

THE DESIGN OF A DYNAMIC EMERGENCY RESPONSE MANAGEMENT INFORMATION SYSTEM (DERMIS)

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ABSTRACT

This paper systematically develops a set of general and supporting design principles and specifications for a “Dynamic Emergency Response Management Information System” (DERMIS) by identifying design premises resulting from the use of the “Emergency Management Information System and Reference Index” (EMISARI) and design concepts resulting from a comprehensive literature review. Implicit in crises of varying scopes and proportions are communication and information needs that can be addressed by today’s information and communication technologies. However, what is required is organizing the premises and concepts that can be mapped into a set of generic design principles in turn providing a framework for the sensible development of flexible and dynamic Emergency Response Information Systems.

A framework is presented for the system design and development that addresses the communication and information needs of first responders as well as the decision making needs of command and control personnel. The

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framework also incorporates thinking about the value of insights and information from communities of geographically dispersed experts and suggests how that expertise can be brought to bear on crisis decision making. Historic experience is used to suggest nine design premises. These premises are complemented by a series of five design concepts based upon the review of pertinent and applicable research. The result is a set of eight general design principles and three supporting design considerations that are recommended to be woven into the detailed specifications of a DERMIS. The resulting DERMIS design model graphically indicates the heuristic taken by this paper and suggests that the result will be an emergency response system flexible, robust, and dynamic enough to support the communication and information needs of emergency and crisis personnel on all levels. In addition it permits the development of dynamic emergency response information systems with tailored flexibility to support and be integrated across different sizes and types of organizations.

This paper provides guidelines for system analysts and designers, system engineers, first responders, communities of experts, emergency command and control personnel, and MIS/IT researchers.

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1. INTRODUCTION

There have been, since 9/11, considerable efforts to propose improvements in the ability to respond to emergencies. However, the vast majority of these efforts have concentrated on infrastructure improvements to aid in mitigation of the impacts of either a man-made or natural disaster. In the area of communication and information systems to support the actual ongoing reaction to a disaster situation, the vast majority of the efforts have focused on the underlying technology to reliably support survivability of the underlying networks and physical facilities (Kunreuther and Lerner-Lam 2002; Mork 2002). The fact that there were major failures of the basic technology and loss of the command center for 48 hours in the 9/11 event has made this an understandable result. The very workable commercial paging and digital mail systems supplied immediately afterwards by commercial firms (Michaels 2001; Vatis 2002) to the emergency response workers demonstrated that the correction of underlying technology is largely a process of setting integration standards and deciding to spend the necessary funds to update antiquated systems.

CONTRIBUTION

This is a normative paper in the specific application area of Emergency Response Management Information Systems. It is written to reach three audiences:

- Practitioners involved with the design of these systems.
- Users and managers concerned with the development and use of these systems.
- Researchers interested in doing further research in the area of emergency response information systems.

It is a prime objective of this paper to trigger professional exchanges among the above communities that will lead to a new generation of these systems.

The contributions of this paper are fivefold, it:

1. Draws together a very diverse literature on requirements in this area and attempts to recover the important findings from some earlier literature and experiences in this field that are largely forgotten today.
2. Develops a set of requirements for the design of Emergency Response Systems.
3. Presents a conceptual design based upon those requirements
4. Emphasizes the need for a single integrated enterprise type system that spans all the functions of emergency response from planning, through execution and recovery, to training.
5. Points out research opportunities associated with:
 - Smart System Requirements
 - Collaborative Knowledge Bases
 - Virtual Command and Control Centers
 - Personalization of information filtering
 - Interface design challenges for use of PDA's in this environment
 - Simulation and gaming requirements and training opportunities

The real demonstration of the 9/11 event is the strategic and technical fallacy of making the integration of communications between incompatible systems (fire, police, medical, etc.) dependent upon a single physical command and control center. Such centers are vulnerable to a planned act of sabotage. If there is any strong technical conclusion from the events of 9/11 it is the requirement to develop an integrated communications capability that can react as a distributed virtual system with no required need for the humans involved to be in a single location (Smith and Hayne 1991). A virtual command center can be created when the authorities, decision and reporting responsibilities, the accountability tracking and the oversight monitoring functions are explicitly represented and present in the supporting communications software for the operation of such a human network. In fact,

those involved should be able to operate from wherever they happen to be at the start of the crisis: their home, office, or in transit. It is this underlying technical goal assumption that is one of the foundation goals of the requirements discussed in this paper.

Our primary concern in this paper is with the functionality requirements that the software needs for those planning and executing the emergency response management function.

Very little has been published recently on specific functional requirements for the first responders to an emergency based situation. We also note that a great deal of the literature on emergency response prior to 9/11 focuses on the response of commercial firms to emergencies or crises largely restricted to the corporate environment (Barton and Hardigree 1995; Braverman 2003; Kim 1998;

Lukaszewski 1987; Massey 2001; Mork 2002; Pearson, Misra, Clair, and Mitroff 1997; Smart, Thompson, and Vertinsky 1978; Smart and Vertinsky 1977 1984) or focused on the public relations aspects of a crisis (Coomb's 2000; Dyer 1995). When an organizational emergency has macro-social effects and causes potential or actual physical harm to people or facilities, it usually leaves the jurisdiction of the single organization and can evolve to be the concern of local, state, and federal agencies depending on the scope and nature of the emergency (e.g. Bhopal, Three Mile Island, Tylenol, and Exxon Valdez). However, there are a number of significant observations that apply to crisis situations regardless of the organizations involved.

An important source for requirements will be the past operation and extensive experience of the Office of Emergency Preparedness (OEP) which existed over 25 years until 1973 and was the only civil agency, prior to the new Department of Homeland Security, which could assume total control of a crisis or disaster situation via executive order of the president and execute the command and control function over all other federal agencies including the military. The remainder of this paper first concentrates on the OEP experience and examines other literature dealing with the functionality to provide those managing a crisis. It then further proceeds to develop a conceptual design approach to an integrated

Dynamic Emergency Response Management Information System (DERMIS). There is a great deal of tacit knowledge gained from experience in emergency response that should influence the design of the functional requirements for emergency response systems

Table 1 (Dermis Design Model) shows the movement from Design Principles (Section 3) and Conceptual Design (Section 4) to General Design Principles and Specifications (Section 5) and Supporting Design Considerations and Specifications (Section 6). An objective of this paper is to set forth some of this wisdom and its resulting relationship to design and to translate that wisdom into feasible requirements relative to modern technology.

2. HISTORICAL INSIGHTS ABOUT EMISARI

In the days of OEP, one of the principal resources was its large network of consultants who were experts and specialists from industry and academia. They were individuals who could be called upon to help address issues and problems in both planning for emergencies and attempting to uncover vulnerabilities that were not being adequately dealt with. They were people familiar with critical industries such as energy, communications, or commodities (gas, oil, chlorine, ferroalloys, etc.).

Table 1 Dermis Design Model (Sections 3-6)

<p>A. Design Premises</p> <ol style="list-style-type: none"> 1. System Training and Simulation 2. Information Focus 3. Crisis Memory 4. Exceptions as Norms. 5. Scope and Nature of Crisis 6. Role Transferability 7. Information Validity and Timeliness 8. Free Exchange of Information 9. Coordination <p>B. Conceptual Design</p> <ol style="list-style-type: none"> 1. Metaphors 2. Human Roles 3. Notifications 4. Context Visibility 5. Hypertext 	<p>C. General Design Principles and Specifications</p> <ol style="list-style-type: none"> 1. System Directory 2. Information Source and Timeliness 3. Open Multi - Directional Communication 4. Content as Address 5. Up-to-date Information and Data 6. Link Relevant Information and Data 7. Authority, Responsibility, and Accountability 8. Psychological and Social Needs <p>D. Supporting Design Considerations and Specifications</p> <ol style="list-style-type: none"> 1. Resource Database and Community Collaboration 2. Collective Memory 3. Online Communities of Experts
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In 1970 a computerized Delphi system (Turoff 1972) was prototyped and this confirmed the ability of a group of 25 people to engage in a collaborative Delphi process via a computer network. The Delphi process (Linstone and Turoff 1975) was the design of paper and pencil based iterative structured surveys to allow large groups of dispersed experts (15 to 500) to exchange knowledge and viewpoints about complex problems. Today Delphi communication structures are also carried out over the Web (Cho and Turoff 2003; Turoff and Hiltz 1995; Wang, Li, Turoff, and Hiltz 2003). It was planned to install that system as a mechanism to better utilize the thousand or so professional volunteer consultants associated with OEP. In 1971 OEP was given the responsibility for a new emergency called a Wage Price Freeze. This event prohibited all changes in prices and wages including those that might have been part of existing contracts for the duration of the event. It fell upon OEP to monitor nationwide compliance, examine, and determine requests for exemptions, and to investigate and prosecute violations. The Delphi system was modified in one week to become an “Emergency Management Information System And Reference Index” (EMISARI) for the Wage Price Freeze. The name was chosen to convey to the hundreds of people around the country involved a sense that the system and OEP was providing them what they needed.

There had been no existing plans in OEP for a “wage price freeze” but since the resulting EMISARI system was designed as a communication system integrating people and data into a single data base where all the objects (people or data) could be dynamically changed by non-technical administrators, EMISARI became the only system that could keep up with the evolution of the procedures and processes governing the operation of the Wage Price Freeze. Designed as a communication system (without explicit content), there was nothing in the design that related to the Wage Price Freeze or any other crisis. As a result it was able to be used for any type of crisis. The design focused on the group communication process (Hiltz and Turoff 1978, 1993; Lewin 1958; Ruben 1992; Turoff 1993) and how humans gather,

contribute, and utilize data in a time urgent manner.

EMISARI provided the dynamic ability to tailor the people, objects, and the various data, informational, discussion items, and action items into whatever template was deemed necessary and to modify that template at any time. Such templates were assigned to the members (contacts) of the system by a system administrator who was a management person without any technical training. About one third of the software was devoted to making it easy for an application professional to act as modern switchboard operator by creating templates and matching people to the functions defined by the templates. The existence of full text descriptions for even a single data item allowed individuals to search for what they needed by content descriptions. Templates for data and other functions could be created and assigned in a few moments by the administrator. Finally, the internal markups let the users themselves tailor dynamic reports on a given situation by reconfiguring the current information in the system. This was done by easily specified Hypertext (Web like links) to any existing data or text template. The reports with these links, when retrieved, would always capture and incorporate the latest updates of the defined templates (Hiltz and Turoff 1978, 1993). EMISARI was a highly structured group communication process that followed basic concepts of the Delphi Method (Linstone and Turoff, 1975). It also provided an internal computer conference capability and its own internal message system that could be used in a delayed or instant message mode (Turoff 1971, 1972).

EMISARI went on (in the Internal Revenue Service, IRS, and the General Services Administration, GSA) after 1973 to be used over a fifteen-year period for transportation strikes, coal strikes, petroleum shortages, chlorine shortages, natural gas shortages and some of the more severe natural disasters (Macon and McKendree 1974, 1975; McKendree 1977, 1978). The lore or tacit knowledge accumulation that takes place in organizations that go through a series of disasters is not often explicitly captured by the organization for reasons we will discuss later. However, natural disasters are valuable events

for developing organizational memories and as "occasions for organizational sense-making" (Weick 1993, 1995). EMISARI incorporated many of the features called for today under the current rubric of knowledge systems (Bieber et al 2002).

EMISARI allowed, with 1970 technology, two to three hundred users scattered around the country to exercise a single coordinated group response to a crisis. Over the years there has been an accumulated literature on EMISARI (Hiltz and Turoff, 1978, 1993; Kupperman and Wilcox 1972; Kupperman, Wilcox and Smith 1975; Price 1975; Renner, et al. 1972; Rice, 1987, 1990; Turoff, 1971, 1972, 2002, Wilcox and Kupperman 1972).

3. THE EMERGENCY RESPONSE ATMOSPHERE OF OEP

The Office of Emergency Preparedness (OEP) in the Executive Office of the President grew out of the original OSS (Office of Special Services) operation during World War II. OEP was a single civilian agency that could exert Command and Control over all federal resources (including military) upon the declaration of a Federal Emergency. In such circumstances it could also exert regulation or actions from companies involved in the emergency situation. This occurred regularly in such areas as transportation strikes, commodity shortages, natural and unnatural disasters. OEP had a mission to assess threats, plan for the reaction to them, and to execute those plans when needed. It also had responsibility to ensure that the government could function effectively in whatever emergency might occur. In practice it was a single agency, at presidential level, where emergency response problems on the part of industry, federal government, state government, and local government could receive attention and action.

In 1973 OEP was dissolved and the various functions of OEP were, in some cases, spread out to other government agencies and/or eliminated from civil government. A number of years later FEMA (Federal Emergency Management Agency) was created as a centralized body, but it has been restricted largely to a reactive role with respect to federal

disaster funds management and no significant mission ability for threat assessment, response planning on an integrated government wide basis, and most importantly, overall command and control in an emergency situation. However, the concept of central authority does not mean that those taking actions and making decisions consistent with their responsibilities have to be in one location or belong to one organization. In emergencies, as in military operations, the central authority delegates decision making to those directly responding to the situation.

One of the significant advantages the OEP had was that in an actual crisis they could draft any federal employee the agency felt it needed to be part of the crisis response group. This meant that for any situation the best possible team could, in principle, be created. Most often the process was one of quick negotiation for the talent it needed and only infrequently did OEP resort to ordering the transfer.

There was a lot of lore and wisdom in the operation of OEP and there were still some senior civil servants and consultants from the WWII OSS (Office of Special Services) days who helped to set the tone and atmosphere of the operations of that agency (Hiltz and Turoff 1978; Kupperman and Wilcox 1972).

With respect to information systems, and in particular command and control versions of those systems, we might try to formulate the OEP philosophy in the following set of premises.

Premise 1 - System Training and Simulation: An emergency system that is not used on a regular basis before an emergency will never be of use in an actual emergency.

It is not just a matter of training but of finding actual day-to-day functions that emergency systems can perform so that there is no need for training in the use of the system when the crisis occurs. Any sort of surprise situation that requires a group to be created to react to the circumstances would represent such training opportunities. While many organizations do not like to admit to these events, they seem to be quite frequent. The only training otherwise possible is a quick

apprenticeship by sitting at the side of someone who already knows how to react in a crisis and how to use the available facilities. We created in the late sixties a very simple multiple choice Computer Assisted Instructional (CAI) System which would provide a scenario on a given situation and present a set of alternative actions a person could take in a disaster response situation. There was always an "other" choice. Both senior and junior staff at OEP could use it and if they felt there were circumstances not specified that would create a new alternative valid answer, they could choose "other" and explain the circumstances. This very simple system allowed the responders to exchange the experiences and knowledge they had acquired. While in those days we considered it such a simple communication addition to a CAI system that we never published it, one can consider it to day a basic collective memory system. One could, for example, do the same for sales personnel exchanging experiences. Even in the same type of natural disaster the specific circumstances in a similar situation could differ considerably. Not everyone's experience was exactly like that of others in even the same disaster.

There are actually many events in commercial and governmental organizations that qualify as "mini emergencies" such as strikes, court cases, cost overruns, delivery delay, accidents, new regulations, supply shortage, natural disaster, budget shortfalls, production delay, product or service malfunction, contract negotiation, loss of key employee, loss of key customer, designing or responding to an request for proposal (RFP), competitive actions, etc. All these sorts of events can be "serviced on a regular basis" by the concept of an emergency response system we will be considering. In fact, it is a system ideal for use by large dispersed and asynchronous, i.e., virtual, project teams.

After the prior Northeast Blackout the utilities in the Northeast created an emergency dedicated phone system to aid in coordinating activities to prevent another such occurrence. In the Blackout of 2003 there was more than an hour lag between the two major power-lines going out in Ohio and the final 90 second collapse in the New York area. The emergency phone system was not used till

after the final collapse throughout the Northeast. One suspects it was a case of a system not regularly used between disasters!

Furthermore, an existing user community is a critical aid during technology diffusion (Rogers 1995) in facilitating the introduction of new and unanticipated users that will always occur within the actual crisis. As a complex operation involving experts in the required areas, the concept of "easy to use" is replaced with "easy to learn" as the primary design objective. Complex situations require a matching complexity of variability in a system designed to respond to such an environment.

Premise 2 - Information Focus: People responding to an emergency are working 14-18 hour days and have no tolerance or time for things unrelated to dealing with the crisis.

This has a significant impact on the design of support systems and rethinking the nature of filters, which attempt to prevent information overload, and searching processes for obtaining relevant information. No one on the front line (physically or virtually) in a crisis has time to read a newspaper, listen to radio or TV, or take or return a phone call without it being clear why they must do so. When involved within an emergency situation they must be able to get the full context surrounding that situation as an integrated process within the system they are using. It also means that one cannot exactly predict what they might be interested in ahead of time.

This also means that the individuals carrying out the roles they are responsible for in the system need to have access to all that is taking place with respect to crisis and one cannot assume that the flow of information can be restricted which usually does occur in a crisis response situation operating under the "threat-rigidity" reaction hypothesis (Rice 1990). Under stress due to the lack of necessary information or coordination awareness people tend to rely on executing action formulas that might be totally inappropriate to the given situation. What may be happening at a different location in the crisis might have an impact on a person's decision about what actions to take.

Premise 3 - Crisis Memory: Learning and understanding what actually happened before, during, and after the crisis is extremely important for the improvement of the response process.

Collecting information on the performance of people and systems in given situations should be incorporated into the design of the systems rather than as an afterthought. The system needs to be designed so that it can be evolved and improved from the understanding provided by prior usage (Keen 1980; Zuboff 1988). Also, capturing the history of what took place without imposing added load on the participants is a critical part of the design objectives. This is related to the next observation.

Premise 4 - Exceptions as Norms: Almost everything in a crisis is an exception to the norm.

There is no way to predict exactly who is going to be doing what, when, why and/or how at the command and control level in a crisis environment. The crisis forces increased decision making by those having to take immediate actions on site. This authority is granted from those above who expect accountability in return so that they can carry out oversight with respect to conflicts for resources and other factors that need to be integrated. Problem solutions and the reallocation of resources go on as a continuous unpredictable process. When a paramedic remains at a site rather than returning with the ambulance it creates a limitation on the use of that ambulance as a fully staffed medical unit to be directed to other sites. What specific data and information is of concern and interest to a given individual is changing rapidly.

Exceptions to the planned response are the critical factors in determining the minute to minute operations. Anything that no one thought of, but which occurs, in the response for a given crisis situation becomes the critical factor in generating problems to be dealt with at all levels in the process. A crisis response system is an information system that has to be an integrated communication and data system where the people involved, their talents, concerns, immediate problems, actions taken, actions planned, situation information, and

consequences information are all part of the underlying database and structure. One cannot separate the data processes from the communication processes or from the human processes symbiotic to “data” and “communication” processes.

This means the end user must be able to reconfigure the system interaction in a dynamic manner and designate changes in priorities, filtering and delivery options at any moment during the emergency response process. It also means the system has to dynamically observe these changes and keep others who need to know about them up to date.

Premise 5 - Scope and Nature of Crisis: The critical problem of the moment is the nature of the crisis, a primary factor requiring people, authority, and resources to be brought together at a specific period of time for a specific purpose.

The crisis response team is a real and virtual community of specialists and experts that must have unrestricted access to one another and is able to act as a collective (Hardeman, Pauwels, Palma, and Van de Walle 1998; Weick 1993, 1995). For specific problems, subgroups with the appropriate talent and backgrounds need to be able to form and function. The system also has to allow for continuity and immediate substitution of individuals when members are lost to the process, forced to reposition their attention, or when they are just plain exhausted. This also speaks to the necessity of training people to undertake multiple roles in a crisis situation and having enough people who can be brought in large scale or prolonged crisis situations (Danowski and Swift 1985).

Premise 6 - Role Transferability: It is impossible to predict who will undertake what specific role in a crisis situation. The actions and privileges of the role need to be well defined in the software of the system and people must be trained for the possibility of assuming multiple or changing roles.

Knowing who is available at the time of action has to be determined and taken as a key element of disaster response and the

requirements for command and control. Knowing what data relative to a problem is current, what the source is, and what is its degree of accuracy or status of the data is as important as the data itself. Concepts such as roles, responsibilities and the explicit status variables of the data and roles (priority, accuracy, source, actions, interests, concerns, etc.) have to be part of the collaborative database supporting the operation.

Premise 7 - Information Validity and Timeliness: Establishing and supporting confidence in a decision by supplying the best possible up-to-date information is critical to those whose actions may risk lives and resources.

Emergency response systems must be able to refine the data and information and focus the sources of data on what is critical to a decision. The system must allow for indirect and implicit communication channels between those dealing with interpretation and actions at different levels in the operation. For example, the OEP system, during the Wage Price Freeze, would track the key words searched but not found in various files such as the policy interpretation file. The list of words that those people in the field could not find would be presented to the weekly meeting of the policy committee examining requests for interpretations and was used to influence the agenda for the meeting. This is an example of the system providing an indirect communication channel between those in the field and a policy setting committee. The people in the field did not have to waste time making explicit communications. Actions taken are always going to be based upon incomplete information and therefore every effort must be made to obtain and direct the information that is available into a common shared database structure that may be undergoing unpredictable change with respect to the nature and structure of what is being entered.

The extraction of cues from streams of communications and data create indirect communications useful as input for any knowledge acquisition system (Hiltz and Turoff 1978; Wieck 1995). In the emergency situation there is a need for important policy committees in the recovery phase and for

prolonged crisis situations which may result in significant differences of view across multiple agencies or government bodies. There can also be a need for very quick reaction committees at higher levels dealing with reacting to possible resource shortages or the integration of outside intelligence into the on going crisis reaction activities.

Premise 8 - Free Exchange of Information: Crises involve the necessity for many hundreds of individuals from different organizations to be able to freely exchange information, delegate authority, and conduct oversight, without the side effect of information overload.

Consistency of response to all stakeholders is considered a primary requirement. Problems in consistency of response result from the "Niche-Width Theory" (Massey 2001). An organization is either a specialist or a generalist in the scope of the environment and this reflects more limited specific strategies or tactics for the specialist organization. While a specialist agency usually has more correct knowledge about their area of expertise, the generalist agency usually has more influence on policy decisions. This can be applied to the many organizations and agencies involved in a crisis. A good example would be the FBI as a generalist organization and the Centers for Disease Control as more of a specialist agency. The differences in response of these two agencies during the Anthrax emergency are an illustration of the coordination problem typical in a crisis situation. Each agency was operating with different assumptions about the real mission and the lack of quick resolution by a clear authority led to mistakes, public inconsistencies in policies, and undermined the faith of the public in what the government was doing. The Centers for Disease Control wanted the public to have all the details on what was happening for an objective of inhibiting further spread of the disease and the FBI did not want those carrying out the spread of the disease to have some of the information which might inhibit catching the culprits. The problem about how to coordinate among the many agencies involved in a crisis has been expressed on numerous occasions in statements to congress dealing with the

formation of the new Homeland Security agency. The challenge is expressed very well by Hale (1997, p. 5 of 15):

...the key obstacle to effective crisis response is the communication needed to access relevant data or expertise and to piece together an accurate understandable picture of reality.

Faced with extreme uncertainty, decision makers tend to increase their search for information – often for symbolic purposes and in self fulfilling ways – while simultaneously shutting down some channels of communication, and relying on familiar or formal information and channels (Rice 1987). Furthermore when information overload (Hiltz and Turoff 1985) sets in, groups tend to restrict their information processing and control moves up the chain of command, leaving little flexibility at the lower levels. High levels of uncertainty and information overload are very harmful to reliable disaster response. Fortunately in most crisis situations we do not have to worry about ambiguity as a data corruption problem at the local and specific event level of response. At the higher response level of oversight and resource allocation considerable uncertainty and some associated ambiguity can exist. However, ambiguity results from the use of language and the communications system which can be minimized by the design of the system and the training in its use.

As long as the responders are trained in their role responsibilities and there is a history of communication among a key nucleus of the situation reporters and the decision making responders there should be no significant ambiguity problem. Furthermore, if the communication system is computer based we have a better ability to put in quick learning aids for those thrown into any situation with out adequate training. If the system knows who they are it can provide additional feedback on what others will think what their words, requests, and actions mean. The system can also enforce apprenticeship by assigning all communications for a “newbie” to be monitored by a real time coach.

The deaths of many of the first responders on 9/11 can be largely attributed to this combination setting in as a result of lost

communications. With out awareness of what was happening, the lack of coordination due to the loss of the physical command and control center, and the overload from the immediate stimulus of what was occurring around them, many of the first responders were following the rules they had been taught with out reexamination. As a result, we had a tragic example of the threat-rigidity hypothesis at work.

Premise 9 – Coordination: The crux of the coordination problem for large crisis response groups is that the exact actions and responsibilities of the individuals cannot be pre-determined.

As we will see this is a result of the uniqueness of each crisis situation, the resulting need for improvising based upon that uniqueness, the reliance on tacit information, and the time-critical nature of the decision process.

Furthermore, governments have certain disadvantages over commercial firms when responding to a crisis. They cannot easily hide what is going on and this in turn results in four factors unique to government agencies (Horseley and Barker 2002).

1. Crisis raises questions about the ineffectiveness of government.
2. Frequency of government (in-)action during crises certainly does not imply that government action is always functional or beneficial.
3. Politics can turn crises from “occasions for decisions” into “occasions for restructuring of power relations.”
4. Military and civilian organizations called upon in a crisis may show their Achilles’ heel during acutely critical situation, e.g., situations they did not expect or plan for.

In theory, government agencies are less likely to get trapped in deceit, as corporations do precisely because they can more easily control and limit information.

New ways to deal with the unforeseen events evolve with the nature of the crisis. The person needing to make a decision must be assured that anything relevant for the decision can be found in a timely manner; but also understand that precisely because it’s a crisis, what might be considered the most

“relevant” information may simply not exist. People can deal with a high degree of uncertainty, e.g., extract cues, to make timely decisions as long as they know it does not result from hidden information that will make their actions appear wrong later. Providing access to all available relevant information at the lower levels is not always the attitude within government organizations.

In a crisis situation authority flows down to where the action is. However, status information and accountability data must equally flow both upward and sideways. In fact, it is also important that teams have accountability as well (King 2002). With the role carrying with it the authority for action and the collection of roles making up a momentary team for dealing with a particular set of related events, we have team accountability as well. This implies a great deal about the functionality designed in an emergency response system. It infers, for example, that the data and actions in such a system must clearly be identified by who is supplying an idea, a plan, a viewpoint, data and/or taking an action.

The sixties and seventies saw considerable academic effort to understand the behavior of individuals and organizations in crisis situations. An excellent report (Dynes and Quarantell 1977) compiled much of this research in to a single document. In their summary they state the following (page 26):

On the basis of what has been described here, the dominance of a normative planning model which emphasizes coordination by plan is, at best, questionable. The crisis event itself creates the conditions where such coordination is inappropriate. This inappropriateness, however, is not likely to be challenged in post-disaster critiques of organizational functioning which utilizes coordination by feedback. The increase in communication is usually taken as a failure of coordination, not a necessary condition for it. Emergency planning, however, can also be directed toward improving and facilitating coordination by feedback, since it is likely to be the dominant mode in emergency conditions, not a chaotic aberration.

The extreme of coordination by plan is complete external control of those in the front lines, while the coordination of feedback assumes internal control by those in the front lines of a disaster situation. The nature of the EMISARI system at OEP was the design of a system dedicated to coordination by feedback and it is this mode of operation that is also the essence of the proposed design that follows.

Refusing to recognize the reality of the crisis situation, which is the movement of authority to lower levels and the need for rapid response, often results in the inadequate design of a system that can handle the oversight function in a timely and effective manner. Because many serious decisions are irreversible (Pauwels, Van de Walle, Hardeman and Soudan 2000) this leads to incorrect decisions that cannot be changed or delays in making a decision which eliminates the opportunity for the better alternatives to be chosen.

Taking the above as the assumptions about the nature of a crisis it becomes clear that an Emergency Response Information System must be viewed as a structured group communication system where the protocols and communication structures are provided, but there is little content about a particular crisis except as an integrated electronic library of external databases and information sources. Others have agreed that Group Communication via a computer may be the most appropriate medium for a complex problem requiring input from large numbers of people (McKendree 1978; Price 1975).

A more recent examination of crisis communications challenges highlights some of the same properties (Horseley and Barker 2002):

- Information overload is typical,
- Heterogeneous groups and individuals must coordinate their activities,
- People must work together who do not do so normally,
- It cannot be accurately predicted who will be available and involved at the time of the crisis or at a given moment in the response sequence, and
- Community and public communication is extremely important in dealing with many crises.

4. RESULTING REQUIREMENTS FOR EMERGENCY RESPONSE AND CONCEPTUAL DESIGN SPECIFICS

The nine premises and their underlying objectives and requirements discussed so far cut across all types of crisis and emergency situations. We need systems that make no presumption as to whether one is dealing with fires, bombs, hazardous materials, transportation interruptions, etc. It is the lack of dependency upon specified content that makes an emergency response system a powerful tool to apply to any emergency once the users have had the training and experience to master it. There may be supporting data bases that contain content information such as the location and availability of specific resources for specific types of crisis situations or information and knowledge about such things as hazardous materials. These database resources could be anywhere, it is only necessary that the local responders know about them and how to be able to use them if needed. However, the system that carries out the response and allows the humans involved to coordinate and exercise various levels of command and control has to be a communication system tailored for the emergency response mission. Fortunately there are communication commonalities to the coordination process in all disaster situations which we can utilize to design the necessary structuring.

Our primary concern is with the design of an Emergency Response Management Information System that will directly support the responders in a local crisis situation and the associated coordination structure among all the involved parties and agencies. We also assume the communications network and computing technology exist to support a reliable network of Personal computers, servers, laptops, and PDA's, mobile phones, and wireless operations. We are focusing on the supporting software and its required functionality. The significant challenge that is being confronted is to provide a functionality that can be adapted for use on the limited screens of PDA's as well as the larger screens of desktops and laptops. While it is desirable and useful to consider multimodal interface capabilities, such as the addition of voice input

and output (to free up hands for other tasks), it will not explicitly be treated except that the limited visualization capabilities of PDA's does make the addition of voice input and output very critical as an alternative interaction mode for anyone needing to use their hands for their response activities (Pyush et al., 2002). The ability to record the details of a situation report may also require the ability to convey useful emotional content to express such things as seriousness, urgency, and conviction. The ability to incorporate sound bites and emotional icons into any text location and the need for graphics and color is also an obvious assumption. The resulting foundation requirements are:

- Extremely easy to learn via training and exercises because it is consistent with the task requirements.
- Useable by people who will have an understanding of their roles and responsibilities in an emergency environment.
- Will focus on a concise and self-evident design demanded by the small screen orientation and the need to minimize learning.
- Will allow the individual users a high degree of tailoring, filtering, and focusing of the interface tailored to their specific roles and responsibilities.
- Will serve to support planning, evaluation, training, exercises, and system updating and maintenance between crisis events.
- Will allow the operation of the response function without the need for a single operational physical center except for the operation and backups for the computer hardware and software acting as a server and distributed resource databases for this operation.
- Will be designed as a structured communication process independent of the nature of a particular crisis.

To accomplish this we will focus on five very specific criteria for the interface design of a group communication system that is extremely appropriate to the emergency response environment: metaphors, roles, notifications, context visibility, and hypertext.

1. The **metaphor or metaphors** of a system are the mental models of a system that a

user can easily learn in order to create a cognitive map that will make it easier to understand the system. The metaphor allows the user to translate the task objectives into interface actions to carry out those objectives. The type of metaphor that allows a human to create a “road map” or model of an information system is sometimes referred to as a boundary object (Star 1989).

2. The concept of **human roles** built into the software of group communication systems (Turoff 1993) and supported by specific privileges and tools for carrying out the actions for those roles.
3. The concept of **notifications**, which are relevant alerts to a user of changes in status, data, and/or information of concern to the given user, brought about by events and/or the actions of other users (Turoff 1993).
4. The concept of **context visibility**, which is the idea that the components of the meaningful data objects are presented in a context that relates to the understandings of the user. By the user’s choice of a particular data element the system can infer the functions that that the user wants to perform at that point in time. When the user is uncertain as to what will be called up or wants to vary the choice they need to be able to obtain all the possible selections as a submenu. This produces a common sense object interface that makes choices self evident and tailored to the particular user.
5. The original concept of **Hypertext** (Nelson 1965) which was the possibility of multiple two way linkages with semantic meanings that allowed a person to utilize any item in the content of the application as a set of menu alternatives to move to other content or functionalities in the interface.

By tying these five concepts together we are able to hypothesize some very specific requirements for the design of a self evident Emergency Response Management Information System.

4.1 Metaphors

In a foundation paper on metaphors (Carroll and Thomas 1982) the concept was

expressed that metaphors were not only useful for training users but that the “right” metaphor could establish the criteria for the actual design of the system, the interface, and its requirements. There is no better illustration of this concept than the emergency response environment. One concept or data construct is understood by all those who deal with crisis management and response: the “event log” of what took place during the crisis. It is the primary concept usually used, after the crisis, to analyze what took place (Hale 1997). Those who have participated in a crisis and tried to understand afterwards what actually occurred, typically use some sort of log of events. The event log is the foundation metaphor for our design.

Instead of a log being a postmortem of what occurs we can turn it into a dynamic evolving record of what is happening as the events of the emergency unfold. Each individual responder would have access to the total log at various levels of summarization. At the highest level would be only the **root or triggering events** from the external environment that cause reactions to cope with the situation. Clicking on any one of them opens the **sub log** of everything associated with the **collection of information** about the event and the resulting **responses** to the root event as well as the associated **resources committed by recorded actions**. Clicking on any of the entities in the log will result in obtaining all the relevant links from that item to the various forms of associated information. The log is the on going roadmap of the emergency, which provides access to all the associated trails being blazed by the resulting actions. The user can quickly travel in any direction that is of concern to them. A responder would **mark** the events they need to track in order to carry out their role and responsibilities. Any resulting actions of a marked event would be delivered to that user in the future.

To accomplish this, the system needs to allow the users to establish templates for an integrated set of logs. A single root log by a single individual can create over time, as a result of future conditions, a whole sequence of related event logs. A typical example of root/parent log and its possible branch/children logs are:

Request resource root event log (location, situation)

- Allocate (or deny, delay, partial allocation of) resource
- Trigger a “maintenance of resource” as a new root event
- Resource in transit to destination
- Arrival of resource at desired location
- Status change in condition of resource
- Status change in condition of situation
- Recycle of current incident event for more of the same
- Resource reassigned before completion
- Completion of original root event transaction for this resource
- Resource in transit to normal location

For example, the above sequence or log template might be used for a medical unit, which is typically composed of an ambulance, a driver, a paramedic, and various supplies along with a fuel supply. However, any given unit might vary in the details (e.g., containing a doctor). Furthermore, during the event the paramedic or the doctor might remain on the scene as the ambulance takes others back to the hospital. A delayed response could occur because the only ambulance available needs to be refueled before it can start to satisfy the original request.

During 9/11 there was no prior plan that called for using a ferry to act as an ambulance to deliver patients to the emergency outdoor medical area set up in Jersey City. Some event sets might have to be generic so that the concept of something like a medical unit can dynamically be redefined for a particular resource request event. In this case a new type of medical unit would have to be established in the resource database during the crisis. This nicely illustrates that particular resource types might need to be established in the database during the crisis. It is the structure and process that comprise the software and not the content. In this manner the system can be adapted to any type of crisis.

The above template for a resource request when started for a specific instance would be time stamped and have the information on the reason, situation, and location that is the cause of the request entered (to the extent information is available, and the form should allow for multiple contributions to

these, as different individuals in different locations will have different reasons, situations, etc.). Such information might be updated as the request is in progress and all updates would identify the human source and the time of the update. There might be a large set of resource requests sharing elements of the basic situation information and at any time details can be updated which in turn might have impacts on the resource requests and their adequacy. In addition, there needs to be the ability for a new type of event template to be created during the crisis situation.

Different people have as part of their “role” the authority for launching a given event type which may be a root or response event in a template. This brings up the use of a secondary but no less important metaphor, that of the “checklist” (Hale 1997; Lukaszewski 1987). Triggering an event brings up a checklist for the person to fill in the appropriate data and check off appropriate choices; but always assuming free form inputs for unexpected “other” unpredicted factors. It would pinpoint the other roles that will be needed and whether they are occupied at that point in time, and display any other conditional impediments that might have to be considered such as the possibility of a delay and the reason for it. If a medical unit cannot be immediately dispatched it might cause the people on the scene to take other or alternative actions (e.g., dispatching some injured in other vehicles).

The person creating an event must be able to have the information that allows him or her to conclude that the related events will be able to proceed with reasonable dispatch. In the original EMISARI system there was a code to indicate that needed data was not yet available which would substitute for the data in the output field. Also with any such item the information was also provided as to who would be responsible for supplying and updating that data item.

A typical mode of operation would be for everyone to receive those root events for the types, locations, and other conditions that they are interested in, i.e., marking them explicitly or having them linked to a marked event. In addition only those events that the user marks for tracking would result in the

future delivery of other logs in the event template when they occurred. In this manner the crisis responder sets up their own filtering mechanisms as events occur. Clearly the person creating a root log event would automatically be delivered all follow on log items. There needs to be an override where one person can determine if another has marked an event for tracking and if not trigger a resending of the event to the person who has not been tracking it. This provides the opportunity for oversight and alerting individuals to items they may have overlooked. The use of codes to designate missing information allows users to search, identify, and undertake efforts to obtain the missing data.

The use of event log templates was added to a derivative of the EMISARI system (PREMIS) which was used to track the actions with regard to violations of federal orders with respect to numerous commodity shortages declared as federal emergencies in the seventies (McKendree 1978). That system specified what actions the responsible party could take for a given event/step in the procedure and depending on the action notified the appropriate role (person) that it was time to take over responsibility for the given event. The proposed concept of a crisis decision unit (Smart and Vertinsky 1977) is a subset of the concept of event templates for crisis situations.

Typical general event categories are: triggering events, resource requests, information requests, situation reports, completions, status changes, role changes, warnings/alerts, and leads/speculations.

4.2 Roles

Roles have always been a key part of any structured group communication process (Turoff 1993; Turoff, Hiltz, Bieber, Whitworth, and Fjermestad 2001). Roles were a key concept in the original EMISARI crisis management system (Hiltz and Turoff 1978; Mckendree 1977, 1978). Any piece of data in that system was always identified by who was responsible for supplying it and updating it. Who could launch what type of actions/events was also very clearly displayed and available for retrieval. A person's entry in the directory had a dynamic (time wise) list of any responsibilities and was searchable by

responsibilities by every member of the systems.

In a crisis it is never certain who will take on which role or which combination of roles. It is expected that people will be trained to be qualified in a number of different roles. While one recognizes that a policeman is unlikely to take on the role of a fireman, when it comes to roles of reporting, making requests for resources and assigning resources we would expect that cross training is in fact feasible. At the time of a crisis the first qualified person active in the system could immediately take on the highest priority role or roles they were pre-qualified for. In some emergency situations individuals might be pressed into roles they are not completely qualified for if there is no one else available at the moment. If this is a likely situation then we need to worry about ambiguity, real-time training, training aids, and more active oversight requirements for monitoring in the system design.

The persons with the authority to assign roles could assign roles to any active member of the system based upon what was needed at that time. Experience has shown that as a minimum, there are eleven fundamental roles that can take place in a large scale crisis situation. Each role should be supported by functionality built into the software (Turoff, Hiltz, Bahgat, and Rana 1993). The roles specific to the emergency response function are:

Fundamental Roles

1. Request resources: **people:** medical, police, fire, military, construction, utilities, etc.; **things:** medical units, transport, fuel, equipment, etc.
2. Allocate, delay, or deny resources
3. Report and update situation
4. Analyze situation
5. Edit, organize, and summarize information
6. Maintain resources (logistics)
7. Acquire more or new resources
8. Oversight review, consult, advise
9. Alert all with a need to know
10. Assign roles and responsibilities when needed
11. Coordinate among different resource areas

12. Priority and strategy setting (e.g., command and control)

In any crisis there are requests for resources; other people must decide if the request can immediately be satisfied or has to be denied or delayed. There is also a need to report the situation at different locations, for different dimensions (medical, fire, police, etc.), and for others to analyze the incoming information to determine the implications for those:

- Allocating resources,
- Maintaining current resources, and
- Acquiring additional resources to meet an expected demand.

In addition we have, in many situations, the need to position resources, obtain specialized knowledge, e.g., hazardous materials, or to raise or lower the level of the current response to the crisis. In the original EMISARI system one could dynamically establish report forms, including quantitative and qualitative inputs and assign them to people responsible for reporting the situation.

Events and roles have an intimate relationship. Event types should be open ended and the user community should be able to define specific event types and their relationships. The following is a possible general classification of event types.

- Triggering Events: cause the need for action or response of some sort
- Resource Requests: requesting the assignment of any type of resource including people or equipment
- Information Requests: expressing the need for more information
- Situation Reports: descriptions of a current situation at any level of detail or scope
- Completion Event: the termination of or conclusion of a chain of events
- Status Changes: a significant change of status of a particular event chain
- Warnings/Alerts: something that needs to be watched for or investigated
- Leads/Speculations: an issue, concern, or possible happening that needs to be considered in the current situation
- Role Changes: a change in who is responsible for a specific role either

temporary or permanent

- Finished events: event process completed
- Interrupted events: a pause in the process of treating the event
- Suspended events: a pause with no expectation of a startup
- Archived events: Event retired from any dynamic modification (frozen)

The above categories apply to all events. Orthogonal to the above event types is a classification for events specific to a given role which has a responsibility for a given event that has the following possible categories:

- New/waiting: events the user has not seen or dealt with yet
- Event task tracking: an event the role is now responsible for handling
- Event monitoring: events of interested being tracked
- Action required: a task for which an action must be taken by this role
- Response required: need for this role to supply information
- Priority change: a priority change in an item the role is handling
- Status change: a status change in an item the role is handling
- Information request: to this role
- Finished events: no need for further tracking, process completed for this role
- Interrupted events: a pause in the process of treating the event for this role
- Suspended events: a pause with no expectation of a startup for this role

The above results in a two dimensional selection table for a user in a role which shows the number of events in each category and allows the user to obtain a list of the set of events by clicking on the count in that category. The categories should be extensible by the user community.

Usually, people deal with medical, fire fighting, law enforcement, military, utilities, and construction resources so that many of these fundamental roles are multiplied by the types of specific resources being considered. This means coordinators must take the responsibility to ensure responses from these multiple resources are not interfering with one another. Typically today the response systems

for these different areas are separate and the details of what is going on with any one of them is not available to all that are involved. In World War II, the army and Navy decoded the Japanese transmissions on alternative days and prepared summaries for the leadership. Too late it was discovered that if the analysts had had access to the total file the likelihood of an attack on Pearl Harbor would have been much more obvious.

In terms of our metaphor of the use of a dynamic log, privileges are associated with each role which in turn authorizes, for example:

- Creating Event log entries of a given type.
- Responding to specific types of event log entries.
- Supplying information or data related to specific events.
- Producing situational and interpretive reports related to sets of events.
- Providing modification privileges over material entered by others.

In general, one can define about 50 primitive digital communication privileges including such things as allowing some one to set links in other people's material or a person inserting material in files he or she cannot read (Turoff 1993).

The role is an explicit object in the database that has specific links to all the other data objects in the system and those links carry privileges for actions on the data in the system (Turoff 1993). Nevertheless, in the actual emergency it will be a human who takes on the role and carries out all the activities consistent with the privileges associated with the role. This was true in the first group communication system (Turoff 1972) for carrying out Delphi Exercises and in EMISARI. Roles can be aided by computer agents and they can be recorded and canned for use in specific training scenario simulation games. However, it is doubtful that one would ever want to assign any decision responsibility to any such agents in real emergency situations.

4.3 Notifications

The critical general property of computer-based communications that we are utilizing in designing a group communication system for crisis response is that only by using

a computer can the content of the information being communicated also be the "address" for delivery (Hiltz and Turoff 1978; Turoff 1993, Turoff, et. al. 2001). People in a crisis have to focus on information needed and the currency of the situation factors that relate to the decisions and actions they are taking. Since what they need to know is very dependent upon the actions and knowledge of others, we need to notify the user of the impact of those particular items that relate to their roles, actions, responsibilities, and what they have decided to track in terms of current events in the system. By having the users and their dynamic properties as an integral part of the data structure of the system, the computer can determine who should be sent what notifications. Any other unstructured alternative like email would quickly lead to information overload (Hiltz and Turoff 1985). Given the unpredictable nature of a crisis and its reliance on tacit (unique) knowledge (Hayek 1945) being generated by the situation, one cannot develop or use algorithmic rules for the delivery of information. The system must allow the users to self-organize the information by their actions. Tacit knowledge can be acquired only through experience such as observation, imitation, and practice (Kim 1998).

As an example, the current number of ambulances that have been assigned and could be assigned is a dynamic variable resulting from events requesting the use of ambulances and the consumption of resources needed to maintain the ambulances. At some point there is a need for a notification to one or more individuals that such a resource will run out at a certain time based upon both usage rate and the expectations of additional causalities due to further possible damage. Someone has to seek an additional assignment of ambulances or vehicles that can serve this function to the resource pool and determine where they should be positioned. Another example of tacit knowledge is the assignment of roles, for example, knowing who would be the best reporter for a given situation at a given time in the crisis. In essence, when the information is not complete and not expected to be, the decisions will be utilizing the tacit knowledge or the intuition of the decision makers.

Depending on the nature and extent of the crisis, resources will start to run out and a very dynamic inventory function is needed just to alert the responders to projected consumptions of resources. A human must determine when an action must be taken. The local road conditions, extent of the crisis and numerous other factors make automatic assignment impossible. Even if the supply of ambulances is running out, only a human can decide if the depletion rate and the demand rate in a given crisis situation will require re-supply.

Another critical type of notification is the “canned notification” (Turoff 1993) which also has roots in automated command and control systems in the military. There are a number of distinct types, including response check-off and fill-in.

The response checkoff type of notification is where someone indicates they want to respond to a particular item and obtains a list of alternatives from which they can choose a response that will become linked to the original item and be received by any one who received the original item. Examples are:

- I agree/disagree with it
- I am taking care of this
- Delay this action
- Give this higher/lower priority

Since the notifications are standardized and are linked to the item they are referencing receiver ambiguity should be minimized. The creation and sending of the notification takes only a few clicks.

The fill in type is where the receiver can fill in a specific item of quantitative or qualitative data with the notification

- Need info on (subject)? (data, e.g. number of injured)
- Will have more info by (time)
- We will need (number) more (supply item)
- What is your best estimate of the injured? (number)

The specific wording of any type of notification is not important since the system should be designed so the local user population can define and change it at any time as an evolving process. What is important is to

capture those short messages that are likely to be repetitive in any crisis and allow people, as a result, to communicate with an absolute minimum of input operations by utilizing preformatted communication items.

Notifications also serve as a retrieval handle in that any click on this notification will bring up the details about the item it is referring to. This leads us to the concept of “context visibility” that is critical to the success of the system.

4.4 Context Visibility

A log event entry has associated with it the categories of information it is concerned with such as:

- Log identification
- Resource type(s)
- Author and/or responsible party
- Relevant location
- Relevant circumstances
- Next expected event or events and role responsibility for action
- Status (associated events in the root log sequence)
- Allowed or generated lateral logs (new root event logs)
- Allowed or generated notifications
- Footnotes or other linkages

An event generating specific maintenance or re-supply of existing medical units or an event to acquire more medical units should be linked to any medical unit requests that have not yet been serviced.

The elements that are attached to a log can act as the menu choices for the users to find out more information about the particular item in the log. For example, clicking on an item in the log brings up various information about the item, as suggested in Table 2.

Words and abbreviations in the specific context of an event log are used in much the same way as an icon is used to launch functions in an interface. The advantage over icons is the much larger vocabulary of choice that the use of semantic memory (see Collective Memory section 6.2) allows us. This concept is an extension of context sensitive help function (i.e., Apple’s Balloon help) in interface design applied to the primary interaction as opposed to only the help

function – similar to Web mouse-overs, or pop-up comments on MTV videos!

The design capitalizes on episodic memory (see Collective Memory section 6.2) to allow people to track cognitively what is taking place in time and the semantic memory to bring up the needed data or information to take required actions. The role of the person determines what root events he or she will receive and there will be a function which allows the user to indicate if that particular log is one that they wish to follow or track with respect to the log items this event will trigger as children or peers. This method of self filtering was first used in the TOPIC System (Turoff, Hiltz, Bahgat, Rana 1993) on Electronic Information Exchange System (EIES) in the late 70’s for hundreds of people to exchange information as a single group communication process structure. In that system any one can send short requests for information but only if the user “marks” the question, as one marks an email message, do they get the replies.

4.5 Hypertext

The concept of Hypertext is far more general than the current operation of the Web which, unfortunately, most people assume, is Hypertext. For the crisis management function one must go back to the originally conceived properties of Hypertext (Nelson 1965) which included:

- All links are two way in that they have anchors at both ends so that if one goes to a location indicated by a link he or she can always trace that link back.
- Links are typed semantically in that they have a specific meaning.
- One can have many links issuing from an anchor point, each with its own semantic meaning.
- The collection of the current links from an anchor point becomes a context sensitive dynamic menu providing context visibility.
- Links are dynamic and can automatically change at any time as a result of collective events and actions by the users..

Table 2. Alternative Object Links (Hypertext Relationships)

Context item	Retrieved possibilities
Log ID	All event logs which are children of this one The parent or root event log Lateral generated “brother/sister” event logs
Resource Type	Current status of this particular unit Status of all unused units Status of all units at location Status of all in use units Status of all units Sources of new units
Author or responsible party	Current responsibilities and status Backup individuals Expected time for completion of action for this log or notification item
Circumstances	All associated status and qualitative information required for this event
Location	A map or diagram of location area and what is there as well as it is known about what is there. A text / table list of what is there
Status	List of completed events in this sequence List of incomplete events in this sequence All events in this sequence
Linkages	Notifications linked to this particular event Notifications linked to this sequence of events Updates and reports relevant to this event
Expected events	Who is to act on which events as a result of this one
Footnotes	Any footnotes of added explanations by anyone concerned with this event

None of the above is yet available as standard Web features. Nelson (1965), in his early work on Hypertext, pointed out that links can have dimensional ordering. A link from something like a medical unit within an event log entry can vary by the degree of generality or specificity. The specificity extreme would produce the details of a specific medical unit. At the generality extreme it could be a report on the status of all the medical units involved in the crisis. One of the many intermediate links could be the status of all the medical units in the given location this particular unit is headed towards.

Whenever a user creates a link they can either indicate they want the most likely link they need or they can request a menu of the possible links from that anchor point. The overall integration of metaphors, event logs and check lists, and semantic typing of links leads to the design of a self evident user interface (Balasubramanian and Turoff 1995) and allows lateral or divergent connections to be made mentally without information overload setting in (Hiltz and Turoff 1985).

Coupling the two concepts of contextual visibility and hypertext creates a powerful integration factor for all the aspects of a crisis response system. In essence, the choices provided to the users are dynamically adjusted to the status of the crisis and the events that have been logged. A typical application that has some of these features are some electronic calendars where clicking on the entry or some subject of the entry retrieves further details about what is scheduled? Today the effort to evolve the Web along these lines has appeared under the new term of the "Semantic Web" (Berners-Lee, Hendler, and Lassila, 2001).

Supporting all the above should be a highly flexible and powerful list processing interaction capability, which can be tailored by each user, each role, and each screen type. The same functionality for list processing should be applied to all types of lists generated by the system. It should allow the user to manipulate lists and to refine lists by establishing various filtering, organizing, and categorizing rules that can be applied for the benefit of the user. The preferences indicated for a user would be a function of the role and

of their problem solving style. A general list processing foundation applicable to and consistent with any list on the system is the key to allowing users to reduce information overload. Lists will be very dynamic as there can be changes occurring to a list by others while a person is utilizing it.

5. GENERALIZED DESIGN PRINCIPLES

There are certain general design principles that should be applied to any emergency response system:

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.

A possible structure for the system we have been describing is:

Directory

- People
 - Background and Expertise
 - Group Memberships
 - Conference Memberships
 - Bulletin Board Editorships
- Roles
 - Responsibilities
 - Log Event Creation Privileges
 - Current active log events
 - Completed log events
 - Notifications
 - Resource Concerns
- Authorities
- Roles
- Events
- Groups (e.g. medical, firefighters, volunteers, etc.)
- Conferences (topic discussions)
- Bulletin boards (Policies, Plans, etc.)
- Databases (resources, information, local, national, etc.)
- Learning materials and scenario game generators
- Other Emergency Systems

Clearly there needs to be a way to form specialized groups that are focused around certain areas of concern and to have supporting group conferences and message lists for these groups. Bulletin Boards represent the semi-static material that a small group of people is responsible for updating.

There is a lot of opportunity in this system for smart software to aid the members of the system:

- Letting individuals know who is the subgroup concerned at some point in time with the same situation.
- Finding information that a given individual is not aware of but should be.
- Helping the user to adapt their linkage filters to meet a changing situation and requirements.

The long term success of the system is clearly dependent on features like “smartness” being evolved as part of an on going development process with feedback from real users and real applications (Gervasio and Iba 1997; Iba and Gervasio 1999; Van de Walle 2003).

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.

This type of system cannot be an anonymous database: there are many situations where the source of the data is important, and that person will need to be contacted. For example, there are resources that will be allocated many times during the course of the emergency and it can be necessary to request an update on the expected release of a resource before it is actually released for reassignment in order to determine if a similar resource that might take longer to accomplish the task is to be committed. Status reports, that indicate why something is not going as expected (exception reports) and why expected data is not there yet, should also be included. When information is incomplete knowing the data source allows others to make contact with the human source or reporter when there is a need to get more complete information. The person who made the early report may not have had time to provide additional updates and might not be aware there is an urgent need for updates that might be available.

A person preparing a report on some aspect of what is taking place should be able to link data or other comments into their report so that the report, when viewed, reproduces the material that is linked and shows the latest data entered which may have occurred after the initial report was prepared. Also anyone in the system should be able to link footnotes to any item in order to make clear any relevant factors they have obtained about that item. This also serves to allow a discussion thread to develop around a particular data item. As a result it quickly becomes clear who the persons are in the system concerned with a particular situation represented by the data item.

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.

There is no way to predict what information is going to be needed and who is going to need it. In fact, people often have to change roles in the course of the emergency and carry out processes they were not originally scheduled to be responsible for. An emergency can continue for many days and some roles may have to be shifted to different individuals at different times due to the finite capacity of individuals and the concept of individual “diminishing returns.” In addition the reduction of what is normally a hierarchical organization to a flat communication network and the resulting change in individual status has been observed in many crisis situations (Dynes and Quarantell 1977). Associated with this is the increase in the number of decisions made at lower levels by those involved in the crisis.

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

This is, of course, one way in which a computer system adds a different dimension to data and information that is difficult to duplicate with other forms of communication (Hiltz and Turoff 1978; Turoff 1993). Individuals involved in the emergency, in addition to sending and receiving information

from other people, are inputting and retrieving information determined by its content. A robust directory structure provides a comprehensive searchable space for people to find what they need and to create their own filters and links accordingly. When people mark an event or data as being of interest or importance, it allows them to develop and organize just the material of interest to them. By adding the very simple feature of allowing crisis personnel to retrieve a list of all people who have marked a particular item as being important and then using that list as a communication address, subgroups of “common concern” can be formed in a very dynamic manner. The formation and nature of such ad hoc groups is difficult to predict or plan. It can be particularly valuable for those having analysis or reporting roles in the crisis.

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.

This is a form of what might be termed “dynamic” linking in that all data exists as a master copy located somewhere in the system which also tracks where in the network of users it also resides. When a user has data in a viewable state the master copy knows this is occurring and anytime there is a change, that change is transmitted to the place where it is being displayed. This means the user can be assured that the status of resources he or she needs is always current. For example, a certain number a user is viewing can change while it is being watched. For events that have been marked by an individual for tracking, a change notification with respect to the original marked event status, information, or new sub-event would be put on the user’s queue for viewing. The user does not have time to search for an event of concern and a change of status in an event of concern should just be delivered and presented. It might well necessitate levels of marking to allow the user to control the amount of delivered material by indicating what events should result in interruptions to the user rather than just being queued.

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.

The concept of linking data is critical to the emergency response operation. Any single item of data is associated with numerous attributes and other pieces of data. The user cannot spend the time to contemplate and devise complex search queries. Therefore a single item of data must have associated with it all the links that express its relationship to other data. Furthermore, these links will have different meanings (link types) and will be two-way links (unlike the current Web). When a piece of data is created or updated all related links will also be brought into existence or updated. If a person has moved through a series of links to arrive at some final data of interest it is insufficient to merely give them the “back” button to move back up in the same sequence. There may have been a choice to branch that they now know they should have taken to examine other data as well. Therefore the system should be able to provide the alternative links they could have taken and allow them to “go” directly to what they now want.

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

This just reinforces the need for everything to be available to those on the scene of an event. Those who are in a remote “command center” are there to ensure that the individual decisions being made in the front lines are not resulting in some negative cumulative result that has to be corrected. The upper chain of command in an emergency operation is an oversight and exception operation with respect to localized actions. They need to be aware of when an action taken appears to be wrong because it is inconsistent or in conflict with other actions elsewhere. Authority for action has to exist with the front line roles, and higher levels should largely deal with monitoring, oversight, resource availability, and threat assessment. Decisions become the launching of an event that is a request for an action to take place. While

there are those empowered to halt an action because of a possible conflict or difficulty, the action will take place unless someone with oversight authority halts it while it is in progress. There has to be clear accountability of who is taking what actions and it should also be clear to all involved when a conflict occurs and how it is being handled. In disaster situations authority is always flowing downward (Dynes and Quarantell 1977).

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

It is necessary that social relationships be allowed to flourish and that the system can be utilized for the maintenance and development of those relationships. This has positive impacts on reducing stress levels and facilitating the handover of roles and dealing with oversight. The system must allow for a “team spirit” to develop. People must get to know one another well enough so that they have no qualms about handing over their role to another person. They must develop a feeling of trust in the others and have a good understanding of each other’s abilities. Knowing what can be asked of an individual in their fourteenth hour on a shift as compared to their first hour can be an important factor. Facilities like tracking the time on station for each user become significant.

As more and more people are included who are external to the everyday organizational teams, the ability to accomplish social networking through “coffee break” conferences and chat rooms in order to develop quick trust is increasingly important. The encouragement of informal language in communications as opposed to only the use of rigid fill in forms with no open text commentaries allowed is also a design factor. No one would think of forbidding socializing in face to face groups but somehow it is still left out of the design considerations of the typical information systems environment. When an emergency system is employed as a dispersed virtual command center, this consideration becomes critical. There is a strong need to be able to rely on one another and to accept frankness in viewpoints as the common norm. This can only happen in a

social network.

The most challenging aspect of the interface design in this regard is the reduction of information overload and allowing the user to view the system as a helper that does not constrain the user to a single approach to problem solving. The user should be able to adapt the system to his or her method of cognitive problem solving and not impose one rigid approach for all the users. Rigidity in the interface is what will inhibit creativity or improvisation in unique problem situations. People in a crisis environment can operate under stress given the morale associated with the mission they are engaged in; however, when their tools do not match the performance levels they are seeking to obtain, this allows the “rigidity threat syndrome” to set in. This area of interface design is still a basic challenge for the state of the art.

6. SUPPORTING DESIGN CONSIDERATIONS

There are a number of general requirements and supporting functionality and systems that are necessary for creating a comprehensive Emergency Response Management Information Systems

6.1 Resource Databases and Community Collaboration

A critical component of any emergency response system is a resource database. This might be a collection of databases providing different types of physical, informational, or human resources. Some national databases that exist in such areas as hazardous materials can provide timely information and clearly would be referenced in any local database. However, the key components of what needs to be in the local database span a very wide range of areas in order to be useful to any of the various types of disaster situations that might be encountered. For example:

- Any type of construction equipment that might be useful in a disaster situation and the people who can operate it.
- Medical facilities and medical personnel including retired volunteers
- Professionals with knowledge relevant to such things as hazardous materials, water treatment, building integrity, road repair,

explosive handling.

- Boats and any sort of possible transporting vehicles and trucks.
- Materials testing equipment, e.g. biological, chemical, etc.
- Utilities: maintenance units and people.
- Hazardous material information

The design of a database to accommodate a very diverse set of possible resources is not difficult today. However, if a local government agency has to pay to maintain and update the data to make sure it is current we then create a very expensive operation (Eichenbaum 2002). The only way a resource database can be maintained by a typical local community or regional area is if the database is designed to be collaborative in nature.

The people and organizations that have resources that could be borrowed, rented, commandeered (with compensation), or volunteered in an emergency situation need to be able to enter and maintain the data they are responsible for and should be able to use the database for their own purposes. The database has to be set up as a community resource. A contractor having an inventory of equipment that might be useful would maintain that entry via online access to the database. It could also be that various organizations might like to be able to find certain resources in a non-emergency situation and such a database can service the potential sharing, exchanging, or renting of resources in the community. In September 11, 2001 there was a rush of contributions by industry (Michaels 2001) and this means it is possible to get community involvement if approached correctly. In many local areas subject to reoccurring natural disasters this has always occurred.

The maintenance of this database becomes a collaborative dispersed responsibility among the members of the community in a specific area. Each person supplying possible resources would have direct access to updating their supplied data. In addition, one would hope government organizations like state agencies, the National Guard, and military units in the area would be significant contributors to such a collaborative resource database. Clearly, on a regional basis, local communities would be able to

access each other's community databases for resources that they might not have, or to deal with large scale disaster situations or extreme events. A successful example of a collaborative dispersed database system is an inter-library loan system.

A resource data base should be geographically-oriented and should integrate with all the data on utilities, buildings, and roads. New York City was quite fortunate that it had such a data base in existence located in Brooklyn instead of the downtown office of the agency responsible for it. It was invaluable in aiding the recovery actions and planning for the city's recovery (Eichenbaum 2002; Thomas, Cutter, Hodgson, Gutekunst, and Jones 2002). Such a database would also be invaluable as an aid in dealing with a spreading crisis such as a hazardous gas cloud.

For organizations dealing with a crisis, the prior involvement of the public in the planning is considered a valuable asset once an actual crisis occurs (Dyer 1995). This has been demonstrated in numerous natural disaster situations where public cooperation inhibits numerous possible complications and provides added manpower during the response phase. Once people are involved in the planning they will also be willing to participate in exercises to evaluate the plan. Given the lack of local and community resources in most smaller urban areas it becomes almost mandatory to try and incorporate community involvement in the crisis response planning and execution activity.

6.2 Collective Memory

Semantic memory or abstract memory provides rules about events, their interactions and dependencies, and how they relate to objects or data groupings. Collective memory evolves from these generalities of cases making up the description of the real world. There is the process of dynamic association between the descriptive events taking place and the prescriptive responses to them. The event log metaphor allows this to occur in a flexible but unambiguous manner that results in a cognitive approach to a collective memory (Warren 1996).

Much work on collective memory and collective learning has been independent of

our understanding of cognitive psychology and sometimes too focused on organizational context. However, it stands to reason that if we can associate the properties of a collective memory with those of cognition, the resulting systems may be much more intuitive to the individual members of the group. This will allow more of the cognitive capacities of the individuals to be focused on the collective emergency response task. Beginning with the merger of episodic (events) memory and semantic (typed linkages) memory and adding the ability of groups to form around content of “common concern” through their marking and action patterns, we have provided the possibility of forming a very dynamic collective memory.

Event logs may be extremely helpful in tracking the course of a crisis and establishing an organizational memory (Hale 1997). Hale further suggested they could be listed on flip charts in the control center! This lack of comprehension as to what we can do with the technology seems to be rather common in local and regional emergency efforts. Much of the current emergency efforts focus on telephone, radio, and face to face verbal communication technology. In 9/11 the emergency responders, after the loss of the communications center and their verbal devices, were supplied with text based pagers and these are reported to have worked very well (Michaels 2001). There is a considerable understanding today of the factors that influence adoption of new digital media (Rice 2002) and sensible management policies based upon those understandings can easily bring about rapid diffusion of such technology.

It is often difficult to codify and communicate knowledge that is only applicable to very specific situations and that is why scenarios are very appropriate for expressing tacit knowledge (Kim 1998). Not everyone has had the same experience with respect to a crisis situation since the events are relatively rare (King 2002). Even “natural” crisis events such as hurricanes, tornados, or earthquakes produce very unpredictable specific impacts when they occur (Barton and Hardigree 1995).

Fine tuning, elimination of ambiguity, assimilating lore (tacit knowledge) from

experienced members, discovering inconsistencies, building team cohesion, upgrading the realism and plausibility of the exercise are all important functions of the system and the associated training exercises (Nyblom, Reid, Coy and Walter 2003). The formulation of a collective memory for dealing with critical situations of any type will ultimately be captured in the event templates, the types of notifications, role responsibilities, the content of the resource database and the training scenarios. While some forms of tacit knowledge are probably impossible to make explicit (Hayek 1945), it is usually possible to capture the consequences, e.g. decisions, actions, of such knowledge (Belardo et al. 1984, Belardo and Harrald 1992; Bieber et al. 2002).

People with experience are important sources of information. Our biggest problem today is the way in which agencies within the same organization resist the release and sharing of information because prior mistakes might embarrass the organization. What we need to foster is the continuous collaborative efforts of experienced people to be able to communicate and exchange information even when they are in different organizations. Some of the most critical knowledge comes from examining the mistakes that have been made.

6.3 Online Communities of Experts

Given the situation that the USA now faces and the fact that certain specialized expertise might not be available in all localities, the original idea of networking experts from 1970 at OEP should be revitalized. This was the basis for emergency planning at OEP and the premise that lead to the initial work on EMISARI (Linstone and Turoff 1975; Turoff 1972, 2002). This system integrated the large number of experts that OEP had on tap to aid in crisis planning by developing an online Delphi System. Today with the Internet the idea of online communities is well established and the federal government should actually encourage such communities, which, in return for being provided the service, would commit to making their expertise available to local communities when a crisis occurs.

There are examples today of informal and formal communities of experts on the Web (Table 3). Typically these are professionals involved in local emergency response planning and response efforts and they exchange some very insightful and practical papers resulting from their experiences. This growing literature is a treasure for developing improved detailed requirements (Cameron, 2003). Another important example is the way our society handles the response to viruses on the WWW. There are other groups in industry that use one another to seek critical supplies and resources needed to adjust to some peak in demand. There are numerous collaborative markets in such areas as rare and used books where the professionals do in fact aid one another when it is of mutual interest. However, there is very little real design work in creating collaborative systems to facilitate such professional communities. Too many people assume that primitive group communications such as linear discussion lists and email are all that is necessary and that is what is used in most of the above examples. The use of a tailored structured communication system as we have been describing in this paper would be appropriate as support systems for online communities in the emergency response area.

Table 3. Professional Communities

International Association of Emergency Managers http://www.iaem.com/index.shtml
The international Emergency Management Society http://www.tiems.org/
Public Entity Risk Institute http://www.riskinstitute.org/
Public Safety Wireless Network http://www.pswn.gov/
Association of Public-Safety Communications Officials, International http://www.apco911.org/
National Emergency Number Association http://www.nena.org/
The American Civil Defense Association http://www.tacda.org/
Techsoup: The technology place for non-profits http://www.techsoup.org
Humanitarian Relief Community http://www.reliefweb.int/w/rwb.nsf

The existence of communities of experts who utilize the same system as would be used in an emergency would minimize much of the training that might be required for the actual emergency. Furthermore in most organizations, whether industry or government, there are always emergencies that surface as sensemaking occasions (Weick 1995): shortages of resources, strikes, budget overruns, bad publicity, disgruntled customers, etc. A well designed emergency response system can be used for normal communications in terms of basic communication needs and the more specific emergency response functions exercised in terms of the more typical short term organizational type crisis situations.

7. CONCLUSIONS AND FINAL OBSERVATIONS

In the emergency response area it is extremely fortunate that we do have a metaphor of the “event log” that most emergency response professionals are very familiar with and which has analogies to the actual way this would work in the computer. In addition this metaphor provides what is called "context visibility" where a great many functions that the system must carry out can be represented by direct links to the elements of the metaphor. This will reduce greatly the effort for the user to learn the system and at the same time minimize the cognitive overhead for carrying out these operations.

More importantly, the concept of events and roles translates to non-crisis activities such as meetings, plan development, committee functions, project functions, and training exercises. It is very easy to conceive of using such a system between actual crises for all planning and coordination to be carried out by all the involved organizations and the liaisons from those organizations.

The planning function is one that can be well served by heterogeneous teams utilizing this type of system. This includes risk identification, risk assessment, crisis planning and preparation, mobilization, and recovery efforts (NyBlom, Reid, Coy, and Walter 2003). All these can lead to improvements in the evolution of the system.

Using the system on a day to day basis for any sort of project activity, and even allowing participating organizations to set up internal copies for restricted use, ensures that people will remain trained and able to respond to a real crisis. In any case there are always, in just about any organization, mini-crises which usually result in special teams or committees that have to work together to find a decent resolution to the situation. Today it is likely they are dispersed geographically and could easily benefit from the type of system we have been describing.

As a communication system it becomes easy to incorporate an event generator driven by clock time to turn the system into a simulation gaming system to exercise a plan for any type of crisis event consistent with the current resource database and available personnel (Van de Walle and Turoff 2001, Van de Walle 2003). Those personnel from other agencies not available for the exercise can be simulated by the same sort of human role event simulation. Being able to carry out the exercise in real clock time adds to the realism of the exercise (Turoff 1997) and the resulting training outcome. A simulation is realistic if it induces the same psychological process in training that occurs in the crisis (Snizek, Wilkins, Wadlington, and Baumann 2002). This is also a good reason why a training exercise should be a surprise to the participants and not scheduled ahead for a certain day and time as is often done. Prior studies of role-event game simulations have shown them to be one of the best mechanisms of learning about a complex experience (Hsu 1989). To further heighten the psychological process one should have crisis response teams from different localities compete with one another using the same game scenarios. This could also lead to establishing "community of practice" (Wenger and Snyder 2000) for responders on a national bases.

These exercises should be used to allow evaluation and evolution of the system according to the feedback provided by the users. If the users are used to making improvements to the system as part of the exercises, they are going to be more likely to avoid the rigidity of response resulting from the threat and its contributing stress factors (Rice 1990; Staw, Sandelands and Dutton

1981). What one would like is a crisis response system that stimulates creative responses by the team members to a specific unpredictable situation, e.g., strike, scandal, environmental problem, proxy fight, non performance on a contract, etc.

What we have defined as a system is a Virtual Organization (Mowshowitz 1997, 2002) made up of a formal and informal organizational workflow processes (Figure 1) and a meta process (Figure 2) to regulate structure.

In terms of the Mowshowitz (1997) virtual organization structure, the uncontrolled events "crises/emergencies" are the requirements and the resources are the "satisficers." The roles are the switching unit that make the allocation of resources to requirements and serve as management in terms of collecting the information necessary to perform the switching so as to meet the objective of "mitigation of the crisis" and maintain adequate resources for allocation. Roles have both an informal mechanism to allow individuals to assume needed roles and a formal mechanism to assign roles that carry authority (that may be delegated) and oversight to ensure resources are used as well as they can be. Taking the system that has been proposed here and allowing it to operate on all phases of the response process as a virtual organization will provide the system with the concept of "virtuality" (Turoff 1997) which means the system itself will influence change, and hopefully improvement, in the response process as an evolutionary process.

In an excellent article by Bigley and Roberts (2001), a series of interviews and surveys of actual firefighting situations resulted in a number of significant observations on potential emergency response organizational structures. A number of the conclusions and observations of that article are excellent, especially on the concept of roles, the need for collective understandings, and the need for delegation of authority. The result of that paper is the proposal for an "Incident Command System" (ICS) which is a highly structured, top-down bureaucratic design with certain elements of flexibility that allow improvisation and authority delegation. It is based upon verbal interaction and people who

are located largely at the site of the emergency. It presents an alternative in some ways to what has been presented in this paper. In so doing it highlights the need for further exploration of emergency response structures.

The view of this article is that the ICS approach would probably work well for a one-dimensional emergency, e.g., a firefighting situation where everyone has a high degree of training and the response group is homogenous in nature. It is not likely to accommodate a

multidimensional crisis situation as the verbal mediation necessary for improvisation and flexibility will fall apart from information overload and the heterogeneous nature of all the individual agencies involved. If we have learned anything about the design of computer based systems and especially communications, it is that automating the common practice from the physical world often does not perform in a manner to make optimal use of the technology.

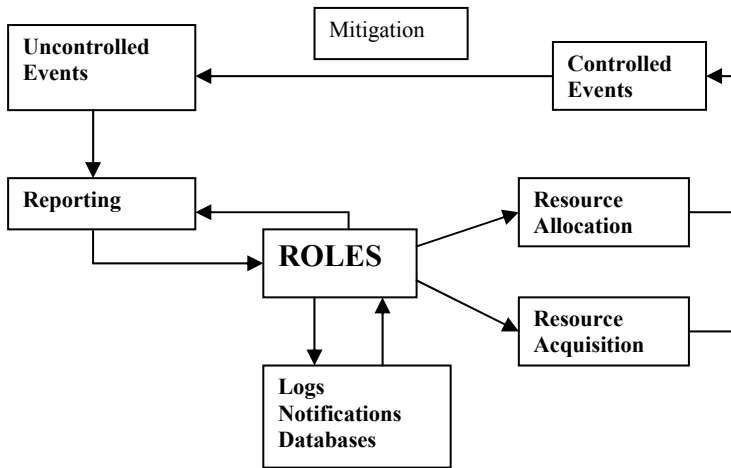


Figure 1: Workflow Communication Process

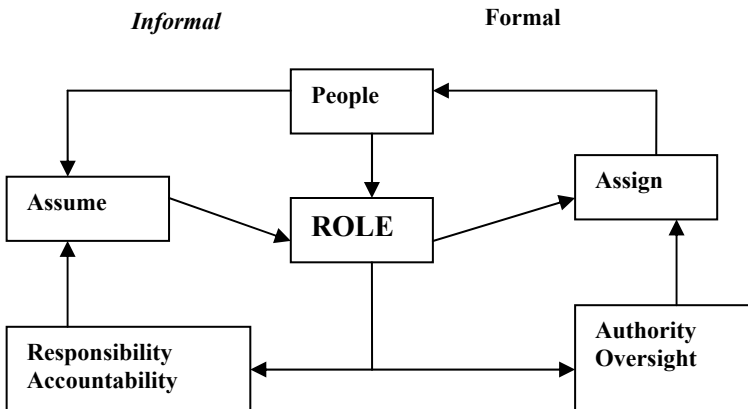


Figure 2: Meta Communication Process

Perhaps the most worrisome concern is the “threat-rigidity” hypothesis developed by Staw, Sandelands, and Dutton (1981) and further discussed by Rice (1990). Individuals undergoing stress, anxiety and psychological arousal tend to increase their reliance on internal hypothesis and focus on dominant cues to emit well-learned responses. In simple terms, the potential response to a crisis situation is to go by the book and use only learned responses. However, if the response situation does not fit the original training the resulting performance may be completely wrong. One needs to ensure that people are encouraged to think about the situation and examine their potential actions to allow some degree of improvising or creativity.

The communication and organizational structure and the flow of information are going to be very critical with respect to whether it encourages or inhibits rigidity. It is our view that a flat organizational structure, one that allows equal participation with respect to access to whatever information they feel they may need to consider, will encourage flexibility of response. In most organizational structures negative information gets more positive as it moves up the chain of command. Flatter organizations with respect to the movement of information tend to reduce this problem especially when the source of report is digital and available to all that are involved at any level. This also has an impact on the attitude of the responders who should feel they are part of a cohesive group of peers all equally striving to do their best to mitigate the crisis. The attitude of those responding to the crisis and the cohesive nature of the teams involved is critical to the success of the effort (Braverman 2003; King 2002). At least one experimental study investigating the nature of organizational response to a crisis showed that friendships and trust that cuts across the organizational units allow teams of crisis responders to be more effective (Krackhardt and Stern 1988). When we talk about a major crisis event we are talking about people across different organizations and agencies becoming a team. This also speaks to the need for regular interaction between the responders and the formation and facilitation of an on going community.

A recent survey (Horseley and Barker 2002) of state government responses in various crises found that the most successful form of communications for dealing with events between various government units was interagency e-mail. Communications between different agencies by people who have not worked together probably contains a lot of ambiguity. The result of ambiguity is that people often think they communicated and agreed when in fact they did not. When asked they would, of course, think the communication went well. This is the common “ambiguity of consensus” that occurs in group meetings, where everyone is later surprised at what they are reported to have agreed to. Clearly the use of group-oriented communication systems dealing with text would have been an even better technology for this task.

It seems that every careful study of local emergency response even for non-extreme events such as tornados shows that coordination is a major problem across different involved agencies and that many officials or professionals in these agencies do not remember or are not familiar with the emergency procedures (McEntire 2001; Parker, LeDuc and Lynn 2002). The coordination problem is the key hidden problem in emergency response that has been largely ignored. Physical reorganization of agencies has never been a solution to the coordination problem. Providing the technology to allow people to form groups dynamically around a crisis is the approach that will address the coordination problem.

With computers in the loop it is now possible to have a number of professionals at different levels observing and reviewing what is taking place so that oversight can work to a much greater degree than in the verbal environment with hierarchical levels of command. Carrying with it the property of accountability also makes people much more likely to give a reasonable degree of consideration to any decision they make. Too often in the verbal environment, who made the decision is sometimes ambiguous. Furthermore, in the standard database approach the identity of the contributor and the

rationale for the content are immediately lost. This lack of accountability in traditional information systems and the problems it produces for organizations has been recognized for a long time (Zmud 1979).

The underlying model we have proposed for DERMIS would allow the introduction of a continuous audit process (Alles, Kogan, and Vasarhelyi 2003). The function of this would be to track and determine if the available information, relevant to a particular problem, has been distributed to all those that need to be involved in the resolution of that problem at that point in time. Such an extension of the design would provide a high degree of assurance for the carrying out of the roles associated with the functions of delegation of authority, accountability, responsibility, and oversight. It would also allow the efficient design of automated agents that could track and alert individuals to when they need to update themselves about a given problem situation.

At this point in time too little attention is being paid to understanding and designing the command and control system for crisis events for local and regional areas. Current

advice on planning still focuses on having an emergency response center and back up center (NyBlom, Reid, Coy and Walter 2003). The concept of being able to have a fully dispersed system is still non-existent and the cost of such physical centers can be prohibitive for many small communities.

However the military and large corporations such as Bank of America and Wells Fargo are investigating virtual command and control systems as well as virtual emergency operations centers (Davis 2002; Roos 2002). The virtual nature of communication has the potential to provide decision makers, at different levels, with a crisis situation visualization in a virtual reality space. The virtual command center can also function from workstations at different geographical locations using Internet technology.

In Chinese the word for crisis is made up of two symbols: danger and opportunity (Kim 1998). There is an opportunity to improve dramatically the design and functionality of Emergency Response Systems and considerable danger to be faced if we do not!

8. REFERENCES

- Alles, M. G., A. Kogan and M. Vasarhelyi, "Black Box Logging and Tertiary Monitoring of Continuous Assurance Systems," *Information Systems Control Journal*, 2003, 1, pp. 37-39.
- Balasubramanian, V. and Turoff, M., "A Systematic Approach to User Interface, Design for Hypertext Systems," *Proceedings of the 28th Annual Hawaii International Conference on System Sciences (HICSS)*, 1995, Volume III, IEEE Computer Society Press, pp. 241-250.
- Barton, L., and D. Hardigree, "Risk and crisis management in facilities: Emerging paradigms in assessing critical incidents," *Facilities Journal*, 1995, 13:9, pp. 10-11.
- Belardo, S. and Harrald, J., "A framework for the application of decision support systems to the problem of planning for catastrophic events," *IEEE Transactions on Engineering Management*, 1992, 39:4, pp. 400-411.
- Belardo, S., K.R. Karwan and W. Wallace, "An investigation of system design considerations for emergency management decision support," *IEEE Transactions on Systems, Man, and Cybernetics*, 1984, 14:6, pp. 795-804.
- Berners-Lee, T., J. Hendler and O. Lassila, "The semantic web," *Scientific American*, May 2001, p. 279.
- Bieber, M., S.R. Hiltz, E.A. Stohr, D. Englebart, J. Noll, M. Turoff, R. Furuta, J. Preece and B. Van de Walle, "Towards Virtual Community Knowledge Evolution", *Journal of Management Information Systems*, Spring 2002.
- Bigley, G.A. and K.H. Roberts, "The Incident Command System: High-Reliability Organizing for Complex and Volatile Task Environments," *Academy of Management Journal*, 2001, 44:6, pp. 1281-1299.
- Braverman, Mark, "Managing the human impact of crisis," *Risk Management*, May 2003, 50:5, 10-.
- Cameron, D., "Technology Planning for Civil emergencies: Prepare your organization to deal with the unthinkable," *TechSoup Article*, 12 November 2003, <http://www.techsoup.org>

- Coombs, W.T., "Designing post crisis messages: Lesson for crisis response strategies," *Review of Business*, 2000, 21:3/4, pp. 37-41.
- Carroll, J.M., and Thomas, C., "Metaphor and the Cognitive Representation of Computing Systems," *IEEE Transactions on Man, Systems and Cybernetics*, March-April, 1982, SMC-12, pp. 107-116.
- Cho, Hee-Kyung and M. Turoff, "Delphi Structure and Group Size in Asynchronous Computer-Mediated Communications," *Proceedings of AMCIS 2003*, Association for Information Systems, <http://www.aisnet.org>, last accessed 9 February 1993.
- Danowski, J., and P.E.-Swift, "Crisis Effects on Intraorganizational Computer Based Communications," *Communications Research*, 1985, 12:2, pp. 251-270.
- Davis, S., "Crisis Management Series: Virtual Emergency Operations Centers" *Risk Management Magazine*, 2002, 49:7.
- Dyer, S.C., "Getting People into the crisis communication plan," *Public Relations Quarterly*, 1995, 40:3, pp. 38-.
- Dynes, Russell, and E.L. Quarantell, "Organizational Communications and Decision Making in Crises," *Disaster Research Center Report 17*, January 1977, Ohio State University.
- Eichenbaum, Jack, "CAMA, GIS, and the Recovery of New York City," *Assessment Journal*, 2002, 9:3, pp. 17-22.
- Gervasio, M.T. and W. Iba, "Crisis response planning: A task analysis," *Proceedings of the Nineteenth Annual Conference of the Cognitive Science Society*, 1997, p. 929.
- Hale, Joanne, "A layered communication architecture for the support of crisis response," *Journal of Management Information Systems*, 1997, 14:1, pp. 235-255.
- Hardeman, F., N. Pauwels, C.R. Palma and B. Van de Walle, "The role of experts in decision making upon urgent countermeasures in nuclear emergency situations," *Proceedings of the Society for Risk Analysis – Europe Conference on "Risk Analysis: Opening the process"*, 1998, (Paris, France).
- Hayek, F.A., "The Use of Knowledge in Society," *The American Economic Review*, September 1945, 35:4, pp. 519-530.
- Hiltz, S.R., and M. Turoff, "Structuring Computer mediated Communication Systems to Avoid Information Overload," *Communications ACM*, 1985, 28:7, pp. 680-689.
- Hiltz, S.R., and Turoff, M., *The Network Nation: Human Communication via Computer*, 1978, Addison Wesley, (Revised edition: MIT press, 1993).
- Horseley, J.S. and R.T. Barker, "Toward a synthesis Model for Crisis Communication in the Public Sector: An Initial investigation," *Journal of Business and Technical Communication*, 2002, 16:4, pp. 406-440.
- Hsu, Enrico, "Role Event Gaming Simulation in Management Education," *Simulation and Games*," December 1989, 20:4, pp. 409-438.
- Iba, W. and M. Gervasio, "Adapting to user preferences in Crisis Response," *Proceedings of IUI 99*, ACM 1999.
- Keen, Peter G.W., "MIS Research: Reference Disciplines and a Cumulative Tradition," *Proceedings of the First International Conference on Information Systems*, December 8-10, 1980, Philadelphia, PA, 9-18/
- Kim, Linsu, "Crisis Construction and organizational learning: Capability building in catching-up at Hyundai Motor," *Organization Science*, July-August 1998, 9:4, pp. 506-521.
- King III, Granville, "Crisis management and team effectiveness: a closer examination," *Journal of Business Ethics*, December 2002, 41:3, pp. 235-249.
- Krackhardt, D. and R. Stern, "Informal Networks and Organizational Crisis: An experimental simulation," *Social Psychological Quarterly*, 1988, 51:2, pp. 123-140.
- Kunreuther, H., and A. Lerner-Lam, "Risk Assessment and Risk Management Strategies in an Uncertain World, Executive Summary," *Columbia/Wharton Roundtable*, April 12-12, 2002.
- Kupperman, R., Wilcox, R., and Smith, "Crisis Management: Some Opportunities," *Science*, Feb. 7, 1975, 187, pp. 404-410.
- Kupperman, R., Wilcox, R., "EMISARI - An On line Management System in a Dynamic Environment," *Proceedings 1st International Conference on Computer Communications*, 1972, IEEE, pp. 117-120.

- Lewin, K. "Group Decision and Social Change" In *Readings in Social Psychology* Ed. Newcombe, T. and Hartley, E., New York: Holt 1958.
- Linstone, H. and Turoff, M. (eds.), *The Delphi Method: Techniques and Applications*, Addison Wesley Advanced Book Program, 1975, now on line via <http://is.njit.edu/turoff>, last accessed 9 February 2003.
- Lukaszewski, J.E., "Anatomy of a Crisis Response: A Checklist," *Public Relations Journal*, November 1987.
- Macon, N., and J.D. McKendree, EMISARI Revisited: The Resource Interruption Monitoring Systems," *Proceedings 2nd International Conference on Computer Communications*, 1974, IEEE, pp. 89-97.
- Macon, N., J.D. McKendree, and R. Wynn, "Computer Conferencing in Emergencies: Some Reliability Considerations," *Proceedings of the IEEE Conference on Computer Networks*, 1975, pp. 69-73.
- Massey, J.E., "Managing Organizational Legitimacy: Communication Strategies for organizations in crisis," *The Journal of Business Communications*, April 2001, 38:2, pp. 153-182.
- McEntire, D., "Multi-organizational Coordination During the Response to the March 28, 2000, Fort Worth Tornado: An Assessment of Constraining and Contributing Factors," *Quick Response Report 143*, 2001, National Hazards Research and Applications Center, University of Colorado.
- McKendree, J., "Project and Crisis Management Applications of Computerized Conferencing," *Bulletin of the American Society for Information Science*, 1978, 4:5, pp. 3-15.
- McKendree, J., "Decision Processes in Crisis Management: Computers in a new role," *Encyclopedia of Communications Science and Technology*, 1977, 6, pp. 115-156.
- Michaels, Sarah, "Digital Disaster Assistance: How and Why selected Information Technology Firms Contributed to Recovery Immediately after the September 11 Terrorist Attack," *Quick Response Report 141*, 2001, National Hazards Research and Applications Center, University of Colorado.
- Mork, L., "Technology Tools for Crisis response," *Risk Management*, October 2002, 49:10, pp. 44-50.
- Mowshowitz, A., *Virtual Organization: Toward a Theory of Societal Transformation Stimulated by Information Technology*, 2002, Quorum Books, Westport, Connecticut.
- Mowshowitz, A., "On the Theory of Virtual Organization," *Systems Research and Behavioral Science*, 1997, 14:6, pp. 373-384.
- Nelson, T.H., "A File structure for the Complex, The Changing, and the Indeterminate," *ACM 20th National Conference*, 1965, pp. 84-99.
- NyBlom, S.E., J. Reid, W.J. Coy, and R. Walter, "Understanding Crisis Management," *Professional Safety*, March 2003, 48:3, March 2003, pp. 18-.
- Parker, Robert, A. LeDuc, and K. Lynn, "Oregon Emergency Management: Evaluating Interagency Communication in the Post Disaster Environment," *Quick Response Report 149*, 2002, National Hazards Research and Applications Center, University of Colorado.
- Pauwels, N., B. Van de Walle, F. Hardeman and K. Soudan, "Irreversible decision making for nuclear emergency planning," *Theory and Decision*, 2000, 49:1, pp. 25-51.
- Pearson, C.M. S.K. Misra, J.A. Clair, and I.I. Mitroff, "Managing the Unthinkable," *Organizational dynamics*, 1997, 26, pp. 51-64.
- Price, C., "Conferencing via Computer Cost-Effective Communication for the Era of Forced choice," in H. Linstone and M. Turoff (eds.), *The Delphi Method*, 1975, Addison Wesley (available on the Web via <http://is.njit.edu/turoff>, last accessed 9 February 2003).
- Pyush, I.R., I.S. Fuhrmann, H. Wang, R.S. Agrawal, A.M. Brewer, C. Guoray, "Designing a Human-Centered, Multimodal GIS Interface to Support Emergency Management," *Proceedings GIS'02*, 8-9 November 2002, McLean, Va., ACM Press, pp. 119-124.
- Renner, R.L., R.M. Bechtold, C.W. Clark, D.O. Marbray, R.L. Win, and N.H. Goldstein, "EMISARI: A Management Information System to Aid and Involve People," *Proceedings of the International Symposium on Computer and Information Science*, COINS, 1972.
- Rice, R.E., and J. "Webster, Adoption, Diffusion, and Use of New Media," in C. Lin and D. Atkin, (eds.), *Communication Technology and Society*, Cresskill, NJ: Hampton Press, 2002.
- Rice, R.E., "From Adversity to Diversity: Applications of Communication Technology to Crisis Management," *Advances in Telecommunications Management*, 1990, 3, pp. 91-112.

- Rice, R.E., "Information, Computer Mediated Communications and Organizational Innovation," *Journal of Communication*, 1987, 37:4, pp. 65-94.
- Rogers, E., *Diffusion of Innovations* (4th Ed), 1995, New York: Free Press.
- Ruben, B., *Communication and Human Behavior*, 1992, Prentice Hall.
- Roos, J., "More Than an Ounce of Prevention: A Virtual Command and Control Center, Other Crises Management Tools, For Homeland Security" *Armed Forces Journal International*, February 2002.
- Smart, C.F., and Vertinsky, I., "Strategy and environment: A study of corporate response to crises," *Strategic Management Journal*, 1984, 5, pp. 199-213.
- Smart, C.F., and I. Vertinsky, "Designs for Crisis Decision Units," *Administrative Science Quarterly*, December 1977, 22, pp. 639-657.
- Smart, C., W. Thompson, and I. Vertinsky, "Diagnosing Corporate Effectiveness and susceptibility to Crises," *Journal of Business Administration*, 198, 9:2, pp. 57-96.
- Smith, C.A.P., and S. Hayne, "A Distributed System for Crisis Management," *Proceedings of the 24th HICSS*, 1991, 3, pp. 72-81.
- Snizek, J.A., D.C. Wilkins, P.L. Wadlington, and M.R. Baumann, "Training for Crisis Decision Making: Psychological Issues and Computer Based Solutions," *Journal of Management Information Systems*, spring 2002, 18:4, pp. 147-168.
- Star, S. L., "The structure of ill-structured solutions: boundary objects and heterogeneous distributed problem solving," in L. Gasser and M. N. Huhns (eds.), *Distributed artificial intelligence*, 1989, pp. 37-54.
- Staw, B., I. Sandelands, and J. Dutton, "Threat-Rigidity Effects in Organizational Behavior: A Multilevel Analysis," *Administrative Science Quarterly*, 1981, 26, pp. 501-524.
- Thomas, Deborah, S. Cutter, M. Hodgson, M. Gutekunst, and S. Jones, "Use of Spatial Data and Geographic Technologies in Response to the September 11 Terrorist Attack," *Quick Response Report 153*, 2002, National Hazards Research and Applications Center, University of Colorado.
- Turoff, M., "Past and Future Emergency Response Information Systems," *Communications of the ACM*, April 2002, 45:4, pp. 29-33.
- Turoff, M., S.R., Hiltz, M. Bieber, B. Whitworth, and J. Fjermestad, "Computer Mediated Communications for Group Support: Past and Future," in J. Carroll (ed.), *HCI in the New Millennium*, 2001, Addison Wesley.
- Turoff, M., "Virtuality," *Communications of the ACM*, September 1997, 40:9, pp. 38-43.
- Turoff, M., "Computer Mediated Communication Requirements for Group Support," in Ron Baecker (ed.), *Readings in Groupware and Computer Supported Cooperative Work*, 1993, Morgan Kaufmann Publishers, originally published *Journal of Organizational Computing*, 1990, 1:1.
- Turoff, M., S.R. Hiltz, A.N.F. Bahgat, and A. Rana, "Distributed Group Support Systems," *MIS Quarterly*, December 1993, pp. 399-417.
- Turoff, Murray and S.R. Hiltz, Computer Based Delphi Processes, in Michael Adler and Erio Ziglio, editors., *Gazing Into the Oracle: The Delphi Method and Its Application to Social Policy and Public Health*, 1995, London, Kingsley Publishers, pp. 56-88.
- Turoff, M., "Party Line and Discussion: Computerized Conference Systems," *Proceedings of the International Conference on Computer Communications*, 1972, pp. 161-171, IEEE Press.
- Turoff, M., "Delphi Conferencing: Computer Based Conferencing with Anonymity," *Journal of Technological Forecasting and Social Change*, 1972, 3:2, pp. 159-204.
- Turoff, M., "Delphi and Its Potential Impact on Information Systems," *Proceedings AFIPS Fall Joint Computer Conference*, 1971, 39, pp. 317-326.
- Van de Walle, B., and M. Turoff, "Towards group agreement: the significance of preference analysis," *Proceedings of Eurofuse 2001*, Workshop on Theory and Applications of Preference Modeling (Granada, Spain), pp. 85-92.
- Van de Walle, B., "A relational analysis of decision makers' preferences," *International Journal of Intelligent Systems*, 2003, 18:7, pp. 775-791.

Vatis, M.A., "The first line of Defense: Tools and Technology Needs in the Aftermath of September 11, 2001," Draft Report, *Institute for Security Technology Studies*, May 28, 2002, <http://www.ists.dartmouth.edu>.

Wang, Yuanqiong, Zheng Li, M. Turoff, and S.R. Hiltz, "Using a Social Decision Support System Toolkit to Evaluate Achieved Course Objectives," *AMCIS 2003 Proceedings*, Association for Information Systems, <http://www.aisnet.org>, last accessed 9 February 2003.

Waren, Yvonne, "Collective Learning, and Collective Memory for Coping with Dynamic Complexity," *Cotech Workshop for ECSCW 95, SIGCHI Bulletin*, July 1996, 28:3, pp. 34-41.

Weick, K., "The collapse of sensemaking in organizations: The Mann Gulch disaster," *Administrative Sciences Quarterly*, 1993, 38, pp. 628-652

Weick, K., *Sensemaking in Organizations*, Thousand Oaks, CA: Sage, 1995.

Wenger, E. C., and W.M. Snyder, "Communities of Practice: The Organizational Frontier," *Harvard Business Review*, January 2000.

Wilcox, Richard H. and R. Kupperman, "An on-line Management System in a dynamic environment," *Proceedings of the 1st International Conference on Computer Communications*, 1972, IEEE Computer Society, pp. 117-120.

Zmud, R.W. "Individual differences and MIS success: A review of the empirical literature," *Management Science*, 1979, 25:2, pp. 966-979.

Zuboff, S., *In the age of the smart machine*, New York: Basic Books, 1988.

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