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SUPPORTING PRE-EXISTING TEAMS IN CRISIS WITH IT: A PRELIMINARY ORGANIZATIONAL-TEAM COLLABORATION FRAMEWORK

EARL H. MCKINNEY, Bowling Green State University

BA 324 College of Business, BGSU, Bowling Green OH, 43403, Tel: 419-372-8336, Fax: 372-2875, Email: emckinn@bgsu.edu

ABSTRACT

A number of pre-existing teams are trained to operate in crisis. These teams can be found in aviation, navy, nuclear power, offshore oil, air traffic control facilities, and trauma centers. Understanding how to support pre-existing teams like these, with IT is essential. To date, most support for these teams is automation support such as an electronic checklist for an airplane flight crew responding to an engine fire rather than collaboration support such as linking paramedics in the field to doctors in emergency rooms. While automated support is rapidly developing, very little consideration has been given to enhancing the collaboration support for teams that face crisis. With advances in network capacity and sensors, IT has enabled pre-existing teams that face crisis the opportunity to obtain collaboration support from others in the organization. Collaboration with other human experts is necessary to aid problem discovery and to consider ramifications of responses. Here we suggest a preliminary set of IT system guiding principles to support collaboration for a particular, but common type of pre-existing team that faces crisis. These principles are based on two frameworks that have been developed to mitigate the effects of crisis. One is an organizational approach called the High Reliability Organization (HRO); the other, a team approach, was developed in the aviation community known as Crew Resource Management (CRM). Here we briefly explain each approach, highlight their principles, and then suggest principles of a Collaboration Crisis IT (CCIT) system to support the collaboration needs of teams that face crisis.

INTRODUCTION

Advances in IT have enabled the creation of new types of organizational teams (Fulk and DeSanctis 1995; Jarvenpaa and Ives 1994). In addition, organizations are engaging in high risk activities as the business environment becomes more complex and the

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rewards increase for successful high stakes processes (Morrison, Kelly, Moore, and Hutchins 2000; Weick and Sutcliffe 2001). To mitigate this risk, organizations increasingly rely on highly trained teams to manage high stakes processes in which a crisis may occur (Serfaty, Entin, and Johnston 1998; Seeger et al. 2003). Unfortunately, research on these types of teams and their IT needs is rare as most crisis research has studied environmental or terrorism events (Turoff, Chumer, Van de Walle, and Yao 2004), organizational responses to crisis (Hale, Dulek and Hale 2005; Kim 1998), or other types of crisis teams such as interorganizational teams (Aedo et al. 2006; Chen and Dahanayake 2006), technology teams (De Bruijne, Van Eeten, Roe, and Schulman 2006) and disaster recovery teams (Robert and Lajtha 2002). Finally, still other research has investigated particular examples of these teams such as flight crews, firefighters, or paramedics (Helmreich 2000, McKinney 2004).

While large scale disasters and organizational crises may last several weeks, here our focus is on the immediate response to a crisis by a particular but common type of pre-existing team of professionals. These crisis teams can be found in civilian aviation, the merchant navy, the nuclear power industry, aviation maintenance, the offshore oil industry, air traffic control facilities, trauma centers, medicine, fire fighting agencies, law enforcement, counter terrorism units, emergency rooms, combat units, container inspection teams at ports, and homeland security teams. These teams share distinct features: they are comprised of a small number of highly trained professionals within one organization, they are co-located at the site of the crisis, the team is trained to face life-threatening risk, the team has the authority to make the key decisions which are typically irreversible, the team has a prior history of

CONTRIBUTION

This paper contributes to IS research in a number of ways. To our best knowledge, it is the first IS crisis paper that examines a particular type of preexisting team. Most all other crisis and IS research addresses large scale disasters, organizational responses, or crisis teams with other characteristics (e.g. ad hoc, widely dispersed or interorganizational teams). During a time of increased terror activities, natural disasters, and man made crises, supporting this common but particular type of team with a conceptually sound IT system is both possible and important.

Secondly, to our knowledge this work is the first IS study to site Crew Resource Management (CRM) research. IS research has long investigated and supported team behaviors. However, this body of research has not used insights developed by CRM researchers investigating flight deck team interactions. Most IS crisis team research has focused on ad hoc teams, or organizational teams not in crisis.

Finally, most of the limited research to date on teams in crisis has focused on automated support. One example of a preexisting team is a flightdeck crew. For these teams research has emphasized automated support such as computer displays, electronic checklists, or access to archived knowledge. Here we suggest that with advances in sensor and network capabilities, robust IS systems can be developed that support collaboration needs of preexisting teams with other professionals outside of the crisis environment.

By identifying a type of previously unstudied team (a particular, but most common type of preexisting team in crisis), an underserved need (collaboration), and new body of research (CRM), we hope to begin a discussion that will lead to development and design of an important new type of team IS. To that end, this study provides an initial list of guiding principles for IT systems to support the collaboration needs of teams in crisis.

This research is expected to be interesting to IS researchers building IT solutions for professional teams in industries with substantial risk. It may prove interesting to a broader audience as it identifies an increasingly common type of professional team for whom technology solutions can be developed.

work together during routine operations, and the team can collaborate with other professionals not physically located with them. While research has supported each of these teams, this report is the first to classify them into a particular type for the purpose of making suggestions common to all. The most significant differences among pre-existing teams, large scale, and organizational crises are summarized in Table 1.

The types of crisis are not completely independent. Large scale disasters are often the impetus for the creation of organizational and pre-existing team crisis. The 9/11 disaster put organizations such as the New York Police and Fire Departments in a crisis as well as a number of their pre-existing teams such as fire fighters and riot control teams. In addition, these three levels of crisis also share several characteristics. At each level decision makers face high risk and make binding decisions under time pressure and in short time horizons with incomplete information. Further, for each level, everything in a crisis is an exception to the norm (Turoff et al. 2004). Because these crisis types share some common elements, a number of IT system design principles identified for large scale crisis should be considered for pre-existing teams. These guidelines are not repeated in the text of this report (see Appendix A for a list of design principles for a Dynamic Emergency Response Management IS (Turoff et al. 2004)).

As mentioned, there are other types of teams that respond to crisis. For example distributed teams of IT professionals from a variety of organizations may be called on to respond to a security threat to the Internet, or a top level crisis response team may have to respond to a large scale disaster. These teams are important to study also, but are not included here as they differ in important ways from our pre-existing teams. These differences include a number of characteristics, such as loosely organized, varying degrees of familiarity, physically dispersed, not life threatening, and longer time horizon.

Collaboration

Collaborative support for pre-existing teams in the past was limited by the available technology (e.g. compatible radios and phone systems). Historically, flight crews, fire fighting teams, or emergency room units could not be collaboratively supported as only the team in crisis knew the local conditions and had access to the stand alone computers that produced and manipulated the crisis data. Teams in crisis had only their immediate resources at hand or preprogrammed automated support. Now, with advances in network capacity and sensors, IT has stretched that hand and teams that face crisis can obtain

Table 1: Types and Attributes of Crisis

	Large Scale Disaster Crisis	Organizational Crisis	Pre-existing Team Crisis
Examples	9/11; Katrina; Bhopal, Three Mile Island	Enron; NASA; Firestone	Aviation, surgery
Recent Studies in Crisis Literature	Hale et al. 2005; Turoff 2002	Weick & Sutcliffe 2001; Venette, Sellnow, & Lang 2003	None
Characteristics of Context	Widespread, multiple organizations, many lives at stake, crisis responders move to location, key decisions made over weeks	Single organization, important external communication needed, organizational survival at stake, decisions made over days	Localized actions, hi tech system or personal breakdown, crisis team present prior to crisis initiation, all decisions short time horizon made by one or two hours
Characteristics of Decision Makers	Dispersed, unknowable prior, informal hierarchy, hundreds of actors, from local state, or federal agencies and private organizations	Centralized, formal hierarchy, tens of actors, from one organization (public or private)	Co-located formal hierarchy, few actors, highly trained, from one organization (public or private)

collaboration support from others in the organization (Chen and Dahanayake 2006). These organizational experts can now see real-time data from the crisis, interact with knowledge bases, and reliably and richly communicate with the team.

Collaboration allows participants to impose a shard view, apply specific understandings and meanings, and evolve their own organizing approaches to a problem (Turoff et al. 1997). A collaborating team works together to support common objectives (Carver and Turoff 2007). Collaborating teams in general and pre-existing teams in particular share data, information, and knowledge via computational resources, and persistent databases for the purpose of taking an action on behalf of an organization (McQuay 2004). Organizations seek to increase collaboration for their crisis teams as it allows knowledge to be shared without exposure to risk, and it makes vital expertise more widely available.

IT Support

To support teams designed to respond to crisis, organizations seek to leverage advances in information technology. Currently IT support for these types of teams includes display systems (Hamblin 2003; Sarter and Schroeder 2001; Vicente 2003), intelligent support systems (Koester and Mehl 2003; Palmer and Degani 2001;Wischusen et al. 2003), decision support systems (Smith, Johnson, and Paris 2004), and a wide variety of other technical solutions (Song 2006; Stoner et al. 2004). A particularly intriguing example of this type of support is a system for efficiently planning traversals of planetary surfaces by astronauts (Marquez et al. 2005). These advances can be classified as *automation* support to the team (e.g. an electronic checklist for an airplane flight crew responding to an engine fire), or *collaboration* support such as linking paramedics in the field to doctors at hospitals. While significant progress is occurring to give automated support to pre-existing teams in crisis, very little consideration has been given to enhancing the collaboration support for this type of team in crisis (Huang 2004; Nunamaker 1997). This lack of attention continues despite recent crisis studies that suggest that even simple tools for collaboration such as communication systems have performed poorly (Netten and van Someren 2006).

Collaboration is essential in a crisis because of the nature of the task. Crises are unexpected, unpracticed, and unprogrammable (McKinney and Davis 2003). For example, for flight crews, an engine failure or low oil temperature on an engine may be an emergency, examples of crisis include being shot, a terrorist attack, or responding to novel combinations of technical systems failures. Emergencies are predefined and therefore amenable to automated support. With an emergency, responders know what is wrong. Responders can be trained to accomplish a specific process and automated IT systems can be designed to support the programmed response. Crisis, by its uniqueness, reduces the utility of automated support. The challenges in all three levels of crisis are figuring out what is happening, dealing with incomplete information, thinking through irrevocable decisions and making them before it’s too late. As a result, automated support, while valuable, should not be the only available support for teams that face crisis. Collaboration with other human experts is necessary to aid problem discovery and to consider ramifications of responses.

For these teams, collaboration typically occurs within one organization. For example, flightdeck crews use electronic checklists during routine and crisis operations that can be displayed and tracked by organizational members on the ground. Emergency room systems are developed by hospitals to provide real time support to the medical team in routine operations and during crisis situations. As a result the system can be tailored to a particular organization and can avoid the common design challenge of having to develop a system that is meaningful and useful to wide range of team members from various organizations..

A collaborative crisis IT system is the interface between an organization and its pre-existing team, permitting both routine and crisis collaboration between physically distant organizational members and the team in crisis. Collaboration implies that the system brings organizational assets and the team together to resolve the crisis. While team characteristics are important to IT design, understanding and supporting organizational crisis related activities is also vital to successful IT design.

Collaboration for our type of pre-existing team has distinct characteristics that must be considered in order to support them well. For example, collaboration with pre-existing teams is mostly synchronous. Further, collaboration occurs within a pre-existing hierarchical structure within the pre-existing team. Finally, organizations identify individuals of the team that will be leaders and decision makers during the crisis (e.g. captains, officers, line officers etc.).

Effects of Crisis on Teams and Individuals

Before it is possible to consider IT enabled collaborative support for teams that face crisis, it is necessary to understand the crisis task. A crisis is an unexpected, low probability, uncertain, unpracticed event with life and death consequences under time pressure with potentially irreversible decisions (Pearson and Clair 1998; Rosenthal 1991). A crisis typically unfolds as a person has an intention, takes action, and misunderstands the world. Actual events fail to coincide with the intended sequence, and there is an unexpected outcome. A crisis typically involves three phases: prevention, response and recovery (Hale et al. 2005). Further, the crisis event is just one of many concurrent activities for which the team is responsible. These other activities or responsibilities, as well as the crisis event itself constitute a crisis event. System design must recognize these concurrent responsibilities. For example, flight deck teams must continue to operate aircraft systems, navigate, and communicate in addition to accomplishing crisis related tasks.

While accomplishing these tasks, responders are under the influence of a number of well known psychological effects. Crisis affects individuals in a number of ways. Here, the individual and team effects are reviewed. A brief listing of these effects is shown below in Table 2. For a more complete review see Morrison et al. (1998) or Olson and Sarter (2001).

Research has demonstrated a number of significant cognitive and behavioral effects of crisis on individuals. A crisis can narrow attention, information search, and deliberation or debate (Cohen 1980). Individuals focus attention on the immediate, highly structured task elements and avoid more important and more complex tasks (Morrison et al. 1998). The stress of a crisis limits the

Table 2: Psychological Challenges of Crisis

narrows information search and restricts deliberation or debate
restricts attention to immediate, highly structured task and not more important and complex tasks
limits ability to notice patterns
situations are difficult to remember in sufficient detail long enough to recognize the emerging pattern
a lack or poor quality of cues makes it difficult to hypothesize the nature and severity of the problem
perceptual narrowing, reduced use of available cues, decreased vigilance, reduction in working memory
restricts the examination and evaluation of multiple possible hypotheses
time is compressed, events seem ambiguous and uncertain
changes the communication patterns of teams
communication is upward (from subordinate to leader)
Implicit communication increases
teams shift from an egalitarian horizontal communication framework to a more classical hierarchical
subordinates more willing to defer to authority
group leader increases receptivity to information from subordinates
new patterns of communication are necessary to correct errors during crisis
prone to latch upon the first good idea that comes along
time pressure is likely to inhibit joint problem solving
members reach agreements sooner, but they make fewer offers and reach poorer joint outcomes
important social or interpersonal cues (such as attention to others' requests or actions) are neglected
likely to shift to a more individualistic self-focus, resulting in poorer overall team performance
members may revert to well learned or dominant responses that may be quite inappropriate
threat rigidity—restriction in information processing, constriction of control (Staw et al. 1981)

individual's ability to notice patterns, as the important features of a developing situation are difficult to remember in sufficient detail long enough to recognize the emerging pattern (Morrison et al. 1998). Poor quality of cues can make it difficult to generate reasonable hypothesis about the nature and severity of the problem (Olson and Sarter 2001). Crisis can lead to perceptual narrowing and a reduced use of available cues, decreased vigilance, and reduction in working memory capacity. Further, a reduction in attentional resources restricts the examination and evaluation of multiple possible hypotheses (Sarter and Schroeder 2001). As attention narrows, peripheral (less relevant) task cues are first ignored followed by restriction of more central or task relevant cues. Individuals display threat rigidity, a reliance on well learned or dominant responses that may be quite inappropriate (Staw, Sandelands, and Dutton 1981). For individuals in crisis, time is compressed; information is incomplete ambiguous and uncertain. Individuals tend to miss important patterns as perception narrows and working memory is reduced.

While these effects have been shown to lead to poorer performance, crisis behaviors do have some positive attributes. Cognitive absorption ability increases to allow individuals to work with more information, and narrowing of attention may help participants focus on a specific task without devoting mental resources to other tasks (Agarwal and Karahanna 2000).

Crisis also has team effects. Individuals were less likely to help or assist others (Matthews and Canon 1975). Stress reduces subjects' ability to discriminate among people occupying different roles (Rotton et al. 1978). Time pressure inhibits joint problem solving (Walton and McKersie 1965) and leads to greater self-focused attention (Wegner and Giuiliano 1980). Under high time pressure, team members reach agreements sooner, but these solutions are typically sub optimal. Team tasks require attention to both direct task-related activities and social or teamwork activities such as coordination and communication. Thus, the narrowing of attentional focus under stress may have both cognitive and social effects. As important social or interpersonal cues, (such as attention to others' requests or actions) are neglected, team performance suffers. In fact, Driskell, Salas, and Johnston (1999) found that team members were less likely to maintain a broad team perspective under stress and were more likely to shift to a more individualistic self-focus, resulting in poorer overall team performance (Driskell et al. 2001).

Crisis also affects team communication behaviors (Hale et al. 2005; Thompkins and Thompkins 2004). A review of team crisis research shows that crisis changes the communication patterns of teams. One change is that during a crisis more communication is upward (from subordinate to leader) than in routine operations. In addition, during a crisis, implicit communication increases and teams shift from an egalitarian horizontal communication framework to a more classical hierarchical and vertical structure (Weick 1990). Similarly, Davis, Driskell and Salas (1991) found that crisis made subordinates more willing to defer to authority. They hypothesized that this increased deferment to centralized authority is due to both social comparison (the leader is of higher stature) and concentration of responsibility (the leader has to answer for this).

Further, new patterns of communication are necessary for teams to correct errors during crisis. According to Weick (1990), in any crisis there is a high probability that false hypotheses will develop and persist. What is needed is diversity of inputs and hypotheses about "what is going on" (Weick and Sutcliffe 2001) as a chief characteristic of early stage crisis is the ambiguity and uncertainty of the cues. The human mind naturally seeks to resolve dissonance (Festinger and Carlsmith 1959) and is therefore prone to latch upon the first "good" idea that comes along during a crisis (Jehn 1999). This is particularly likely to occur if someone in authority introduces the idea (Kern 1997). Weick (1990) suggests that it is largely through open exchange of messages, independent verification, and redundancy that the existence of false hypotheses can be detected and corrected. These studies suggest crisis increases and alters the communication among team members.

Outline

Next, we suggest a comprehensive and theoretical set of principles to guide IT design of systems to support the collaboration needs of pre-existing teams that face crisis. These principles are derived from two main sources. The first is High Reliability Organizational research. The second, and less well known source, is from the aviation domain. It is known as Crew Resource Management (CRM) research. The collaborative IT system must support both organizational and team needs, HRO principles support the former, CRM principles the later.

High Reliability Organization (HRO) research seeks to describe and improve the activities and processes for organizations that face crisis (Bourrier 1996; Fiol and O'Connor 2003, Swanson and Ramiller 2004; Vogus and Welbourne 2003). This research suggests five activities. These include preoccupation with failure, reluctance to simplify interpretations, sensitivity to operations, commitment to resilience, and deference to expertise. Supporting crisis teams with IT should be based on these five organizational characteristics.

While support for these organizational activities is important to crisis team success, it is also valuable to consider what might, by contrast, be labeled team-only needs. The activities of teams in crisis have been the object of military and airline flightdeck research for 25 years. This research effort, labeled Crew Resource Management (CRM), suggests that team-only needs might include situational awareness, decision making, communication, team work, resource use and leadership.

Many of the following examples of HRO and CRM principles are from the aviation domain. The aviation community performs thousands of successful flights under difficult conditions and this research setting has matured to the point where a wide range of cases and examples have been written (Ginnett 1993; Helmreich, Merritt, and Wilhelm 1999). These examples and insights have been applied beyond the flightdeck--to teams solving organizational problems, emerging management teams, and IT teams that develop and maintain large scale computer programs (Boehm-Davis, Holt, and Seamster 2001; Davies 2001). The principles for a Crisis IT system for each field are listed in Table 3.

Table 3: Principles of a Crisis IT system

HRO Principles
Record widespread and detailed accounts of near misses or errors that captures new attributes
Track and display a wide variety of unsimplified data and disconfirming evidence for a variety of expert interpretation by team and organizational participants
Increase the visibility of operational performance measures that lead to operational enhancements and build an IT system to adapt to these operational enhancements
Create a flexible system that enables simultaneous action and analysis with mental simulation of courses of action for both team and organizational participants
Identify, and alert experts with on going problems and support collaboration and analysis between crisis team and experts
CRM Principles
The system should be simple to use and not overly filter or over process the original data
Help reduce mental effort by supporting feature matching and adaptive story telling.
Display historical trends, minimize calculations, and support chunking of information in order to reduce cognitive overload
Provide a mechanism to direct the attention of an operator to important events while minimizing the cognitive costs of interruption
Mitigate the tendency of decision makers to attend to only confirming information
Compensate for deficiencies in action selection and adaptively support the multiple cycles of decision making
Enable and support communication value sharing
Aid increased vertical communication, effective dissent, and alternative hypothesis generation during crisis
Enhance accuracy and sharing of common models on the state of affairs

CCIT System Guiding Principles

HRO-Organizational Activities and CCIT System Principles

Weick, Sutcliffe and Obstfeld (1999) originated the HRO framework. High reliability organizations operate under constantly threatening conditions. HROs are typically interactively complex with unpredictable, but highly dependent interactions of subsystems (Perrow 1994). These organizations are labeled highly reliable because they have lower than expected accidents or incidents. Typical organizations cited as HROs are nuclear power aircraft carriers, air traffic control centers, and power plants, organizations that operate large physical objects. Interestingly each of these organizations employs pre-existing teams. These organizations are not free of errors, but errors do not disable it (Van den Eede, Van de Walle, and Rutkowski 2006**.** HROs seem to share a number of activities and processes. Of the five HRO principles described below, the first three address crisis prevention while the fourth deals with response and the fifth speaks to crisis recovery.

1. Preoccupation with failure

Members of HROs are anxious about failure and distrust success. As a result, they constantly seek to identify lapses or minor incidents that, if ignored, might later reoccur and contribute to a crisis. This preoccupation with failure is impervious to success and does not become stale. Members of HROs recognize that success can narrow perception and breed overconfidence. This misplaced confidence in judgment and in its existing procedures can limit necessary changes to the organization and its processes.

One way HROs fight the lethargy of success is by building and motivating participation in attribution-free error reporting procedures. Anyone in the organization can report errors of any magnitude and are assured that those errors will not lead to sanction. These error reports are never automatically or thoughtlessly processed by the HRO. Rather the data collected are turned into active incident reviews and in depth analysis that are widely communicated.

An error reporting system derived from a preoccupation with failure occurs in the airline industry (Chidester 2003). The Aviation Safety Reporting System (ASRS) is one national system, and all major airlines have their own internal systems. Pilots make inputs to the systems via anonymous reports (see ASRS at http://asrs.arc.nasa.gov/). Data from these systems are then analyzed by trainers and researchers. Their reports are widely shared and the results of the studies have had significant impacts (Gunther 2003). Results from ASRS lead to new error frameworks and mitigation processes (Chidester 2003). Recently, these reports have helped build a model of communication error in abnormal situations (Haney and Gertman 2003; Muthard and Wickens 2003).

These near misses and errors may contain warnings of future problems but in the din of daily activity appear as only weak signals of impending crisis. The IT system must be designed to find and amplify these weak signals for the crisis team and their collaborators to notice. Unfortunately, weak signals, by their nature, are not readily found as they defy easy classification or categorization. If categories or attributes of errors were already known to the organization, the errors that occur would also be known and procedures established to respond. For example, jet engines break down, and therefore airlines have learned to classify these failures as engine problems. However, most weak signals are not easily classified (e.g. a small wing crack might be classified by length, thickness, location or some other dimension). As a result, most organizations can not respond until the wing crack leads to a break and a crisis occurs. Thus, the crisis IT system should permit detailed descriptions or detailed reporting of odd events, near misses, and weak signals. From these details, common attributes, such as the length of a “must repair” crack can later emerge, and teams can be trained to respond effectively. Once these new attributes are known, tolerances can be set for future inspections and reporting, procedures can be written for teams to use, and attention can shift to finding new attributes or categories.

System principle 1:

Record widespread and detailed accounts of near misses or errors that captures new attributes

2. Reluctance to simplify

High reliability organizations do not simplify the complex events and processes in which their teams participate. Although all coordination requires some degree of simplification, in HROs, participants minimize this simplification and constantly seek to see more, and render more complete and detailed their understanding of their actions, processes and the environment. Further, when actions are taken or new processes put into place, they avoid seeking confirming evidence that their actions were appropriate. Rather, they seek disconfirming evidence and new sources of data that expectations and experience can conspire to hide.

HROs generate disconfirming evidence for their crisis teams by assigning members with varied and overlapping backgrounds. The variety in backgrounds and experiences tends to increase scrutiny of data and thereby increase the variety of what can be noticed. With varied backgrounds comes varied experiences and expectations and skepticism of simplification. By creating teams with members who have overlapping experiences the team is more able to communicate what they notice and see a more complete perspective on their actions and the environment. In addition to the variety of the team, the search for disconfirming evidence is also enhanced by a varied search of a wide variety of sources. Therefore, an IT system that limits simplification would have a variety of sensors that records a variety of data for a variety of participants.

System principle 2:

Track and display a wide variety of unsimplified data and disconfirming evidence for a variety of expert interpretation by team and organizational participants

3. Widespread sensitivity to operations

HROs value operations above strategy. This focus on operations, or processes (e.g. communication) is designed to find hidden or underlying lessons about weaknesses in the operation. These latent failures may be found in many operational areas including poor supervision, inadequate procedures, and deficient training. HROs also demonstrate their commitment to operations by their focus on correcting even minor issues. The result is continuous improvement in operations. To sustain this incremental improvement, HROs seek operational suggestions from the entire organization. They widely disseminate and seek feedback on both operational performance and performance measures. This operational precedence is apparent in other ways-- in the interest devoted to even small interruptions in operations, in the numerous meetings on operational status, and in organization structure designed to broadly distribute real time data about operations. The DERMIS system introduced earlier also calls for sensitivity to operations (Turoff et al. 2004). That system suggests collection and analysis of event logs that track courses of action during a crisis. This collection of events would be in real time.

Effective hospital emergency rooms are committed to operations and studies are beginning to emerge that apply HRO principles to hospitals (Gaba 2005; McKeon, Oswaks, and Cunningham 2006). Doctors and administrators collect and collaborate on a wide variety of performance data to track patient progress and optimize diagnosis under crisis and expensive equipment use. Patient surveys are collected, and inputs from the entire organization are routinely obtained in order to improve operational processes. Despite constant strategic turmoil on insurance, liability, and government intervention issues, emergency room procedures are continually improved by the organization's commitment to operations.

IT systems supporting teams in crisis should be designed to widely disseminate the state of current operations within the organization. The system should make operational data, training schedules, equipment use and other process information increasingly available for oversight and improvement. This should result in improvements to operational procedures from a variety of sources. In addition, one implication of continual process change is that the IT system itself must change. Therefore, the system must be flexible enough to adapt to changes to operations.

System principle 3:

Increase the visibility of operational performance measures that lead to operational enhancements and build an IT system to adapt to these operational enhancements

4. Commitment to resilience

HROs are built on the premise that error is unavoidable. As a result, HRO managers take delight in putting out fires. Unlike managers in other organizations who see fire fighting as a breakdown of planning and a sap on resources, HRO managers know that recovery from mistake is their primary activity. Because of this priority they seek deep knowledge of their systems, processes and people. In addition, they excel at adapting to swift feedback, learning quickly without multiple errors, recombining existing responses, and mentally simulating courses of action. Further, they have learned to act while diagnosing and to adapt to threats based on feedback from action.

The professional aviation community has realized that error is inevitable. In fact, one report estimates the frequency of pilot error at 5-10 mistakes per hour (Amalberti 1996). As a result, flight systems, training, technical systems, and procedures are designed to respond and recover from these errors. Further, pilots are taught detailed knowledge about their aircraft systems, and their environment in order to more accurately diagnose crisis and think through courses of action.

System principle 4:

Create a flexible system that enables simultaneous action and analysis with mental simulation of courses of action for both team and organizational participants

5. Deference to expertise

As implied earlier, HROs intentionally employ a wide variety of expertise to avoid simplification when responding to crisis. Not mentioned earlier is how HROs are organized to deploy that expertise. Expertise is not employed in a stiff organizational structure, rather experts are expected to self organize around a problem. In addition, they are permitted to make decisions and commitments without multiple levels of supervision common in more hierarchical organizations. By pushing responsibility and authority down and out to where the organization meets its environment errors are caught earlier and problems more rapidly addressed. Moreover, when the signals emanating from the crisis are noticed, experts can find the problem and resolve it at a low level. Quick, accurate, and expert decisions by those closest to the action are emphasized. Westrum call this coordinate leadership (Westrum 1997). In the DERMIS model for large scale emergency response this need is labeled Open Multi Directional Communications. It is based on the concept that during an emergency there is no way to predict what information is going to be needed and who is going to need it. That system recognizes that online communities of experts responding to a crisis will need a collaborative communication system far beyond the primitive group communication such as discussion lists and email in use today.

An example of collaboration with organizational expertise can be seen in outage planning at a nuclear power plant (Bourrier 1996). The plant, Diablo Canyon, had no detailed plan or predetermined structure to deal with a power outage. Instead, the plant depended on delegation of power to experts supported by the complete availability of top management. This flexibility permits problems to quickly receive attention and appropriate collaboration to emerge.

To support better use of expertise the IT system for teams in crisis must permit data and analysis to migrate to appropriate experts. It should encourage crisis teams close to the action to alert the right experts in the organization about anomalies. As a result, exception reporting, and other signals of problems should not just go to team members or executives but be shared widely within the organization. This collaboration or “reach back” capability is a key concept in responding to large scale disasters and military operations (Chumer and Turoff 2006, Neal 2000).

In addition, the IT system must be configurable to support the unique collaboration needs of each crisis. In contrast to this need for unique structures, traditional IT systems typically have the effect of making organization decision making rigid and predefined. The goal for a crisis system should be to support the needs of both the crisis team and their organizational expert collaborators. Rather than emphasizing planning, an HRO builds IT systems that can change with the circumstances and handle new communication processes on the fly.

Deference to expertise, like the other four HRO principles, is an organizational principle. This is not the same idea as the individual behavior mentioned earlier labeled deference to authority. Individuals on teams during crisis tend to be more upward and classically hierarchical in communication. However, organizations supporting those teams should rely on deference to experts, allowing experts to self organize and collaborate with the team.

System principle 5:

Identify, and alert experts with on going problems and support collaboration and analysis between crisis team and experts

CRM--Team Activities and CCIT System Principles

Crew Resource Management (CRM) seeks to find ways of mitigating human error on the flightdeck (Wiener et al. 1993). Insights from CRM have been credited with significant reductions in aviation related mishaps and are currently being exported to non aviation domains such as operating rooms, merchant navy, and fire fighting (http://www.wright.edu/isap/). One goal of this current study is to bring CRM insights to the attention of the crisis and IT research communities.

CRM accepts individual error as inevitable, but attempts to mitigate error by training in decision making, communication, and situational awareness as well as other topics (Helmreich and Foushee 1993). These topics form the conceptual breadth of CRM, but CRM is also a methodology for employing the concepts. This method involves indoctrination and awareness training, practice with feedback, and continuous reinforcement. The method frequently employs flight simulators to mimic actual emergencies and crises, and instruction by domain experts who have been educated on the CRM principles. Finally, CRM involves both individual as well as team capabilities. In fact, every CRM topic has both an individual and team component. For example, in decision making one pilot may make “the decision” but all crewmembers on the team have input and other responsibilities. CRM has been shown to be so effective that both International and United States federal oversight agencies now require CRM training for flight crews (see ICAO 2002; FAR Part 121). Recently CRM insights have been applied to medical teams (Gaba 2005; Helmreich 2000; Sexton, Thomas, and Helmreich 2000).

The principles of CRM can be clustered into three general categories: decision making, communication, and situational awareness. Here we explain each, how it is used in aviation as an example for crisis in general, and the principles of an IT system designed to support this team activity in any domain. CRM has also developed principles beyond decision making, communication, and situational awareness such as workload sharing, stress, leadership and others (Helmreich and Foushee 1993). These less central, less commonly accepted activities are not discussed here in order to focus IT system design on the most essential activities. The principles outlined below apply to both the physically collocated team (e.g. the paramedics) and the extended team (e.g. the doctors standing by in the emergency room).

CRM literature is largely absent from the information systems crisis response research domain. Interested readers are directed to several texts (Kern 2001; Salas et al. 2001) as well as ongoing research communities (http://www.wright.edu/isap/; http://homepage.psy.utexas.edu/homepage/group/HelmreichLAB/; http://www.crm-devel.org/)

6. Decision Making

CRM models of decision making in crisis domains typically identify two primary phases: situation assessment (what is happening), and action selection (what to do about it) (Tolcott 1992). More specifically, situation assessment includes cue detection, cue interpretation, and integration, while action selection subsumes hypothesis generation and selection (Smith et al. 2004). The decision making process is described elsewhere as observe, orient, decide, and act (Hammond 2001; Turoff et al. 2006). This process forms a loop when feedback creates information input for another round of the decision process (Transport Canada 2002). Although one member of a team is typically responsible for the decision, the decision making process is considered a team process as others on the team inform, check, and deliberate with the decision maker.

Within the aviation community, decision making instruction emphasizes both individual characteristics such as decisiveness, assertiveness, and critical thinking as well as team attributes like legitimate dissent, think aloud, and debate (for a more complete exposition on flightdeck decision making see Transport Canada 2002 and Wiener, Kanki, and Helmreich 1993). Moreover, CRM recognizes that making a decision during a crisis requires the crew to overcome a number of significant emotional and cognitive challenges listed earlier in Table 1.

To compensate for these limitations, a crisis IT system should support a wide range of decision making activities and processes. Fortunately, supporting the decision making aspect of the crisis has received considerable research attention compared to the other seven crisis activities described here (see Cannon-Bowers and Salas 1998; Kern 2001). Although few systems have been constructed explicitly for team crisis decision making, experimental and theoretical studies have suggested the following six distinct principles for supporting decision making of teams in crisis with IT.

Simplify data, minimize filtering

Morrison et al. (1998) conducted an empirical study of tactical displays for naval officers responding to simulated threats. The officers seemed to prefer systems that displayed decision making data that was not heavily filtered or preprocessed (Hutchins et al. 1996, Morrison 1998). They favored data in its basic or original form (velocities, heading, range etc.) and not summed or fused into more complex abstract concepts such as threats or planning forms. In a study with similar findings Vicente (2003) reported that in health care, professionals seemed to perform better with less complex systems. That study suggests that serious medical errors were intercepted more often with simple systems in contrast to more sophisticated systems. One explanation is that more complex systems are given unwarranted prestige and diagnoses by these systems were not as often questioned as they should be.

System principle 6:

The system should be simple to use and not overly filter or over process the original data

Support feature matching and story telling

Experienced decision makers on pre-existing teams seem to rely of two basic strategies for decision making in a crisis (Klein 1993). The most common strategy is to match the problem features of the crisis to known problem types. If this fails, decision makers tend to create a story that succinctly explains the situation and provides guidance on necessary next steps. In feature matching, the pattern or story, once recognized, immediately suggests a course of action without consideration of alternatives. In story telling, once a story is generated, the decision maker begins to act on that story and continually evaluates and adjusts the story until the crisis is resolved. As a result, the crisis system should support feature matching and adaptive story telling by helping the decision makers to categorize the crisis according to features, to record or edit the working story and to integrate the available information into a **context or story**, which may include a history of events, the presumed goals and capacities of key systems, potential risks, and opportunities..

System principle 7:

Help reduce mental effort by supporting feature matching and adaptive story telling.

Reduce cognitive overload

One of the most significant limitations on decision making during a crisis is the cognitive overload highlighted in Table 1. As a result, the crisis IT system should be designed to reduce this load. One technique for the system is to represent physical object (e.g.

aircraft, patients, uranium levels) data as trends over time or on other scales. This will help the decision maker be more informed as changing quantities of physical objects will be displayed and not committed to memory and compared over time.

Another technique is to minimize manipulations or calculations by the decision making team (Tolcott 1992). For example, during a decent a pilot often must calculate whether the current rate of descent will be sufficient to arrive at a point in space at the correct altitude.

A final method to reduce overload is for the system to support well known categorizing and chunking of information. For example systems should support categories of malfunctions, categories of procedures, and categories of crisis checklists. As the flightdeck team completes a checklist on gear malfunctions the flight deck team and the collaborating experts on the ground can both immediately display the next entire checklist using aviation classification shorthand. Another way to reduce mental workload by categorizing information is to display scenarios. For example the system should allow teams to conduct "what if" analysis such as displaying fuel consumed if an aircraft has to divert away from one airport to go to another. Displays of physical objects, calculations, and categorization by IT systems can reduce cognitive overload.

System principle 8:

Display historical trends, minimize calculations, and support chunking of information in order to reduce cognitive overload (Solodilova et al. 2003)

Direct attention efficiently

Crisis team members must continually scan their environment as they resolve a crisis. This requires team members to continually shift their attention among a number of ongoing tasks. As a result, a key risk is that an important cue will be missed. Therefore, an IT crisis system should be designed to aid the team by altering members to important cues when needed.

For example, a new head mounted display for anesthesiologists will include the display of an alert if key patient information dips below specified levels (Sanderson et al. 2005). Anesthesiologists on the operating team are required to monitor a wide variety of data sources and participate with other surgical members on the team and can have their attention diverted from key data.

These cues should be immediately obvious and should not require the user to take action in order to obtain important information (e.g. selecting windows, activating pop ups). The crisis system should be simple and have a single indicator to show if an alarm is present and waiting.

System principle 9:

Provide a mechanism to direct the attention of an operator to important events while minimizing the cognitive costs of interruption (Holbrook 2003)

Reduce confirmation bias

As mentioned earlier, during a crisis, team members tend to latch onto an early hypothesis and maintain it despite evidence to the contrary. This is a form of confirmation bias where decision makers become biased to data that support their pattern or hypothesis and appear deaf to disconfirming data. This can be particularly dangerous during a crisis when team members do not have the cognitive resources to evaluate alternative explanations. As a result, the system should help team members to recognize if a hypothesis does not fit the crisis situation. For example, in the study of naval decision makers mentioned earlier, the crisis system was designed to flag misfit objects in a different color (where a misfit object might be an aircraft that was labeled hostile, but did not continue to behave according to that profile).

System principle 10:

Mitigate the tendency of decision makers to attend to only confirming information (Morrison et al. 1998)

Adaptively aid diagnosis and action selection cycles

As mentioned earlier, most CRM decision making research for experienced decision makers in crisis suggests that experts use pattern matching rather than more formal decision models to diagnose a situation. They seem to almost immediately recognize a situation and act rather than develop alternatives, apply criteria, and determine a solution that formal models suggest. However, several studies have suggested that even when a situation is accurately perceived, experienced decision makers, when confronted with a once in a lifetime crisis, can revert to novice like performance when selecting a course of action (McKinney and Davis 2003; Simmel and Shelton 1987). As a result, the crisis system should be designed to help the decision makers evaluate alternative actions.

One of the design suggestions for the large scale DERMIS system is for system adaptation (Turoff et al. 2004). The system adapts to the ongoing crisis as situations are assessed and actions selected. This adaptation takes several forms—letting participants know who else is concerned with a particular issue at this time, finding information the individual should be aware of prior to action selection, and helping users adapt their information search. The adaptive system supports the ongoing cycle of decisions and actions beyond the first situation assessment.

System principle 11:

Compensate for deficiencies in action selection and adaptively support the multiple cycles of decision making (McKinney and Davis 2003)

7. Communication

Communication in CRM is defined as a process of exchanging ideas with verbal or non verbal means. The CRM community uses the classic objective "sender-receiver" model to explain communication and suggest challenges. This practical and measurable perspective implies that communication occurs when a signal leads to a common understanding for both sender and receiver. In addition, CRM trains pilots on the non-objective aspects of communication including the desire of participants to avoid looking foolish, that people respond to both feelings and facts, and the importance of trust (Transport Canada 2002). Finally, CRM identifies two roles that communication plays. First, communication is the process that allows teams of pilots to catch and correct errors and prevent them from exploding into crisis (Hackman 1990; Helmreich, Merritt, and Wilhelm 1999). Second, communication supports all the other team activities on the flightdeck such as decision making, workload sharing, error detection, and situational awareness (Sampson 1999).

Recent CRM studies have suggested that communication for teams before they face crisis is enhanced by the expression of communication values (McKinney et al. 2003, McKinney et al. 2005). Communication values are catalysts for effective early performance of teams. Like all values, communication values are standards against which actions and outcomes are judged; they are positive ideals about communication. Communication values include openness, questioning, candor, attentiveness, respect, support, appreciation, calmness, confirmation, assertiveness, non judgmentalness, and turn taking. Early expression of communication values provides necessary guidance for team members on how information will be exchanged, the context in which communication is to be employed. Once these values are surfaced, communication processes can develop rapidly (Hirokawa and Poole 1996).

System principle 12:

Enable and support communication value sharing

While communication helps prevent crisis, CRM also holds that crisis changes communication (Jehn 1995; McKinney et al. 2005; Te'eni 2001). One change is that during a crisis more communication is upward (from subordinate to leader) than in routine operations. In addition, during a crisis, implicit communication increases and teams shift from an egalitarian horizontal communication framework to a more classical hierarchical and vertical structure where subordinates defer more willingly to authority (Davis et al. 1991; Weick 1990). Further, crisis also caused the group leader to increase receptivity to information from subordinates. New patterns of communication are necessary to correct errors during crisis. In any crisis there is a high probability that false hypotheses will develop and persist (Weick 1990). To overcome this, what is needed is diversity of inputs and hypotheses about situation assessment ("what is happening") (Weick and Sutcliffe 2001). However, the human mind naturally seeks to resolve dissonance (Festinger and Carlsmith 1959) and is prone to latch upon the first "good" idea that comes along during a crisis (Jehn 1999). It is largely through open exchange of messages, independent verification, and redundancy that the existence of false hypotheses can be detected and corrected (Weick 1990).

System principle 13:

Aid increased vertical communication, effective dissent, and alternative hypothesis generation during crisis

8. Situational Assessment

Within the CRM community, situational awareness is defined as an accurate perception of reality (Transport Canada 2002). According to this view, every crew member develops a "Theory of the Situation", an assumption about the current state of affairs. Further, if reality and an individual's Theory of the Situation" differ significantly, a loss of situational awareness (SA) occurs and an error chain could begin (Transport Canada 2002).

As defined, situational awareness appears to be an individual attribute. However, CRM extends situational awareness to be a team principle. This shared SA occurs when the mental model of each member corresponds to the actual state of affairs. To ensure a shared SA, team members communicate to update each other's SA, and if the communication remains effective, team members develop and maintain a common, shared mental model of the situation. The resulting shared SA is vital to performance according to a number of studies (Serfaty et al. 1998). For example, Orasanu (1990) found that the communication between the captain and other crew members facilitates the building of a shared SA and is essential to high team performance. On the other hand, many crew difficulties arise when individual SAs do not overlap or when team members do not recognize that other members hold a different SA. Further, collaborating experts in the organization may not share the SA of the pre-existing team.

An aviation example of an IT system designed to enhance shared SA is an electronic checklist. These are lists of actions to accomplish at predetermined times during a flight and to respond to well documented emergencies. Crews routinely accomplish 10-20 checklists per flight and frequently practice the 20 to 30 emergency checklists during simulated flights. Checklists keep crew members on the same page, and allow both crewmembers to see at a glance a common reference on how many steps or items remain, the next item, and what has been accomplished. These checklists became electronic in order to allow the pilots to mark a step as skipped or to take steps out of order and not have to remember what was skipped. The move from paper to electronic checklists also made it much easier during an emergency to interrupt a checklist to accomplish another list and return to correct step in the first checklist. Checklists enhance the shared mental model of crewmembers by providing a common model on the current state of affairs. With this system, greater collaboration with ground based support is possible. The status (complete, postponed, and incomplete) of each item should be transmitted to these experts to enhance the shared SA among the extended team.

System principle 14:

Enhance accuracy and sharing of common models on the state of affairs

SUMMARY

To date, little work has investigated supporting the collaborative needs of pre-existing teams that face crisis. The uniqueness of the crises event suggests that in addition to automated support, teams that face crisis would benefit from real time collaboration from other experts in the organization.

The goal of this investigation was to develop an initial list of guiding principles for IT systems to support the collaboration need of teams in crisis. To accomplish this, two main frameworks of crisis were reviewed. The first, High Reliability Organizations, suggests that to mitigate the effects of crisis, organizations should be preoccupied with failure, avoid simplifications, attend to operations, commit to resilience, and defer to expertise. The second, Crew Resource Management posits that crisis teams must effectively make decisions, communicate, and share situational assessment to effectively response to crisis. Using these eight activities 14 specific guiding principles, of a CCIT system were presented.

Future research should further refine this list, evaluate its completeness, and assess its generalizability. However, future studies will face the same challenge as the present one--empiricism is difficult. The uniqueness and risk of crisis makes it fundamentally difficult to collect a sufficient number of observations from one context or conduct experiments. On the other hand, as cockpit voice recorders and flight data recorders become more common, more scientific analysis of the system principles suggested here might be increasingly possible.

APPENDIX

General Design Principles and Specifications for DERMIS (Turoff et al. 2004)

Design Principle 1 - System Directory: The system directory should provide a hierarchical structure for all the data and information currently in the system and provide a complete text search to all or selected subsets of the material.

Design Principle 2 - Information Source and Timeliness: In an emergency it is critical that every bit of quantitative or qualitative data brought into the system dealing with the ongoing emergency be identified by its human or database source, by its time of occurrence, and by its status. Also, where appropriate, by its location and by links to whatever it is referring to that already exists within the system.

Design Principle 3 - Open Multi - Directional Communication: A system such as this must be viewed as an open and flat communication process among all those involved in reacting to the disaster.

Design Principle 4 - Content as Address: the content of a piece of information is what determines the address.

Design Principle 5 - Up-to-Date Information and Data: Data that reaches a user and/or his/her interface device must be updated whenever it is viewed on the screen or presented verbally to the user.

Design Principle 6 - Link Relevant Information and Data: An item of data and its semantic links to other data are treated as one unit of information that is simultaneously created or updated.

Design Principle 7 - Authority, Responsibility, and Accountability: Authority in an emergency flows down to where the actions are taking place.

Design Principle 8 – Psychological and sociological factors: Encourage and support the psychological and social needs of the crisis response team.

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AUTHOR

Earl McKinney is Associate Professor of MIS at Bowling Green State University. His Bachelor of Science degree is from the United States Air Force Academy and his Master of Engineering degree from Cornell University. His Ph.D. in MIS was received from the University of Texas at Austin. His research interests include crisis sense making, e-commerce adoption, and information theory.