE taxonomy, has addressed the identified five elements, or has utilized sufficiently well trained accident investigators over a sufficient period of time.

The implication is that existing accident databases cannot be relied upon to provide objective and definitive information on HOE in marine systems. Much data base development has its roots in the nuclear power and chemical processing industries and in the military (organizations which are developing a healthy skepticism about the quality of such data). Our research indicates a prevalent tendency to over use or over believe quantitative or 'hard' approaches (e.g. probabilistic risk analyses based on event trees, fault trees, and influence diagrams). The qualitative or 'soft' approaches frequently lack rigor and consistency.

The other approach is to use experienced based empirical methods that utilize information from past accidents to help remedy causes of infrequently occurring accidents. A large body of experience is the basis for identifying and implementing effective safety measures. Many work safety practices were derived from such methods.

Information from infrequently occurring accidents can provide insights to identify progressive changes to remedy accident causes. Regulations and safety measures put in place following major accidents are symptomatic of this approach. Both of these retroactive strategies represent a fall back position based on the near impossibility of studying accidents in the making 'real time'.

Because of their rarity, management of very low probability - high consequence events generally must rely on predictive analysis of possible accidents. Traditional experienced based empirical and analytical safety and accident prevention approaches should not be relied on exclusively in developing strategies to manage high consequence, low probability accidents.

The approach developed during this research relies on real-time management of safety. This approach is focused on managing unfolding combinations of 'weird' events that pose catastrophic hazards or risks to marine systems. It involves detecting the hazardous developments in the systems, evaluating and defining appropriate responses, and returning the systems to safe states. Alerts and the weeding out of near-misses, and incidents are symptomatic of the success of this second approach. Our work and the work of others (e.g. Lagadec, 1993; Huey, Wickens, 1993; Cook, Woods, 1994; Boeing, 1996) indicates that such real-time management is frequently responsible for keeping systems running safely on a day-to-day basis. A purpose of our research is to understand how to enhance real-time management strategies and techniques.

Many accident investigations stop with identification of the initiating events or factors and fail to examine or identify the contributing or propagating factors. Our research identifies the vital importance of the contributing events in determining the initiating events and the compounding events in allowing the initiating events to escalate or propagate to catastrophic proportions (Bea, Roberts, 1994). This identification is critical to the development of proactive accident prevention measures and crisis management measures (focus on both initiating and propagating events).

The majority of the initiating events involve individual errors of commission (approximately 80%) in which the action or actions carried out by individuals are erroneous (Reason, 1990). Application of more sophisticated classification systems (taxonomies) indicate that these errors of commission most frequently involve communications, selection and training, cognitive (information processing), and violation (intentional) errors. Sliced another way, skill based and knowledge based actions and violations are principally involved in these initiating events.

The majority of the contributing events involve organizational errors (approximately 80%). These errors include those of incentives (rewarding 'A' while hoping for 'B') (Kerr, 1975), communications (who knows what and when) (Bea, Roberts 1995), management (planning, organizing, leading, and controlling to avoid errors) cognitive processing, and violations. Similarly, the majority of contributing events involve organizational errors (Roberts, 1993).

Qualitative, quantitative, and 'mixed' auditing or assessment approaches have been developed and applied in accident prevention. Each has its powers and weaknesses and each is being further developed as a part of this research (Bea, 1996).

The most frequently overlooked and under appreciated element involves the user or auditor applying any one of these approaches. Any of the tools are only as good as the people who apply them and interpret their results. However, all of these tools if properly used can be used to good advantage in certain circumstances in the attempt to

proactively evaluate or assess systems, identifying potentially 'weak links', and then identifying how best to improve their safety.

IMPROVING CRISIS PREVENTION

The usual approach to investigating crises in the interests of improving crisis prevention is to look for maintenance and design failures to equipment, particularly in the marine industry. If the human element is considered at all it is the hands-on (directly involved) 'operators'. The investigation is usually closed after operator blame is established, particularly if the operator fails to survive and is, therefore, out of the picture.

If one accepts our definition of crisis, this focus on operators is clearly misleading. A rapidly developing sequence of events in a system implies the contribution of more than a single or a few operators to the outcome. The term system suggests the simultaneous activities of many system subunits. The five critical elements in marine failures discussed previously also alert attention to the larger system with its many players.

The three stages of crisis discussed (perception, evaluation, and action) direct attention to the importance of perceiving organizational activities appropriately. In perceiving organizational activities people come to make sense of their perceptions. In recent years a considerable amount of attention has been directed to the process of sensemaking in organizations (Weick, 1995a).

For purposes of reducing risk or improving crisis prevention we need to look at two aspects of sensemaking, how individuals make sense of things and how groups and organizations make sense of things. We need to tease out of these implications for management policy and future research needs.

People construct events. "How they construct what they construct, why, and with what effects are the central questions for people interested in sensemaking (Weick, 1995a, p. 4)." "In real world practice, problems do not present themselves to the practitioners as givens. They must be constructed from the materials of problematic situations which are puzzling, troubling, and uncertain. In order to convert a problematic situation to a problem, a practitioner must do a certain kind of work. He must make sense of an uncertain situation that initially makes no sense (Weick, 1995a, p.9)." To engage in sense making is to construct, filter, and frame perception into something more concrete (Turner, 1987). In dealing with crisis prevention it is in part parsing activities into those which might be initiating, contributing, and propagating events.

At the heart of sensemaking is the sensemaker who says according to Weick, "how can I know what I think until I see what I say?" Weick cautions that no individual acts as a single sensemaker. He or she is in fact, a myriad of persons. He or she thinks of an audience even when inventing monologues. Thus, sense making is grounded in the identity construction of the sensemaker. It has six other characteristics. It is retrospective in the sense that it makes sense of events after they happen. It enacts sensible environments and is driven by plausibility rather than accuracy. People extract cues from their environments from which they draw sense and they try to produce the environments they're in. It is social and ongoing suggesting that the individual never really makes sense of things alone.

These seven characteristics of sensemaking have some implications for people who must perceive changes in risk in their organizations. One implication is that people need to talk constantly with one another to see what they say. They need to create a climate in which differences in perceptions are accepted and the acknowledged work is to develop as rich a picture of the organization as possible, that includes all of its interacting participants. Organizational members need to clearly understand that each of them brings a different set of identities to the task. They need to be alerted to the fact that their prescriptions of future events are based on sensemaking of the past. Writ large, this acknowledges what militaries have long known, in practicing for the next war they fight the last war. They should also be aware of the fact that they draw limited cues from their environments and that environments may not be as sensible as they enact them to be, but that trying to draw some order from chaos may have positive implications in terms of directing otherwise turbulent activity. It may be artificial to parse activities as initiating, contributing and propagating factors but this parsing provides a framework on which to develop a control plan. The social and ongoing nature of sensemaking draw our attention to the fact that an individual in isolation is almost never the total sensing unit. About as close as one comes to that is in sensemaking in isolation with only thoughts about other people's reactions, inputs, etc.

ENTER THE ORGANIZATION

Wiley (1988) discusses three levels of sensemaking above the 'individual' level. In ascending order they are intersubjective, the generic subjective, and the extrasubjective (Weick, 1995, p.70)." Intersubjective meaning occurs when a person's thoughts, feelings, and intentions are merged into conversation in which the individual is transformed from I to we. People are joined or merged. Organizations are included at the next level, the level of social structure. "Social structure implies a generic self, an interchangeable part - as filler of roles and follower of rules-but not concrete, individualized selves (Weick, 1995, p.71)." Sensemaking through generic subjectivity is the main work of the organization. In stable times generic subjectivity takes many forms, including scripts or SOP's (Standard Operating Practices). When something happens to disrupt stability, such as the introduction of a new technology, the current form of generic subjectivity no longer

works. Inter-subjectivity is the focus of sensemaking because new views of what's going on emerge and have to be synthesized.

Weick argues that organizing is the umbrella over the movement from intersubjective to generically subjective. Organizing is a mixture of intersubjective understandings and understanding that can be picked up, expanded, enlarged, perpetuated, etc., by people who did not participate in the original intersubjective construction. Organizations are adaptive social forms. As intersubjective forms they create, preserve, and implement innovations that arise from contact. Generic subjectivity focuses and controls the energies of that intimacy. That control drives out innovation and one needs to worry about keeping a balance between the two. Intersubjective processes detect through monitoring, cues about potential destabilizers. Intersubjective and generic subjective processes develop control plans or actions and steps for implementing those plans and actions. Together these processes can extend the time of increased performance in high stress situations.

If organizations are understood to be nets of collective action undertaken to shape the world, with interlocking routines and habituated actions that allow for substitutability, we might look at crisis prevention in a different light than we do now. First, we would almost never look to the human operator as the single source of failure. Returning to Rasmussen's six stages of crisis decision making, our monitoring and detection systems would focus on the content of intersubjective interactions. We would begin to build taxonomies of content interaction that do and do not result in safe performance. Our interpretations of the current state of things would focus on the innovative intersubjective interaction and the generic subjectivity controls. We would look for accord as well as tensions between the two. Our control plan might be formulated with many more possibilities than we usually see, because we would reward the flowering of a thousand visions knowing that generic subjectivity is the mechanism for enhancing as well as pruning those visions. Feedback would be obtained in a different way relying as it would on assessment of its ability to mirror the collective action.

Wiley's (1988) final level of analysis, culture is extra-subjective. A generic self that occupies roles is now replaced by 'pure meanings' (Popper, 1972) without a knowing subject. This is a level of symbolic reality such as we might associate with capitalism or mathematics, each viewed as a subjectless batch of culture (Weick, 1995, p.72)." Again, returning to Rasmussen, his stage of crisis decision making we failed to address previously is determining the implications of the current state of affairs. To do this, decision makers in the organization need to look well beyond the organization's skin to identify those institutional aspects of society that both infiltrate the implications and may be impacted by those implications. Some possibilities are the values a society places on the loss of life and property, and the values it places on selection and education that in the current crisis or pre-crisis state is needed by the organization.

Our research clearly shows that the culture of an organization has important influences on its ability of to operate safely. Others have found the same thing (Pidgeon, O'Leary, 1994; Zohar, 1980; Turner, 1978; 1990; Weick, 1995a; Wenk, 1988). The culture of an organization is not a simple thing to define, characterize, or measure. It is rooted in the organization's history and the society in which it exists. Culture has many potential layers and facets. Organization cultures are extremely resistant to change. Many researchers would contend that organization cultures are impossible to change rapidly.

Organization culture can be defined as a system of observable expectations, incentives, and behaviors (Rohner, 1984). Alternatively, organization culture can be defined as a system of meanings or a shared cognitive system (Turner, 1978).

In this second context, a 'safety culture' can be characterized as the "set of beliefs, norms, attitudes, roles and social and technical practices within an organization which are concerned with minimizing the exposure of individuals, both within and outside the organization, to conditions considered to be dangerous" (Pidgon, O'Leary, 1994). Study indicates that a safety culture can be translated to five categories of activities by the organization:

1) Commitment to 'safety first' at a strategic management level that results in a real and long-term demonstration of concern and action (top-down),
2) Distributed attitudes of care, concern, and action that permeate the entire organization (bottom-up),
3) Appropriate norms, rules, and procedures that remove explicit and implicit conflicts in safety versus production or service, promote proactive safety, and provide for real-time management of crises,
4) On going reflection, audit, critique, and feedback on the health and well being of the system (including its human parts); and
5) Timely, effective, thorough, and honest communications (verbal, non-verbal) that effectively bind individuals, teams, and the organization together.

Our work clearly indicates that the existence of a strong safety culture is one of the first requirements for an organization to be able to successfully manage rapidly developing crises. The marriage of different organizations in performing operations frequently leads to severe problems because of the clash of cultures (Libuser, Rousseau, 1995). Here again, the use of subcontractors whose organization culture is very different from that of the owner can lead to dramatic problems in managing rapidly developing crises.

CRISIS EFFECTS

One of the most important aspects of crisis is initial surprise and the rate at which the danger to the system increases (Huey, Wickens, 1993). In a rapidly developing crisis, the rate of increase in danger is so rapid there is little time for reflection, exploration, and experimentation. There is little time for optimized decision making and no time for a 'time-out.' This creates significant 'stress' for those faced with crisis management. Stress results from our reactions to real or imagined threats to our welfare. Stress is dependent on both the person and the situation (Nickerson, 1995).

This stress has many potential effects resulting in disintegration of performance skills, escalating aggravation, development of avoidance mechanisms, regression to simpler behavior, degraded judgment, exaggerated personality traits, degraded interactions, depression, withdrawal, deformation of data, instability, defensive management, hyper vigilance, narrowed focus, rigid reasoning, arbitrary decisions, reduction in abstract reasoning, reduction in tolerance for ambiguity, and contraction in authority (Lagadec, 1993). Huey and Wickens (1993) identified the critical effects of stress on crisis management as attentional tunneling (focusing of attention on one particular task), loss of working memory, degradation in communications, disruption of long-term memory, development of strategic shifts (changes in processing strategies), and degradation in decision making.

Research (Yerkes, 1908) has identified an overwhelmingly important potential effect of stress on individuals faced with managing crisis. As shown in Fig. 11, as the level of stress or arousal increases, cognitive abilities increase resulting in increased performance. However, a point of 'overload' is reached which decreases cognitive abilities resulting in decreased performance. As indicated in Fig. 8, a variety of approaches can extend the time of increased performance and high performance in this regime. These will be discussed later.

Stress handling approaches include either eliminating or weakening the stressors, reducing or coping with the stress reactions, selecting stress resistant personnel, training personnel to manage stress, and designing procedural and physical aspects of the system so crisis management goals can be achieved despite stress (stress proofing). Guidance has been developed for how to implement these stress handling approaches (Yates, Klatzky, Young, 1996). Of greatest concern is the effect of stress on cognitive processing because this processing is critical to the detection and management of unimaginable crises (Kontogiannis, Lucas, 1990). Decision making capabilities can be dramatically impaired during high pressure situations.

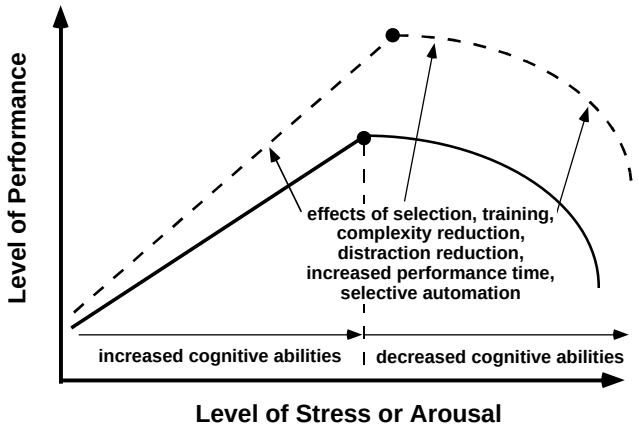

FIG. 11 - EFFECTS OF CRISIS STRESS ON PERFORMANCE

Study of a wide variety of industrial accidents by Kontogiannis and Lucas (1990) has identified a number of cognitive processing phenomena that develop during crises (Table 1). These phenomena help explain the cognitive mechanisms that can precipitate and propagate errors under stress. The cognitive processes important in managing crises will be discussed later in this paper.

IMPROVING REAL-TIME CRISIS MANAGEMENT

Table 2 identifies key problems that develop during a crisis and some primary skills involved in arresting its development (Mumaw, et al., 1994). Each phase that characterize development of a crisis is identified (Fig. 2). Definition of the problems that develop during each phase of a crisis and the skills that are needed to help arrest the crisis provide important clues about how to improve system and people support to arrest crises.

Two fundamental approaches to improving crisis performance are: 1) providing people support, and 2) providing system support (Bellamy, 1994).

People Support.

People support strategies include such things as selecting personnel well suited to address crises, and then training them so they possess the required skills and knowledge. Retraining is important to maintain skills and achieve vigilance. The cognitive skills developed for crisis management degrade rapidly if they are not maintained and used.

Crisis management teams should be developed that have the requisite variety to manage the crisis and have developed teamwork processes so the necessary awareness, skills and knowledge are mobilized when they are needed. Auditing, training, and re-training are needed to help maintain and hone skills, improve knowledge, and maintain readiness. Crisis management teams need to be trained in problem 'divide and conquer' strategies that preserve situ-

ational awareness through organization of strategic and tactical commands and utilization of 'expert task performance' (specialists) teams. Crisis management teams need to be provided with practical and adaptable strategies and plans that can serve as useful 'templates' in helping manage each unique crisis. These templates help reduce the amount and intensity of cognitive processing that is required to manage the crisis. Such a template could include:

a) throughout, question, anticipate, and take initiatives;
b) avoid radical responses, be moderate in seeking gains;
c) capitalize on the opportunities offered by the crisis;
d) look for anything that may add flexibility and slow escalation;
e) avoid making irreversible commitments;
d) do not forget the post-crisis period (recovery, rescue); and
e) keep all communications channels open.

TABLE 1 - COGNITIVE DEVELOPMENTS UNDER STRESS

Development	Characteristics
defensive avoidance	Selective inattention to threatening cues. Avoid thinking about dangers through distracting activities. Passing the buck where someone else is relied on to make the decision. (Kahneman, Tversky, 1979)
reinforced group conformity	Tendency of group to protect its own consensus. Place pressure to confirm on those who disagree. Screening out external information which might break complacency of the group. (Janis, 1972)
increased risk taking	Individuals take greater risks when they operate within a group. Illusion that system being controlled is invulnerable. Diffusion of responsibilities for potential problems. Increased familiarization of problem and decreased concern through discussion. (Stoner, 1961)
dwelling in the past	Concentrate on explaining facts which already have been superseded by more recent events.
trying to over control	Try to over control the situation rather than delegate responsibilities. (Roberts, Stout, Halpern, 1994).
adopting a wait and see strategy	Individuals are more reluctant to make immediate decisions as consequences become more critical. Wait to obtain redundant information.
temporary mental paralysis	Incapacitation of the capability of making use of available information. Cognitive lock-up due to sudden switch from under to over stimulation. (Tversky, Kahneman, 1983)
reduced concentration and attention	Abilities to deploy attention on demand decreases as stress increases.
cognitive tunnel vision	Hypothesis anchoring. Person tends to seek information which confirms the initially formulated hypothesis. Disregarding information which dis-confirms the initial hypothesis. (Nisbett, Ross, 1980)
rigidity in problem solving	Tendency to use off-the-shelf solutions which are not necessarily the most effective or efficient.
polarization of thinking	Explaining the problem by a single global cause rather than a combination of causes.
vagabonding, strategic shifting	Individual thought flits among issues, treating each superficially (free associating). Topics and issues dwelt upon to excess and small details are attended to while other more important issues are disregarded. (Huey, Wickens, 1993)
stereotype takeover	Reversion to a habitual or preprogrammed mode of behavior derived from past experience with a similar situation (Kahneman, Tversky, 1979)
hyper-vigilance	Panic leading to disruption of thoughts. Failure to recognize all of the alternatives. Latching onto a hastily contrived approach that appears to offer an immediate solution. (Kahneman, Tversky, 1979)

TABLE 2 - PROBLEMS AND SKILLS IN EVOLUTION OF A CRISIS

Phase	Problems	Skills
Perception & Recognition	loss of data misleading data access to data limited no data too much data	attention, working memory perception, interpretation discrimination, sensory alertness communications (individual, team)
Identify Problems & Causes	obscure critical evidence ignore critical indicators effects show up elsewhere incorrect schema representational limits confirmation bias transfer of decision authority	mental models inferences correlation links to system understanding of system links to existing procedures communications (individual, team)
Identify Alternatives & Consequences	goal conflicts distant effects representational limits	mental representations definition of goals, goal prioritizing goal conflict resolution recognition of correlation team evaluations
Evaluate & Choose Alternatives	other involved time pressures uncertainties misconceptions inappropriate existing plans buggy procedures / systems lack of understanding of system	improvisation determining action sequence identifying appropriate existing responses formulating new responses evaluating responses recognition of links to existing procedures team input
Implement Alternative	ambiguities, unfamiliar roles confusion, uncertainty stress, performance anxiety very rapidly degrading or destabilizing systems communication breakdowns	managing execution of response executing control actions management skills coordination of control actions
Observe Results	poor discriminability diminished information uncertain information work overload confirmation bias diminished observation memory limitations attention limitations needless shifting	anticipation of effects of actions evaluations and assessments observations alertness determine desired effects evaluating appropriateness coordination of observations analysis

System Support.

Improved system support includes factors such as improved maintenance of the necessary critical equipment and procedures so they are workable and available as the crisis unfolds. Data systems and communications systems are needed to provide and maintain accurate, relevant, and timely information in 'chunks' that can be recognized, evaluated, and managed. Adequate safe haven and life saving measures need to be provided to allow crisis management teams to face and manage the crisis, and if necessary, escape. Hardware and structure systems need to be provided to slow the escalation of the crisis, and restabilize the system. Safety system automation needs to be provided for the tasks people are not well suited to perform in emergency situations.

One would think that improved system support would be highly developed by engineers. This does not seem to be the case. A few practitioners recognize its importance (Kleitz, 1991; Bea, 1992), but generally it has not been incorporated into general engineering practice or guidelines. Systems that are intentionally designed to be stabilizing (when pushed to their limits, they tend to become more stable) and robust (damage and defect tolerant) are not usual. Some provisions have been made to develop systems that slow the progression of some crises. Fire deluge systems, heat insulation on critical structural elements and fire walls, and blast pressure

relief panels are examples of some of the provisions. Our work indicates that system robustness is achieved through a combination of redundancy (alternative paths to carry the loads), ductility (ability to redistribute loads and deform without compromising safety), and excess capacity (to carry the redistributed loads) (Bea, 1992). These guidelines also apply to the organizational or people components of systems (Bea, Roberts, 1994).

Effective early warning systems and crisis information and communication systems have not received the attention they deserve in providing marine system support for crisis management. Systems need to be designed to clearly and calmly indicate when they are nearing the edges of safe performance. Once these edges are passed, multiple barriers need to be in place to slow further degradation and there should be warnings of the breaching of these barriers. More work in this area is definitely needed.

Development of Cognitive Skills.

A critical element in providing people support is developing cognitive skills in crisis management teams under high stress conditions (Yates, Klatzky, Young, 1995). So equipped, people faced with managing crisis are able to proceed more rapidly and accurately through the primary steps required to manage it. Managing the 'unimaginable' requires highly developed cognitive skills. Such skills are needed where established procedures do not exist, procedures may not be as detailed as needed, or procedures may be incorrect or 'buggy' for the situation at hand (Mumaw, et al. 1994).

Cognitive skills are involved with how people acquire, store, and use knowledge. This includes representation or how knowledge is stored in the memory, and processing or how knowledge is retrieved and applied. Cognition involves a combination of data driven and knowledge driven processes. Data driven processes are associated with the absorption and interpretation of information. Knowledge driven process are attempts to fit existing notions or schema onto incoming information, thus creating expectations of outcomes.

Cognitive failures develop from a variety of causes such as perception (unaware), interpretation (improper evaluation), decision (incorrect choice), discrimination (not perceiving distinguishing features), diagnosis (incorrect attribution of causes or effects), and action (improper activities). A fundamental purpose of cognitive training is to develop capabilities in individuals to minimize the occurrences of cognitive failures. Selection of individuals with natural cognitive talents and capabilities for jobs that potentially involve crisis management is very desirable (job task performance talent matching). Training resources can then be leveraged.

Memory can be organized into two primary categories: long-term (LTM) and short-term working (STM). LTM is virtually unlimited. STM is very limited. At a given time, for most people 5 to 10 items of information can be retained in STM. Thus, successful crisis management systems rely as much as possible on LTM and as little as possible on STM. STM places severe limitations on attention unless 'chunking' of information is developed. Information chunking skills or relation and integration of information capabilities can be expanded with practice. Attention is a limited resource and nothing can be discovered or changed without attention. Attention 'tunneling' can lead to a loss of situation awareness and a cognitive 'lock-up.' Thus, a primary strategy in management of rapidly developing crises is to preserve and maximize attention resources, avoiding unnecessary deflection of attention resources.

Mumaw, et al. (1994) identified six critical elements of cognitive skills needed to successfully manage crises:

1) task relevant knowledge (what's and why's of the system, knowledge of theory, systems, phenomena, interconnections, underlying logic, facts, and relationships),
2) meaningful organizations of knowledge (mental models, organization of information in the system context, development of methods for extracting information from the system based on meaningful patterns),
3) task relevant rules that can be used to modify existing mental models (proceduralized knowledge for the performance of specific tasks, reduction of biases),
4) task sub-goal sets that provide efficient paths to the goal (analysis of tasks into organized collections of goals and objectives that must be effected to successfully achieve the tasks),
5) strategies that can be used to achieve sub-goals (rules that can be applied to achieve desired results), and
6) metacognitive skills that guide selection and execution of individual skills.

One of the most important cognitive skills to be maintained in crisis management is decision making. In a crisis situation, the decision making function must be firmly rooted in the capability to gather and redistribute information, intelligence, power and resources (Legedec, 1993). Some rules to maintain the decision making capabilities under stress that have been developed from this research include developing a complete survey of alternatives and objectives, consideration of the risks and consequences associated with the alternatives, maintaining a scan to include new information that could be useful in assessing the choices, before taking the final decision - reviewing the potential positive and negative consequences, and finally preparing implementation plans for the chosen option, keeping as many options open as possible. Most important is to avoid premature closure, terminating the decision making processes before all alternatives are considered.

Organization for Crisis Management

Empirical studies have been conducted to determine the effectiveness of cognitive skills training for both individuals and operating teams (Roth, et al., 1994). Even with training, there is wide variability in individual and team performance characteristics. The most outstanding characteristic of teams which accurately and quickly managed unusual and rapidly evolving crises was a 'divide and conquer' strategy. Using this strategy, members of the team were assigned management of different aspects of the evolving crisis (Fig. 9).

The teams organized into three components: 1) strategic command, 2) tactical command, and 3) task performance. The strategic command acted as a mega-brain central point for information, verifications, planning, and situation awareness. The incident commander maintained the bubble , accessed the necessary requisite variety to understand the overall problem and identify the alternatives available to solve the problem/s.

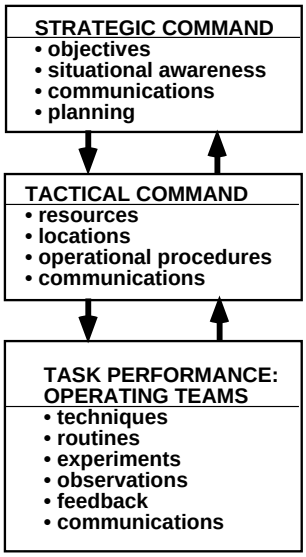

FIG. 9 - DIVIDE AND CONQUER CRISIS MANAGEMENT TEAM ORGANIZATION

Tactical command determined resources, their locations, operational procedures, and served as a central communications link. Strategic command determined what should be done, and tactical command determined how it should be done (procedures), who should do it (personnel), and what would be required (hardware, system support). Most importantly, tactical command acted as a central communications link between the strategic command and the task performance team/s.

Task performance was relegated to the operating teams that provided techniques, routines, observations, feedback, and 'experiments' with alternative measures to help arrest development of the crisis. The operating teams had to possess highly developed operating skills, had to utilize rule-based behavior and adopt this behavior to the unique circumstances of the crisis (improvisation), and had to have basic knowledge of the system that was managed (Table 2).

The degree of success of crisis management team depends on an accurate assessment of the nature of the problem/s at hand. This 'sensemaking' is obtained through pattern recognition, a basic mechanism in learning. Pattern recognition relies on past experience in which the new problem may look something like a problem previously encountered. This permits the team to recognize applicable solutions or adaptations much earlier in the crisis (Table 2). This is the reason that training and experience are so important. Experienced people bring pattern recognition skills with them. This enables them to identify the crucial pieces of information from the mass of information that floods in during a crisis and the crucial pieces that may be missing. Inexperienced personnel can only process protocols and execute available skill based behaviors.

Sarna (1996) identified 9 characteristics of effective crisis management teams in law enforcement:

1) requisite variety - team roles, expertise, perspectives,
2) migrating leadership - decisions made by those with the most information,
3) non-stop talk - briefings, critiques of content and process,
4) dual forms of organizations (hierarchical, dispersed),
5) analysis of position and decision premises,
6) deliberate thinking (logical brainstorming),
7) over-ride mechanisms - common vocabulary, time-outs, symbols,
8) balance between inquiry and advocacy - divergence and convergence, and
9) clear, agreed-upon goals.

A team-related crisis management technique used successfully by the airline industry is Crew Resource Management or (CRM) (Helmrich, 1994, 1995; United Air Lines, 1996a; 1996; Boeing, 1996). This technique has been successfully applied on the flight deck and on the tarmac (ground teams), and successfully extended to hospital operating rooms (Helmrich, 1994).

Helmrich identifies the following factors that influence how teams perform in crisis situations: individual aptitudes, personality and motivation, physical and emotional states, composition of the team, organizational climate and norms, time pressures, and the environmental conditions. The critical performance factors in CRM include information, inquiry (assertion, advocacy), management (briefings), technical procedures, communications, workload distribution (avoidance of distractions), decision processes, situation awareness, and resolution of conflicts.

United Airlines' C/L/R (Command / Leadership / Resource) management program (Hutchings, 1996) addresses command authority, crew climate, crew member training and development, communications, problem definition,

decision making, inquiry, advocacy, conflict resolution, critique (feed-back), workload management, situation awareness, and use of resources (United Airlines Inc., 1996a, 1996b). The knowledge, skills, and observed behaviors associated with the United Airlines' CRM elements are summarized in Table 3.

Management of the crisis action plan starts with the premise: keep the plane flying (maintain the vital functions). It is followed with displaying options and essential objectives, anticipation and taking the initiative; tracking down gaps, mistakes, and weak points in the plan; recognizing, resolving, and managing contradictions, and keeping the airplane flying (Hutchings, 1996).

Training in simulators in which the crew behavior is video taped has proven to provide valuable feedback on how crisis situations are managed (the camera doesn't blink). A formal training program to impart knowledge, skills, and observable behaviors has been documented and carried out, and the process institutionalized through flight operations policies. United Airlines contends this program has proven itself to be extremely valuable and it is now being used for ground crew operations (Boeing, 1996).

Given this background, it is no wonder that there have been and will continue to be problems in crisis management operations involving 'contract crews.' Often, although not always, these crews do not possess the requisite variety and knowledge of the system or training to deal with it. Experience with the system, requisite skills and knowledge are frequently lacking. In addition, at the interfaces between the parent operating organization and the contract crew/s, communications breakdowns and inefficiencies can and should be expected (Libuser, Rousseau, 1996). The different organization cultures and motivations can lead to important communications barriers. Interfacing different organization cultures and motivations can lead to important communications breakdowns and breaching safe operating barriers (Meshkati, 1995).

Deployment of Resources

A critical issue in management of crises is deployment of resources (Fig. 10). Boney (1995) organized resources into three general categories: personnel, procedures, and equipment.

The first step in determining how resources should be deployed is to identify the critical functions that have to be maintained to allow the crisis to be managed. In the case of a building fire, these functions might consist of provision of water for the fire fighters and provision of non-toxic air for the occupants. In the case of a medical crisis, this might consist of maintenance of blood pressure and breathing (Cook, Woods, 1994).

The next step is to define the resources required to maintain these critical functions. Review of past accidents and incidents permitted London Fire Brigade teams to identify the basic types of equipment required to enable them to manage the vast majority of crises. Back-up equipment was provided for the vast minority of crises and for the basic types of equipment. This permitted teams to focus on provision of and maintenance of a far smaller subset of tools. This allowed the deployment of fewer specialized personnel and tools for crisis management. Most importantly, this allowed scarce training resources to be focused on the proper use and maintenance of the basic equipment.

Procedures for crisis management then focused on issues such as team work, migrating decision making (discussed in next section), auditing strategies, and communications. The procedures addressed problems of resolution of conflicting goals or critical functions using OODA loops (Orr, 1983). OODA loops consist of repeated cycles of Observing (actions and effects), Orienting (to the unfolding situation), Deciding (on next actions), and Acting (implementing the actions). The crisis operating team personnel focused on the specifics of their particular situation. The OODA loops provide the operating team's requisite variety in acting to solve the problem and provide feed back on the activities and effects. This operating strategy, provides a 'fluid' deployment of personnel to take advantage of special operating skills and knowledge, and yet permit continued communications and situation awareness.

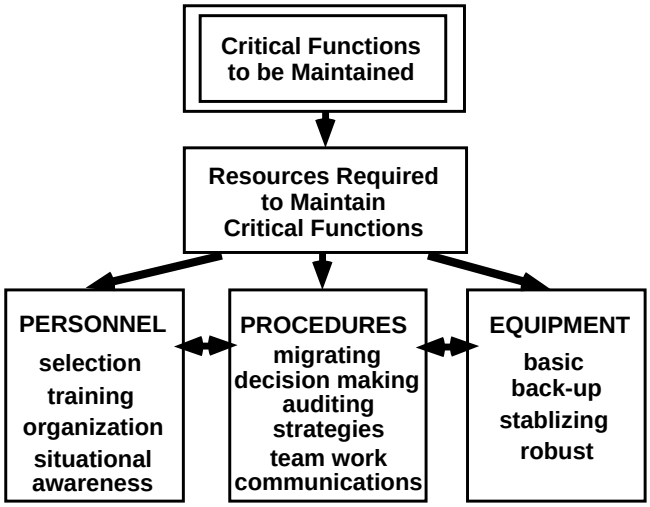

FIG. 10 - DEPLOYMENT OF RESOURCES

TABLE 3 - CREW RESOURCE MANAGEMENT

Element	Knowledge	Skills	Behaviors
Captain's Authority	emergencies management use of authority responsibilities leadership decision making	command supervision direction management coordination leadership	timely decisions balance appropriate operational provide direction solicit information
Crew Climate	synergy stress management behavior styles team building diversity	respect confidence briefings communications encouragement	admit mistakes interactions inform before act request input listening
Crew Development	learning process thinking association competence instruction C/L/R elements	encourage explanation feedback discussion demonstration professional	describe feedback professional reinforcement use of C/L/R experience
Communication	listening verbal comm. non-verbal comm. barriers to comm. impact of systems	communications questions non-defensive listen verify	sharing objectives defined decisions defined ask questions clear statements
Problem Definition	information obstacles biases strategies conditions	recognition assess information. recognize wrong recognize bias formulate conclusions	state when wrong discuss significance considerations scan, monitor question
Decision Making	tools & methods individual & group inquiry, critique advocacy responsibility anticipating conflict resolution	use resources resolve differences communicate use inquiry resolve conflict advocate solutions	request information. question information. discuss information. state decisions state analyses focus on what is right, not who is right
Workload Management	indicators regulation of informa- tion flow task prioritization task assignment planning, preparations	sequence demands clarity planning recognition of indicators take initiative	communications assignments acknowledge briefings expressions plan for expected & unexpected
Situation Awareness	operational conditions environmental cond. distractions preoccupations irregularities emergencies stress, fatigue	monitoring projecting assessment recognition	observing, monitoring communications avoid distractions select information ask questions continually assess where been, are, and are going
Resource Use	internal resources external resource factors affecting time, risk, safety, avail- ability	use of crew use of passengers use of information systems use of manuals use of data	ask crew ask passengers ask external sources search manuals search data

A critical crisis management resource is information. Those faced with crisis need to be provided with an autonomous information gathering capability, must seek to validate incoming information (eliminate erroneous signals), and must develop information on the initial events and other hazards that may be developing, the effects of events and the way they are changing, and available reac-

tion and control capabilities. Most important is the development of information on what else can happen in order to develop a dynamic view of the unfolding crisis and he reactions it is triggering or may trigger.

The concept of 'migrating decision making' (Fig. 11) (Roberts, Stout, Halpern, 1994) is a particularly important concept that has been integrated into many successful crisis management procedures and organizations. For normal daily operations, where the pace or tempo of operations is low, a hierarchical, bureaucratic type of management with centralized authority is attractive. In these operations, the emphasis is on normal and daily operating skills. As the pace or tempo of the operations picks up and approaches emergency and crisis operations, there is a need to change the operating organization. The shift is toward highly decentralized authority; hence migrating decision making or decisions made by those with the requisite knowledge and skills. There is an emphasis on high expertise operations in which knowledge, rules, and skills must be successfully integrated in control strategies.

The final resource is personnel. Here, considerations are with selection, training, and organization of the crisis management personnel.

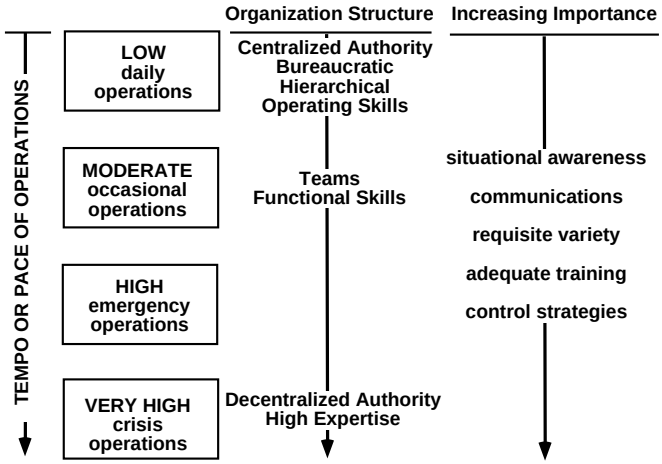

FIG. 11 - MIGRATING DECISION MAKING

The Right Stuff

Selection and training of personnel are critically important in building effective crisis management teams. Selection and training of crisis management personnel are discussed by Flin and Slaven (1995) for offshore platforms and Schager (1993) for ships. The 'right stuff' consists not only of leaders, but as well followers. Both leaders and followers must be team players. As the nature of the problem changes, leaders can become followers and vice versa. This syncopation of leadership and followership will be discussed in the next section of this paper.

Slaven identified selection criteria as: technical comprehension, intellectual capacity, perceptiveness, sociability, self-control, and stress tolerance. Psychological tests were developed to shed light on the capacity for logical thinking, stress- tolerance, perceptiveness, technological comprehension, the capacity for simultaneous performance, understanding instructions, self-assertiveness, responsibility, emotional stability / self-control, vigilance, accuracy, sociability, and tempo.

Flin and Slaven organized the selection criteria into three general categories: technical and professional qualifications, managerial and leadership qualifications, and demonstrated abilities to command and control emergencies. Based on research regarding a wide variety of types of emergencies, including those on offshore platforms, they identified eight key competencies (Table 4) and ten key attributes of 'the right stuff' (Flin, Slaven, 1996).

All research on crisis management indicates the importance of training. Training is intended to help reduce the amount of cognitive processing required (Fig. 2, Table 3). It is intended to help prevent cognitive 'traps' that can develop during an emergency (Table 2) and develop key competencies needed in managing crises (Table 3).

The how's of crisis management training are tricky. Training should not endanger the trainees. However, training should be realistic. Training in the field with the system of concern is the most desirable form of training as long as the training can be realistic and the danger to personnel and the system minimized.

Training in simulators is the next most desirable form. Simulators must develop realistic and physical mental images of an actual system in emergency situations. Danger to personnel must again be minimized. And, it is here that simulators have one of their major limitations: the trainees know that it is not likely that they will die in the simulations. The trainees also know that the most desirable reactions and actions in the simulation are those that will produce safety; thus, the trainees are relieved of realistic production versus safety goal identifications and resolutions. Another major challenge for simulator training is to capture the unfolding and interactive nature of unpredictable events and the organization - crew interactions so important in such events.

TABLE 4 - CRISIS MANAGEMENT PERSONNEL

Criteria	Competencies
• technical and professional qualifications • managerial & leadership qualifications • demonstrated abilities to command and control emergencies	• leadership • communications • delegating • team working • stress management • situation evaluation • planning • implementing
Attributes	
• task oriented • goal oriented • flexible • information seeking • sanctifying	• status leveling • self confidence • emotional control • self reliance • strength of personality

Improv Time

Management of a rapidly developing crisis is similar in many ways to the transition that a symphony orchestra must make as it changes from a highly structured and rehearsed piece of music to jazz improvisation. Our question was how do they make such a transition and what makes the process and outcome successful? Weick (1996) addresses this question and suggests three properties of improvisation especially sensitive to changes in organization variables. These are adaptation, learning, and renewal.

At the core of successful improvisation is a "simple melody that provides the pretext for real-time composing" (Weick 1996). This is the base upon which the musicians are able to look behind at what has been played and look ahead at what will be played. Important features such as simultaneous reflection and action, rule creation and following, action informed by codes, continuous mixing of the expected with the novel, and a heavy reliance on intuitive grasp and imagination come from skills of improvisation. Weick suggests 13 characteristics of high capability improvisation groups:

1) willingness to forego planning,
2) developed understanding of available resources,
3) proficient without 'music',
4) able to identify minimal structures for embellishing,
5) open to reassembly of departures from routines,
6) models on which to draw for action,
7) recognition of relevance of previous experience,
8) confidence in skills to deal with nonroutine events,
9) presence of committed and competent associates,
10) skillful at team interactions,
11) ability to maintain pace and tempo,
12) focused on coordination here and now and not distracted by memories or anticipation, and
13) preference for process rather than structure.

Weick notes that "the faster the tempo at which a musician plays, the more likely he or she is to fall back on the predictable use of a formerly mastered vocabulary....This suggests that there are upper limits to improvisation." Perhaps, we have much to learn from successful improvisation musicians about how to manage one category of rapidly developing crises.

CONCLUSIONS

From our research we have learned the pervasive importance of the organizational influences on safety and reliability. Some industries, such as the marine industries, fail to realize this because they often subjugate the goals of safety and reliability to the goals of production and profitability. This is a problem, because there must be profitability to have the necessary resources to achieve safety and reliability. Perhaps, with present high costs of lack of safety and reliability, these two goals are not in conflict. Safety and reliability can help lead to production and profitability. One must adopt a long term view to achieve the goals of safety and reliability, and one must wait on production and profitability to follow. However, often we are tempted for today, not tomorrow.

The second important thing we learned, is the importance of selecting, training, and organizing the 'right stuff' for the 'right job.' This is much more than job design. It is selecting those able to perform the daily tasks of the job within the daily organization required to perform that job. Yet, these people must be able to re-organize and re-deploy themselves and their resources as the pace of the job changes from daily to unusual (it's improv time!). Given most systems, they must be team players. This is no place for 'super stars' or 'aces.' The demands for highly developed cognitive talents and skills is great for successful crisis management teams. In its elegant simplicity, Crew Resource Management has much to offer in helping identify, train, and maintain the right stuff. If properly selected, trained and motivated, even 'pick-up ball teams' can be successful crisis management teams. If not, expect disaster.

The physical systems must provide adequate support and security for crisis management teams to accomplish their tasks. They must provide adequate warning of approaching danger and important data that do not overload cognitive resources. The systems must provide protection, and if finally necessary, a good chance of escape. Most important, these systems must be tolerant of human errors through the incorporation of adequate measures of robustness and stability.

Our research has not identified how to preserve readiness for crisis management for the crisis that may never happen (low probability, high consequence events). The results of training degrade rapidly when the results are not used. Apathy can develop relatively quickly in the normal pace of daily activities, particularly when these activities are

successful (crisis and incident free). Vigilance is replaced by complacency. Identifying mechanisms to help preserve the right degree of crisis management readiness is an area for future research.

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