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Designing an Emergency Information System:

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by

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Executive Summary

Achieving efficiency in disaster operations requires the informed balance of time, knowledge, energy and resources in a complex, dynamic environment. The task is inherently complex, as the organizations participating in disaster operations require differential levels of knowledge and differing types of skills. Interactive exchange of information within and between participating organizations contributes to achieving the continuous reciprocal adjustment essential to sustain the balance between the four components. Patterns of information exchange, further, shape alternatives formulated for action. In the dynamic environment of disaster operations, information, not money, becomes the primary resource for increasing efficiency.

Information plays a critical role in the interdependent, uncertain context of disaster operations. It serves as the principal means of activating differential levels of performance or adjusting reciprocal actions among the participating organizations. Disaster operations are characterized by four primary conditions. The tasks are: 1) multidisciplinary; 2) multijurisdictional; 3) multiorganizational; and 4) time-bound. Without adequate information processes, the cumulative burden of information repeatedly overloads existing human systems in disaster operations.

Increasingly, public and private organizations have sought to develop computerized information systems that meet their particular organizational needs under emergency conditions.

Several factors impede the use of organizational databases for the wider purpose of decision support to practicing emergency managers in disaster operations: 1) single agency design; 2) different terminology for the same phenomena, different types of measurement for the same processes; 3) conflict of interest between public need for information and continuing research development, and proprietary interests in maintaining trade secrets; and 4) incompatible formats in data representation and incompatible hardware.

An interdisciplinary research project to develop a demonstration model of an interactive information system in a practicing emergency management context is currently in progress at the University of Pittsburgh. Funded by the Federal Emergency Management Agency, the project addresses the problems of interactive communication between multiple organizations and jurisdictions and integration of information from multiple data bases to support coordinated action in multi-jurisdictional disaster operations in the Pittsburgh Metropolitan Region. The objective is to provide decision support to the respective managers participating in the multijurisdictional disaster operations process. The initial model focuses on problems involved in mitigation for technological hazards and response to chemical emergencies.

The model presents three components as an interrelated set of information processes designed to serve practicing managers in the multijurisdictional emergency management process. The set includes:

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I. The Problem of Efficiency in Emergency Operations

Under the urgent time constraints of disaster operations, the problem of efficiency is subordinated to the immediate needs of saving lives, protecting property and restoring community life to normal activity. In the weeks following a disaster, when costs are tallied and actions are reviewed, the efficiency of disaster operations in the use of both resources and time becomes a significant measure of effective performance for all participating organizations. As costs incurred in disaster relief, reconstruction and recovery are tallied over time, across organizations and jurisdictions, the efficiency of disaster operations becomes a primary factor in evaluating existing performance of participating agencies and designing alternative modes of disaster mitigation, preparedness and response.

Achieving efficiency in disaster operations requires the informed balance of time, knowledge, energy and resources in a complex, dynamic environment. This balance is difficult to attain, and even more difficult to maintain over the changing phases of disaster operations. Experienced disaster managers seek this balance by using 'heuristics,' or rules of thumb drawn from cumulative experience with previous disasters or familiarity with similarly uncertain conditions (Kahneman, Slovic and Tversky, 1974). The task is inherently complex, as the organizations participating in disaster operations require differential levels of knowledge and differing types of skills. Yet, coordinated action depends upon the integration of these levels of knowledge and skills by multiple participants, sequentially and concurrently, in order to achieve a collective community response. The interactive exchange of information within and between participating organizations becomes central to achieving the continuous reciprocal adjustment essential to sustain the balance between the four components. Further, the patterns of information exchange shape the alternatives formulated for action. Given the demands of balancing time, knowledge, energy and resources in disaster management, information, not money, becomes the primary resource for increasing efficiency in disaster operations.

The characteristics of information as a resource merit attention in studying processes of community interdependence, because they generate differing types of professional organization and individual contribution to collective action. Information, as characterized by Harlan Cleveland (1985, pp. 186-187), public executive and educator, is "expandable, transportable, diffusive and shareable." Further, because it enables the formulation of more efficient alternatives in community action, it is possible, under some conditions, to substitute information for material goods or to lessen the collective demand upon finite physical and vulnerable biological resources (Cleveland, 1985, p. 187.) These characteristics make the consideration of informarespective communities. Since information is inherently "leaky," that is, not easily controlled, the design of an information system to serve this community goal is critical to constructive action.

II. Information as a Primary Resource in Disaster Operations

Information plays a critical role in the interdependent, uncertain context of disaster operations. It serves as the principal means of activating differential levels of performance or adjusting reciprocal actions among the participating organizations. Developing systematic processes for the search, synthesis and dissemination of information to multiple decision-makers during disaster operations allows the adjustment of informed action to the changing needs of the disaster environment. Consequently, establishing an appropriate information system is fundamental to professional disaster management. Timely, accurate, easily accessible information drives the disaster operations process (Comfort, 1988a.) Without it, disaster managers may miss important opportunities for corrective action or lose control of their coordination processes (Turner, 1978.)

Information requirements for disaster management recognize four primary characteristics of the disaster operations process. It is, first, multidisciplinary. That is, the professional skills and knowledge required for appropriate action in any major disaster include, at minimimum, technical, organizational, system can serve to integrate appropriate responses for the municipality.

Finally, information in disaster operations is time-bound. That is, information may decay, in accuracy, utility or relevance to the multiple participants in the disaster operations process, over time. Consequently, the search for information is necessarily continuous, and its utility to disaster managers requires that it be verified and updated, with dated information removed from the current operational knowledge base to an historical file. Confronted with threatening events, disaster operations personnel determine actions under urgent pressures of time. If accurate information is available, they will use it. If not, they may be compelled to act on the basis of limited information, reasoning that no action is worse than uninformed action when lives and property are at stake. In logical terms, they are reasoning both "in real time" and "against time," (Dodhiawala, Jagannathan, Baum and Skillman, 1989: 79) on the basis of changing information and dynamic conditions of disaster operations.

Without adequate information processes, the cumulative burden of information repeatedly overloads existing human systems in disaster operations. Under these adverse conditions, human cognitive processes are likely to err and performance among interdependent organizations drops (Comfort, 1985b). The discrepancy between actual performance and system values compels a reexamination of existing information processes for both designed, several factors impede their use for the wider purpose of decision support to practicing emergency managers in disaster operations.

First, the data bases were designed largely for single agency purposes. Disaster operations necessarily involve multiorganizational and multijurisdictional processes. Consequently, no single data base serves the comprehensive need for decision support for coordinating multijurisdictional disaster operations. Second, the data bases frequently use different terminology for the same phenomena, different types of measurement for the same processes. These discrepancies may generate misunderstandings and delays in communicating needs and new information between relevant organizations and to the public. Third, with some proprietary data bases, there is an awkward conflict of interest between public need for information and continuing research development, and proprietary interests in maintaining trade secrets that inhibits the free exchange of information among multiple organizations needed in time-critical disaster operations. Finally, data bases, developed independently of one another, are frequently characterized by incompatible formats in data representation and incompatible hardware that limit sharing of information as needed for a multijurisdictional emergency management information system. The problem of integrating differing public and private data bases to serve as decision support to practicing disaster managers is under study managers participating in the multijurisdictional disaster operations process. In concept, the model may be extended to all hazards, although the initial model focuses on the problems involved in mitigation for technological hazards and response to chemical emergencies.

The focus on technological hazards was selected for several reasons. First, the 1988 oil spill in the Pittsburgh region vividly demonstrated the need for interactive information processes between jurisdictions and, within jurisdictions, between organizations with emergency responsibilities. In an interdependent metropolitan community, active coordination of public, private and nonprofit actions was critical during the 1988 disaster operations as emergency responders sought to contain the emergency and restore the community to normal functioning (Comfort, Abrams, Camillus, Ricci, 1989.) Second, federal legislation under the Emergency Preparedness and Community Right to Know Act (Superfund Amendments and Reauthorization Act, Title III) of 1986 requires that communities develop local plans for the mitigation of risk and management of operations in the event of chemical emergencies. Consequently, this current legal requirement compels both public and private agencies to assess risk as well as capacity for response to chemical emergencies in their respective communities. Finally, but importantly, public and private managers with emergency responsibilities in Pittsburgh and Allegheny County have voluntarily formed a Mutual Aid Council (PAMAC) to address shared solve a general problem. It consists of three major elements: 1) knowledge bases, which are maintained as separate and independent units; 2) a blackboard data structure, which serves as the shared database for problem-solving accessed by all participating units, comparable to a "situation board" maintained in strategic military or business operations; and 3) control procedures, which direct the sequence of steps in processing information and maintain the focus of the problem-solving process (Zadeh, 1986.) These procedures are activated in response to information processed by the system.

This design allows solutions to a shared problem to evolve from interaction among multiple organizations and other knowledge sources through a common representation of the problem, mutual adjustment in coordinated action and systematic updating and feedback of information among responsible actors as problem-related events progress in time. As the situation changes, participating organizations acting as knowledge sources, respectively, update their reports, communicating critical information to the set of participants through the blackboard. By this means, all participating organizations have access to the most current, complete information available on the status of the problem. This global situation report may, in turn, trigger independent actions by specific organizations as they interpret the current information in terms of their own responsibilities and vulnerabilities to risk. Separate organizational actions, respectively, are reported back through the shared database or conditions or events that have substantive community impact or legal mandate. The control procedures will specify which knowledge bases participate in the jurisdictional problem-solving process under what conditions, the equivalent effect of activating the municipal emergency plan.

The purpose of the blackboard is to create a working database for managing a given disaster. Consequently, it draws information from multiple knowledge sources, but only that information relevant to action for the event in progress.[2] It is essentially a "situation board" to which information is contributed opportunistically from differing knowledge sources in a goal-driven search for solutions to problems generated by a given event. That is, the blackboard seeks to create the capability of applying the right information at the most opportune time in problem-solving strategies (Dodhiawala, Jagannathan, Baum and Skillman, 1989: 78.) Alternatives for action may be crafted from information available from multiple knowledge bases or organizations accessed through the jurisdictional blackboard and transmitted, in turn, to the appropriate participants. Further, use of the blackboard raises the level of information available to the multiple participants in the disaster operations process, so they may adjust their own actions in a more timely, appropriate manner to the dynamic sequence of events.

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2. The blackboard concept of problem solving draws from the theory of problem solving presented by Allen Newell and Herbert A. Simon in their book, <u>Human Problem Solving</u> (Englewood Cliffs, NJ: Prentice Hall, 1972.)

Figure 1

A Layered Knowledge Base for Multijurisdictional Emergency Management

Federal Jurisdiction

Public Agencies	Associations of Private Businesses	Associations of Non-Profit Organizations
FEMA USCG EPA ...	CMA Chamber of Commerce...	Red Cross, National .....

State Jurisdiction

Public Agencies	Associations of Private Businesses	Associations of Non-Profit Organizations
PEMA PA DER PENNDOT....	Ben Franklin Partnership...	Red Cross, State....

County Jurisdiction

Public Agencies	Associations of Private Businesses	Associations of Non-Profit Organizations
CEMA Maintenance Police Fire Councils of Government...	Greater Pittsburgh Chamber of Commerce; Allegheny Conference...	Red Cross, County Level...

Municipal Jurisdiction

Public Agencies	Private Corporations And Businesses	Non-Profit Organizations
DPS Public Works Water Planning....	Mobay Westinghouse USX...	Hospitals, Churches Schools...

Organizations Listed are Illustrative Only

Figure 3

Unix System Thu June 29, 8:59 am

DISASTER PROGRAM
COORDINATOR'S MENU

1. Field Status
2. Jurisdictional Emergency Plans
3. Prioritized Actions
4. Actions in Progress
5. Situations Resolved or Stablized
6. Notification Directory
7. Decision Support Programs
8. EPA E-Mail
9. CAMEO Program
10. FEMA IEMIS Simulation
11. NOAA Geographic Database
12. CHEMTREC Chemical Database
13. Title III Database
14. CAER
15. PEMA EIS
16. ORSANCO Bulletin Board
17. Send Message to User
18. Read Message from Users
19. Assign New Coordinator
20. Quit Program

Enter an appropriate number and press return:

Unix System Thu June 29, 9:03 am

USER MENU

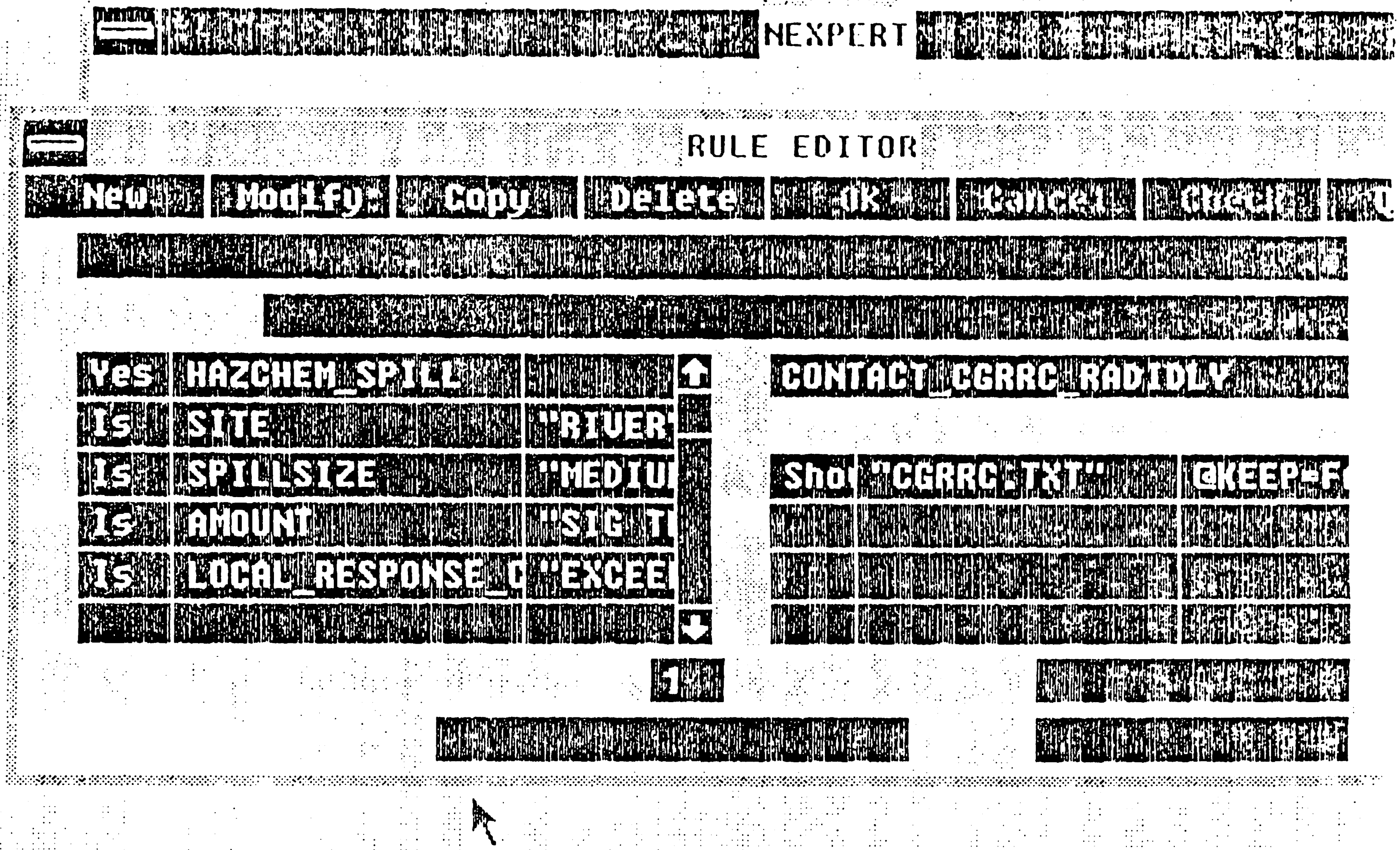
1. Field Status
2. Jurisdictional Emergency Plans
3. Prioritized Actions
4. Actions in Progress
5. Situations Resolved or Stabilized
6. Title III Database
7. Who is the Disaster Management Coordinator?
8. Send Message to Disaster Management Coordinator
9. Read Messages from Coordinator
10. Quit Program

Enter an appropriate number and press return:

designation of sequence and accessibility to certain types of information in the problem-solving process. For example, certain types of information may be labeled "public" and accessed by all users of the blackboard. Other types of information may be designated as "private," and accessed only by designated users at designated times. Dated or inaccurate information may be deleted from the blackboard under specified conditions, or a time limitation may be placed on information reported to the blackboard, warning users to revalidate that information against pos--sible changes after a certain period of time. (Zanconato, 1988) These features will aid decision-makers in the difficult tasks of dealing with sensitive information in a public arena and in coping with changing information in a dynamic environment. A succinct summary of the blackboard framework, drawn from the work of Penny Nii (1987: 43-44), is included in Appendix A.

The second component is the spatial representation of information assembled from the blackboard onto computerized maps of designated areas. This component is currently in development. We are exploring ways to use the mapping capacity of the Integrated Emergency Management System (IEMIS) within the blackboard architecture to allow the transfer of information from the blackboard to designated geographic areas on the computerized maps. The capacity to represent complex information visually to multiple users simultaneously will likely increase the common understanding of the evolving disaster events. In turn, this shared understanding is likely to facilitate informed action,

Figure 5



RULE 2 - FEDERAL

IF	YES	HAZCHEM SPILL	
	IS	SITE	"RIVER"
	IS	SPILLSIZE	"MED"
	IS	AMOUNT	"SIG-THREAT"
	IS	RESPONSE CAPABILITY	"EXCEEDED"

-----> CONTACT CGRRC RAPIDLY

These three components, operating in reciprocal relationship, constitute an interactive intelligent spatial information system (IISIS) that is designed to provide support to practicing decision-makers in the interjurisdictional emergency management process.

IV. Design Principles for the Interactive Intelligent Spatial Information System.

Six principles underlie the design of this interactive intelligent spatial information system (IISIS), intended for application in the complex, multijurisdictional context of disaster management. These principles are:

1. To utilize existing knowledge bases and information systems where possible
2. To facilitate the functional integration of diverse knowledge bases in disaster management
3. To maximize accessibility to any organization that has legitimate emergency responsibilities and authorized users, as well as flexibility in the system's capability to meet the respective user's information needs
4. To maximize portability across both hardware and software
5. To increase the content and exchange of information among emergency managers in multiple organizations and jurisdictions participating in the dynamic emergency operations process
6. To maintain an open-ended research, development and

tions to maintain internal information processing on their own systems.

Functional integration of information also derives from the practical approach of building on work already in use and linking existing systems to serve specific purposes under designated conditions in emergency management. Integrating data around emergency functions follows from the practical requirement of designing action within the constraints of available resources and time. In practice, disaster managers may need to build response actions to emergency conditions across organizational and jurisdictional boundaries. This task is facilitated if the information involved is organized by function in the global database. For example, the practical matter of accounting for costs incurred by personnel and equipment used in a given response action, usually maintained by organizational and/or jurisdictional units, can be tabulated by disaster function, with subtotals calculated by jurisdiction and organization. Allocation of resources, a major task of disaster coordinators, can be greatly facilitated across jurisdictional and organizational lines with the utilization of a community-wide knowledge base and information-processing system.

Accessibility to multiple users is essential as the disaster escalates to broader jurisdictions and more organizations become involved in response operations. Flexibility in application allows the role of disaster coordinator to move up and down the jurisdictional levels, while the information processes designed face processes between existing data bases in graduated sequence as disaster operations escalate and de-escalate will be scheduled in the next phase of project development.

Second, the function of search and retrieval of information on hazardous materials developed from data collection processes required by SARA Title III may be facilitated by this interactive information system. Title III databases are maintained at the county jurisdictional level in Pennsylvania, but they may be easily accessible to municipal, state and federal jurisdictions via this interactive information system. Important in establishing its usability across organizational and jurisdictional boundaries will be the definition and acceptance of a common set of terms and measurement standards in the management of hazardous materials emergencies.

Third, standards for continuing the research and development of an interactive information system need to be defined, discussed and accepted by the organizations with responsibilities for local emergency response operations. These responsibilities include those defined in law, as well as those accepted voluntarily by community organizations as part of responsible participation in the community (Turner, 1978.)

Standards intended to support optimum flexibility in the development of an interactive community information system need to establish public, relational data bases that are: 1) non--proprietary; 2) non-machine dependent; and 3) capable of integration. These standards encourage the organization of the hazardous materials in our communities is a critical factor in the development of community emergency preparedness.

In complex environments, key actors regress to a mean of common understanding before they are able to coordinate their actions effectively. This phenomenon, which Comfort (1988c) has observed repeatedly in disaster environments and termed the "criterion of regret," has a dysfunctional effect upon disaster operations if serious discrepancies exist between participating organizations in reference to shared tasks. While the common goal of saving lives drives action in disaster operations, clear functions provide the basis for integrating action across disciplinary, jurisdictional and organizational lines. Designing an interactive information system with two-way patterns of communication and opportunity for reflection, feedback and redesign is a primary means for developing this common base of understanding essential to timely, appropriate action in disaster operations.

An interactive information system serves to structure organizational action through establishing the sequence and content of information exchange. For example, practicing decision makers seek to achieve a common understanding of shared tasks through heuristics of experienced judgment. They intuitively calculate the proportional difference from the mean understanding of the collective goal for each actor in the disaster operations process and increase the information flow to that actor accordingly. The appropriate use of information technolprivate affairs.[5] Organizations that are able to learn from previous emergencies and continuing experience with hazardous materials are better able to achieve the informed balance between time, knowledge, energy and resources requisite to increasing efficiency in disaster operations.

The IISIS model, carefully developed and implemented, can contribute to the development of a "policy organization" (Meltsner and Bellavita, 1984) directed toward the continuing development of mitigation and preparedness for chemical emergencies. Such a 'full-time policy organization,' drawing its 'part-time membership' (Meltsner and Bellavita, 1984:) from interested professionals with responsibilities for emergency management in public, private and nonprofit organizations, does not establish a separate hierarchy of administration for emergency management. Rather, it incorporates emergency functions into the set of continuing commitments for responsible participation in an interdependent, metropolitan community.

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5. Robert Reich presents the concept of 'illusion' in economics in a thoughtful article in Foreign Affairs, 1987. Essentially, this concept refers to economic conditions or relationships that, unnoticed, seriously affect economic growth or stability.

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