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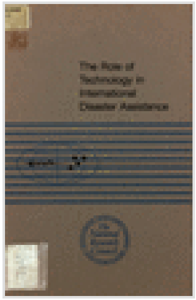

The Role of Technology in International Disaster Assistance: Proceedings of the Committee on International Disaster Assistance Workshop, March 1977 (1978)

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Committee on International Disaster Assistance Workshop
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Commission on Sociotechnical Systems
National Research Council

NATIONAL ACADEMY OF SCIENCES
Washington, D.C. 1978

NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the Councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the Committee responsible for the report were chosen for their special competences and with regard for appropriate balance.

This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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Workshop Summary

To what extent can scientific and technical knowledge be applied to prevent, prepare for, and assist in mitigating the effects of disasters? Answers to this question were sought at a workshop sponsored by the Committee on International Disaster Assistance of the National Academy of Sciences-National Research Council in March 1977. Technical experts and officials charged with disaster response in the U.S. government and foreign governments participated. This report covers the proceedings of that conference, including papers presented and summaries of discussions.

The primary focus of the conference was upon floods and earthquakes. For discussion purposes, disaster response was divided into phases such as emergency relief (the few weeks following impact), recovery (the approximately 3 months following impact), and rehabilitation (the period of reconstruction). Because the scope of assistance provided by the Agency for International Development Office of Foreign Disaster Assistance is limited to the emergency and immediate postemergency periods, the emphasis of the workshop was on the applications of technology during those periods. The main topics discussed were emergency shelter, search and rescue operations, and emergency communications. A special presentation on the possible uses of space satellites for disaster warning, monitoring, and damage assessment was also given.

The importance of preparedness emerged as one of the main themes of the workshop. Even if relief organizations' mandates extend only to the emergency period, that emergency relief effort is conditioned by what was or was not planned before the disaster. Cited as particularly important were prior analysis of vulnerabilities, organization and training of indigenous personnel to help themselves and others during a disaster, coordination of existing communications and other systems, and some stockpiling of materials and equipment (not necessarily high-technology items).

Similarly, the importance of independent postdisaster evaluations of relief response was emphasized. Disaster covers such a wide range of phenomena with different causes, processes, and effects–many of them difficult to predict and control–that planners can never assume in advance exactly what disaster-induced needs and appropriate responses will be. Postdisaster analysis of disaster agents, phases, and operations can point up ways in which the handling of this situation could have been improved or that failure could have been avoided. This information is obviously applicable to handling future disasters.

The workshop participants looked for specific areas in which a technological remedy can be directly applied, or areas for which one must be created. Most of the previous attention directed toward using technology to alleviate disasters has been random and uncoordinated. The hardware orientation of Western technological aid—that is, the exportation of finished products made in developed countries according to their assumptions about the problems in the disaster-prone, largely developing countries abroad—has been criticized.

There is a significant contrast between technological development and utilization of technology in handling disasters. Because little equipment and few systems have been specifically designed for response to disaster, the technology actually used in disaster operations is largely *ad hoc* or makeshift. Equipment or devices are improvised or borrowed—often from military sources. There is little standardization or compatibility among disaster equipment so mobilized. Then too, utilization of sophisticated technology requires technical management that is usually scarce in developing countries; hence disaster relief efforts tend to be labor intensive rather than dependent upon modern technology. Indigenous solutions—materials, construction designs, social coping mechanisms—have in many cases proved generally more appropriate than imposed, high-technology solutions.

What role then remains for technologists hoping to improve their assistance when disasters strike? Highlights of the points raised in answer to this question in the workshop sessions follow.

Emergency Shelter

The basic goal in emergency shelter is to respond to the critical habitational needs of disaster victims. A related goal is to coordinate donor responses in order to facilitate the immediate provision of shelter. The needs vary with the disaster (earthquakes frequently destroy shelter, while floods may just temporarily evict inhabitants) and with the climate of the affected country. Western, consumer-oriented society is inclined to think in terms of material solutions like tents, emergency housing, and some permanent housing, while persons in developing countries tend to prefer social mechanisms such as extended family accommodation coupled with accelerated reconstruction.

The problem is one of understanding local conditions and developing appropriate solutions, rather than designing abstract solutions to assumed problems. The emergency shelter phase cannot be considered independently of the rehabilitation and reconstruction phase. The content of emergency aid should be compatible with long-term need, and the long-term solution rests with understanding the normal building processes in the predisaster period in a given country.

The remarkably competent indigenous response in the wake of disasters is the key element in emergency shelter. Yet the international community cannot always assume that indigenous solutions will be adequate. Disasters, almost by definition, are abnormal. Hence it is often not feasible for a small population or small area to appropriate resources for dealing with a unique problem. When the small areas are pulled together to form a larger target, help becomes feasible. Once the target area becomes large enough, similarities among cases emerge, and solutions that would not occur from isolated cases begin to present themselves.

More education and research are needed in rapid reconstruction of local housing with predominantly local materials and significant additions of key materials, plus technical assistance and public education are needed to carry out building improvements. Some examples exist of improvement of building details and rapid reconstruction of locally accepted types of buildings, and aid programs can do more along these lines.

Search and Rescue

Because the greatest need for search and rescue occurs within 72 hours of disaster's impact, prime emphasis should be upon improving in-country, grass roots capabilities to handle emergencies. Necessary measures include analysis of local geographic and man-made hazards, local education for survival, development of local leadership, and organization and training of local disaster response teams. Coordination emerged as the most essential ingredient in search and rescue.

Different disasters obviously require different search and rescue skills and equipment. Earthquake-prone areas should have teams trained in debris removal; communities with potential flood hazards can prepare by stockpiling boats and training volunteers in scuba skills. Buoyant rope (designated the single most valuable piece of search and rescue gear in floods), ladders, and Stokes litters can easily be stored around the world. Special situations may require outside support, but generally the immediate delivery of high-technology equipment like helicopters is inappropriate. Those attempting to deal with the confusion of the immediate emergency will more likely benefit from the efforts of a well-trained indigenous rescue team.

The working group developed many suggestions for particular types of technologies that might be applicable to search and rescue. Many U.S. techniques and types of equipment are of interest abroad, but they may not be directly exportable unless they can be adapted to other cultures and geography. It was suggested that AID's Office of Foreign Disaster Assistance establish a technical team to collaborate with disaster-prone countries to determine which of the problems of the emergency period lend themselves to currently available or possibly new technical solutions. Caution was expressed that any devices developed should be designed primarily to make untrained personnel more effective. Special study should be made of the use of indigenous materials in improvising equipment on the scene.

Emergency Communications

The technological problem in communications is one of improving management of communication systems, not developing new communication equipment. Adequate technical hardware already exists for all tactical and strategic communication needs. The technical capability also exists to deliver that hardware, piecemeal or in complete packages, anywhere in the world within 24 to 48 hours from designated stockpiles. The key issues involve availability of equipment to disaster-prone countries and management problems in the use of the equipment at the time of disaster.

Recognition of the importance of communications recurred throughout the workshop. Obviously, at the time of disaster, communications are necessary to coordinate rescue efforts and needs assessment and to manage resources. If the disaster is of a kind that permits advance warning, communications can help prepare for it, thereby reducing damage and injury. Strengths and vulnerabilities to disruption from disaster were compared for various kinds of communication systems, from the highly vulnerable telephone to troposcatter links, cable, various kinds of radios, and satellites. For effective communications during a disaster, existing long-range microwave systems, regional systems, and citywide systems must be tied together in a network.

Establishment of indigenous communication planning teams for disaster assistance was suggested. Each should be headed by a communications expert who is also a member of the overall disaster-preparedness planning team. A military communications expert, public communications expert, and representatives from key agencies such as police, fire, health, and public works should also be included. The team would review the performance of communications during previous disasters; review the efficiency of the early warning system; update analysis of hazards since the last emergency; and consider national, regional, and local priorities.

Adaptation of existing systems to the emergency network will require cooperation of many organizations with differing interests and disciplines. Legal availability and technical capability of the system to be integrated into the emergency network must be considered, and radio frequencies established and cleared.

AID's technical representatives are working with disaster-prone developing countries on their long-range planning, including their communication support plans. The major problem is coordination of communication technologies existing in various countries with what might be needed in the event of disaster.

It was pointed out that although improving information management can mitigate the problems of coordinating international disaster assistance, it cannot completely solve them. Coordination problems are linked to social, economic, and political matters that have little to do with information management.

Space Satellites and Disaster Warning, Monitoring, and Damage Assessment

Remote sensing from nonmilitary space satellites could contribute to disaster warning, monitoring, or damage assessment either now or in the future. Among the areas in which it is technically feasible to use remote sensing are droughts, floods, great storms, earthquakes, volcanic eruptions, fires, locust outbreaks, and maritime oil spills. The key question is whether it is sensible to use remote sensing as an operational component in an international disaster-monitoring system.

Some problems that must be resolved include the following: (1) Few developing countries have the capacity to absorb much high technology. Increasingly sophisticated competing technologies are producing increasingly voluminous data, while developing countries are already running to try to keep up with the present technology. (2) Allocation of scarce resources to a high-technology area may not be the wisest investment policy for a developing country. (3) Remote sensing does not offer a single approach proper for all. There is competition between aircraft and space systems, and between regional and central ground-receiving stations, with implications for centralized or diversified disaster-monitoring programs.

There are many reasonable, and much more cost-effective, alternatives to remote sensing. Among them is better land communication with microwave or satellite telephone communication. Disaster-warning responsibilities could be added to in-place government functions in developing countries. Simple reporting may require a less technically demanding response and less highly trained personnel than does remote sensing.

In any case, any use of remote sensing for disaster assistance must be in the context of some management system already in place, established for purposes other than disaster relief. To establish an independent system only for disaster warning and monitoring would be too expensive and impractical.

An illustrated exposition followed concerning what is technically feasible now and what may be technically feasible in the near and more distant future.

Conclusion

As urbanization accelerates, disaster casualties grow. One of the greatest needs to mitigate disasters is to help relief agencies refocus their energies away from relief provision toward predisaster planning and postdisaster reconstruction. Preoccupation with emergency relief artificially restricts the effectiveness of AID's Office of Foreign Disaster Assistance. It is essential to be concerned not just with emergency but with the problems of disaster assistance in general. The current administrative distinctions are arbitrary, and they tend to inhibit the effectiveness of international disaster aid.

Because disasters are more than physical events, solutions for the problems disasters create encompass much more than just technological remedies. Disaster-related planning in many industrialized countries has in part been characterized by invention of technological solutions for nontechnological problems. It is important that the same mistake not be made in planning for assistance to developing countries.

Many dilemmas remain unresolved. How do we reconcile the desire of technologists to create new gadgets with the evidence that suggests a greater need to apply existing, particularly indigenous, technology more effectively? In seeking to improve international disaster assistance, should we start with improved needs assessment, or with new delivery systems? Are we using technology as a symbolic gesture, or are we seeking to make it an effective part of the reconstruction process? What are the implications of disasters for long-range development in the society that receives external aid?

It is hoped that this report will contribute to the continuing efforts of many public and private agencies to prevent, mitigate, and relieve the damaging human, ecological, and physical consequences of disaster.

Introduction

Foreword

The problems of applying technology to international disaster assistance was the subject of a workshop sponsored by the Committee on International Disaster Assistance (CIDA) of the National Academy of Sciences-National Research Council in Washington, D.C., March 28-29, 1977. Participants included scientific and technical experts on selected problems that commonly occur in responding to disasters, members of the U.S. Agency for International Development's Office of Foreign Disaster Assistance (AID/OFDA), and disaster-preparedness officials from other countries.

The CIDA is composed of representatives of many disaster-related fields. The committee was formed in September 1976 to identify problems in disaster prevention, preparedness, and relief operations to which scientific and technical knowledge could be applied. Specifically, the committee's mandate is to advise the AID/OFDA on (1) the role of the United States in international disaster assistance; (2) major problems in the AID/OFDA foreign disaster assistance program toward which scientific and technical knowledge can be applied; (3) the state of the art in scientific and technical fields relating to disaster assistance; and (4) deficiencies in scientific and technical knowledge about disasters that need to be addressed in future research and development activities. The major first-year activity of the CIDA was a thorough review and assessment of the U.S. government's foreign disaster assistance programs at the AID/OFDA. The committee's findings and recommendations are summarized in a recently published final report.* This summary of the workshop proceedings supplements that final report.

The first three sections of this report of the proceedings summarize workshop activities in the areas of emergency shelter, emergency communications, and search and rescue. All include introductory papers by experts, brief summaries of the discussions that followed presentation of these papers, and the final reports, including recommendations, of the working groups dealing with various topics. The fourth section summarizes a dinner speech concerning the role of space satellites for hazard warning, monitoring, and damage assessment in the context of various disasters.

*Committee on International Disaster Assistance, Commission on Sociotechnical Systems, *The U.S. Government Foreign Disaster Assistance Program*. Washington, D.C.: National Academy of Sciences, 1978.

Both the overall framework and nature of this workshop should be carefully noted by the reader. A principal objective of the workshop was to encourage the presentation of many different perspectives and ideas on the role of technology in international disaster assistance programs. No effort was made to impose a single framework of reference or to reconcile differing views on the various subjects that were discussed. Moreover, the workshop presentations and dinner speech were designed for a nontechnical audience. Informal in nature, their purpose was to stimulate a creative, imaginative response to the problems posed rather than to present scientific papers strictly bound by the formal rules of scientific scholarship and evidence. The three working groups were asked to summarize their deliberations as succinctly as possible and, where feasible, to provide specific suggestions and recommendations. It should be noted, however, that the views presented by the individual commentators and the suggestions and recommendations offered by the working groups are not necessarily endorsed either by the CIDA or by the AID/OFDA. Rather, they should be interpreted as ideas and hypotheses that should be subjected to further research, analysis, and critical interpretation.

On behalf of the committee, I wish to thank the participants in this workshop for their individual and collective contributions. I believe that the discussions during this 2-day meeting provided all of us with new insights and perspectives on the application of technology to the problems of emergency shelter, emergency communications, search and rescue, and the use of satellites for hazard warning, monitoring, and damage assessment. In publishing this report on the workshop proceedings, we hope to share with others what I believe to be an important and useful exchange of ideas and information on the role of technology in international disaster assistance.

Russell R. Dynes
Chairman

Problems in the Application of Technology in International Disaster Assistance

C. JOSHUA ABEND
The Abend Group

Some persons see technology as a servant of mankind—even a panacea; others believe it generates more problems than it solves.

Can technology really solve human problems? Consider such an elementary example of technology as the shovel, which a man can use to dig a well or an irrigation ditch and thereby alleviate his thirst. Or consider a spear, to conquer hunger; a rope, to ascend a mountain; a jet engine, to conquer vast space and enable us to come together for direct exchange. Man has always turned to technology to help solve his difficulties, so who can say technology cannot at least alleviate some social problems?

Technology is a complex tool with dimensions ranging from elementary to sophisticated. We shall be examining this tool to determine which of its many dimensions can be harnessed to preserve life, to mitigate suffering, to reduce loss, and to restore order.

We want to apply technology to solve problems, but that particular class of problems labeled *disaster* continues to defy perfect solution. Disaster has several baffling characteristics not generally present in other classes of problems. Disaster is unpredictable. It is largely uncontrollable. And it is destructive; it has the capacity to cause vast disorder in the natural world, in human society, and in national economies.

Disaster's challenge to technology is this: Manage the unmanageable, and failing that, minimize the crisis.

This task will not be accomplished overnight, but it can be done. What we need to do is sort out how and where technology can be applied in order to minimize the adverse effects of disaster. We must identify those specific areas to which a technological remedy can be directly applied or for which one must be created.

We need first to examine disaster agents, phases, and operations to establish "disaster failure modes." Disaster case histories have documented the disruptions caused by disasters and the inadequacies of response measures, but the historians generally have not pinpointed those failures susceptible to technological remedy. The case histories rarely ask the question: In what ways could this situation have been improved or avoided?

In the area of search and rescue, for example, we need to know more about the requirements of search: What conditions govern a search? How and where should the search be conducted, and by whom? What problems are encountered during a search, and why do searches fail? Similarly, with respect to communication during a disaster, who is communicating with whom, at what times, and for what purposes?

The following approach is recommended: We should first rank our concerns relative to disaster agents. This has been done to some extent already; primary emphasis in this workshop is being placed on floods and earthquakes. We have also limited the enormous range of subject areas to those of the immediate impact relief phases.

Then we should establish a method for determining which technological resources should be used in response to disasters and when and where they should be mobilized. Next, we should develop a procedure for gathering and assessing operational and technological data. Finally, we must establish criteria for implementation of the disaster response and create the means by which plans will be implemented.

We must attempt to pretest our proposed solutions against the social, cultural, political, and economic constraints of the areas in which the solution will be applied. As technological donors, we must also be concerned with utilization of relief supplies and assistance as well as with maintenance and training—all of which may be aspects of relief beyond our control. We must be sensitive to the introduction of possible Western biases or priorities that may be somewhat incompatible with the self-determination values of our client hosts.

We need to state the specific problems identified in terms of impact, relief, delivery systems, or emergency concerns. For example, with regard to food delivered to a disaster area, protection from infestation and weather spoilage could be stated as a problem. So could restoration of potable water supply in floods; alleviation of port congestion by unloading cargo offshore; protection or transport to unaffected regions of crops in flooded or threatened areas; emergency evacuation in very difficult terrain; and rapid transport inland of relief supplies. So also could development of easily deployed aerial devices for quick damage assessment and reconnaissance; portable vehicular traffic control devices and signs; flood warning and alarm systems; devices to facilitate rapid removal of debris; extrication devices; electronic detectors to find survivors in earthquakes; mass sanitation, waste disposal, and hygiene facilities; and easily erected flood control devices.

Each of these problems represents a gap technology may be able to close. Of course, attention has been directed toward using technology to alleviate disasters in the past, but the interest has been random and uncoordinated. Interest in both the public and private sectors is growing, however. For example, this year the International Council of Societies of Industrial Design sponsored a program featuring disaster-related designs submitted by students from 130 colleges and universities. They developed concepts relating to sterilization equipment, mobile surgical lamps, field graphic and signage systems, medical symbols, airdrop packaging, boating systems for evacuation of people from flooded areas, emergency camps, rain and wind shelters, specialized transport systems, stretchers, and other items. The feasibility of many of these solutions remains to be seen, but these creative designs may offer useful new alternatives in this area.

In addition, dozens of new products such as rescue clothing and breathing apparatus are being developed around the world. Even agencies and laboratories that are not necessarily disaster related appear to be spinning off applicable ideas, devices, and solutions. In the United States, NASA's Research in Life Sciences programs recently reported such novel developments as a septic fluid transflow system, graphite-reinforced bone cement, automatic electroencephalography, a remote water-monitoring system, a multiposition rescue litter, a short-range biotelemetry system, a packaged meal system, caution and warning systems, and the like.

This list is only partly indicative of technical activities in such areas as warning, recovery, emergency communications, protective measures, hazard reduction, and instrumentation.

What, then, is the current state of the art of disaster-related technology? There is a significant contrast between technological development and the actual utilization of technology in handling disasters. Disaster-related technology is unfocused and often duplicative. It ranges from the merely sophisticated to the highly exotic. It is not directed toward any single objective in this country or internationally. Developments depend on the motivation or interests of individual researchers or inventors, and their solutions may fail totally to take into account human, environmental, or other factors relating to disaster relief. Since disaster-related technology is not an economically profitable field, it is apt to be funded erratically if at all. Moreover, disaster technology or engineering does not yet appear to be recognized as a legitimate field of professional specialization, so it draws its professionals from related sciences and the arts.

Because very little equipment and few systems have been designed specifically for response to disaster, the technology actually used in disaster operations is largely *ad hoc* or makeshift. Equipment or devices are improvised or borrowed–often from military sources. Naturally, there is little standardization or compatibility among disaster equipment so mobilized. Sophisticated technology, of course, requires technical management, which is usually scarce or nonexistent in a disaster. Hence relief efforts are generally labor intensive rather than dependent upon modern technology.

The costs of development and utilization of disaster-related technology have not yet been measured. Calculations must include research costs, capital outlays, training costs, and operating costs. One area may be well funded, while another is neglected. A fiscal accounting of the relationship between disaster-oriented research and technology and the consequences of disaster is in order. Such an accounting may need to reflect what technology can mean in terms of life, property, and national economics. We hope this workshop will provide a point of departure for such analysis, from which hardware and systems will ultimately emerge.

Part I

Emergency Shelter

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It is encouraging that the Committee on International Disaster Assistance (CIDA) is concerning itself with emergency shelter, for this interest comes amid other efforts to explore this topic. For example, later this year there will be an international conference on disaster housing in Istanbul, and, in Britain, the Disaster Unit of the Overseas Development Ministry has just completed a study of the immediate, 72-hour, relief period.

The Office of the United Nations Disaster Relief Coordinator (UNDRO) is sponsoring a major international study of emergency shelter and related services following disasters. The first stage of this project has now ended, and a draft report on this phase of the study has been submitted to UNDRO.[10]

For far too long, emergency shelter policies have been incoherent. It is therefore encouraging to note the growing realization of this fact by agencies in this field. What is needed, and what we hope to see emerge from the CIDA study and the UNDRO study, are a statement of the problem and an accumulation of knowledge upon which to base better policies and future research.

One major reason for current concern is the increase in casualties from disasters. Last year was one of the worst years for earthquakes thus far in this century: 600,000 to 700,000 people killed in Tangshan, China; 1 in 5 persons homeless in Guatemala; the Friuli earthquake in Italy, the worst disaster in Europe since Skopje of 1963; major disasters in the Philippines; and in November, the worst winter earthquake in Turkey in about 40 years. The earthquake in Turkey elevated the shelter issue from its normal position (low in any priority scale) to that of a major concern for the Turkish authorities and external donors.

With the growth of world population and the acceleration of urbanization it is inevitable that casualties will grow even further. For example, in the past 2 years there have been projections of the potential effects on the present populations of San Francisco and Tokyo of earthquakes of intensities identical to those of the 1906 and 1923 disasters[3]:

San Francisco			
1906		1976	
Population	400,000	Population	3.1 million
Dead	500	Dead	8,750
Homeless	220,000	Homeless	500,000
Tokyo			
1923		1976	
Population	400,000	Population	12 million
Dead	140,000	Dead	500,000-1 million

With regard to the particular focus of this workshop, the role of technology in disaster assistance, it is necessary to observe that past disasters have been characterized by an unquestioning trust in Western technology and its appropriateness in diverse contexts. Van Huyck has written of this attitude in his study of urban planning in developing countries:

> It is this arrogance of technical assistance which has so greatly held back the contribution of the foreign expert in the developing countries. There is no quick way, or panacea, for the problem of the developing countries in housing or any other field. The role of the foreign expert is not to bring solutions, but to guide the host country professionals in their search for indigenous solutions.[12]

Essentially, the role of donor activity in both manpower and technology is supportive, to do what people are unable to do themselves. I will approach the subject of shelter provision from the predisaster context, that is, starting at the condition of vulnerability.

Philip O'Keefe of the Disaster Unit in Bradford, England, has depicted a disaster as a relationship of hazards and vulnerable conditions. Impacts of floods, earthquakes, hurricanes, typhoons, and droughts are worsened by conditions such as rapid urbanization, badly sited homes (in steep ravines or floodplains), high poverty levels, and lack of local spanning materials. Of those people most likely to suffer from disasters, the team from Bradford has observed the following:

> They often live in the most dangerous and unhealthy places. It is no accident that the San Juan (Puerto Rico) slums are frequently inundated by high tide; that Rio's infamous favelas climb slopes of alpine difficulty; that the poorest urban squatters in much of Asia live on hazardous flood plains. The poor are often clearly aware of their own vulnerability. Why else would the slum dwellers of Guatemala City refer to the earthquake as a class quake?[15]

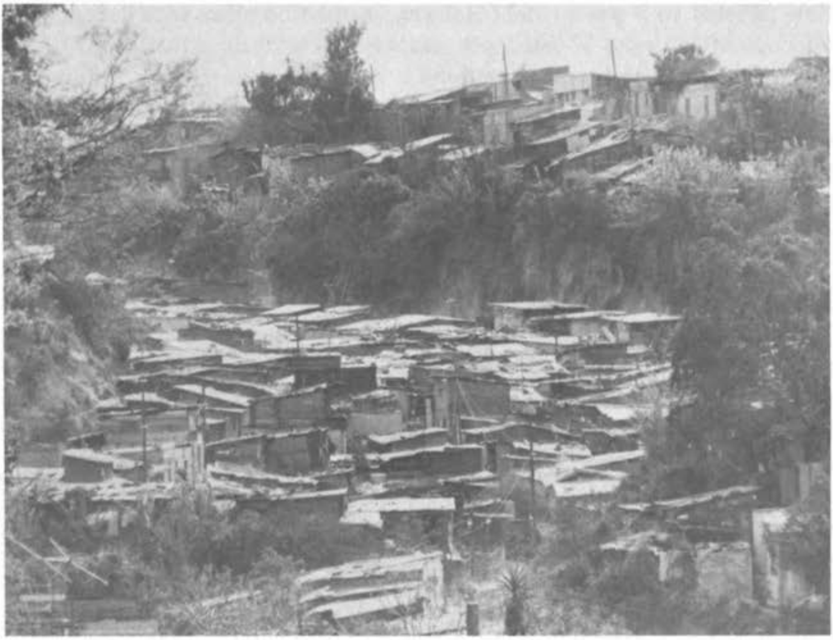

FIGURE 1 *Vulnerability*: This shows dangerously sited ravine housing in Zone 3, Guatemala City, Guatemala. Thousands of these houses fell down the ravines during the earthquake of February 4, 1976.

According to statistics provided by UNDRO to the Habitat Conference, 95 percent of all deaths from disasters in a given year occur within developing countries.[9] The growth of hazard mapping and vulnerability analysis will probably tell us with some certainty the most disaster-prone areas. These may then become the international focus for planning mitigation measures before disasters occur.

Factors Affecting Need for Emergency Shelter

There are numerous aspects to the question of emergency shelter. These include time in relation to the occurrence of the disaster, economic factors, modes of shelter, climate, and types of disaster and the accompanying aid response.

Time may be divided into four stages: (1) the predisaster planning phase; (2) the period from the impact of the disaster to 48 to 72 hours following impact, when survival is the immediate problem; (3) the period from initial flow of relief to 3 weeks; and (4) the reconstruction phase with its long-term implications. Donors of assistance can best focus their activities in stage 1, predisaster, or stage 4, reconstruction.

The rationale for this advice is shown in Figure 3, which relates construction time with per capita income. Housing can be built very rapidly in poor countries, perhaps in 2 or 3 days. From the shaded area of the graph, it can be seen that permanent housing in poor countries can be built within the 2- to 3-week emergency period.

A better understanding of these facts with regard to housing construction time could bring about changes in the type of emergency shelters sent to low-income areas suffering disasters. Makers of high-technology temporary shelters design them on the theory that to rebuild a substantial structure from scratch in a disaster area takes a long time. They do not understand that disaster victims in poor countries can rebuild a house from scratch within a few days at most.

With regard to *economic factors* and the shelter issue, available evidence indicates that the economic level of the population left homeless following a disaster reaches its lowest point for the occupants of temporary housing. The more affluent disaster victims appear to find alternatives to temporary shelter.

Relief agencies must build on what assets disaster victims do possess, and the prime one is human resourcefulness. Presenting evidence to the UNDRO project, Otto Koenigsberger, head of the Development Planning Unit of University College in London, said:

> The relief and reconstruction is a very big job and therefore the only way to do it is to use what little help international relief agencies can give to stimulate people into action themselves, and use the one capital which they have plenty of, which is human ingenuity. The public sector must *not* touch any job the people can do themselves. The last thing the public sector should do is the construction of houses.

As for *modes of shelter*, there are many varieties, as Figure 4 shows. The types of shelter shown can be classified as social solutions and material solutions. Included in the first category are extended family accommodation, government evacuation policies, and transfer of settlement to less vulnerable locations. Kinds of shelter can also be categorized according to indigenous solutions and donor-provided solutions. Some examples appear in Figures 5-14.

Our Western consumer-oriented society is inclined to think in terms of material solutions–tents, emergency housing, and some permanent housing–while developing countries tend toward social mechanisms. Available evidence indicates that disaster recipients tend to rank their preferences for shelter in this order: (1) extended family accommodation, (2) improvised shelter if it can be near to the original dwelling, (3) converted buildings, and (4) officially provided shelter such as tents, emergency structures, and the like.

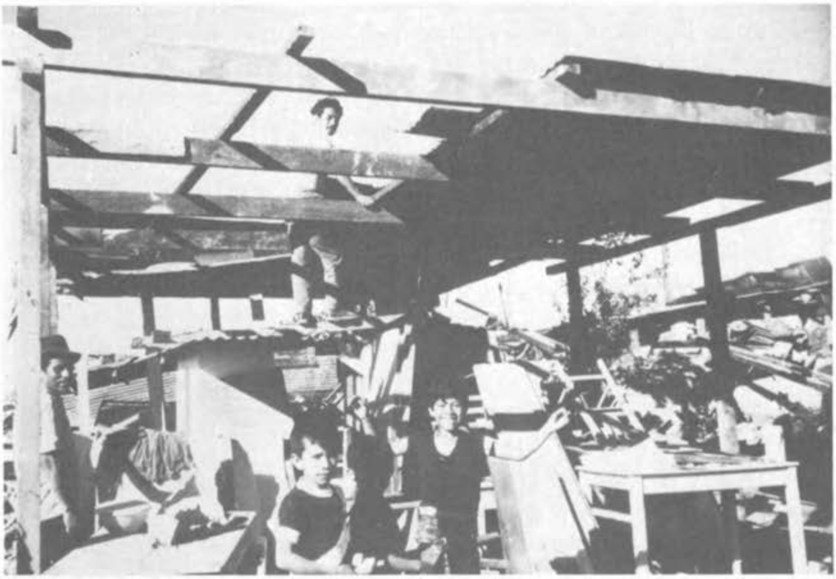

FIGURE 2 *Rapid Reconstruction*: This illustrates reconstruction in Zone 3 of Guatemala City 7 days after the earthquake.

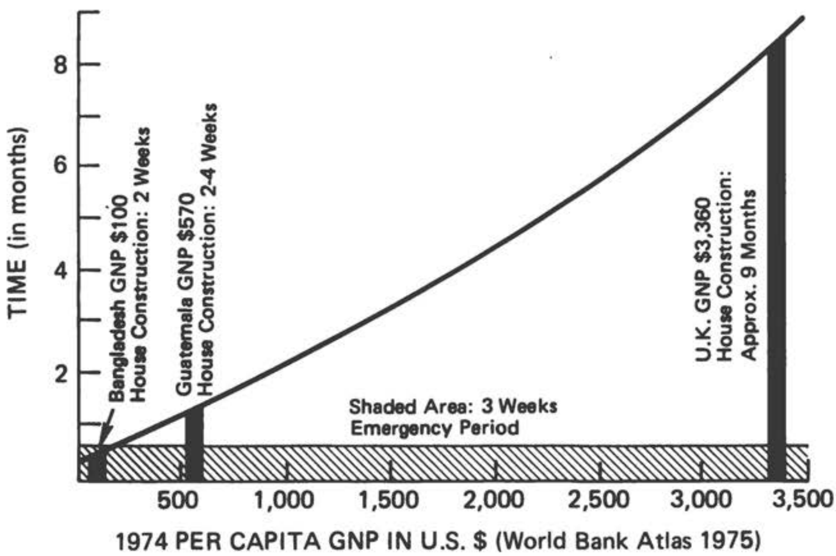

FIGURE 3 Estimated average housing construction period related to per capita income.

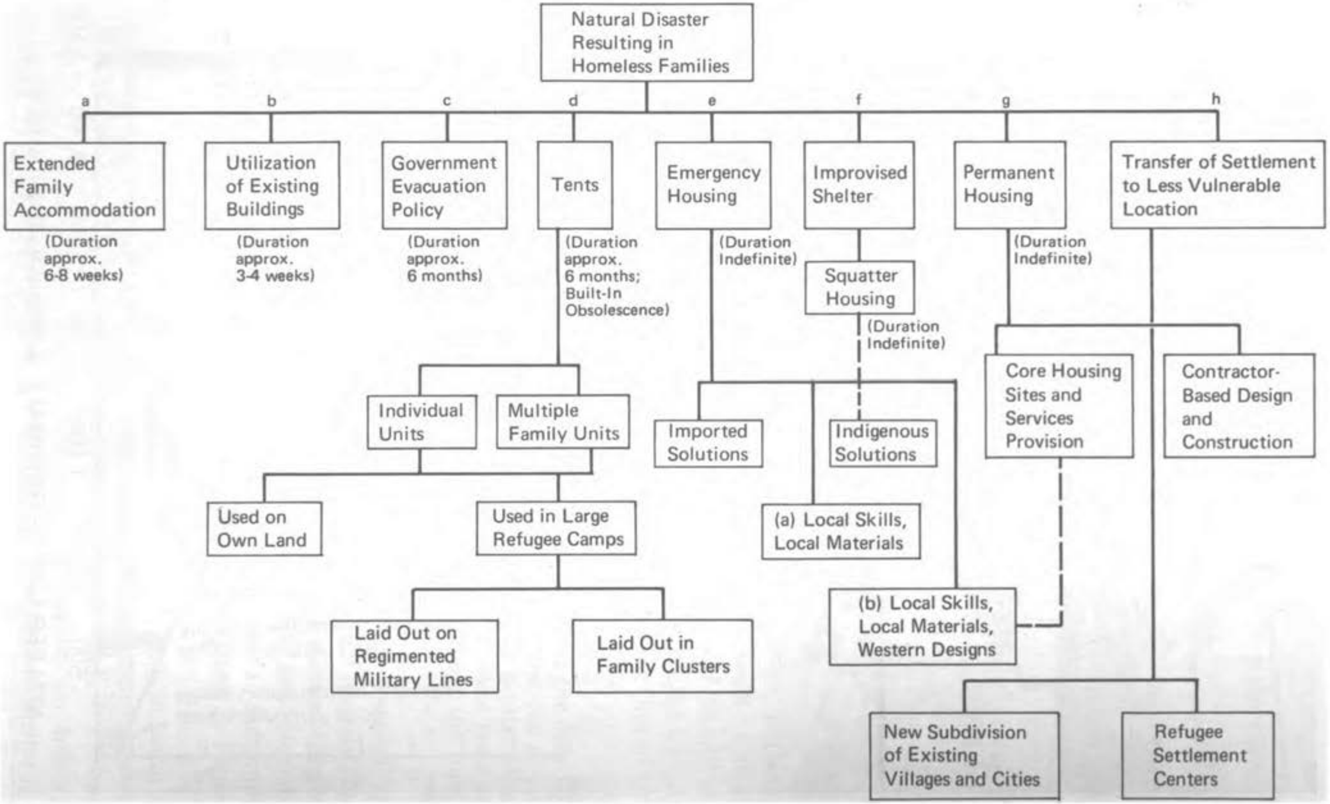

FIGURE 4 **Modes of emergency shelter and housing provision.**

FIGURE 5 *Shelter Improvisation*: About 50,000 families moved into these improvised shacks in Guatemala City following the 1976 earthquake.

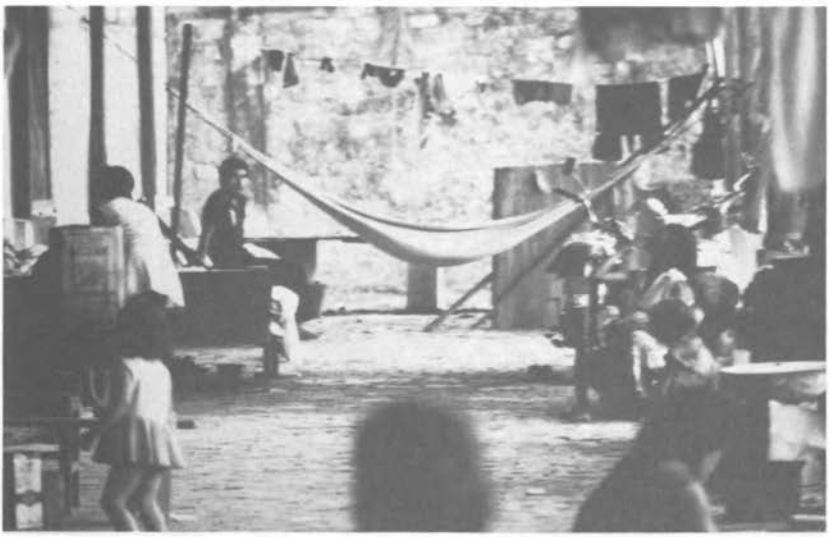

FIGURE 6 *Shelter in Existing Buildings*: This convent in Trinidad, Bolivia, was used for temporary accommodation following flooding in February 1974. Use of existing buildings is a vital mode of shelter.

FIGURE 7 *Self-Help Housing*: "Stack sack" housing is pictured in Masatepe, Nicaragua, 1974. This technique provides earthquake-proof construction, but the high cost of cement and burlap sacks limits its applicability by placing it out of range for poor families.

FIGURE 8 *Low-Technology Shelter Solutions*: An example of low-technology solutions is the Intertect/Carnegie-Mellon University A-frame emergency housing shown here being field tested in Guatemala. The system was subsequently used in Bangladesh refugee camps.

FIGURE 9 *Low-Technology Solutions*: A total of 11,000 of these U.S. AID wooden housing units were built in Managua, Nicaragua, within 3 months of the disaster there. They were described as temporary when built, but they have inevitably become permanent.

FIGURE 10 *Prefabricated Housing*: These prefabricated housing units in Skopje, Yugoslavia, were built within 8 months following the earthquake of 1963.

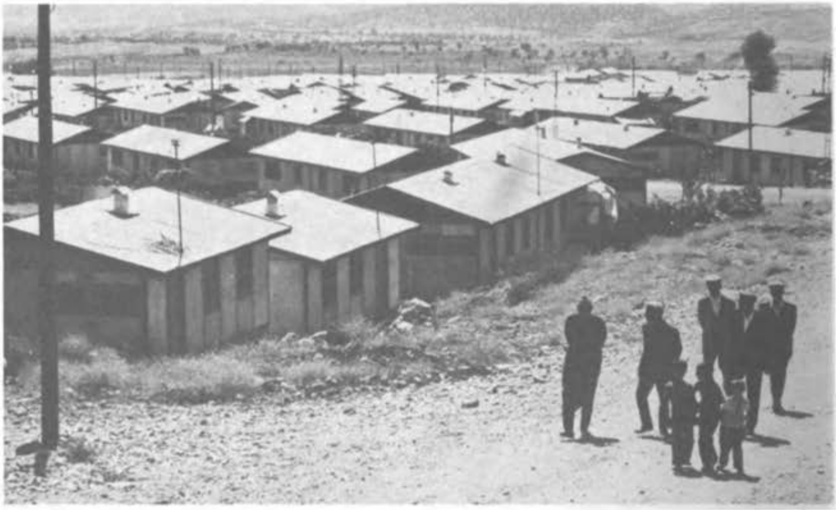

FIGURE 11 *Prefabricated Housing*: A total of 1,500 of these prefabricated houses were built by the Turkish Ministry of Reconstruction and Resettlement in Lice, Turkey, following the earthquake of September 1974.

FIGURE 12 *Imported Shelter Solutions*: Oxfam's polyurethane igloos are pictured in use in Lice, Turkey, following the 1974 earthquake. By the time these "temporary" units arrived, 60 days after the disaster, the 1,500 "permanent" prefabricated houses had been completed (see Figure 11).

FIGURE 13 *Imported Shelter Solutions*: The igloos in Diriamba (San Marcos), Nicaragua, were extensively modified by the occupants.

FIGURE 14 *Imported Shelter Solutions*: The Bayer/West German Red Cross polyurethane igloos at Masaya, Nicaragua, 1973.

As for the relationship of climate to shelter, the range of variables is great. This climatic range may not be simply a matter of geographical spread; the annual climatic cycle is also involved. For example, in a tropical dry season there may be no exposure problem, while a few months later the monsoons and typhoons could completely change the priorities in shelter needs.

With regard to the *types of disaster and the accompanying aid response* as they relate to shelter, the number of variables is vast. Matters to be considered include the location and magnitude of the disaster, the response of the media to it, the political affiliations of the afflicted area, and the existing aid relationships. The precise combination of these variables will, in turn, condition the response from external donors.

To further complicate assessment, there are numerous variables relating to donors. These include the political constraints and economic needs of the affected country; the social needs of the victims; the political, economic, and social needs of the donors; and the competition between donor agencies. Figure 15 depicts possible characteristics of relief activity and their significance to various participating groups. Figure 16 depicts possible differing donor and recipient priorities of concern during the initial relief period.

What is clear from both illustrations is the divergence between the concerns of the affected families and the motivations of those who are supposedly attempting to help them. This dichotomy is depicted in Figure 17.

When the two sets of arrows are kept in mind, what appeared to be "irrational" responses in shelter provision in the past become more "rational"—even if they are still ludicrous. Obviously, donors, like recipients, have needs, and they will probably exercise more influence on aid provision, including shelter, than the needs of recipients.

Some Concepts Relating to Shelter

Shelter is essentially a process; it may involve provision of a physical structure or it may be a social mechanism. It is not purely a life-maintaining process, for it is also concerned with the qualities everyone associates with his or her house, or, more personally, home. Shelter can take the form of emotional protection, a location, a place to store belongings, a structure, a place used solely for the receipt of service, or a staging point for future action.

The provision of shelter by donors reflects a different interpretation of the meaning of shelter. It may be devised by the "developed" world for the "developing" world, by commercial firms or relief agencies on the assumption that there is a need for a universal disaster shelter; by a commercial firm as a public relations exercise with strong advertising and goodwill potential; by a relief agency as a fund-raising, media-attracting device; or by relief agencies or commercial firms motivated by genuine altruistic concerns.

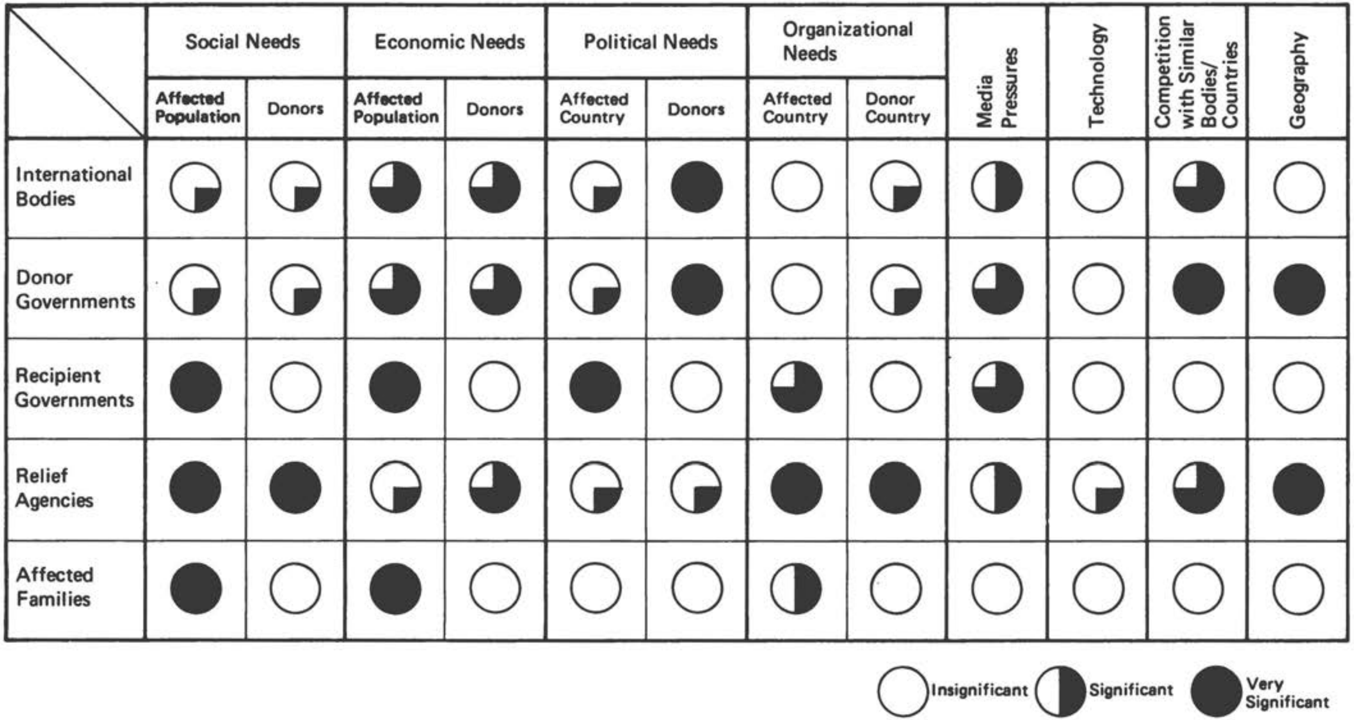

FIGURE 15 Characteristics of relief activity.

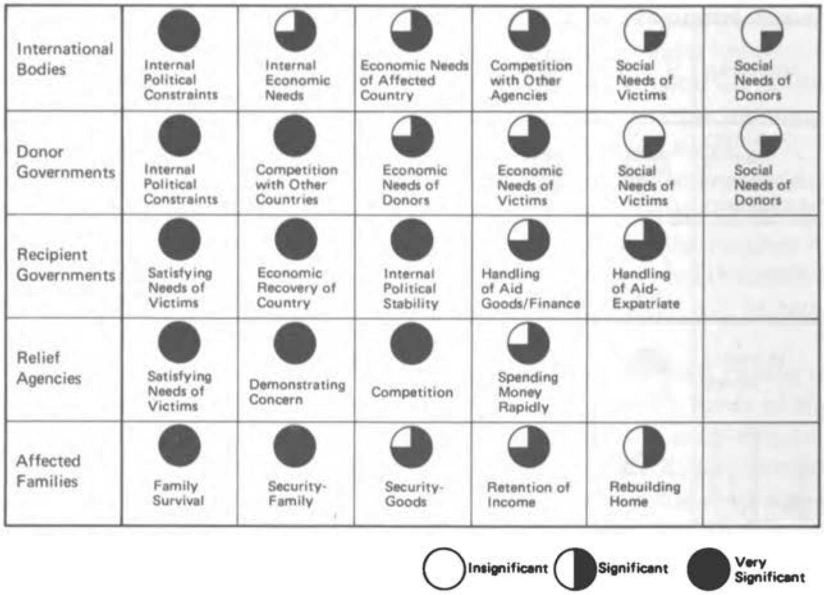

FIGURE 16 Donor and recipient priorities of concern (during initial relief period).

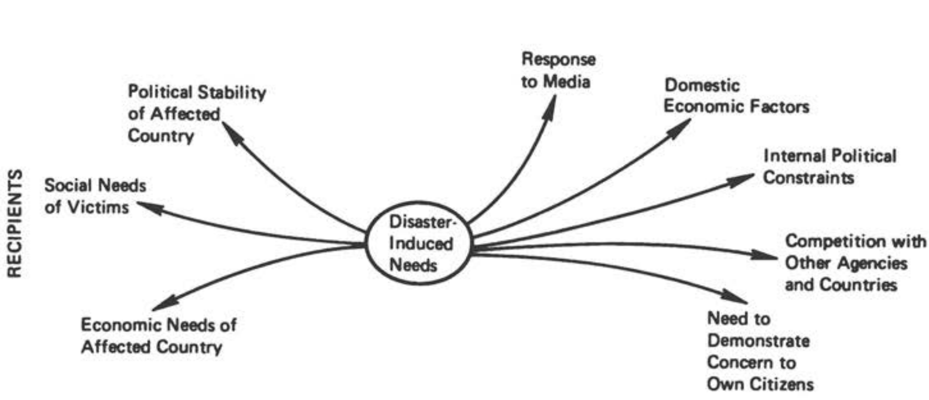

FIGURE 17 Divergence of donor and recipient needs and related factors.

Temporary housing may be used in one or all of the following contexts: when land tenure is unresolved, when there are political constraints, or when persons needing shelter are being encouraged to accept housing that is below their expectations.

Donors of shelter include the following agencies or bodies that "intervene" in disasters: United Nations or other international agencies such as the League of Red Cross Societies, donor governments, national governments in countries struck by disaster, relief agencies, and experts.

Three Strategies for Shelter Provision

Before we can discuss alternative technological options, it is necessary to establish the basic strategies for shelter provision. A discussion of technology presupposes that a "product" is needed, and this may not always be the case. Frederick Krimgold has developed a diagram to indicate the three basic strategies of shelter (see Figure 18).

Strategy 1—to devise housing that will survive a disaster—is clearly our objective. One of the most vital contributions donor governments or relief agencies can make is to provide help with disaster prevention or mitigation. This means safe housing on safe sites and measures such as flood control and windbreaks to lessen the disaster's effects. The technology should be appropriate to local conditions, and it will be low in any scale for housing. The applications of technology to disaster mitigation, however, may be highly sophisticated; even so, operational needs will almost certainly require that measures be implemented within the normal, everyday technology of a given locale.[2,8]

There are two major problems with this suggestion for predisaster activity: First, certain donor agencies are barred from such activities by their operational mandates. Second, societies rarely take significant steps toward predisaster planning without the impetus of manifest failure following a disaster.

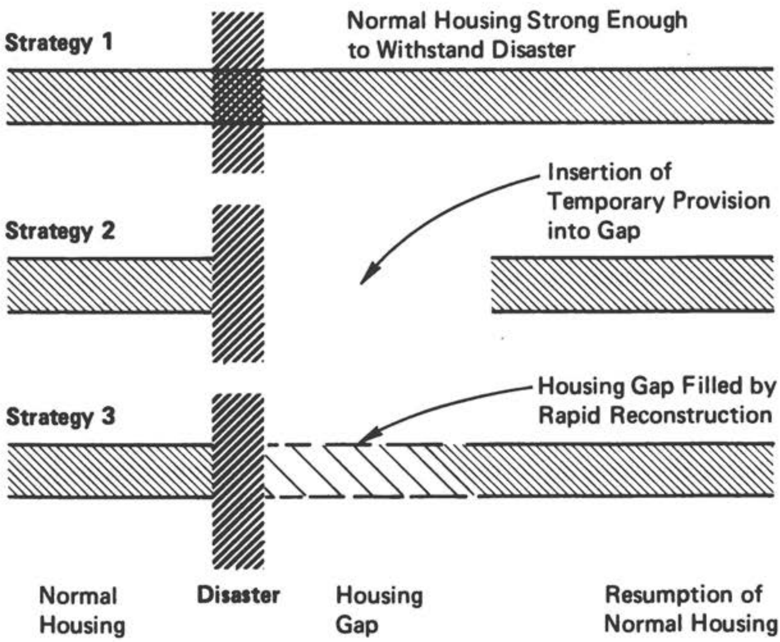

FIGURE 18 Three strategies for provision of shelter.

Thus most building codes and ordinances or modifications in building techniques have been triggered by a disaster; one classic example is the London building acts following the Great Fire of 1666.[7]

Strategy 2 probably represents the way many donors think of disaster relief. An earthquake has flattened an area. Dazed, helpless people are wandering about in a sustained state of shock, and they sit around awaiting the jet-loads of donor tents or temporary housing. In effect, a yawning gap exists, which is waiting to be filled from external sources. Many studies have shown this to be a parody of the actual situation.[5,6,13,14]

One of the salient conclusions from the UNDRO research project on shelter provision is that the need for a significant donor presence in the immediate relief period is not vital except when local resources are unable to cope fully. The extended family "sponge" is just one of the many social mechanisms that provide a very useful resource in the relief period. It is therefore fallacious to imagine a gap waiting to be filled from outside; a housing gap may exist, but it will be filled primarily by strategy 3, accelerated reconstruction.

When we examine the scale of housing loss in a major disaster, it is all too obvious that an indigenous response is the only way to satisfy the needs. For example, housing destruction in Skopje totaled 40,000 dwellings; in Managua, 50,000; and in Guatemala, 177,000. Set against these figures, it is unlikely that donors will provide more than 20 percent of the necessary new housing, and in most instances donor provision may be well under this percentage.

All logic, therefore, points toward the donors' encouraging a rapid local response. And the need is for labor-intensive programs and utilization of local materials wherever possible as a means of stimulating local industrial and commercial recovery.

The obvious question mark over such a policy relates to safety. What if the normal housing system is unsafe? Is it wise in this context to advise rapid reconstruction?

The answer is that within the Third World, rebuilding takes place irrespective of anyone's advice or even governmental edict. Some agencies and governments have taken this issue seriously, however, and have attempted to modify construction techniques following disasters. The work of the Ministry of Reconstruction and Resettlement in Turkey is one example[1,11]; another is the work of the Oxfam/World Neighbors housing program in Guatemala that Frederick Cuny has been directing.[2,4]

One of the major myths to be dispelled is that Western technology can, if only it is tooled up for the task, provide an answer or fill a gap. All the evidence suggests that the reverse is true; ideally, the donor response is to support *what is already taking place*, and the technology will by definition be that of the locality.

Capital Outlay Programs

We have attempted to suggest that donors apply their resources in the predisaster and reconstruction time spheres, because the immediate relief period is generally taken care of by indigenous responses.

Help in the predisaster context is so varied in form that it is beyond the scope of this paper. In the reconstruction context, help may take the form of such items as the following:

- *Finance* for local purchase of goods. Items purchased may include corrugated iron sheeting, which costs about eighty-four dollars per house in Guatemala (using 8 × 10 inch sheets of 26- to 30-gauge roofing sheets). Oxfam has spent over $2 million on this material alone in Guatemala.[4] Consideration should be given to stockpiling key materials like sheeting, since it fulfills a dual function; it can be used as immediate shelter on an improvised house and then reused for permanent roofing on the new house. Other items inevitably needed are tools and timber sections.
- *Manpower.* Volunteer workers supplied by donor agencies can be helpful in local recovery. (They can also be a mixed blessing.)
- *Expertise.* Donors may offer to provide assistance in rebuilding safe houses, but to be effective, such help will have to be closely coordinated with the work of local groups operating in the area in question.
- *Public Utilities and Service.* When local resources are inadequate, donors may install or repair water, electrical power, telecommunications, transportation, and other utilities or lifeline systems that provide essential public services.
- *Education.* At every level there is a vital need to educate people to disaster-related needs and responses to those needs. One function of donor agencies is to assign funds for this purpose. The target audiences for such workshops would be the local populations within vulnerable countries, relief agencies, donor governmental agencies, designers (engineers, architects, and industrial designers), and manufacturers.

Future Research and Development

In an attempt to chart the main gaps in our knowledge on shelter provision and to suggest a research strategy to rectify them, the UNDRO study on shelter previously mentioned has suggested twelve principal areas for future research.[10] These may be summarized as follows:

- Explore ways of making donors accountable to victims.
- Develop estimates of expected losses from natural disasters in developing countries; evaluate feasible levels of investment for mitigating these losses;

and develop an inventory of resources that can be utilized in hazard mitigation and disaster assistance efforts.

- Examine the long-term consequences of decisions relating shelter provision made in the immediate postdisaster period.
- Examine ways of improving the assessment of disaster-induced needs and conduct postdisaster evaluations of the effectiveness of relief programs aimed at meeting these needs.
- Investigate land tenure in relation to reconstruction policies.
- Study the historical development of international disaster assistance in relation to the different values and attitudes held by donors and recipients.
- Continue to monitor the progress of three Guatemalan villages following the 1976 earthquake that had maximum, average, and minimal aid.
- Conduct more detailed study of local preferences relating to indigenous versus imported housing technologies.
- Explore the options for developing strategies to provide complementary assistance in support of local and indigenous shelter processes.
- Conduct a pilot study within a vulnerable country of predisaster planning mechanisms relating to shelter provision.
- Further study the particular shelter problems associated with disasters of different types (e.g., earthquakes, floods, drought, refugees, etc.).
- Study and identify those situations in which donor shelters are essential (e.g., areas suffering drought, those in which the populations have low morale, and refugee camps where access to local materials is denied.)

Conclusion

On a global scale, the overall outlook with regard to disasters gives cause for tremendous concern. As urbanization accelerates, disaster casualties grow. Disaster mitigation measures have totally failed to keep pace with the threat, which represents the major problem facing agencies in the field of disaster assistance with a concern for shelter. One of the greatest needs is to assist these agencies in refocusing their energies away from relief provision–with which they have too long been preoccupied–and toward predisaster planning and postdisaster reconstruction. Similar refocusing is necessary more generally to educate the voters of donor governments and the contributors to relief agencies.

To end on a hopeful note, it is important to remind ourselves of the remarkable degree to which indigenous response to disasters almost always meets the massive needs. This local resource is the key element in emergency shelter. Sadly, the help from Western sources has often swamped, diverted, or converted this resource into a dependent relationship. If nothing else, therefore, the present direction of research will, we hope, make all of us aware of the dangers of ill-advised intervention and the need for a realignment of our aid programs to give help where it is needed most.

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Excerpts from Emergency Shelter Discussion

FREDERICK CUNY, Executive Director, Intertect: Before any discussion about emergency shelter or rapid reconstruction in a developing country can be made, the normal housing process in that country must be understood. Shelter is not a design problem; it is a development problem. We must understand the development process and how it works in relation to housing before we can put any kind of housing or shelter units into that country.

For purposes of defining need for shelter, I categorize disasters not as earthquakes or hurricanes, or as natural or man-made–but rather as sporadic and continuing. A sporadic disaster is an event that occurs and stops the normal process of life. Then, after a period of disruption, normal life resumes. Nobody has had to move, and little has changed. In a continuing disaster, by contrast, there is a need for emergency shelters because people are removed from their normal housing. An example is a situation that causes refugees to cross a border into another country; as long as the refugees have to keep moving, the situation is a continuing disaster. The question is whether shelter to meet a continuing disaster should be of an indigenous type or whether it is more cost effective to install tents or other kinds of shelter.

When we tackle the question of what kind of emergency shelter or postemergency housing to provide, we must start with what the people had before the disaster occurred. Housing in any given country has evolved over centuries into culturally and climatically suitable dwellings. After the earthquake in Guatemala, relief workers said, "The adobes failed; therefore we must build better adobes, add cement to them, show people how to stabilize them." In fact, it was not the adobes that failed, but the way in which they were situated. The strongest adobe possible will come down on somebody's head if it is put up without regard to incorporating basic earthquake-resistant principles.

Moreover, if what is provided as emergency shelter is unsuitable–as small wooden shelters with a lightweight roof and unbalanced high walls proved climatically unsuitable in Nicaragua–the recipients will modify it. In this case, wood was pried off the side, and adobes were constructed;

those shelters today are more dangerous than were the original houses because of the unsuitable modifications.

It is also important to remember, when any emergency shelter is being installed, that almost inevitably it will evolve into a permanent structure. Hence the supplier of temporary shelter should take into account the form of the permanent shelter in deciding what to supply.

It is important to remember that disasters are rooted in political problems. For example, people died during the Guatemalan earthquake because the houses of the poor are relegated to steep hillsides, which not only slide with the first tremor but even slide in heavy rains. Land reform, not better shelter or houses located in the same place, is the solution. We should not even be involved in providing emergency shelter that will perpetuate the political problem.

A last word about cost effectiveness. In many countries, relief agencies have followed the one-two-three approach to housing: first, put up emergency shelter, then build a temporary house, and then help put up permanent housing. Is this a cost-effective approach? The 10,000 emergency shelters the president of Guatemala decided to buy at a basic cost of $300 each were to be offered for sale through cooperatives, financed by loans. Calculations of total costs must include shipping charges from California to Guatemala, assembly costs, and shipping costs from the capital to other locations. Also to be considered is whether the units can be transported into remote areas. If the roads cannot be used, can the unit be broken up so someone can carry it? If it has to be disassembled, who is going to supervise proper reassembly in remote areas?

In contrast, consider the fifty-six dollars it costs the average Guatemalan to construct his own full, permanent, three-room house in the highlands. Once the total costs of the one-two-three approach are calculated, we might conclude the best approach is to settle for something similar to what the inhabitants originally lived in and simply teach them how to improve its construction enough to enable it to perform somewhat better under stress.

WILLIAM DALTON, Assistant Director for Planning and Evaluation, AID/OFDA: We at AID/OFDA do believe there is a need for temporary shelter in the wake of a disaster. We have found the tent to be generally a good emergency answer. Originally, in the mid-1960s, we used the Sears Roebuck Weekender, or something similar, but over the years our tent has been enlarged and upgraded into a sturdier product. It remains a lightweight, easily transportable shelter, and it costs $300 delivered. We have not yet been able to find anything to compete with a tent for getting people out of inclement weather during that vital 3- to 6-month period following a disaster. We do not want emergency shelter that will last longer than 1 year; if you put up a tent that will last for 5 years, people will live in them for 5 years. We are interested in only temporary emergency shelter, but we should think about permanent shelter when we start putting money into either temporary or interim housing.

Tents, however, are not the answer to emergency shelter for a sophisticated urban population, such as the people in Managua. We discovered they would have been quite unhappy trying to live in a tent for more than a weekend. Hence, we had to produce for them what was, in effect, a hard tent. The small wooden shelters with corrugated roofs we used were developed by AID/OFDA, American architects, the Managua Housing Bank, the Nicaraguan government, and thirty-five Nicaraguan entrepreneurs. The entrepreneurs argued that the structure was better than a tent, and it could be built with local labor and material for about the same price as our $300 tent. So we accepted this solution despite the fact that we knew we were building instant slums. We rationalized that 85 percent of the material was recoverable for permanent housing, but we did not know whether in fact it would ever be recovered. In retrospect, I am not happy with the solution to this shelter problem, but tents were not the answer either.

Nor are tents the answer for handling enormous numbers of homeless. A big tent year to us is one in which we dispense 10,000 tents. Tents could not begin to handle the displaced millions in Bangladesh or India who were victims of the tidal bore and civil war. The only thing affordable in that disaster was a roll of plastic that the refugees shared and improvised with. It was a very bad answer to a tragic situation.

So now we are looking for better answers to the problem of temporary shelter.

FREDERICK KRIMGOLD, Research Associate, Department of Civil Engineering, Massachusetts Institute of Technology: What we have seen so far appears to be a pretty clear indictment of previous attempts to apply science and technology to disaster relief. The best solutions have been proved to be the largely indigenous ones. So what do we have to offer toward solving the problem of disaster aid if indigenous solutions are, or appear to be, the best? How can we help in an emergency?

Basically, what has been criticized is the hardware orientation of our technological aid: the exportation of a finished product developed here according to our own assumptions about the problem abroad. Our approach is rooted in a "disaster consumer mentality" that prompts us to put something on the disaster market to see if it flies.

We need to take a broader view of possible scientific approaches to the problem. Those of us concerned with technology may still play a useful role in a disaster if we take into account the social and political context in which the shelter, or any other contribution we make, will be used.

Many of the improved reconstruction solutions involve contributions from outside. The contribution we concoct here may not be the final design, but an element of change is essential. What we add must be in response to what failed in the predisaster solution. We have to find a specific response to a specific problem.

The time element is, of course, important. We need to recognize that, realistically, external relief agencies cannot expect to participate in the emergency phase–the 48- to 72-hour period following the disaster's impact. It is not a question of aircraft speed, distance to the nearest landing field, or efficiency. The difficult problems of assessing damage, holding political discussions, and weighing reconstruction options are social processes that our technology has not managed to speed up significantly. Our participation in the emergency, therefore, must be in terms of support to local organizations, use of materials on site, perhaps support to prior local planning.

In this regard, we need to remember that prevention is the best protection. It is quite clear now that we can more or less predict where particular types of natural disasters are likely to occur. We can also identify which kinds of structures are most likely to fail. But this information is not being applied. Somehow this problem falls between jurisdictions or responsibilities because the agencies that would be involved in education and long-term replacement of vulnerable structures in high-risk areas are not the operational disaster agencies, the ones primarily involved in relief.

It is the relief organizations that recognize the risk and the consequences, and they must communicate their knowledge to the organizations that are making long-term investments in human settlement development.

As for the priority of shelter among our concerns, we have found that in some cases of disaster, shelter needs were not severe. The immediate AID/OFDA interest in shelter appears to be in direct response to the earthquake in Van, Turkey, where shelter was very important. If we are trying to draw up a coherent, global strategy for disaster assistance, we need to recognize objective, geographic differences. Military climate studies dividing the world into nine climate categories provide an excellent basis for contrasting the seriousness of exposure in Van with that in Central America. Of course we are referring here to the need, or lack of need, for shelter in physical survival, not taking into account the uses of shelter as a social instrument, a point of psychological regrouping, or step toward recovery.

My final point relates to reasons why the international community cannot always assume that indigenous solutions will be adequate. Disasters, by definition, are abnormal occurrences. Hence it is often not feasible for a small population or small area–a small target–to appropriate resources for dealing with a unique problem. When the small areas are pulled together to form a larger target, planning becomes feasible. We are all aware that systematic and sustained attention to disaster as an international problem has developed largely in the past 20 years; the AID/OFDA has developed in the past 13 years. Once the target area becomes large enough, similarities among cases emerge, and solutions that would not occur from isolated cases begin to present themselves.

Summary of Working Group Discussion on Emergency Shelter

What Is Emergency Shelter?

The first problem addressed by the Emergency Shelter Working Group was the definition of emergency shelter. Emergency was defined as a time constraint. After accepting the division of postdisaster operations into emergency, intermediate, and permanent reconstruction phases, the group tried to define the conditions immediately following a disaster—that is, what distinguishes phase 1 from the two subsequent phases of postdisaster operations. The duration of the emergency period may range from the initial 48 hours to 3 weeks, or whatever seems appropriate in a given situation.

The group tried to define shelter as broadly as possible. Protection from climatic exposure is an obvious part of the function of shelter, but social functions and security functions are also very important. These include establishment of a physical point of orientation for people who have lost their normal points of physical orientation; a place for receipt of services, that is, a place where survivors can be counted, identified, and served; a place for collecting family and possessions; and a staging point from which victims can reorganize their lives and begin the recovery process. These functions do not relate to the physical form of the shelter, insulating capacity, or the actual material of a structure, but they are certainly functions of an emergency shelter in our broader definition.

The emergency phase, it developed, cannot really be effectively understood without a look at the predisaster and postemergency periods.

How Valid is the Emergency Shelter Concept?

The validity of the concept of emergency shelter came into question. Was the group examining emergency shelter merely because the AID/OFDA was told to look at emergencies and was interested in shelters? Furthermore, is it possible to distinguish relief and rehabilitation from reconstruction without being arbitrary, since any such distinction depends very much on the context? It is hard for policy makers to understand that the same piece of material may function first as an emergency shelter, later as a temporary shelter, then as a part of rehabilitation, and eventually as a part of permanent reconstruction. Thus instead of struggling with fine distinctions in shelter, we prefer to talk of a *housing process* and the *attempt to maintain housing continuity*.

If planners are really to look at the nature of the shelter problem rather than to impose arbitrary administrative distinctions, it may be necessary to stretch our administrative mandate for dealing with this particular problem. That is, this group may be focusing on a problem or a part of a problem that is too circumscribed to be dealt with coherently in the real world.

Relevance of Disaster Agent to Shelter Loss

Disaster agents that cause damage to shelters include—not necessarily in order of importance—the following: earthquakes, floods, civil strife, volcanic eruptions, fires, avalanches, rockfalls, landslides, tropical cyclones, and tsunami.

The concept of shelter loss is only indirectly related to the need for emergency shelter. For example, victims of floods that do not involve the total destruction of buildings but only the temporary expulsion of occupants may require only short-term emergency shelter. After a brief period, such people may be able to move back into their original dwellings. Similarly, tropical cyclones are often characterized by short-term dislocation. The primary damaging element in a tropical cyclone is floodwater; wind damage is not really a long-term factor causing permanent relocation.

Conversely, earthquakes very often destroy shelter. The time required for permanent reconstruction after a quake may vary from weeks to a year or more. Volcanic eruption is a relatively rare occurrence that affects a very limited number of people, but it may involve both short-term evacuation and long-term reconstruction. Victims of civil strife, something of a wild card in this list, may require either short-term or long-term provision of shelter. Fire is another category about which it is hard to generalize; response must vary according to the incident and the pattern of damage.

Another set of disaster agents relates to the separation of people from their normal shelter without necessarily implying damage to that shelter. Such agents include drought, or other forced population movement—evacuation, expulsion, migration. Civil strife could also belong on this list of agents that remove populations from their resource base.

In all of these cases of disaster, several factors relating to shelter need to be noted:

- What is the ratio of damage to surviving structures?
- What is the relationship between the damage and the type of building and siting? (In some instances, the particular construction type determines vulnerability; in others, the particular siting does.)

- What is the scale of loss?
- What is the effect of the disaster on building materials? (Some disasters may take buildings apart but leave the building material, whereas other disasters, like floods, tsunami, and fire following an earthquake, may destroy material. The situation is aggravated when there is no local resource base for an immediate, or even a temporary, reconstruction effort.)

Evaluation of Potential Need for Emergency Shelter

What factors contribute to an estimate of probable shelter loss from disaster in a given area? Included on the list are the distribution of population, distribution of natural hazards, and distribution of vulnerable structures. The mapping of climatic extremes combined with the mapping of probable shelter loss provides an estimate of emergency shelter need.

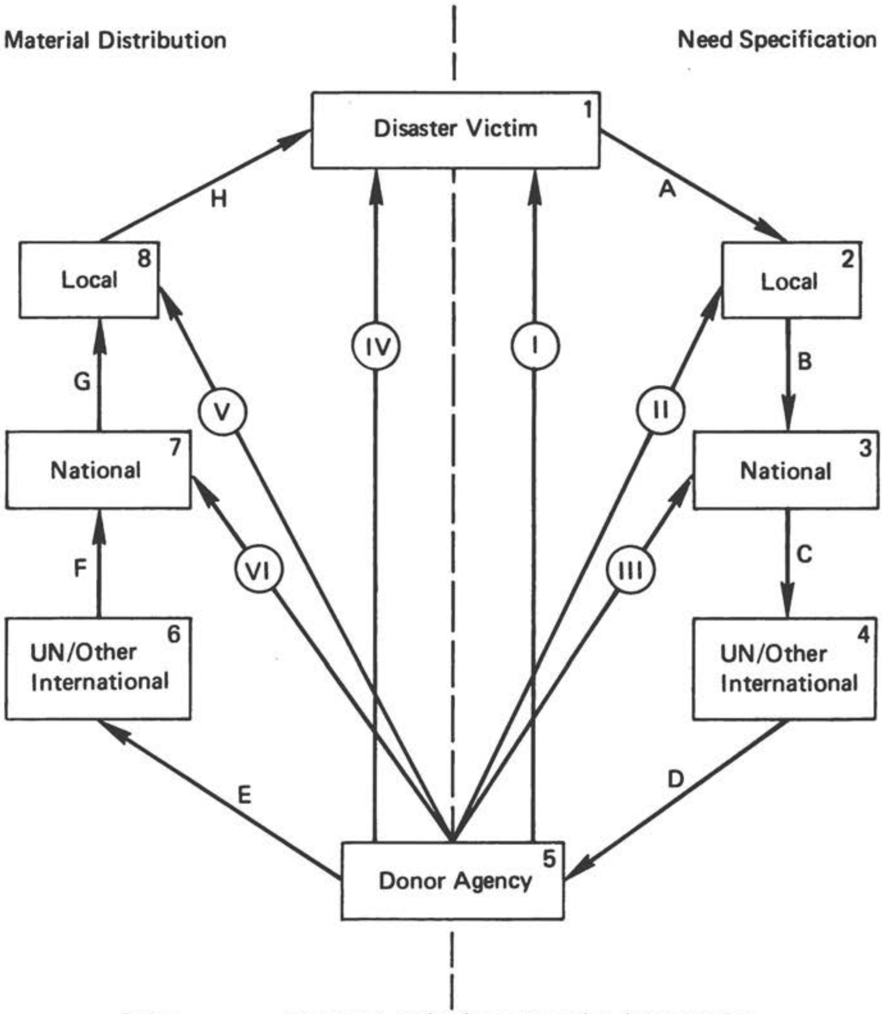
Climate at the point of shelter loss is the overriding consideration in establishment of priorities for immediate provision of shelter. Once climate has been taken into account, the gross shelter deficit can be calculated on the basis of social coping mechanisms. These include the administrative possibilities of evacuation, the alternative use of surviving structures, the use of public buildings for temporary shelter, and indigenous solutions such as absorption of the displaced population into extended families. It was reported that in many cases of disaster as many as 80 percent of the persons who lost their homes were accommodated locally by these social mechanisms. Thus the number of individuals needing emergency shelter may not be the same as the number of those who have lost their dwellings; these two factors should not be equated.

The need for emergency shelter, therefore, is quite specific, and it is restricted to a rather limited number of people. It is neither a general, automatic consideration in every disaster nor a consideration for the entire population affected by the disaster.

The Needs Specification Process

Figure 19 is an attempt to diagram the needs specification process. It was developed by some members of this discussion group to show the interaction between the elements involved in assessing the need for and allocating emergency shelter, but it may be applicable to other areas of relief specification. The design is open to modification. Obviously, this is an analytical model rather than a representation of reality in any norm.

At the top of the diagram is the disaster victim, and at the bottom, the donor agency, in this case perhaps AID/OFDA or any other national donor organization.



Boxes: Assessment, evaluation, aggregation, interpretation, setting of priorities, insertion of values.
Need Specification: 1, 2, 3, 4, 5
Material Distribution: 5, 6, 7, 8, 1

Arrows: Transmission of information or material.
Need Specification: A, B, C, D
Material Distribution: E, F, G, H

Short Circuits: Need Specification: I, II, III
Material Distribution: IV, V, VI

FIGURE 19 Simplified diagram of need specification and relief distribution.

The basic goal is to correlate victim needs and donor response. Ideally, stated victim needs are congruent with the material they receive, but such congruence becomes difficult to achieve through a multilayered process. One problem is that there are subjective areas in needs specification, such as the expression of need from the victim, which is communicated to some local agency. This message is sent, in turn, to some national agency in the victim country. Each of the boxed entities receives the facts and interprets, evaluates, abbreviates, and transmits them. At each step, this process necessarily involves some distortion in the message, some loss of information, some addition of irrelevant information, and some modification of priorities.

By the time the message reaches transmission C, it is often questionable whether what emerges from box 3 is the same as what went out from box 1. The problem is one of local and national reliability, and donors require direct accountability. The insistence on the right to verify in the field the needs stated here in C and D stems from distrust of the adequacy, honesty, or capability of the organizations represented by boxes 2, 3, and 4.

Misinterpretation within boxes 4, 5, and 6 can be reduced by isolating the international part of the operation and ascertaining that output F at least corresponds with input C. This judgment can be made fairly independently of the victim and of the receiving country.

On the distribution side, the supply of material to a disaster victim presents the same problem because of the requirement on the part of many donors for independent verification. This requirement is rooted in distrust of the capability, dedication, or honesty of those running the distributive system within the country.

Unwillingness to depend on local and national agencies in victim countries results in "short circuits," or bypassing of channels. If disaster victims distrust their local agency, as is sometimes the case, they may take their requests for help directly to representatives of national or even international organizations.

For their part, donors may, in their desire to respond to the emergency, go directly to the victims (I) and make their own assessment of need, thereby bypassing all of 2, 3, and 4. Furthermore, donors very often make their own applications of relief, thereby skipping 6, 7, and 8.

This model of information and material flow may be applied to the housing situation or to the emergency shelter problem. An example of the communication problem occurred in the attempt to assess and to meet the need for shelter in Van, Turkey, following a recent violent earthquake. Disaster victims in Van were exposed to 12°F temperature, falling snow, and the prospect of much more brutal weather to follow. The message from box 1 to box 2 was, "We need protection from the winter." The message from box 2 to box 3 was, "We need some sort of shelter in the stricken area to deal with the winter conditions." At box 3 the message was, "We need arctic-polar tents." The Turkish language apparently makes no distinction between arctic and polar. Arctic, however, corresponds to a classification of U.S. Army tent, while polar does not. From box 4 the message was unintentionally abbreviated to "polar tent." Nobody at box 5 knew what a polar tent was, because there is nothing on the market by that name. What was intended, however, was discovered through information from out-of-channel contact by routes II and III.

Many of the American and British tents sent were adequate, but more than 3,000 other tents flown to Van were inadequate. One brand named "Himalaya" turned out to be a one-man mountain tent shaped like a hot dog.

Despite this example of the value of "short circuiting," there is a price paid for the process, although the amount is debated. Many donor organizations believe that some bypass of channels is essential for efficient humanitarianism. Other persons believe the bypass option no longer exists—that it is no longer realistic to assume that an outside donor can work in a sovereign country by ignoring its government and its social system. They maintain that it is inappropriate for a donor, especially for a governmental one, to assume the right to deal directly with the victim.

Relationship of Technology to Relief Levels

What is the link between the kind of technological response to the need for shelter and the level of the intended recipient? The disaster victim is assumed to be at what is called the indigenous level. A victim of disaster in Los Angeles may require a response involving a high level of technology, while a victim of a rural disaster in the Third World would probably require a response involving indigenous technology based primarily on local materials and local building skills.

At the national relief level, different technology may be required from what is required at the local level. The recipient government may desire to build up its local or national industrialized processes. It may have a commitment to development of, for example, a national cement industry or a government building or a construction organization. This commitment might imply an intermediate technology, such as a simplified modular housing system.

At the donor level, typically the technology is rather sophisticated, with an emphasis on totally industrialized systems, a high capital-labor ratio, and minimum user participation in construction or in maintenance.

There are, of course, exceptions to these generalizations. The level of technology requested will vary according to the level of the group with which one communicates in the need specification loop of the model. In the direct short circuit of distribution route IV, the organization offering help must be able to work with and complement the indigenous technology. A typical request from a national government is bulldozers, rather sophisticated technical equipment, representing a nonindigenous level of technology. Attempting a bypass like IV might result in direct delivery of totally inappropriate novelties like plastic domes.

The primary principle established in these discussions about shelter continuity is this: In reconstruction, seek to minimize the change of normal building patterns of the area. Only marginal improvement of local practices should be attempted to meet specific disaster failures, as when buildings have fallen because of lack of lateral reinforcement, heavy roofs, or other poor construction practices.

Acceptable Phases for Relief

In the discussion of the suggested divisions of disaster relief into (1) emergency shelter phase, (2) intermediate shelter phase, and (3) permanent reconstruction phase, some alternatives were proposed. The first suggestion was that the first two proposed divisions were not valid and that, instead, aid providers should jump into rapid permanent construction. This approach would be limited by climatic considerations in some areas, such as eastern Turkey in the winter, where provision of immediate shelter is vital. But in areas such as Central America, where climate is not an immediate threat, a strategy of permanent construction alone could be by far the most effective and, in the long term, beneficial approach.

A second suggestion was to coordinate plans for phase 1 and phase 3, as by providing materials for the emergency phase that will also be usable in the permanent reconstruction phase. For example, corrugated iron sheet useful as a lean-to in the emergency could later provide a light roof for a permanent shelter.

A third suggestion was to consider both phase 1 and phase 2 as contributory to a well-planned phase 3. If immediate rapid reconstruction is impossible, the standard emergency shelter might be improved. Such an improved shelter might permit a longer period for planning and reorganization before final reconstruction had to begin.

All of these arguments imply that the emergency shelter phase cannot be considered independently of the reconstruction phase—that the content of the emergency aid should be compatible with the long-term need.

This conclusion points up the need for understanding what the long-term solution is going to be. The best basis for this lies with understanding normal building processes in the predisaster period. Unfortunately, since the AID/OFDA has a mandate to deal only with the emergency phase, the reconstruction phase is at this point beyond further consideration.

State of the Art of Shelter Provision

It is hard to assess how much is currently known about shelter needs and what is involved in achieving marginal improvement in shelter provision. Some examples exist of improvement of building details and rapid reconstruction of locally accepted types of buildings. In Iran, for instance, some buildings were reconstructed without foreign assistance to remedy specific failures recognized in local design. Similarly, in Guatemala, World Neighbors, Oxfam, and AID/OFDA have been rapidly reconstructing local housing with predominantly local materials, but with significant additions of key materials (roofing, fastening materials) and lateral reinforcement. Technical assistance and public education on carrying out building improvements have also been provided.

This approach to providing shelter significantly changes the manpower and material requirements from those of previous shelter programs. The projects involve much more education and research than was the case in the past. The problem becomes one of understanding local conditions and developing appropriate solutions, rather than sitting in isolation and designing abstract solutions to assumed problems.

Part II

Search and Rescue: Requirements and Limitations

BLAIR E. NILSSON
State of Colorado Search and Rescue Coordinator

Almost every community encounters, at some time, the need for a search and rescue (SAR) capability. Discovery of this need is often all too sudden—as a result of a flood, an earthquake, or a serious highway accident. Moreover, requirements for search and rescue operations may vary greatly. A highway accident will require rescue alone, while an earthquake will require both the search of collapsed buildings for survivors and their rescue when located. The child who has wandered away from home is the object of a search, but a person in immediate danger requires rescue—merely to establish his location is not sufficient.

Search, then, is the effort expended by one or many to locate a missing person and determine whether that person is safe. Rescue is the saving, freeing, or delivering to safety of a person in imminent danger.

No community can anticipate every emergency it may be called upon to face, but most hazards are of geographic or man-made origin. Communities located near a geological fault should be prepared to handle earthquakes. Communities along the coast or in a hurricane belt can anticipate high winds and flooding in the season. Communities with a history of heavy thunderstorms should be prepared to deal with flash floods. In an industrial community, chemical accidents or electrical hazards might present the clearest danger. In a major financial center, the handling of high-rise fires would have high priority. Elsewhere, mine cave-ins or water accidents might be anticipated. Transportation accidents can occur anywhere, and handling those involving toxic substances can require particular care.

The conditions in which people may be found following a natural or man-made disaster vary considerably, and all bear upon their rescue. They may be trapped or pinned. They may be suffering from shock, burns, exposure, or major or minor injuries. They may be unconscious, or they may be in a state of panic.

Because each type of disaster presents different problems, and because disasters are hard to predict, advance preparation is critical. Some general preparations applicable to all contingencies include (1) creation of a disaster plan detailing the responsibilities of individuals and organizations and their coordination, (2) organization of disaster response teams, and (3) training and testing of the organization.

Predictably, different disasters require different responses from SAR teams. An earthquake that has demolished buildings calls for a team trained in debris removal. It is sometimes hard to recognize a body in the midst of rubble, so picks should not be used where there is any possibility of buried victims. Shovels and other tools must be used carefully; any debris close to a casualty should be removed by hand. Workers must avoid unnecessary walking on debris lest they trigger a new collapse of walls, ceilings, or floors and cause additional casualties.

Different disasters not only require different rescue skills but also different equipment. Earthquake teams, for instance, should carry flashlights and extra batteries even in daytime to facilitate search of darkened buildings. Other equipment needed by earthquake teams includes several pairs of work gloves, sheets, towels, sturdy rope, splints, shovels, and crowbars.

Floods require very differently trained and equipped teams. A major objective in a flood is to locate stranded inhabitants and motorists and to get them to safe locations. The most practical solution is to employ helicopters and amphibious vehicles, equipment not readily available to most communities. But almost any community with a potential flood hazard can provide in advance for different kinds of boats. It is also advisable to train team members in scuba techniques for use during floods.

Other disasters may involve a combination of the threats already noted. For example, a hurricane poses the problems of a flood plus the threat of buildings collapsed as a result of high winds, plus other destruction most often associated with earthquakes. Persons marooned by high waters must be rescued, and there must be a search for casualties among the debris.

It is even possible to have fire and flood in combination, as when damage to oil or gasoline storage facilities spreads a film of flammable material on floodwaters. At the time of the Big Thompson River flood in Colorado, propane bottles from recreational vehicles floated on the floodwaters, leaking gas and posing a hazard to SAR workers.

In addition to analyzing and preparing to meet the most likely contingencies, planners need to examine their communities for special vulnerabilities. Generally, areas that include large numbers of aged or poor citizens will require the most aid in an emergency. Disaster teams and equipment should be located close by the known high-risk area so that when disaster strikes, the response time is as short as possible to those areas of greatest probable need.

Although communities can do a good deal on their own to prepare for disaster, there is some expensive and sophisticated equipment that few communities can afford. It may be possible, however, to obtain such equipment as amphibious vehicles and helicopters, cranes, power shovels, or tractors as military surplus. Alternatively, it may be possible to coordinate planning with nearby military installations so as to have access to such equipment in an emergency.

The continuing need to upgrade military equipment means that the armed services, including the reserves and the National Guard, are constantly selling, scrapping, or otherwise discarding outdated but still useful types of equipment. An SAR agency can frequently acquire surplus military equipment at a fraction of the cost of the same equipment on the open market. Moreover, at the time of transfer an agreement can be made for care and maintenance if the disaster agency does not have that capability.

Certain SAR techniques may be available only from the military services—for instance, helicopter evacuation and mobile surgery units. While such units may already be charged with a mission of assisting in the event of civil disaster, SAR teams will do well to develop a close relationship with their military counterparts and to become familiar with their capabilities.

In some areas near a military post, military assistance to safety in traffic (MAST) programs have been set up. Highly trained rescue helicopter crews serve the community by responding to traffic accidents and other emergencies. The program keeps them in a state of readiness by giving them the opportunity to practice what they learn in training. The same plan can be used by engineering battalions and other parts of the armed services.

All of which brings us to the key question of organization. The timely response to any disaster depends on the existence of an effective disaster relief agency. The federal government has three organizations involved in disaster relief, the Defense Civil Preparedness Agency, the Federal Disaster Assistance Administration, and the Federal Preparedness Agency. Actually, the United States could handle its disasters with one agency, and so can other nations. But whatever agency is responsible for coordinating preplanning, disaster response, and recovery, it should have official representation down to the level of the smallest community likely to need help. The agency in question should have no responsibility except disaster preparedness and response, and it should include an SAR coordinator among its senior staff.

Training should have top priority. The United States government has a search and rescue training school on Governor's Island, but other countries may want to start with a cadre of instructors who travel from community to community training the citizens. Contrary to popular belief, most people do not panic in disaster but attempt to help others worse off than themselves. By training its citizens to cope with the most likely hazards, a community makes maximum use of this civic consciousness and cuts its dependence on government aid during a disaster.

Almost as important as training is the availability of adequate communications, to enable the SAR team on the scene to report the extent of the disaster and the community's requirements to meet it. Another high priority should be placed on provision of emergency housing and medical treatment for persons evacuated. In the Big Thompson flood we were fortunate to have access to a school. In La Paz, Mexico, authorities made good use of cellulose fiberboard for temporary housing; they were able to use these structures for 6 months while the town was rebuilt.

We can learn much from the first recorded great disaster, the Great Flood described in Genesis. Noah was in fact the first search and rescue coordinator. He analyzed the risk and trained his sons. Ignoring the ridicule of those whose vision was less keen than his, he constructed his rescue vehicle; gathered his family; searched out the animals to perpetuate all known kinds; and, when the flood came, he set sail. While we may lack Noah's direct communication with the Lord, the lessons of the Ark–analysis, equipment, and training–are as valid today as they were in Noah's time.

Excerpts from Search and Rescue Discussion

PATRICK H. LaVALLA, State of Washington Search and Rescue Coordinator: The job of search and rescue coordinators is to augment the existing forces of the government to respond during an emergency—whether the emergency consists of an individual lost in the backcountry or an earthquake.

An initial point is that search and rescue equipment does not have to be elaborate—it can be very simple and virtually free. Many workers in this field are ingenious at improvising devices out of almost nothing. For example, a volunteer made a ground direction-finding device for locating downed aircraft for thirty-seven dollars; another fashioned one with a quarter-mile range from a coffee can and three dollars worth of parts.

Organization and training of volunteers can be very important. Trained volunteers can participate in mountain rescue; take part in the civil air patrol; or work with dog units, sheriffs' posses, and similar units. Volunteers can also help in crisis relocation, should great numbers of people have to be evacuated as a result of a terrorist threat or disaster. However, they can supervise volunteers/sightseers who enter a disaster area but do not know how to help. Well-meaning but unorganized volunteers can increase the confusion, and when they arrive on the scene unprepared, they use up food and blankets intended for disaster victims.

Disaster preparedness—simple awareness of dangers—is vital for individual families in all our communities. When disaster strikes, there is always a period before help is mobilized when every family is on its own. Through ignorance, individuals also create their own hazards as, for instance, by looking for a gas leak with a candle during an earthquake.

Preparedness training can be as simple as instructing people to carry their own potential body shelter at all times—a plastic garbage bag. This instant, individual emergency shelter can provide important protection from precipitation and exposure.

STANLEY W. GUTH, Assistant Director for Operations, AID/OFDA: I want to comment briefly on the fact that AID/OFDA's activities today are worldwide in scope. We can all benefit from an exchange of ideas on similar problems. What we have learned in search and rescue operations following collapse of bleachers at the Indiana State Fair Coliseum some years ago is applicable to rescue of people from buildings damaged or destroyed by earthquakes in the Philippines and Romania. Search and rescue operations during floods are similar, be they in Bolivia, central Luzon, or the Indus plains.

Preparedness is the key. I recall a series of tornadoes that hit 42 different locations in Indiana in 1965. One small town was completely leveled, and there was huge loss of life. We had search and rescue operations in many localities at the same time. According to our history, the Indians always called this particular belt north of Indianapolis the Valley of the Winds, and they would never pitch camp in that area because of the tornado risk. Yet today we have major industries and large populations there and the same tornadoes.

LT. COMDR. KEN C. CUTLER, Division of Search and Rescue, U.S. Coast Guard Headquarters: How much of what we have discussed with respect to search and rescue operations is applicable to disaster relief after the initial emergency phase? We of the Coast Guard believe that preplanning for search and rescue can be very valuable for providing quick answers to minor relief problems that if not answered become serious problems. A major deficiency in disaster-relief planning is that much of it is done by people in higher echelons of government who do not actually get to the scene of the disaster. We do not learn from the incidents themselves.

Relief agencies can also use the people trained in search and rescue and the communications capability developed. Instructing individuals in developing nations on ways to help themselves in advance of an emergency has simultaneously taught them to cooperate better in a crisis. When the time comes to apply their knowledge, trained persons can help others as well as themselves.

C. JOSHUA ABEND, The Abend Group: There are a number of unsolved questions relating to search and rescue. First is the matter of life detection and debris removal. In a large-scale disaster, how does the rescuer know where victims are, and how can debris be removed without endangering possible trapped victims? Can technology be applied on a larger scale and more expeditiously than is now being done?

Then there is the problem of bringing equipment to the site. How do we get the ropes and ladders and Stokes litters where they are needed? Actually, these items can be scattered around the world. They are appropriate for relief work in the areas we have been discussing, and it would be helpful to distribute them in disaster-prone places.

Since the initial rescue efforts will most likely be conducted by victims and volunteers on the scene, preplanning and education are obviously important.

Another search and rescue problem is that of reuniting families. This problem really complicates disaster relief, and it seems to occur universally. I was impressed that a week after tornadoes had struck Xenia, Ohio, in the mid-1970s, people were still looking for lost relatives. What had happened to the relatives? Where did they go? Where were they sent? We need to share with other countries our experiences in handling problems of this nature.

Summary of Working Group Discussion on Search and Rescue

Search and rescue (SAR) can generally be described as the immediate response (within a limited time period) following a disaster to save and protect the lives of victims by removing them from the area of danger. The SAR working group hoped to improve existing practices or equipment by generating new answers to specific problems encountered in the immediate emergency period. Deliberations concentrated chiefly on certain hazards associated with floods and earthquakes that lend themselves to application of technology.

While the search and rescue process does not necessarily constitute a priority for the Committee on International Disaster Assistance, it deserves study by the AID/OFDA as part of its management efforts in the emergency phase of a disaster. Both hosts and donors regard search and rescue as important, and visualization of the SAR drama frequently motivates funding and relief assistance. Many American SAR techniques and types of equipment are of interest abroad, but they may not be directly exportable unless they can be adapted to other cultures and geography. For example, SAR in the United States may involve highly sophisticated sea and land rescues by the Coast Guard or the Air Force or by special wilderness teams provided by volunteer groups. Many SAR devices would require redesign for the untrained person in a developing country to find them useful.

Because the time of greatest need for search and rescue efforts occurs within 72 hours of the impact of a disaster, it appears logical initially to consider improving the in-country, grass roots capabilities to handle emergencies. Necessary measures include local education for survival, development of self-help within the community, and greater reliance upon trained local leadership. Special situations could still require outside support, but generally the immediate delivery of high-technology equipment like helicopters is inappropriate. Those attempting to deal with the inevitable confusion of the immediate emergency period would more likely benefit from the efforts of a well-trained indigenous rescue team.

Coordination emerged as the most essential ingredient in the emergency; a concomitant is good local communication, which should be established at an early stage. Disaster difficulties are often compounded in places where no prior communications network exists.

Prior analysis of factors that may affect the success of the search and rescue effort can be helpful. Age affects ability to survive; generally, the most vulnerable are the very young, the aged, women with children, and the poorest members of the community. It might be helpful to establish a survival index to identify the needs of particularly endangered population groups.

Social and cultural attitudes can be important in SAR efforts. American help in the form of training as well as provision of useful equipment could augment local initiative in times of emergency, but acceptance of training may depend on awareness education at the family, neighborhood, and community levels. Self-reliance may not be consistent with village psychology in some places; disinterest in self-help and a mood of fatalism may be difficult to overcome.

Working Group Suggestions for SAR Measures in Floods

Typically, when a flood strikes, the affected area has no plans to meet it: no leaders have been identified in advance, no command posts or assembly areas arranged. Then spontaneous self-help efforts appear. Volunteer workers, largely untrained, set to work. Some trained workers are imported. The efforts of groups trying to help are uncoordinated and their efforts overlap. Goods of questionable value converge on the area. Communications are poor. It is difficult to locate missing persons and reunite families.

What assistance can technology give in such a situation? The workshop group devised the following list of useful hardware for distribution:

- Rope. (This appears to be the single most valuable piece of SAR gear. Rope or line used in the SAR activity should be buoyant for use in water rescue.)
- Boats, motors, and fuel.
- Individual and group flotation devices.
- Disposable, single-unit, first aid equipment.
- Potable water.
- Communication devices (including voice amplifiers).
- Maps and schematics (treated to resist water).
- Signals and signal marker equipment.
- Lighting (including portable flashlights) and heating devices.
- Lightweight blankets and water-resistant clothing or outer garments.
- Waterproof bags.
- Identification tags for family, location codes, and medical needs.

Working Group Suggestions for Earthquake SAR Measures

Earthquakes present many of the same problems as floods, plus others that require a higher degree of SAR technical skills. In addition to loss of housing, disruption of transportation and communication lines, water contamination, and injuries, earthquakes often entail hazards from gas leaks, open flames, aftershocks, and collapse of weakened structures.

The chief SAR task following an earthquake is location of survivors; this is of necessity a hasty and labor-intensive process, but searches of debris for victims often continue up to 8 days. Usually, attempts are made to establish voice communication, but these are not a totally effective means for determining the presence of survivors. Survivors who have been located but cannot be reached require life-sustaining supplies such as food, water, or oxygen.

Devices to locate human life quickly and with certainty are needed. In the United States, trained dogs have proved effective, but for many reasons their use may not be practical abroad. Some of the technologies developed to handle cave-ins and other mine disasters might be applicable to the problem of earthquake rescue. Chemical "sniffers" developed by the U.S. Army to detect ground personnel might prove applicable.

Any SAR devices developed should be designed to make untrained personnel more effective. Indigenous materials, readily available and familiar to local persons, could be studied for use in improvising equipment on the scene. Alternatively, existing or new SAR devices could be furnished from abroad. Any new devices designed should be simple, portable, and cost effective. Some specific suggestions follow:

- Flotation devices to rescue families and large groups of stranded people. Such "gang rafts" could be constructed of available metal drums or they could consist of air-inflatable plastic devices that could be airdropped and connected on the scene.
- Life-saving flotation survival gear. Although this suggests obvious equipment (such as life vests), such survival gear would have to be simply designed and compressed in size so that large quantities could be quickly and easily delivered.
- An airborne "people locater" for use in searching out victims in rubble. For ground use, sensitive listening equipment, perhaps a directional microphone to detect voices, might prove practical. A chemical or electronic scanner to detect signs of life could also be used on the ground to sweep over debris.
- Airborne communications relay to assist and coordinate rescue activities. A miniaturized television camera that transmits to a command post might be used.

- A lightweight gin pole* to facilitate hand sifting of debris. Other devices for quickly clearing rubble without danger to possible survivors can also be developed.
- Containers especially designed for delivery of water by air.
- Devices for extrication and lifting of heavy equipment.
- Special lighting from flares or other illumination sources for nighttime search and rescue. The use of infrared light has been suggested, and existing hardware could be employed.
- Visible or audible distress signals to be distributed or airdropped in flood conditions to locate victims in need of rescue or other assistance. Such signals could consist of guide markers.
- An all-purpose rescue-storm personnel kit to provide the essential ingredients for warmth, shelter, and energy. Such a pocket-sized and relatively inexpensive device was exhibited at the workshop. The distribution of such devices could have a valuable effect on morale as well as augment the idea of self-help.
- Temporary wind and rain shelters to be used in immediate staging areas, consisting of lightweight, disposable plastic devices that can be easily erected. A large plastic garbage bag can be used as an instant personnel shelter or as a device for protecting people from wind and water. It can also be used for storing foodstuffs, clothing, and other materials and for disposing of garbage and debris.
- Specialized flotation gear for rescue of stranded livestock and other animals, which may constitute the sole resources of a family or community.
- A small disposable radio receiver, approximately the size of a playing card and a quarter-inch in thickness. It could contain a chemical battery that would be energized by moisture and might have a receiving range of approximately 5 miles. It could be designed with a simple cord to be worn around the neck. Such receivers, airdropped or otherwise distributed, could give a command post direct contact with the affected population for transmission of directions, information about location of medical facilities and location of kin, rescue instructions, and other disaster-related messages.

Working Group Recommendations to AID/OFDA

As a result of the workshop discussions, the group recommended that AID/OFDA establish a technical team to collaborate with host countries to spot specific deficiencies in handling disasters that technology might help alleviate. For projects designated as worthy, equipment prototypes could be developed and evaluated by both host country and AID/OFDA. Systems or equipment judged technically successful could then be produced for testing in the field.

*A single pole held in a nearly vertical position by guys to support a block and tackle used for lifting loads.

It was also suggested that AID/OFDA work to match technological data with disaster phases and agents, to produce a current, and continuously updated, picture of available technologies and applications as they relate to disaster relief needs. There was a recognition that while many problems of the emergency period defy solution and successful management, others do lend themselves to technical solutions. With more information and systematic effort, the latter problems could be solved. There was agreement that even a small application of technology can sometimes mitigate human suffering.

Part III

Emergency Communications

DANIEL K. CLARK AND HARRY KOTECKI
Motorola, Inc., Communications International Division

Our objectives are to bring together your knowledge and our knowledge and to establish a dialogue that will result, if possible, in a basic plan for use in your future communications planning.

Why are communications important in a disaster?

The key word is *management*. In a time of disaster, there is a need to coordinate resources, to direct, to inform, and to be informed. If the disaster is of a kind that permits advance warning, obviously communications can help prepare for the disaster and thereby possibly reduce damage or injury. After the disaster strikes, communications can aid in the coordination of rescue activity, evacuation of the injured, restoration of order, distribution of emergency supplies, and establishing of temporary shelter.

In summary, communications equipment and systems put *control* in the hands of decision makers. With the proper communications system, control can be maintained at all times, whether at the central headquarters or at the on-site emergency operations center.

What then is a communications system? If you are an engineer, it is a combination of products, each designed to do a specific job, connected in a sequence that will provide communications from one point to another. If you are a user, it is an operational tool that provides a means of improving the efficiency of the organization by increasing safety, by decreasing costs, or by improving your ability to deploy resources rapidly.

There are many different types of communication systems and methods: telephone; satellite; troposcatter; cable; microwave radio; high-frequency, single-sideband radio (HFSSB); and frequency-modulated very-high-frequency (VHF) and ultra-high-frequency (UHF) radio.

Everyone is familiar with the telephone system, so familiar that the fact that the system is one of the most vulnerable means of communications in a disaster may be overlooked. The very nature of the telephone system—massive, sophisticated, and dependent on many different communications media—eliminates the telephone as an absolutely reliable instrument during a disaster. Even if the public telephone network is undamaged, the system may be overloaded by the abnormally large number of calls following the disaster.

Some alternative to the telephone system should be considered in planning any disaster communications system.

Satellite systems are expensive. They can and do fill a vital need, and they have the advantage of providing international as well as shorter-range communication. With proper planning, satellite links can be made reasonably resistant to disruption, particularly when transportable earth stations are used. Service on an existing satellite can sometimes be leased and the expense justified by using the satellite for normal or routine communications.

A troposcatter link is a radio communication system used for links of as much as several hundred kilometers in length. Generally using radio frequencies from 400 megahertz (MHz) up into the microwave region, such systems depend on the scattering of radio signals from turbulent air masses in the upper atmosphere. Such systems can be used for many simultaneous channels of speech. Troposcatter systems have the advantage of reliability, and they could with some foresight be made resistant to natural disaster. Long distances over inaccessible terrain can be covered without the use of intermediate relay stations. Unfortunately, troposcatter systems can be very expensive. Because of the high radio propagation losses inherent in the method, several kilowatts of transmitter power are usually required. In addition, very large antennas, perhaps the size of a two- or three-story building, may be required. For successful operation, troposcatter links also require careful choice of transmitting and receiving sites.

A cable system—that is, the buried, multiconductor cable commonly used in telephone systems—can be relatively safe from destruction except perhaps in an earthquake. But, being part of the telephone system, a cable system is vulnerable to the disruption in any other part of the network. If a telephone central office goes out of commission, even though the cable remains intact, communication will be lost.

Microwave radio is a good alternative to cable and in many countries is replacing cable. Microwave can be defined as several point-to-point radio links arranged in a chain, generally using frequencies about 1,000 MHz. Depending on the equipment, such links might be capable of carrying 1,000 or more telephone channels. Microwave systems may be many hundreds of kilometers in length. Unfortunately, microwave reliance upon intermediate relay stations makes the system vulnerable during a disaster, because if one station becomes inoperative, the entire system is dead. Microwave can also be expensive, especially for long-distance systems. Many sites must be developed, with buildings, antenna towers, access roads, and emergency power. Although microwave radio is generally reliable, a long-range backup system should be considered for emergency use.

One such backup system is high-frequency, single-sideband radio. These radio links generally use radio frequencies in the 3- to 30-MHz range; they depend on signals reflecting or refracting from various layers of the earth's ionosphere to achieve long-distance communication of the order of 500 to 2,000 kilometers. Such systems have the advantage of requiring no intermediate relay stations; for this reason they can be quite resistant to disruption in a disaster. An HFSSB communications link is very useful during earthquakes, floods, widespread fires, storms, and other widespread disasters. It is probably the least expensive long-range communicating method; and since both mobile and fixed station equipment are commercially available, the system can be highly flexible. Antenna systems are relatively simple; setting up an emergency station antenna might consist of installing a wire on a convenient tree or building. Unfortunately, high-frequency systems are subject to variations in the ionosphere, and several frequencies must be used to insure continuous communications at all times of the day and all seasons of the year.

Frequency-modulated VHF and UHF radio is probably the most flexible and inexpensive method of communicating. It is generally used for short- and intermediate-range operations, although with proper system design, regional and even nationwide coordinated systems are possible. Hand-carried, vehicular, and fixed station types of equipment are widely available. Since the mobile and portable equipment normally operates from batteries and since most modern and base stations can operate from batteries, they are not vulnerable to loss of power. Such systems can be used for point-to-point communications as well as the more familiar mobile and portable applications. These systems can be very flexible when connected to other communications media, such as the telephone system. VHF and UHF radio might be very useful for areas without highly developed communications networks.

Many types of VHF and UHF radio systems can be used for disaster communications. Not only can such systems serve as a substitute for telephone lines in point-to-point communications, but also they are commonly used for base-to-mobile communication. Mobile-to-mobile communication over extended distances is possible using repeater stations that retransmit mobile communication over a wide area. Typically, these systems provide two-way, person-to-person voice communication, but digital information, teleprinter communication, and secure voice can also be used on them.

New technology has made possible extended communication to portable units from base stations, mobile units, or other portables. Such communication is invaluable for any type of disaster, since it is available in streets, inside buildings, or almost anywhere a person can go. Commercially available equipment can retransmit portable transmissions from a vehicle when the operator is outside the vehicle, thus making possible extended communications ranges from compact, low-power portable equipment.

Paging equipment provides key people with personal communication. Alert monitor receivers can warn of an impending disaster. Equipment is available for providing telephone service in remote areas where wire lines or microwave radio are impractical. And yes, the future will probably bring hand-held portable telephones.

One other subject that should be mentioned here is command centers and command vehicles. Command centers can be designed to provide total control of the most sophisticated system, even including computer access. Vehicular command posts should not be overlooked for efficient emergency operation.

Having addressed the "why" and the "what" of communications, we can now tackle the subject that brings all of these possibilities together—planning.

Many of the systems mentioned may already exist in some countries. Telephone companies, power utilities, railroads, and the military services may have long-range systems using microwave. Local government agencies may be using regional systems. Police, fire, and utilities use citywide systems.

Our observation has been that while these systems may exist, they generally exist for the use of the organizations controlling them. Combining these systems into a total, coordinated communications system for disaster use may be very difficult, but it should be investigated.

For effective communications, these existing systems must be tied together. It is necessary to establish a total emergency communications network in order to be prepared for a disaster.

Preparedness means planning, and in planning for communications a logical procedure should be established. Normal systems analysis is applicable here: Define the problem, generate possible solutions, make a cost/benefit study, decide on a specific solution, implement that solution, and test the system against new needs or new technologies.

This procedure can be complicated by the necessity to establish rapport with other agencies that already have communication systems that must be incorporated into the disaster network. These organizations have differing interests and disciplines.

One of the most important steps, therefore, is to create a communications planning team. This team should be headed by a communications expert who is a member of the overall disaster-preparedness planning team. A military communications expert, a public communications expert, representatives from industry, and representatives from key agencies (such as police, fire, health, and public works) should all be included. Talent may also be available in colleges and universities.

Once established, the team of communications experts should then define the problem. An analysis of hazards to communication is the basis for this part of the procedure. During the review of the history of recorded disasters, consider the effectiveness of the existing communications network. How did it perform before, during, and after the disaster?

Then, in the event of a disaster, consider how well the early warning system would work. Who would initiate the alarm, and how much time would elapse between the impact of the disaster and receipt of the initial communication? To whom would it be directed? Does an emergency operations center exist?

During the disaster, consider whether the needed resources can be deployed as a result of the early warning notification. Will the various resources be coordinated?

Review the hazards to communication, considering networks that were available but not used. What happened during loss of electrical power? Was there any damage to equipment during the crisis? Look very closely at the communications response time and the degree of control maintained during the emergency.

Then add one more item to your hazard analysis: What has happened since the last emergency that could change the situation? New housing, airports, and flood control projects are all factors that may have changed the requirements of a communications network.

Next comes consideration of priorities. National priorities, regional priorities, and local priorities all have to be determined. Where are the significant potential problems? For example, it may be determined that dealing with disaster in large cities presents the greatest challenge; or that the transportation system is the key item to be considered; or that remote towns and villages with little or no communications service could be the point of catastrophe; or that communications *between* urbanized areas takes the highest priority.

After the hazards are evaluated, with an emphasis on communications, it should be possible to identify the problem areas. Communications experts should be able to identify the general type of communications network required for effectiveness in a particular country and to what extent some elements of this network already exist there.

After the problem is defined, it is necessary to generate some functional solutions; this step involves preparing a list of required communications. For each type of emergency anticipated, consider who must talk with whom and what are the priorities of these communications? Once these requirements have been set down, communications experts can review them and recommend concepts or functional solutions for national, regional, or local networks.

At this time, the team should also review the existing radio communications systems in detail. The first job is to contact government officials who regulate and license communications, since they will be able to identify the organization with systems that may be adaptable to disaster use. Then, by obtaining detailed systems descriptions from these users, the team can determine how these systems might be adapted to the proposed emergency network and what modifications might be needed. These detailed descriptions of existing systems should include systems diagrams, description of operation, frequencies used, equipment lists, emergency power capabilities, history of system malfunctions, and age of the equipment.

If the communications experts establish that some of these systems might be used in an emergency network, two factors must be considered. One is the legal availability of the systems; this might require some legislative activity and cooperation among the various users. The other is the technical capability of the system to be integrated into the emergency network.

Frequency management should not be overlooked, for common frequencies provide a good means of establishing communication among the various networks. Following the generation of functional solutions comes consideration of costs: What can you afford to spend?

Cost analysis is an essential part of the planning procedure. The communications experts will have provided sufficiently detailed requirements for determining the cost of implementing all or part of the network. The team may then be directed to specify those parts of the network to be built immediately, which will comprise the specific solution.

The proposed solution should be described in great detail, so that radio propagation can be checked and radio frequencies can be chosen. If existing equipment is to be included, equipment compatibilities must be carefully checked. At this point too, a decision should be made on scheduling the proposed system. The solution will probably be planned by degrees; that is, What will be implemented this year, next year, or 5 years from now? At what point will the local, regional, and national systems be in place and operating?

Then comes implementation. The availability of commercial equipment will have been considered during the previous planning stages. Some modification of system design might be needed to insure a wide choice of commercial equipment, so planners will want to write specifications covering the procurement, installation, and testing of the various system parts.

A critical, and often neglected, area remains: the follow-up activities that insure that the system adopted is continuing to perform its intended functions. Continuous testing of the communications system against new needs and new technologies as they become available is vital.

Continuous follow-up is important because communications needs are always changing. Not only do disaster-preparedness needs change, but the needs of subsystems users in your network also change. Organizations may have added new equipment, frequencies may have been changed, even entire systems concepts may have been altered. Information must be constantly updated, and all elements of the disaster network should be regularly reviewed.

After emergencies, the communications system should be examined to determine if it performed properly and if the requirements should be modified.

In conclusion, a manager's direction of personnel and material requires reliable communications between the manager and the resources. Delegation of authority cannot occur without communication. We have shown you some of the major elements to be considered in your planning.

Excerpts from Emergency Communications Discussion

WESTON L. EMERY, Senior Planning Officer, AID/OFDA: Communications are, in essence, movement of information from one place to another. The requirements and objectives in communications in a disaster vary as greatly as disasters vary. The AID/OFDA responds to 40 or 50 disasters a year; since many of them may require attention for 1 or 2 months, several disasters are always being handled concurrently. They may range from the precipitous earthquake in Guatemala, to the drought that developed gradually in Haiti, to the somewhat predictable flood in Bangladesh, to the air crash in the Canary Islands.

Communications can be classified as tactical or strategic. In the first category is the exchange of information among persons working at the immediate disaster site. In the case of an air crash, the area may be quite small; in the case of the Guatemalan earthquake, it can stretch 30 to 40 miles.

Strategic communications–from the scene of the disaster to operational headquarters some distance removed–present different problems. Communications from the disaster site to the capital of the country may involve many legal and operational variables, but timely transmittal of accurate information from the area of impact to the capital is of great importance. Also, very important from our point of view is communication between the capital of the stricken country and AID/OFDA in Washington.

Most of the very large number of disaster-prone countries are developing nations, but it is hard to generalize about their systems of communications. All of them have some sort of communications system, but the sophistication of these systems varies widely. AID/OFDA has developed country profiles for countries likely to experience disasters. Perhaps if enough information can be acquired for these files, an instant communications system could be superimposed on the technology existing in a particular country in the event of disaster.

BRUCE S. OLD, Senior Vice-President, Arthur D. Little Company: It is important to note that in seeking to apply technology to improve communications, our problem is not one of developing new communications equipment. We already have the capability to operate in the three areas we have been discussing: We can collect data in the field, we can coordinate fieldwork through the base station, and we have access to worldwide communications to help direct relief efforts. We are using "technology" here to encompass systems management or management information systems. Planning for establishment of communications networks, therefore, is our concern.

FREDERICK CUNY, Executive Director, Intertect: In my experience with eleven or twelve disasters, adequate communications generally exist between the disaster area and the capital, and between the capital and the outside world. Either there is an existing system, or something can be set up fairly quickly by using existing equipment. The big problem is communication in the field, where the available technologies are not electronic communications. Only after the immediate emergency has passed can the more sophisticated equipment come into use.

It is important to keep immediate communications open if at all possible, but in any case, decisions for field operations should not be based upon the first few minutes of information. Decisions must be based on accurate information from the field. I believe the most important factor in communications is the quality of information transmitted, not the technology by which it is transmitted. If you have good information, it can be sent by cable, telephone, or courier.

ELWOOD REAMS, Warning and Communications Officer, State of Virginia Office of Emergency Services: I want to endorse the view that it is essential for communications officers to participate in the predisaster planning. When disaster strikes, the communicator is operating in a vacuum if he has not been involved in hazard analysis. Planners need to analyze hazards and then ask their communicator, "How can you support my plan in the event of these specific disasters?" Also, control is vital. It cannot be haphazard. There is no control in citizens' band radio—users constitute an electronic mob. Someone has to have tactical and strategic control of communications.

WILLIAM DALTON, Assistant Director for Planning and Evaluation, AID/OFDA: Ham radio operators provide a very valuable service, and they are often the only link to the outside world immediately following a disaster. However, they can contribute to the confusion. They may have a myopic view of a disaster and as a result may transmit incorrect interpretations to the outside world.

FREDERICK KRIMGOLD, Research Associate, Department of Civil Engineering, Massachusetts Institute of Technology: The complexity of the planning operation and the importance of thorough arrangements and evaluations of equipment strategies have been emphasized. This process hardly seems one that can be effectively carried out in the emergency phase of a disaster. What has been discussed is a preparedness operation. Is this compatible with AID/OFDA's operations? Can AID/OFDA act in response to a hazard analysis rather than having to wait for an actual disaster? Can it support this kind of study?

E. E. ANDERSON, Director, AID/OFDA: Our Technical assistance representatives do try to help with long-range planning in foreign countries. That is, we look at a country's national plan and at its supporting communications plan. Where there are shortcomings, we do our best to help that country develop the necessary communications plan to support its national disaster plan. We have done a lot with Latin American countries, and we have a lot more to do in this regard. It takes a lot of time.

LEON O. MARION, Executive Director, American Council of Voluntary Agencies for Foreign Service: Three questions for Mr. Clark: (1) What is your definition of short and intermediate ranges? (2) What practical steps can be taken to prevent communications blackouts? (3) Are troposcatter links dependent upon the Heaviside layer–ionospheric propagation–and, if so, how reliable is the system?

DANIEL K. CLARK, Staff Engineer, Motorola, Inc.: (1) Short range is approximately 50 kilometers. A well-located VHF-UHF mobile unit should have a range of 40 to 50 kilometers. Intermediate range is about 100 kilometers.

(2) The only answer to communications blackouts is foresight. In a disaster-prone country, communications systems could be stored for use in emergencies. Emergency power should, of course, be available at each installation.

(3) Scatter propagation is not dependent on ionospheric propagation or the Heaviside layer, which is not a reliable mode of communication, since it requires considerable operational expertise and use of different frequencies depending on ionospheric conditions. Tropospheric scatter depends on turbulent air layers and is a very reliable method of communication. It is always there, in every season. High-frequency single-sideband links do, however, depend on ionospheric propagation.

Summary of Working Group Discussion on Emergency Communications

Emergency communications in disaster assistance is a complex subject. The Office of the United Nations Disaster Relief Coordinator, many different governments, and many volunteer agencies—as well as the media—all seek accurate information from the host country in order to help bring relief to the victims.

Several factors complicate communications. First, there is a broad range of communications capability among host countries; the range is from countries with complete, modern communications networks to countries completely closed to all communications. Second, disaster is likely to disrupt the normal communications network of any country. Third, agencies working in a disaster area have varying motives and objectives, so even a perfect communications system might not lead to the most effective management of disaster assistance response.

Within the disaster relief community no fixed organizational hierarchy is possible, so cooperation and coordination rather than tight systems management must prevail. Because the collection and dissemination of accurate information through establishment of an efficient international emergency communications network is so essential to effective disaster response, more emphasis should be placed on predisaster communications planning and readiness. Postdisaster assessment of communications operations is also important in order to improve the system continuously.

There is no lack of technical hardware appropriate for all tactical and strategic communications. The technical capability also exists to deliver that hardware, piecemeal or in complete packages, anywhere in the world within 24 to 48 hours from designated stockpiles. The key issues, therefore, involve the availability of equipment to disaster-prone countries and management problems in use of the equipment at the time of a disaster.

Improving information management can mitigate the problems of coordinating international disaster assistance, but it cannot completely solve these problems. Coordination difficulties are linked to social, economic, and political matters that may have little to do with information management.

Working Group Recommendations

1. The disaster-preparedness seminars of the Office of Foreign Disaster Assistance, AID/OFDA, should provide relatively detailed information on communications hardware. The seminar approach could be continued and expanded.

2. The pros and cons of providing communications hardware as part of AID/OFDA's technical assistance programs should be carefully considered.

3. AID/OFDA should be prepared to lend emergency communications equipment to foreign governments during the emergency phase of disasters, and AID/OFDA personnel should be prepared to use such equipment themselves for disaster operations in foreign countries when appropriate.

4. Communications equipment should be stockpiled for emergency use. Included in the stockpile should be VHF or UHF radio systems for ranges up to approximately 50 kilometers and HFSSB radio equipment for ranges of 500 kilometers or more.

5. Individual country disaster contingency plans and AID/OFDA's country-preparedness profiles should be continuously updated.

6. AID/OFDA should help develop the concept of an international communications network for disaster response, specifying administrative and technical requirements.

7. Disaster-prone societies should be urged to establish predisaster communications networks for disaster response. These networks should use indigenous resources as much as possible, and be linked to the broader international system. AID/OFDA should be prepared to provide technical assistance for development of such networks where needed.

8. Communications frequencies to be used during emergencies should be pre-established by individual countries and cleared internationally. Any potential legal problems with regard to use of the communications network in an emergency should be eliminated in the planning period.

9. A common or standard language for description of commodities for disaster assistance should be developed. International donors should be more specific about the commodities they are prepared to provide and about delivery schedules. At the same time, countries requesting assistance should be more specific in detailing what commodities they want and when they want the commodities delivered. It is important to record systematically the dates commodities and services are delivered.

10. Possible mechanisms for postdisaster assessment of response should be studied carefully.

Part IV

Possible Uses of Space Satellites for Disaster Warning, Monitoring and Damage Assessment

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In many types of disasters, remote sensing from nonmilitary space satellites could contribute to warning, monitoring, or damage assessment, either now or in the future. Among the areas for which it is technically feasible to use remote sensing are droughts, floods, great storms, earthquakes, volcanic eruptions, fires, locust outbreaks, and maritime oil spills. The key question is this: Is it sensible, as well as technically feasible, to use remote sensing as an operational component in an international disaster-monitoring system?

Before considering areas where satellites might be used for disaster warning and relief programs, it is important to point up some problems relating to developing countries and disaster-related technology.

1. Few developing countries have the capacity to absorb much high technology. Some, such as Brazil, are nearing full development and have already demonstrated that they can accommodate the latest technologies. Conversely, the countries located in the Sahel region of West Africa have such a small cadre of scientific and technical personnel and such a weak infrastructure with poor communications and transportation–including roads that are impassable in wet weather–that even if warned of impending disaster, they would be unable to mobilize their resources effectively, much less employ new disaster-relief technologies. Satellite warning systems are of little use if the countries so warned cannot take action efficiently.

2. In addition to lacking an adequate scientific institutional base to absorb and use the great amounts of data produced by modern technology, many developing nations have cultures in which research and administrative persistence are not regarded as the norm. Because of this cultural mismatch, the problems of absorbing a high technology in developing countries may be greater than would be the case in our society. In addition, the rapid promotion of able people in all areas of science in the developing countries means

constant re-education. Capable persons rapidly ascend the government ladder, so once a skilled worker is trained, someone else will soon need training to take his or her place.

We might also add that the allocation of scarce resources to a high-technology area may not be the wisest investment policy for a developing country in any case.

3. Although many developing countries may express a need for technology, national pride may prompt elements in those same countries to resist the foreign technicians who bring the technology. This is not true in all developing countries or in all sectors of particular countries, but it is true for some countries and sectors, and very understandable for all. For example, at the 1976 International Conference on the Survival of Humankind in the Philippines arranged by Imelda Marcos, some of the younger Filipino scientists tended to maintain that there was no role for foreign scientists in their country, even though Mrs. Marcos had explicitly invited foreign scientists to assist them. Similarly, participants at a recent space technology meeting in Zaire expressed a clear desire for technology and funds but not scientists.

4. In addition to all these problems the developing countries have with technology in general, remote sensing in particular does not offer a single approach proper for all. There are several options involving remote sensing that might be followed, not to elaborate on the many reasonable alternatives to remote sensing that could be much more cost-effective than remote sensing. Among the alternatives is better land communication with microwave or satellite telephone communication. Disaster-warning responsibilities could be added to in-place government functions in developing countries. Simple reporting may require a less technically demanding response and less highly trained personnel than does remote sensing, which uses M.A.'s and Ph.D.'s, not clerks.

With respect to remote sensing, there is competition between aircraft and space systems and even between various types of space systems. Space sensing generally connotes systems such as Landsat,* which provides images through transmitting signals to appropriate ground stations. Landsat can also receive data from ground transmitters in a disaster area. These transmitters may send data on items such as excessive rainfalls or flood depth, and from remote data collection platforms in volcanic areas, Landsat may send seismic and tiltmeter data, which can be more useful than image data; together they may be invaluable.

Competition between regional and central ground-receiving stations also exists, with implications for centralized or diversified disaster-monitoring programs. Several regional Landsat ground stations exist, but few currently serve

*Landsat is the term used to describe the first of the Earth Resources Technology Satellite series of NASA.

the developing countries. There are three in the United States, two in Canada, one in Brazil, and one in Italy. The Italian station is under the auspices of the European Space Agency. Government decisions have been made and agreements are under negotiation for a station in Sweden, also under the European Space Agency. Together with the Italian station this will complete the coverage for all of Europe. A station is under construction in Iran and will be completed in 1978. Negotiations are under way to begin construction of a station in Mar Chiquita, Argentina. Agreements have been signed for construction of stations in Zaire and in Chile, but it is not certain that these countries will have the necessary resources to build them. Australia, Japan, and India have decided to build stations and are currently negotiating the necessary agreements with NASA. Among the other countries considering building regional stations are Mexico, the Philippines, and Thailand; and a station at Ouagadougou, Upper Volta, is planned, with financing provided by Canada, France, and the United States. Venezuela briefly considered installing a Landsat receiving station but decided the cloud cover problem was too great. Considering the few Landsat stations actually in existence today, it is unrealistic to expect it to provide images on a real time basis over large areas of the developing world at the present time. However, assuming normal construction schedules, most of the stations now planned could be in operation by the time that Landsat D is launched.

Another problem is the cost of remote sensing as a result of NASA's new policy to recoup a portion of its original and continuing investment from foreign ground stations. Early agreements between NASA and the countries requesting regional stations introduced the option of cost sharing; subsequent agreements definitely state that there is an assessment fee. NASA actually began collecting the fees for the first time in 1976. It currently charges $200,000 per year per station, and it has commissioned a study to examine different approaches to cost sharing (including charges based on GNP per capita, area of coverage, a royalty fee on data sales, etc.). However, a basic question remains: How many developing countries will be willing and able to pay their share of these charges?

A competing technology is also in the offing which, according to some analyses, may be much more cost effective than regional ground stations for many, if not all, Landsat data. The Tracking and Data Relay Satellite System (TDRSS) requires centralized stations rather than regional stations. Such stations could be in the United States, or one could be located, for example, in Nairobi, Kenya, at the headquarters of the United Nations Environmental Program. Unlike disaster warning systems tied to regional stations, a system using centralized stations is not likely to involve direct participation by many countries in the data collection and analysis efforts.

To compare technologies, the Landsat satellites were designed to obtain data in areas out of sight of ground stations, record the data on tape, hold the data until within line of sight of a receiver, and then dump them to the ground stations. Tape recorder technology is the weakest link in the Landsat operation. The machines are expensive and unreliable. Landsat-1 no longer records, while Landsat-2 has a tape recorder that functions very imperfectly. Areas outside the range of receiving stations are, therefore, in the hazardous position of relying on an uncertain tape recorder.

In contrast, the TDRSS does not require a tape recorder. The United States may well decide to adopt TDRSS. Such a decision may make centralization more certain, but it need not do so.

The centralization inherent in TDRSS technology may strengthen the possibility that a disaster-monitoring center operated by the United States or the United Nations might be established, rather than the possibility that the regional centers would take on the responsibility for disaster monitoring. The advantages and disadvantages associated with U.S. and U.N. operation of such facilities are reviewed in a recent National Academy of Sciences study.*

Yet the developing countries have problems with TDRSS. Not only do they associate it with feared centralization, but also they are suspicious of the system as a symbol of United States-dominated technology. The Third World's general antagonism toward the West, coupled with its apprehension about multinational companies' involvement in space technology, may well cause them to view TDRSS technology as "big brotherism."

All these technologies produce enormous streams of data. For example, Landsat-D, to be launched in the early 1980s, will have data volumes more than 10-fold that of Landsat-2. The radars of the mid- and late-1980s, which may be orbited on free flyers, are likely to have a 20- to 30-fold increase in data. Even the meteorological satellites of the future will have substantial data streams. Such volumes will be very costly to handle.

In summary, then, what we have are increasingly sophisticated, competing technologies producing increasingly voluminous data, and a community of developing nations already running to try to keep up with the present technology. These nations want their own stations but cannot pay the annual fees. They are restive about TDRSS and the United States' role, but may not care for United Nations-operated centers either. All these questions must be resolved before satellites can be used in disaster relief.

Furthermore, in my view, it is important to remember that any use of remote sensing for disaster assistance must be in the context of some management system already in place, established for purposes other than disaster relief. To establish an independent system only for disaster warning and monitoring would be both too expensive and impractical. Once a remote-sensing system is in operation as part of a resource and land evaluation

*Board on Science and Technology for International Development, *Resource Sensing from Space: Prospects for Developing Countries.* Washington, D.C.: National Academy of Sciences, 1977.

system, disaster assessment can be added as a rational but modest component. The United Nations, the United States, or the developing countries as a group will have to finance the establishment of such a system.

In essence, therefore, developing countries are offered no slick solutions with remote sensing for dealing with disasters. They should weigh many investment choices, including remote sensing and the numerous alternatives to it. Each developing country has a unique assemblage of likely disasters, talents, financial reserves, and ability to tap the international community. Each will have its particular problems relating to politics, finance, technology, and locale and its own capabilities to solve them.

Having considered this extensive set of cautions, we may examine what is technically feasible now, what may be technically feasible in the near future, and what could be technically feasible several decades from now in satellite sensing of disasters. From this point on, the emphasis will be on technical feasibility.

The Present Satellites

Landsat-1 contains a four-frequency, multispectral scanner (MSS) with roughly 80-meter resolution, as well as an inoperative return beam vidicon (RBV) camera. Now that the tape recorder has failed, it is usable for image generation only by direct line of sight over Brazil, the United States, and Canada every 18 days.

Landsat-2 employs the same sensors. However, it has a barely functioning tape recorder and can get data only occasionally 18 days apart for disasters in developing countries. One can hardly base a disaster warning and monitoring system on such infrequent coverage, except for slowly evolving disasters (i.e., droughts rather than floods).

The Landsat satellites are at present only marginally useful. Only Brazil, the United States, and Canada are now able to use both satellites together on day 1 and days 6, 18, 24, 36, and so forth (that is, 6 and 12 days apart), but only in line of sight.

As was noted earlier, Landsats-1 and -2 can also receive transmissions from data collection platforms. A number of devices useful in forecasting disasters may be coupled to these platforms. Tiltmeters and seismometers are used with data collection platforms on the major volcanoes in Iceland and on other volcanoes around the world. Rain gauges, snow depth-measuring devices, and river stage and flood-warning devices have all been used with data collection platforms.

Tiltmeters and seismometers tell us something about earth bulging and the increase in seismic activity which usually precede volcanic activity, so they may give advance warning. The purpose of the snow depth-measuring device is obvious. It tells us something about the snowpack and gives some warning of potential spring floods.

The stream gauge-monitoring device and rain gauges tell us something also about floods or droughts in the making. All would be located in remote watersheds or remote, volcanically active areas. Landsats-1 and -2 still receive and retransmit data collection platform data.

In addition to the Landsats, meteorological satellites may be used. The National Oceanographic and Atmospheric Administration (NOAA) has a series of satellites that twice daily observe areas in the visible and near infrared. These may be used for estimating rainfall in areas subject to droughts.

Potentially the most useful meteorological satellites for developing countries are those known as synchronous meteorological satellites/global-observing environmental satellites (SMS/GOES), stationed in synchronous orbit 36,000 kilometers from the earth. They look at the same area every 20 minutes, and can monitor the growth of storms, thereby enabling meteorologists to improve their assessments of rainfall above the level possible with a sparse rain gauge network.

The value of these meteorological satellites is that major storms can be tracked as well as rainfall, floods, and the progress of droughts. Of course, such tracking requires trained meteorologists and other technicians; also further research and development are needed before these satellites would be fully operational in the developing countries.

The meteorological satellites receive data from radio-equipped environmental data collection platforms, then retransmit to a receiving station at Wallops Island, Virginia, which, in turn, is linked to the control and data dissemination center in the World Weather Building in Washington, D.C. The satellites can collect and distribute environmental data measured on remote, unattended data collection platforms on land, water, or in the atmosphere. The data can be collected on a scheduled or emergency basis, from a minimum of 10,000 data collection platforms.

This relay arrangement has been used in the operational all-weather Great Lakes Ice Information System, which consists of U.S. Coast Guard aircraft flying an imaging radar in winter over the Great Lakes. The data collected are digitized and then transmitted via SMS/GOES to the U.S. Coast Guard Center in Cleveland, Ohio. After ice cover interpretations are made, an ice chart is sent out in near-real time via weather facsimile to vessels plying the Great Lakes to reduce hazards and delays associated with winter navigation. This example may provide a model of a system that could be used in international disaster relief.

The meteorological satellites also have a weather facsimile subsystem, which could serve as a model for transmission of specialized interpretive data in disaster monitoring from a centralized U.S. or U.N. disaster center. The weather facsimile (WEFAX) is a communication system as well as a service provided by SMS/GOES to users in remote locations with no access to normal satellite data outlets. The service consists of acquisition and processing of meteorological satellite data on the ground and retransmission of these data via the spacecraft to relatively low-cost receiving units within viewing range of SMS/GOES spacecraft. This practice began during the applications technology satellite operation, and it utilized automatic picture transmission ground stations. These ground stations required modification in order to receive the meteorological satellite S-band WEFAX broadcasts. Such a system might easily be employed as part of a disaster-monitoring program.

The Near Future

Landsat-C will be launched in mid-1978. It will provide resolution which is twice as good as that of Landsats-1 and -2 in the RBV channel. It will also have a thermal band in the MSS that may improve our assessment of some disasters.

Landsat-C may survive through 1980. If Landsat-2 has not quit in 1978, we will have 9-day, partial tape recorder coverage of developing countries for as long as the recorders hold together. Data collection platform transmission to Landsat and SMS/GOES should also still be possible. These capabilities should permit receipt of data by some developing countries, but those countries will not be able to collect the data themselves. The data will have to come to the United States and then be forwarded to them by WEFAX or some comparable method. So, for the next 5 years, except for information received through the data collection platforms, we have little prospect of getting useful data on disasters in developing countries from Landsat. Generally, the meteorological satellites will prove more useful.

For floods and great storms, there is evidence to indicate that the combination of the meteorological satellites and the data collection platforms would provide excellent warnings. They are not used for such warnings today, but on the basis of preliminary work in NOAA and in Earth Satellite Corporation and on a study by Jaime Amarocho of the Department of Hydrology at the University of California (Davis), I believe that the combination would work well. AID or other funding would be necessary to develop operational procedures.

For flood monitoring, which requires higher resolution than does warning, the prospects are modest because of the infrequency of Landsat observations and high cloud cover. (We have some illustrations of flood monitoring by Landsat, but they constitute flukes of timing: one could not base a disaster system on infrequent, nonguaranteed delivery.) For flood assessment, the prospects are moderate to good, because during a major flood, high waters may last for weeks, during which time Landsat can make some assessment.

Meteorological satellites and the data collection platforms can also play a significant role in prediction of droughts in the near future. In fact, Earth Satellite Corporation, NOAA, and NASA have all been working on this problem.

If meteorological satellites can provide early warning on drought, does it matter whether Landsat can monitor or assess? Probably not much, but based on recent studies, Landsat would provide confirmation of the warnings.

As for earthquakes and volcanic eruptions, it is technically possible now to use data collection platforms with tiltmeters and seismic devices, as we have already mentioned. Charles Robinove of the U.S. Geological Survey has reported on four studies utilizing these with Landsat.* They all came to the conclusion that it was indeed a technology that should be studied carefully. All these devices do, however, is measure an activity that is strongly, but not perfectly, correlated with advance indications of earthquakes or volcanic activity.

For major forest fires and grass fires of a type that are a national disaster, a meteorological fire prediction model comparable to the type used in the Pacific Northwest today appears to be the best answer.

It is possible that fire hazard could be estimated on the bases of weather and the presence of potential forest fuels. Just as the meteorological satellites could be used to measure drought or major floods, so too could they provide an opportunity to assess the likelihood of major fires. Research would be necessary to realize these objectives. It is important to remember, however, that fires must be triggered, and despite the presence of hazards, the triggering may not occur.

It may be possible to monitor some fires, but clouds will prove a major obstacle for Landsat. Assessment of postfire spread could be made, and such assessment might prove useful in planning for replanting.

Working together, meteorological satellites and Landsat have a very good chance of predicting locust outbreaks. The etiology of the process demands concentrated rainfall on the desert fringe. Concentrated rainfall is needed whether the particular locust community is on a 9-year, 18-year, or 20-year cycle. The meteorological satellite data would warn of a possible site for an outbreak. Landsat would confirm the possibility by observing the greening after heavy rains. The chance of observing areas of locust damage by satellite, however, is less good.

Oil spills on water represent another possible disaster for monitoring by satellite. The heavy oil traffic from the Middle East and Indonesia to Japan

*Charles J. Robinove, *Worldwide Disaster Warning and Assessment with the Earth Resources Technology Satellites.* Washington, D.C.: U.S. Geological Survey, Project Report (IR) NC-47, 1975. (This report was prepared for the Office of Science and Technology and the Office of the Foreign Disaster Relief Coordinator, Agency for International Development.)

poses the possibility of disaster in the Straits of Malacca or any of the other fishing areas along the shipping routes. There would be no warning and only a slender possibility of monitoring–certainly nothing to show up dramatically on a 9-day or 18-day cycle. Moreover, Landsat's inability to see through clouds suggests that if we are ever to monitor spills from satellites, it will be with radar.

The More Distant Future (1980-1990 and Beyond)

Technology for monitoring disasters will probably advance in the following directions in the 1980s:

- Significant improvement in the sensitivities and spatial resolution of multispectral scanners.
- Use of microwave sensors (radar) to make observations through clouds.
- Wide coverage with synchronous meteorological satellites.

Landsat-D, or Landsat Follow-On, scheduled for launch before 1982, will carry an advanced multispectral scanner known as a Thematic Mapper. The satellite will be in 9:30 A.M., sun-synchronous orbit. With two satellites launched 9 days apart, and with each satellite having an 18-day repeat cycle, the same area will be covered each 9 days. Using 6- or 7-channel data of 30-meter resolution and high radiometric fidelity, Landsat-D should make an important contribution to disaster monitoring, clouds permitting. By concentrating more clearly on single energy-matter interactions such as the chlorophyll absorption band, the narrower bands in Landsat-D should provide more suitable coverage for natural resource sensing in developing countries than did the earlier mappers of the Landsat series. Similarly, the better spatial resolution will lead to superior identification in the area of small field agriculture so common in developing nations.

The exact band numbers, widths, and other performance criteria of the Landsat-D sensors are still under review by NASA in response to internal analyses and recommendations by a committee of the National Academy of Sciences. From what is now known of their approximate ranges, however, the new bands will not only provide more accurate crop identification, but will also be of value in providing background data in disaster areas by assisting in the following tasks:

- Delineating water/land boundaries, and contributing to studies of water bodies and coastal bodies.
- Recognizing soil/crop contrast and discriminating soil boundaries.
- Detecting surface soil moisture shortly after rainfall.

- Detecting crop stress.
- Discriminating active green vegetation and accurately classifying green vegetation with full ground cover.
- Estimating moisture in fire-prone wild land vegetation.
- Assessing range feed conditions.
- Identifying geologic strata and better identifying fractures.

These capabilities, improvements over those of Landsats-1, -2, and -C, should permit quite detailed background studies to be made in disaster areas.

Space shuttle, a manned space aircraft, is expected to be operational by 1982 with some flight tests during the previous year or so. With a capacity almost as large as a Boeing 707, the space shuttle will be capable of carrying an extraordinarily diverse array of instruments needed for different experiments. The shuttle flights will be launched about once a month and each mission will last from 7 to 14 days.

The shuttle will be a convenient vehicle for placing in orbit earth resource satellites, meteorological satellites, and communications satellites, as parts of an integrated system. There will be potential applications in agriculture, geology, energy, minerals, forestry, land use, oceanography, and hydrology. The orbits may be tailored to the individual uses and experiments of prime concern during an individual mission.

The high-resolution cameras and imaging radars to be carried on some flights of the shuttle will improve information about areas subject to various disasters and will foreshadow the results likely with radar free flyers (discussed below), which will operate continuously. Thus far no program for shuttle missions for disaster monitoring has been planned. But in the event of a major disaster in the Ganges, for example, it would be possible to launch the shuttle and tailor its orbit so that it looked every 6 hours or so at the Ganges and ignored other area repeat coverage. Whether the results would warrant the multimillion-dollar effort to put it into orbit and keep it up for 10 days is another question.

Resolutions of the shuttle's cameras are expected to be from 10 to 20 meters, and those of the shuttle's multifrequency radar imagers, 30 meters. It is very likely that the radar imager will be most useful for surface soil moisture detection and vegetation detection, both of concern in monitoring the progress of droughts. Theoretically, the shuttle could carry cameras capable of resolutions of a few feet. It is easy to imagine the political complications of carrying cameras of such resolution characteristics for peaceful monitoring, but about 5 meters might be allowable by the international community, and this resolution would certainly be useful in many disaster-monitoring problems.

The *radar free flyers*, which may be developed as a result of shuttle *experiments*, will be able to see through clouds. They will probably operate on a

9-day cycle, so a developing country would be guaranteed coverage every 9 days with the *possibility* of more frequent coverage through employment of a low-latitude orbiting satellite to cover most developing countries that lie in the tropics. If this becomes a reality, even short-fuse disasters such as floods might be monitored. Major floods of the sort that affect the Indus, Ganges, Brahmaputra, Niger, Yangtse-Kiang, and other great rivers sometimes take weeks to roll down the system. With radar free flyers, it would even be possible to get an assessment of those areas likely to be affected and to make a preliminary data base in advance of a flood's arrival. The complexities of processing radar data, however, would ensure that such studies could be made only in the United States or in some central U.N. facility.

Radar is sensitive to differences in plant geometry, to differences in soil moisture, and to land-water contrasts. Hence radar could be helpful in analyzing crop condition and potential yield as well as in analyzing water resources, determining soil moisture, mapping flood areas, measuring snow accumulation, and the like as shown in Table 1.

TABLE 1 A Summary of the Principal Roles for Radar within Major Application Areas for Space Program Imaging Radars

Application Area	Role
Water resources	Measuring soil moisture, extent of flooded area, snow accumulation and snowmelt, and watershed boundaries
Exploration mineral/petroleum	Emphasizing strong fracture lineament to improve siting of oil and gas wells and locating gravity groundwater, prospective mineral locations, and emplacement drilling
Vegetation	Monitoring crop acreage, soil moisture, and crop condition and yield; improvement of crop/forest identification in support of Landsat and other sensors
Mapping and land use	Updating of planimetric special-purpose map in cloudy, marine, and high-latitude areas and improving within-urban categories and rural land use categories by merging with Landsat
Oceans	Observing waves, sea and lake ice, icebergs, oil spills, and coastal and open-ocean storms in progress for sea state and damage
State/regional applications	California–water Alaska–sea ice/energy Great Northern Plains–saline seeps Gulf Coast–wetlands

The first *synchronous earth-observing satellite* (SEOS) will be placed in earth-synchronous (36,000 kilometers) orbit sometime between 1981 and 1985 to sense the entire Western Hemisphere. It will be designed specifically for disaster monitoring by NOAA. High-powered telescopes will allow for high resolution (about 6 meters) with long dwell times and repeated imaging of particular areas; the satellite will have a useful life of 24 months. Instrumentation for the SEOS will include solid state cameras, new generation telemetry, and spectrometers for pollution detection. The satellite is intended principally for studying short-lived hazards such as extensive flooding, violent storms, and major fires, but it can also cover areas of civil unrest, estuarine dynamics, and the like. An equivalent satellite of potential value in disaster monitoring is likely to be launched over Africa by a European consortium; a SEOS located about the longitude of Nigeria would serve Western Europe and West and South Africa. The Soviet Union and Japan may launch others during the same period. A Soviet SEOS over Karachi would serve the bulk of Southwest Asia and much of East Africa. A Japanese satellite located about the longitude of Jakarta would cover the bulk of Southeast Asia.

In the mid- to late 1980s and beyond, therefore, we can expect an assemblage of satellites and spacecraft sensors and ground instruments that could be welded into a very effective, but demonstrably high-technology, system for disaster warning, monitoring, and assessment. The group includes meteorological satellites; data collection platforms; the weather facsimile subsystem; Landsat-D and later satellites; high-resolution cameras on space shuttle (possibly for occasional use in disasters); especially imaging, all-weather radar systems; and the SEOS systems.

High-altitude aircraft may also serve usefully in disaster monitoring, but mobilization is no small problem. The U-2 of course has an undesirable image in the developing countries. Getting a U-2 from Korea to Indonesia during a recent major earthquake reportedly stirred up serious financial, political, and administrative problems. There may be fewer drawbacks with the synchronous earth-observing system with which observations could be made every few hours in disaster areas, day after day or week after week, if necessary. In the Western Hemisphere, the SEOS will be able to focus on disaster areas in Central and South America to latitudes 45°N or 45°S.

Some Illustrations

Landsat has two devices on it, the RBV, which has been little used, and the MSS, which has become the principal instrument.

The MSS covers a swath 100 nautical miles wide (see Figure 20), scanning continuously. NASA chops the swath into 100-nautical-mile squares, giving 10,000 square nautical miles in a single Landsat scene, with a spatial resolution in each picture element (pixel) of roughly 80 meters.

Each day Landsat flies north to south on the daylight side of the earth at about 9:30 A.M.; as already indicated, it is sun synchronous. The following day the next swath is laid down partially side-lapping the first day's swath. It takes 18 days to progress in this side-lapping fashion until a new start is achieved.

The amount of side-lap increases with the latitude. It is approximately 15 percent in low latitudes. At latitude 50°N, there is over 60 percent side-lap, so there the same spot is seen on 2 successive days, not 18 days apart. It is therefore possible for those developing countries in high latitudes (of which there are few) to escape the 18-day separation. For the developing countries in the tropics (of which there are many) 18 days apart is the rule unless there are two satellites, which yield a 9-day separation, or three satellites, which yield a 6-day separation. (If Landsat passes are 9 days apart in West Africa, that frequency may be adequate to help in disaster relief efforts there because the dryer areas of West Africa are relatively cloudless most of the time.)

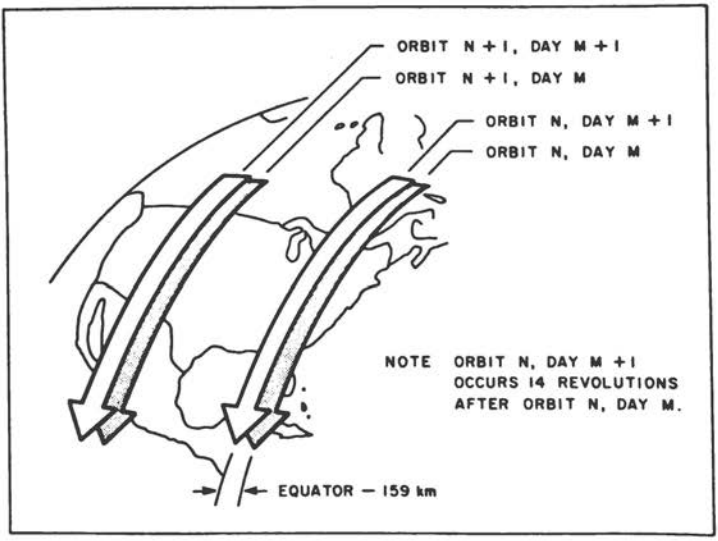
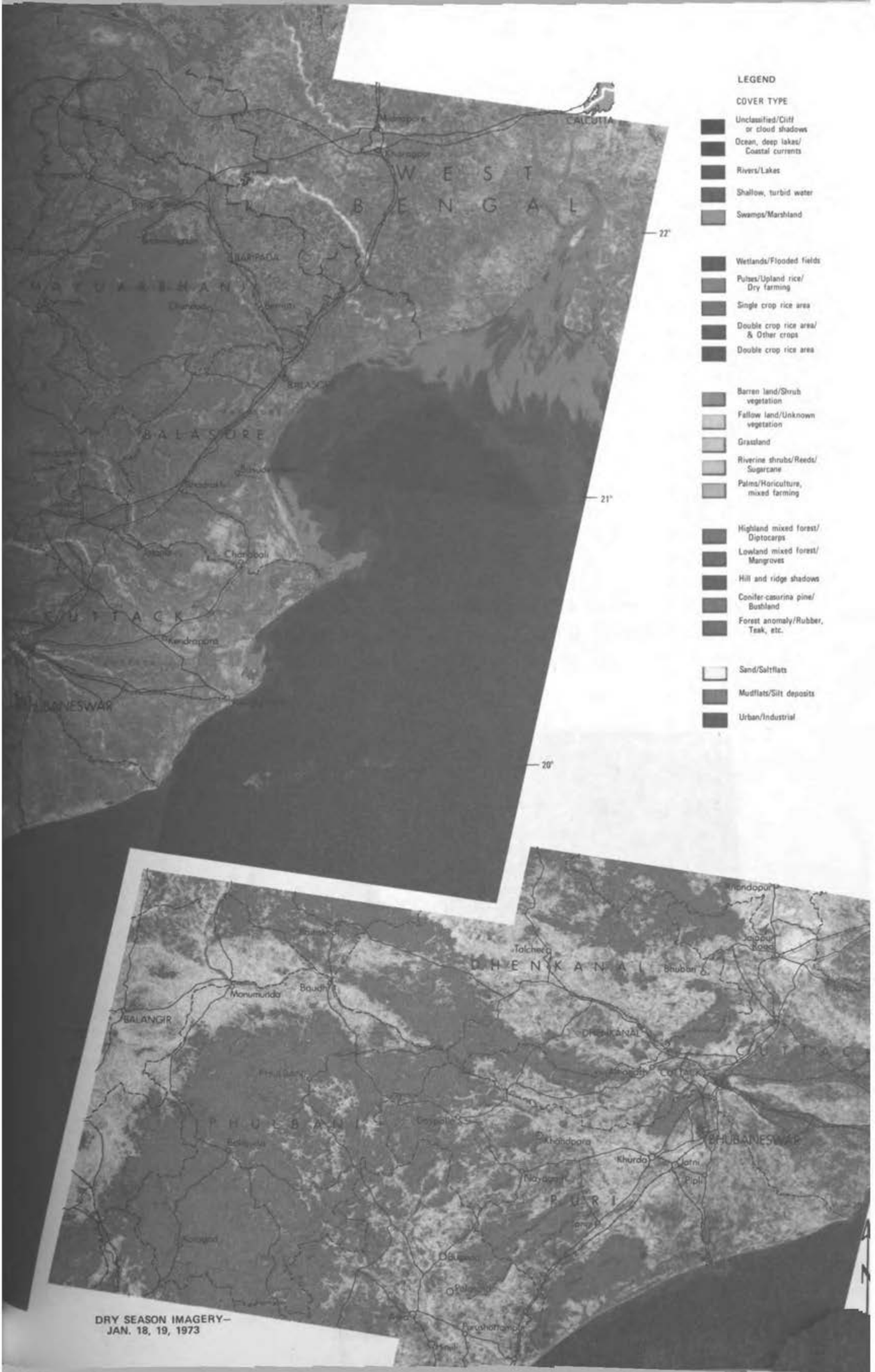


FIGURE 20 Landsat orbits repeat on an 18-day cycle. Adjacent swaths on adjacent days overlap some 15 percent near the equator; the overlapping becomes progressively larger at higher latitudes.

FIGURE 21 Illustration of computer tape processing. The Orissa, India, Land Cover–Land Use Association mosaic illustrates the type of detailed information obtainable from sophisticated computer tape processing of Landsat data. The example shown is a tremendous reduction of a mosaic "map," measuring approximately 10 square feet at the 1:250,000 scale. A cartographic overlay shows roads, railroads, towns, and political subdivisions of the state that are not fully visible to the naked eye on this reduction. The mosaic is a composite of thirteen Landsat scenes, each covering an area of 10,000 square miles, taken from orbital overflights on 4 consecutive days right after the monsoon and just prior to the harvest of the state's main rice crop. The inset mosaic, in the lower right corner, shows portions of three scenes including the Mahanadi River delta at the height of the dry season in which the "second" rice crop, produced only under irrigation, shows up clearly as dark green areas. (Prepared by W. Drewes, J. McKenna, and K. Willett, Resource Planning Unit of The World Bank.)

ORISSA, INDIA
LAND COVER-LAND USE ASSOCIATION

PREPARED BY IBRD



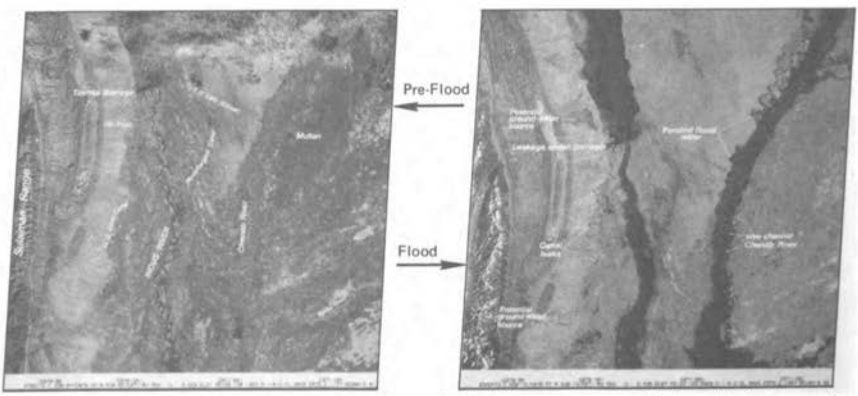
DRY SEASON IMAGERY—
JAN. 18, 19, 1973

Many developing countries already successfully use data from Landsat in simple image format. Bangladesh authorities, for example, were able to predict areas likely to experience major flooding and choose new lands in which development could take place by simple visual interpretation of what are essentially pretty pictures.

In the future, however, interpretation will be partially automated, particularly if a United Nations- or United States-sponsored central facility employing much computer software and many well-trained interpreters and analysts is established. Figure 21 shows an example of this kind of advanced computer tape processing of the Orissa area in India.

Landsat analysts train on selected data, predict for other data, and identify the land feature in question with accuracy ranging from 60 percent to well above 90 percent. The presence of floodwater can be predicted with nearly 100 percent accuracy. For certain classes of land use, preparatory work might be done before disaster occurs; an example is the areas of likely flooding shown in the Orissa photograph.

Figure 22 is an example of the use of Landsat for flood area mapping when an area is cloud-free. It shows the areas of the Indus and Chenab rivers in Pakistan before and during the flood. After the rain-bearing clouds have disappeared, both water and the area saturated from previous flood passage show up strikingly on Landsat images.



Flood image reveals the following:
- Total flooded area
- Changes in river channel
- Ponded water in floodplain after recession
- Leakage under the barrage (dam)
- Breaks and leaks from canals
- Groundwater discharge along mountain flanks

FIGURE 22 Landsat has detected major floods in many parts of the world where the floodwaters persist for long periods of time. This scene shows floods on the Indus and Chenab rivers in Pakistan in September 1973. The earlier (left) Landsat scene is from December 1972. This is a black and white reproduction of a color composite photo prepared by using Landsat bands 5, 6, and 7. In the color photo, the flooded areas are deep brown and the dry areas are in varying tones of light brown and yellow. (Original furnished by Morris Deutsch, U.S. Geological Survey.)

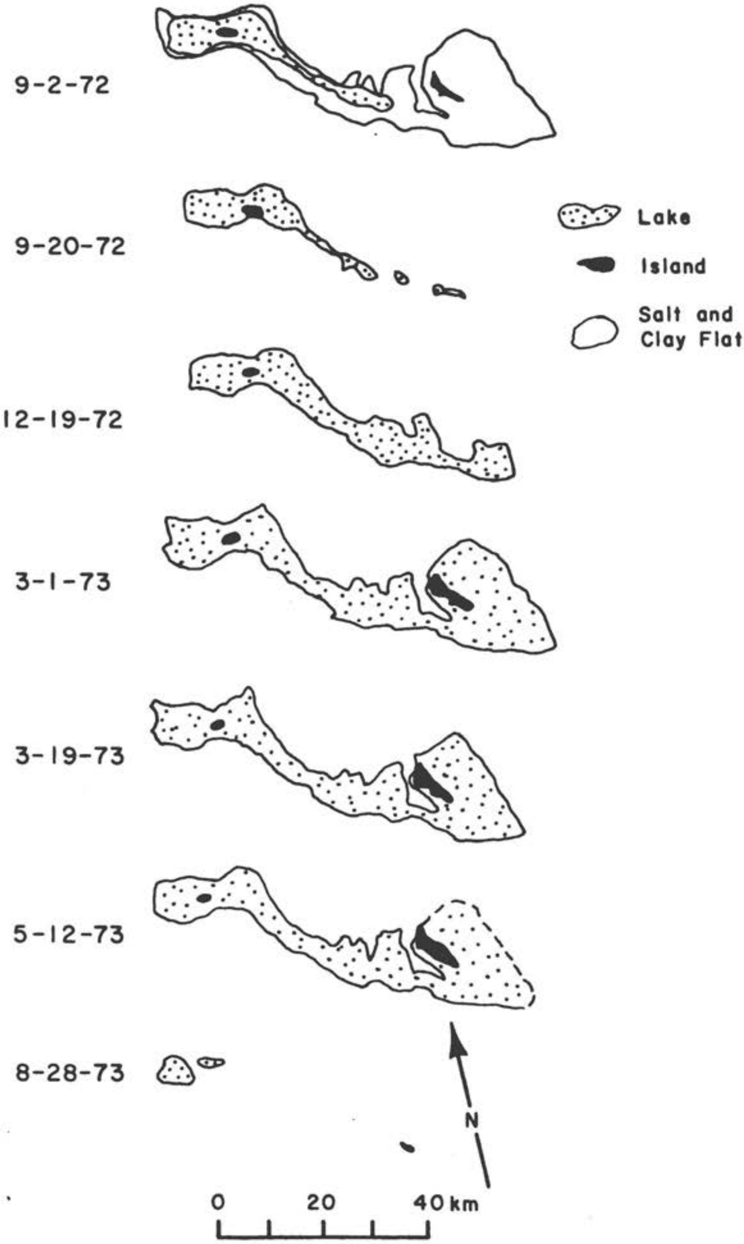


FIGURE 23 Landsat shows a sequence of lake filling and drying in Iran. These fluctuations are in the Neriz Playa, 1972-1973, as determined from Landsat-1 images. After Daniel B. Krinsley, Lake fluctuations in the Shiraz and Neriz Playas of Iran. In R. S. Williams and W. D. Carter (eds.), *ERTS-1: A New Window on our Planet*, U.S. Geological Survey, Professional Paper 929. Washington, D.C.: U.S. Government Printing Office, 1976, pp. 143-149.

Some big lakes in Asia and Africa are bordered by populous settlements. Occasionally, the lakes flood, leaving the communities isolated or washing them away. Figure 23 depicts an example of Landsat mapping of seasonal fluctuations in a lake filled with snowmelt in Iran. Mapping can also be done in those interior regions of Asia and Africa occasionally subject to severe floods.

If Landsat coverage occurring more frequently than at 9-day intervals materializes or when SEOS satellites are in operation, it may be possible to monitor in detail patterns of ash distribution from volcanic eruptions. The Landsat image in Figure 24 is of an eruption of Mount Nyirangongo in Zaire. Synchronous meteorological satellites could even provide some information on the general distribution of ash, to suggest areas for disaster relief or areas which would present serious obstacles to relief parties.

In earthquake-prone regions, Landsat may provide information on geologic structures and faults by various angles of solar shadowing. Radar can do the same and has the additional advantage of showing directions other than those provided by sun shadowing. The model in Figure 25 shows the different geologic structures emphasized with different solar illumination or radar illumination angles. Landsat has greatly improved our understanding of fracture patterns associated with seismic activity.

The new Landsats-C and -D and super-high resolution photography on the space shuttle will facilitate exceedingly detailed structural analyses in seismic areas. One practical use of the information so gained will be to advise governments planning new urban development about which areas are likely to be subject to earthquakes or seismic activity or possibly unusual floods. Many areas in which major fracture systems are located are not only mineralogically important, but they are also subject to high seismic activity; radar has been used to delineate such regions in both North and South America.

In monitoring the progress of widespread drought in developing countries, there is no doubt that both meteorological and earth resource satellites have significant roles to play. As an example of progress in this area, Figure 26 shows evapotranspiration as measured by the Penman model compared to actual pan evaporation from a number of sites in the Great Northern Plains. Obviously, they track very closely. There is a correlation coefficient of 0.89 between the measured pan evaporation and evapotranspiration calculated using Earth Satellite Corporation's METRUN computer program.

Many additional examples could be given of research and development under way in all these areas that are likely to be of value in warning, monitoring, and damage assessment. Enough has been shown, however, on technically feasible roles for remote sensing in disaster mitigation and relief programs. In particular, as was emphasized earlier, combinations of meteorological satellites (notably SEOS), earth resources satellites (Landsat-D, etc.), and possible radar free flyers, data collection platforms, and facsimile transmissions have a

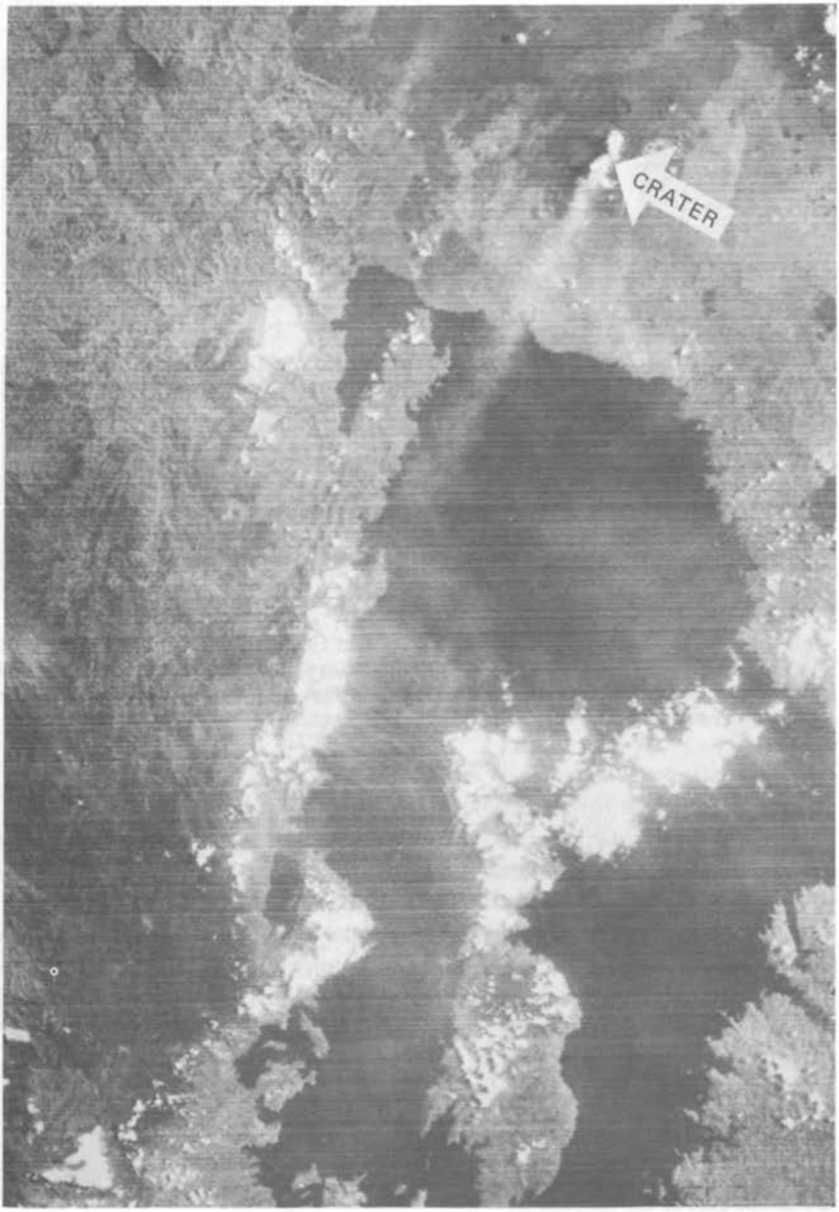


Figure 24 Landsat-2 photo of volcanic eruption of Mt. Nyirangongo, located in the Lac Kivu area in Zaire. This image, collected on March 12, 1975, shows the smoke plume drifting over the lake downwind from the crater. On the basis of spectral analysis of the Landsat data, the lava in the crater was interpreted to be hot or incandescent, indicating a pre-eruptive condition. An actual eruption occurred on January 10, 1977. (Original furnished by Morris Deutsch, U.S. Geological Survey.)

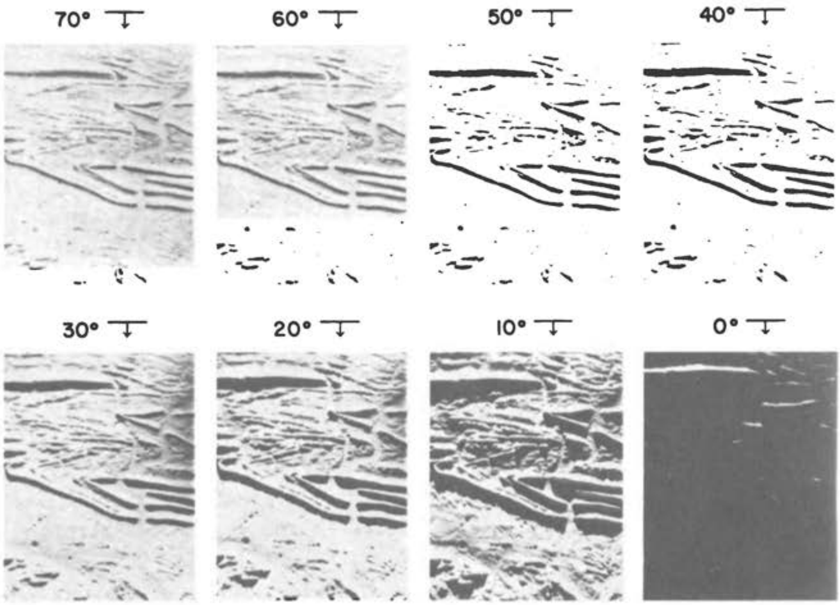


FIGURE 25 Differential emphasis of geologic and topographic structures is shown by different angles of solar or radar illumination. This model simulates both. It is clear that subtle topographic and geologic features need shallow angles of illumination, whereas major structural features would still be identifiable with steeper illumination angles.

very high *potential* for disaster warning, monitoring, and damage assessment. Whether this potential is realized depends both on the complexities of international politics and technical decisions over the next decade. If the AID/OFDA and the international community wishes this area to receive continuing and thoughtful attention, they must take some major initiatives. NASA may fund the necessary research and development only if substantial interest is expressed by the appropriate organizations and agencies. NASA would, of course, prefer to share those costs and risks in cooperative ventures with other agencies.

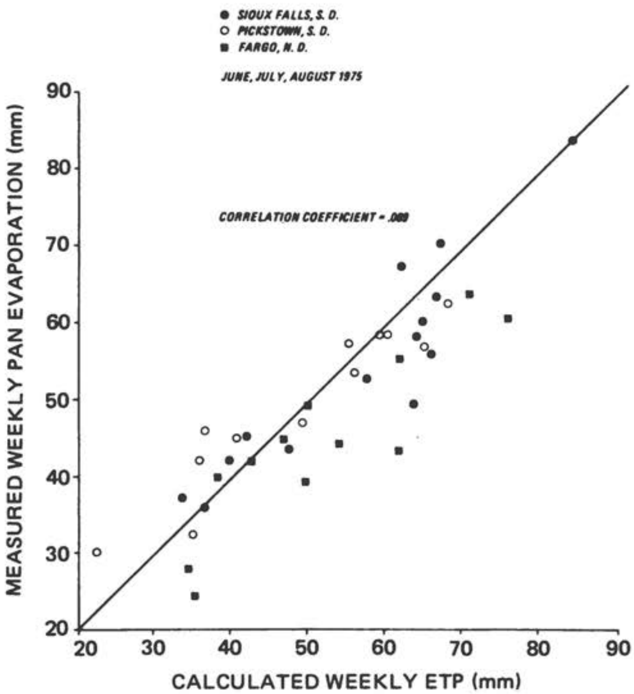


FIGURE 26 Comparison of weekly measured pan evaporation and evapotranspiration calculated by the Earth Satellite Corporation computer program known as METRUN during June, July, and August 1975 for Fargo, North Dakota, and Sioux Falls and Pickstown, South Dakota.

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