DESIGNING AN INTERACTIVE, INTELLIGENT, SPATIAL INFORMATION SYSTEM FOR INTERNATIONAL DISASTER ASSISTANCE

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and the

Interdisciplinary Disaster Research Group

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The Interdisciplinary Disaster Research Group is an informal working group of faculty at the University of Pittsburgh who are engaged in the study of disaster, its consequences and potential alternatives for action. Participants include Joel Abrams, School of Engineering, Bruce Buchanan, Department of Computer Science, John Camillus, Graduate School of Business, Edmund Ricci, Graduate School of Public Health, Ernesto Pretto, School of Medicine and Eugene Miklaucic, University Center for Social and Urban Research and Louise Comfort, Graduate School of Public and International Affairs. Other faculty members offer advice and consultation on specific projects. Peter Safar, International Resuscitation Research Center, Miroslav Klain, Department of Anesthesiology, Samuel Tisherman, Department of Surgery and David Crippen, Critical Care Medicine, St. Francis Hospital are acknowledged for their contribution to the study of disaster reanimatology and medicine. All are valued colleagues who have informed the discussion of interdisciplinary information processes that is central to this paper.

Designing an Interactive, Intelligent, Spatial Information System for International Disaster Assistance

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and the Interdisciplinary Disaster Research Group[1]
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I. Disaster: A Global Problem

Over the last two decades, disaster has emerged as a formidable international problem. Globally, disasters have cost three million lives, destroyed the homes of 820 million people and incurred $100 billion in property losses since 1970.[1] Further, recent studies of disaster operations have shown recurring problems of interdependence, organization and efficiency in disaster environments that, regrettably, limit capacity for community response to reduce the losses in lives and property by timely, appropriate action (L.K. Comfort, 1989a; 1989b). Inherent in our human ability to manage information in complex environments, these problems reflect the difficulty of designing strategies of action that enable communities vulnerable to seismic or other types of risk to plan for hazardous events in interdependent environments, organize collective response when disaster does occur, and use available resources efficiently to reduce losses in lives and property.

The complexity of disaster environments poses an extraordinary burden on human decision-makers to take timely, appropriate action in uncertain conditions. The information load escalates beyond our limited cognitive capacity for processing information (H.A. Simon, 1969, 1981; L.K. Comfort, 1988a), yet timely action is critical when lives are at risk. The information burden increases with size and complexity in disaster environments, impeding action despite available resources and committed personnel (Comfort, Woods and Nesbitt, 1990). Urgent constraints of time and disruption of ordinary operating procedures compel responsible managers to invent means of individual and organizational learning to cope with the dynamic events of disaster unfolding in an interdependent com-

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[1] This paper draws upon the work of an interdisciplinary working group in disaster research at the University of Pittsburgh. I acknowledge the contributions of my colleagues, Bruce Buchanan, Joel Abrams, Edmund Ricci, John Camillus, James E. Nesbitt, Eugene A. Miklaucic, and Theresa R. Woods to the formulation and development of the IISIS concept. This paper represents an adaptation of the IISIS concept to the problem of efficiency in international disaster assistance. I also acknowledge the assistance of Peter Safar, Ernesto Pretto, Miroslav Klain, Samuel Tisherman and David Crippen in adapting this concept to the organization and delivery of medical services in disaster environments. Also please see Louise K. Comfort, James E. Nesbitt and Theresa R. Woods, "Designing an Emergency Information System: The Pittsburgh Experience" in Tom Housel, ed., Information Systems and Crisis Management (JAI Press, in press, 1990).

munity. There is evidence that the capacity for individual and organizational learning can be enhanced through structured information processes (Comfort, 1990). The problem, however, can be observed directly only in the crucible of actual disaster operations.

Considering previous disaster operations as experiments in individual and organizational learning, we may observe demonstrated improvement in performance in complex disaster environments with increased professional design, training and public awareness of risk. For example, data from three recent earthquake disasters of similar magnitude show strikingly different rates of loss. The following table presents data from the earthquakes of March 5, 1987 in Ecuador (6.9 Richter scale); December 7, 1988 in Armenia (6.9 Richter scale); and October 17, 1989 in Loma Prieta, California (7.1 Richter scale).[2] Although the earthquakes differed in location and distance from populated areas, each engendered severe destruction, loss of life and required mobilization of disaster response. The relatively low loss in lives (65 dead) in the 1989 California earthquake demonstrates that it is possible to design infrastructure for human communities that will withstand major earthquakes and that organizational response can be mobilized more efficiently with prior training and an informed citizenry.

The complexity of operations involved in the organization and coordination of international disaster assistance challenge the most experienced public and private managers. In any given location, a major disaster is likely to occur only once in a lifetime. Yet, across the world, these events occur with sobering regularity and stunning losses in lives and property. On a global basis, the problem of disaster can no longer be ignored or dismissed as a rare event. The question is whether lessons learned in one disaster environment can be transferred appropriately to other areas of the world vulnerable to seismic or other types of risk.

II. The Problem of Efficiency in International Disaster Assistance

The problem of efficiency involves improving the uses of time, organization and coordination to achieve appropriate response to disaster. In a major disaster, complexity in response actions escalates geometrically with the numbers of people involved, the size of the affected area and the capacity to mobilize appropriate resources and technology. In international disaster environments, complexity increases still more dramatically when differences in language, training, equipment, and experience require coordination across organizational, national, and cultural boundaries (Comfort, 1986;1987;1990) to attain effective response.

Each disaster has unique characteristics, but common to all disasters is the function of response. By definition, disaster means that local resources are overwhelmed, and response necessarily involves the mobilization, organization and deployment of external resources to the stricken area. Improving the capacity

for timely, appropriate response, therefore, is likely to increase the efficiency of disaster operations. In major disasters such as the Armenia Earthquake of December 7, 1988, response comes voluntarily from international sources. Without planned organization prior to the disaster, the complexity of the process virtually guarantees inefficient operations. Disaster snarls the interdependent threads of communication and organization that facilitate collective action in human settlements. When that action crosses disciplinary, organizational and jurisdictional boundaries to deliver external assistance to a stricken area, alternate forms of communication and organization that allow timely, flexible coordination over the entire span of disaster operations are essential.

The paradox of international disaster assistance has been discussed in detail in other research. In general, international disaster assistance is characterized by enormous good will, quantities of donated goods and humanitarian concern for the victims. In practice, massive effort and generous contributions of time, personnel and equipment by many nations produce meager results in terms of lives saved or losses diminished. The discrepancy between effort expended and results achieved has been documented in most recent disasters (Cuny, 1982; Comfort, 1986; National Research Council, 1989).[3] Regrettably, this discrepancy indicates an ineffective use of resources and time. It is a serious matter for professional design.

Professional design offers three characteristics to international disaster response. First, professional design provides continuity in practice by clarifying functions and responsibilities for action for major actors in the process. Second, it stimulates innovation in meeting current needs by creating a knowledge base of shared information among the participants. Third, it serves to integrate critical actors and resources in effective action. In application to a problem as complex as international disaster assistance, professional design includes exploring the appropriate uses of information technology.

III. The Potential for Information Technology in International Disasters

Are there ways to increase our understanding of individual and organizational learning processes in complex disaster environments and further, to share this knowledge with the wider international community? It may be possible to establish a systematic means of learning from recurring disasters on a global scale through the potential of information technology. Information technology facilitates four critical functions in international disasters. First, the use of information technology collapses time and distance through the possibility of instaneous communication and transfer of information from the disaster site to international centers of assistance and resources.

Second, information technology allows the creation of a shared

knowledge system for all those participating in disaster response. Through careful design, it is possible to generate a disaster-specific database that provides a continuously updated record of events, actions, conditions, consequences, needs and available resources. This database may be accessed by multiple participants simultaneously and used to inform responsible action in disaster operations.

Third, information technology, well-designed, reduces the complexity of information flow to disaster managers. By identifying critical areas of disaster operations and representing them graphically for simultaneous monitoring, by relating specific events to known characteristics of the community and region, by sorting incoming information in reference to pre-established priorities for action, information technology enables decision-makers to monitor the whole set of disaster operations more effectively, yet allowing detailed consideration of specific problems at particular sites.

Finally, information technology enables local participation in an international network of assistance in disaster response and recovery. By facilitating the interactive exchange of timely, accurate information, local participants can take more appropriate action in response to needs reported from the disaster-affected area. These four functions, taken together, create the potential for increasing organizational learning in disaster operations. As organizational learning increases from actual disaster events, efficiency in response operations is also likely to increase in the global arena.

IV. A Design for an Interactive, Intelligent, Spatial Information System (IISIS) in International Disaster Assistance

Current information technology allows the design of an interactive, intelligent, spatial information system (IISIS) for use in international disaster assistance operations. The goal of such a system is to provide responsible decision-makers with flexible capacity to obtain an overview of the entire set of disaster response operations, while retaining the capacity for detailed examination of specific problems at any given time. The intent is to create a disaster-specific information system that allows practicing managers to draw relevant information from multiple sources in systematic ways. The design of such an information system, for use here or abroad, would rely on similar principles as those used by the National Communications System.[4] These principles, adapted for an international IISIS that may be developed over a period of years, include:

1. an international geographic information system consisting of distributed, user-maintained segments coordinated by a single international agency

2. use of the same data base systems that serve everyday operations for contributors to the information stream;

these data bases, in turn, would be updated by entries from transactions evolving through the international stream in reciprocal process

3. maintenance of an international, multi-media communications system by a consortium of organizations that includes international, national, state, local and private entities with responsibilities for disaster response and assistance

4. use of professional standards of measurement and calibration in the development of models to estimate the effects of potential hazards or failure of vital systems affecting the public and the testing of such models through field observations

5. assurance of either redundant capability or surge capacity for all equipment involved in a potential role in the mitigation of disasters; this capability could be financed in the original capital investment on the basis of a specially defined risk assessment[5]

Building upon these principles, an IISIS includes three components. They are:

1. An interactive field status board that creates a disaster-specific database to support decision-making in international disaster operations

2. A graphic mapping capability that allows the spatial representation of information from the field status board to multiple organizations and jurisdictional users

3. A capacity for logical inference from information reported on the field status board to relevant knowledge bases included in the system[6]

These components, operating interdependently, create a capacity for improving the timeliness and validity of information available to disaster managers engaged in separate but related functions vital to international disaster operations. By improving the information available to support decision-making, an IISIS facilitates interactive communication and coordination among participating agencies to increase the efficiency of international disaster operations. It also allows the creation of a continuing record of innovative performance and effective response to disaster events that may inform global strategies in disaster response and recovery. Information technology, appropriately designed and used, serves as a vehicle through which responsible individual managers may activate broad organizational response to disaster. More importantly, it serves the cumulative function of organizational learning in a global sequence of disasters.

V. Requirements for an IISIS in International Disaster Assistance

Four conditions are requisite for the development of an interactive, intelligent, spatial information system for international disaster assistance. First, acceptance of the concept by responsible disaster managers is fundamental to creating the basis for their understanding and use of the system. Second, formation of an international, interdisciplinary advisory group is essential to guide the development of the system and to ensure its practical application in actual disaster environments. Third, utilization of existing international information systems, such as UNIENET, UNDRONET and Red Cross networks, are necessary to avoid duplication, conflicts in outcomes. Finally, it is important to develop a demonstration model for an IISIS to test its feasibility in actual international disaster operations.

VI. An Initial Strategy for an IISIS in International Disaster Assistance: A Demonstration Module to Support the Organization and Delivery of Medical Services in Disaster Environments

In order to test the feasibility of an IISIS for international disaster assistance, the concept needs to be translated into a working model. While the construction of a full, interdisciplinary IISIS requires a major commitment of resources and time, a practical means of testing the concept is to build a demonstration model based on actual experience gained in disaster operations following the Armenian earthquakes. The Armenian experience demonstrated significant international collaboration and cooperation in providing medical assistance to victims of the earthquakes and documented the number and types of medical teams from 14 nations that responded to the massive medical needs generated by the disaster.[7] This extensive response allows a rich basis for study. It is possible to draw on the Armenian experience, focusing on the commonality of response from participating organizations and jurisdictions, to design a demonstration model to provide decision support for the organization and delivery of medical services in disaster environments.

Such a model would serve three goals important to organizational learning in the disaster management community. First, it would acknowledge the urgency of time as a measure of efficiency. Second, it would accept the humanitarian commitment to saving lives as the basis for action at the international level. Finally, it would begin a continuing record of innovative response to disaster that may inform global strategies in disaster response and recovery. Strong leadership has already been demonstrated by physicians in humanitarian response to disaster, for example, the bold work of the International Physicians for Peace against Nuclear War, Medecins sans Frontiere, Doctors without Borders and members of the Armenia Ministry of Health in the organization of this conference. It is fitting that a medical model be the first segment of an interactive information system to support decision-

making in international disaster assistance.

In its design, it is important to clarify the relationship of the medical model to the whole information system. The design for the knowledge base of the whole information system will be layered by jurisdiction: local, regional, national and international. Within each jurisdictional layer will be a modular knowledge base, organized by disciplinary perspective, function and time phase in disaster operations. For each jurisdiction, disciplinary perspectives may include technical, organizational, medical, political and cultural types of knowledge required for appropriate response to disaster. Other perspectives, such as economic or psychological, may be added as appropriate for specific areas. Within each disciplinary perspective, for example, medical, further sub-categories of knowledge and skills needed for response may be specified. The objective is to design a working knowledge base to support decision-making across the range of participating organizations and jurisdictions in order to mobilize, organize and deliver medical care in disaster environments more efficiently.

VII. A Proposal for Action

Returning to the global problem of disaster, we propose the following steps toward the goal of minimizing losses in lives and property in recurring events:

1. Design of an initial model to support the organization and delivery of medical services in international disasters, using the IISIS concept

2. Demonstration of this model in an international setting

3. Evaluation of the model by an international, interdisciplinary advisory group

4. Request for international funding and participation in the development of such a model for international disaster assistance, with cooperation from national and international organizations engaged in disaster response and recovery

Taken now, at the beginning of the International Decade for Natural Hazard Reduction, these steps would represent a substantial contribution to increasing the timeliness and validity of information available to international managers responsible for disaster assistance operations. Working together, we may achieve a significant increase in the efficiency of international disaster assistance over the ten-year period of the Decade, or by the year 2000. Such a project would serve as a living memorial to the victims of the Armenia Earthquake of December 7, 1988. We invite your comments, participation, and assistance in the accomplishment of this goal.

End Notes

1. "Decade Spotlighter," US Decade for Natural Disaster Reduction, Summer/Fall, 1990.

2. Data for the table are drawn from reports of the United Nations Economic Commission for Latin America and the Caribbean, Ecuadorian Civil Defense; Armenian Civil Defense; US Geological Survey; California Office of Emergency Services.

3. See also reports from the United Nations Economic Commission for Latin America and the Caribbean, United Nations Disaster Relief Organization and the United States Office of Foreign Disaster Assistance, 1980-1990.

4. Robert T. Jaske, "The Geographic Information System as the Ultimate Data Management System -- Policy Issues for the 1990s." Paper prepared for presentation at the International Geographic Information System Symposium, Baltimore, MD, March 18-19, 1989, p. 2. See also Robert T. Jaske, "Some Considerations of Data Management Standards in Achieving a National Distributed Data Processing System," presented at the Geographic Information Systems Conference, March 7-9, 1090, sponsored by the U.S. Professional Development Institute.

5. These principles are adapted from a research proposal designed to create an IISIS for a US metropolitan region. See "Communications and Information Systems in Disaster Management: A Model for Metropolitan Regions," University of Pittsburgh, Pittsburgh, PA, May 15, 1990, pp. 1-2. This proposal is currently under review by the US Federal Emergency Management Agency.

6. These components of an IISIS have been discussed in detail in L. Comfort, T. Woods and J. Nesbitt, "Designing an Emergency Information System: The Pittsburgh Experience" in Tom Housel, ed., Crisis Management and Information Systems (JAI Press, in press, 1990.)

7. See, for example, the Telemedicine Project that created an international medical consultation process between LDS Hospital in Salt Lake City, Utah and other US Telemedicine sites through a US satellite uplink and turnaround in Roaring Creek, Pennsylvania to the Republic Diagnostic Center, Yerevan, Armenia SSR. The project utilized satellite communication facilities provided by the US National Aeronautics and Space Administration and was termed the US-USSR Spacebridge. A.D. Ausseresses. 1990. Telemedicine: Technology in Practice. Salt Lake City, UT: LDS Hospital. Report prepared for an International Symposium - "Medical Aspects of Earthquake Consequences in Armenia," Yerevan, Armenia SSR, October 9-11, 1990.

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