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SATELLITE COMMUNICATIONS FOR DISASTER RELIEF OPERATIONS

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ABSTRACT

Severe natural disasters that occur in the developing and underdeveloped areas of the world require the assistance of the world community to minimize the impact on the effected populations. Reliable communications during the periods of relief activities are essential to maximizing the timeliness and efficiency of relief operations.

This paper will discuss the use of existing and planned communication satellite systems to provide assistance in the implementation of disaster relief operations on a global basis. Focus of the paper will be on satellite communications system implications and their potential impact on field operations in disaster situations. Consideration will be given to the utilization of both INTELSAT and MARISAT systems operating at frequencies ranging from 1.5 to 4 GHz and to the size and type of ground terminals necessary for satellite access. Estimates of communication requirements for a global system will be given. Some discussion of cost estimates for satellite services to support relief operations will also be included.

The information to be presented is a result of several years of study and experimentation within NASA relative to the use of satellite systems for communications to remote regions. These efforts have included studies of communication satellites for both pre and post disaster applications conducted for NOAA as well as recent experiments conducted in conjunction with the Office of Foreign Disaster Assistance of the Agency for International Development.

INTRODUCTION

This paper will address from an overall systems perspective the role that satellite communications systems can play in assisting in the timely and effective reaction of the world community to major natural disasters. In any systems approach it is essential to determine as clearly as possible a definition of the problem to be solved. The service requirements necessary to effect a problem solution must also be identified in order to establish the system alternatives available to the system analyst.

Disaster related activities are generally separated into six stages or phases. The phases cover the events from disaster detection to rehabilitation. The time periods of greatest concern include the time interval just preceding a natural disaster and the time during and immediately following the occurrence. Three general classes of services are required, one deals with the collection of information dealing with the possible onset of a disaster, the second deals with the communications services required to disseminate alerting information prior to an occurrence and the third with the services dealing with responding to the needs of the effected area following an occurrence. This paper will deal with the requirements associated with the second and third classes of service.

On a global basis the world population is less than adequately educated or informed on what to do in an impending disaster situation and even less able to cope with the consequences of a major natural disaster despite much good work by international organizations such as UNDRO and Red Cross. The lack of adequate communication services to many areas of the world underlie this condition. In the world today where satellite technology permits communications between any two points on the globe, this situation need not persist.

In order to deal with both pre and post disaster situations a highly responsive and geographically flexible communication system is needed.

Since disaster events can and do occur in all parts of the world, a communication system that utilizes satellites as an integral part of a globally interconnected system offers the potential needed to deal with the geographically diverse requirements. The community concerned with disaster related activities fortunately has now at its disposal two global communications satellite networks, INTELSAT and MARISAT upon which to build a disaster communications network. This paper will present a possible system scenario for effective disaster communication operations using existing and planned systems and review the status of hardware technology available for use at this time.

PROBLEM STATEMENT AND REQUIREMENTS

In order to address the question of what communication systems is best, it is necessary to establish a clear statement of the problem to be solved by the systems under consideration. Too often a less than clear understanding of the problem is held by all parties involved and the resulting confusion prevents an acceptable system solution. Even when the problem can be clearly stated and agreed to by all, it is necessary to define the range of system requirements permitted in order to facilitate comparison of alternate solutions.

With regard to the Problem Statement, it is important to establish the major aspects of a disaster situation that are to be considered in the system assessment. One such scenario segments a typical disaster event into six major phases as shown in Table 1.

TABLE 1 General Phases of Disaster Problem

Phase	Event
1	Detection
2	Preparation
3	Warning
4	Assessment
5	Relief
6	Rehabilitation

The communication capability necessary to provide services required in the six phases range from remote data collection to interactive voice to broadcast voice and in some instances video. The general set of services for each phase is shown in Table 2.

TABLE 2 General Requirements During Disaster Phases

Phase	Type of Service	Purpose
Detection	Remote Data Collection and Imaging	Monitor Disaster Parameters
Preparation	Voice and Video Program Distribution	Educate Population and Disaster Teams
Warning/Alerting	Voice Broadcast	Initiate Safety Procedures
Assessment	Two-Way Voice, Data, Slow Scan Video	On-Site Assessment of Damage and Relief Requirements
Relief	Two-Way Voice and Data	Coordinate Near Term Relief Operations
Rehabilitation	Two-Way Voice and Data	Long Term Coordination of Area Rehabilitation Activities

In each of the phases there is a potential role for satellite services as part of a global disaster assistance system. Remote sensing satellites can and do contribute to information required to assist in prediction and detection of possible disaster situations. However without a reliable global communications network to convey the information to the effected parties none of the six phases can be accomplished effectively. It is this required communication network that will be discussed in some detail herein with attention given to utilization of existing satellite systems and current technology capability.

A schematic of a general communications network using satellite system capability is shown in Fig. 1 for the predisaster situation. Services pertaining to detection, preparation, and warning are provided and the network permits interconnection among the capitals of disaster prone areas with the major disaster assistance agencies, UNDRO and AID. Service penetration within a given country for education purposes is possible from the local capital via satellite broadcast to receive-only terminals distributed throughout the country as required.

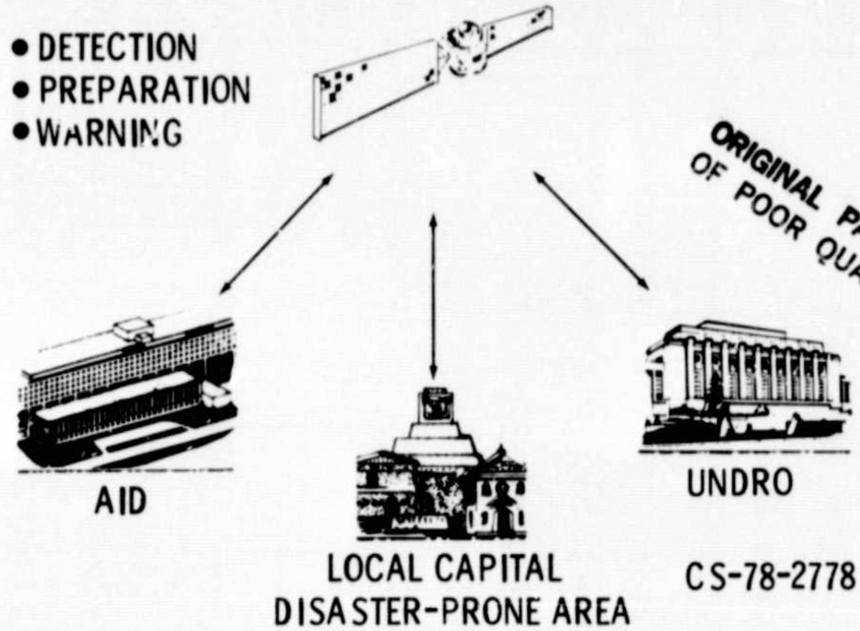

Fig. 1. Satellite communication system - pre-disaster.

In the post disaster situation, the network is depicted in Fig. 2 where the disaster area is linked with the local capital using transportable ground terminals. Communications to the outside world is then linked via the capital. This communication service is by and large interactive voice, data, facsimile and slow scan video.

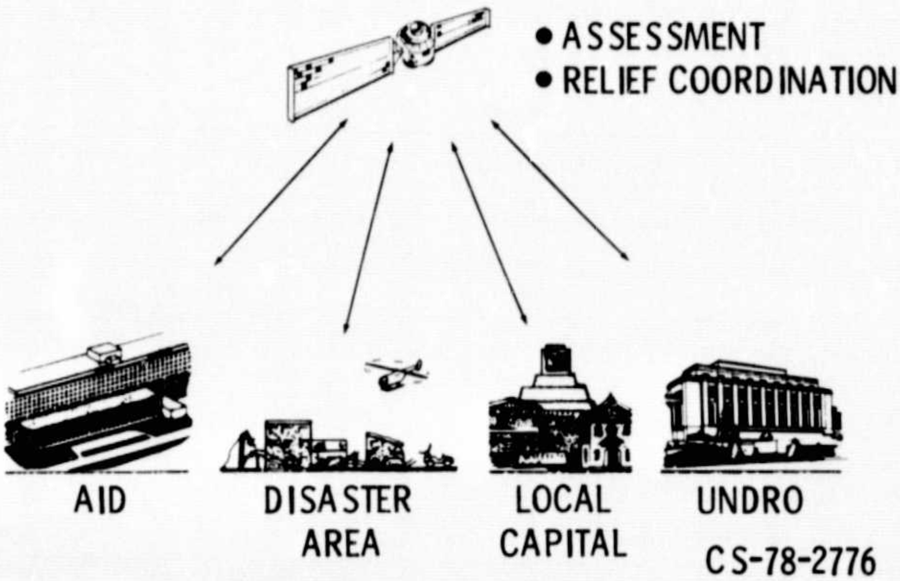

Fig. 2. Satellite communication system - post-disaster.

The broadcast type of service is a capability inherent in any satellite system; however, it is necessary to consider very carefully both the technical and political implications of rendering such a service. The participation of the local capital is a way of assuring local control in the system network.

A GLOBAL DISASTER NETWORK

Current international and planned regional satellite systems permit interactive as well as distributed (broadcast) services to a variety of ground terminal configurations. In the INTELSAT system global service is available in a receive-only video mode to relatively small, 5 to 7 meter, earth terminals. Extensive demonstrations of this type of service have been conducted in Nigeria and Sudan. Experiments have also been conducted to demonstrate interactive voice and data services with similar size terminals. Photos of typical small INTELSAT terminals are shown in Fig. 3, Fig. 4, and Fig. 5. The operating frequency band for the INTELSAT system is C-Band (4/6 GHz).

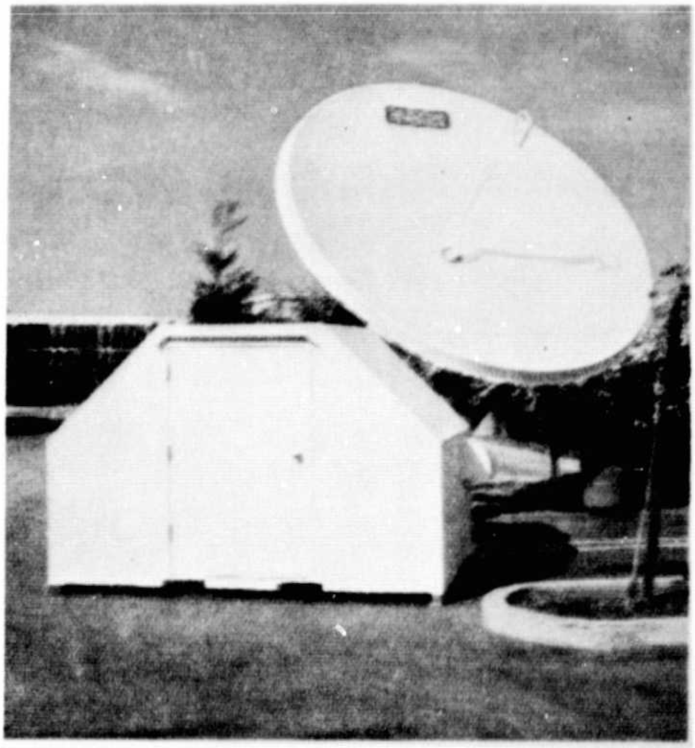

Fig. 3. Transportable terminal

Fig. 4. 6 meter truck mounted terminal - deployed

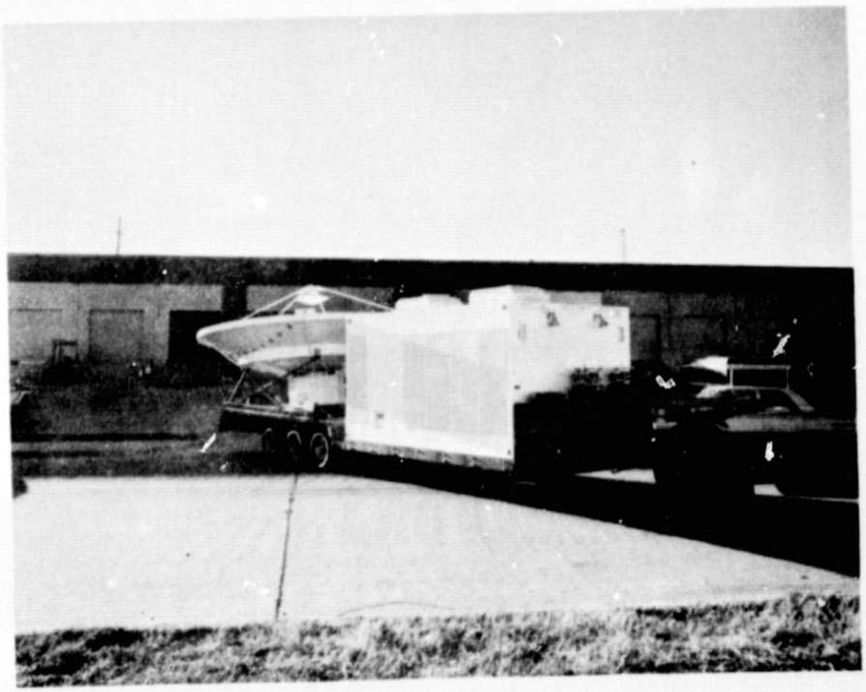

Fig. 5. 6 meter truck mounted terminal - stowed

Maritime communications services are currently being provided with the global coverage afforded by the MARISAT system. Interactive voice, data and teletype service is provided to ships at sea with terminals of 1.2 meter aperature. Typical MARISAT terminals are shown in Fig. 6 and Fig. 7. The operating frequency band to the small terminals for MARISAT is L-Band (1.5 GHz).

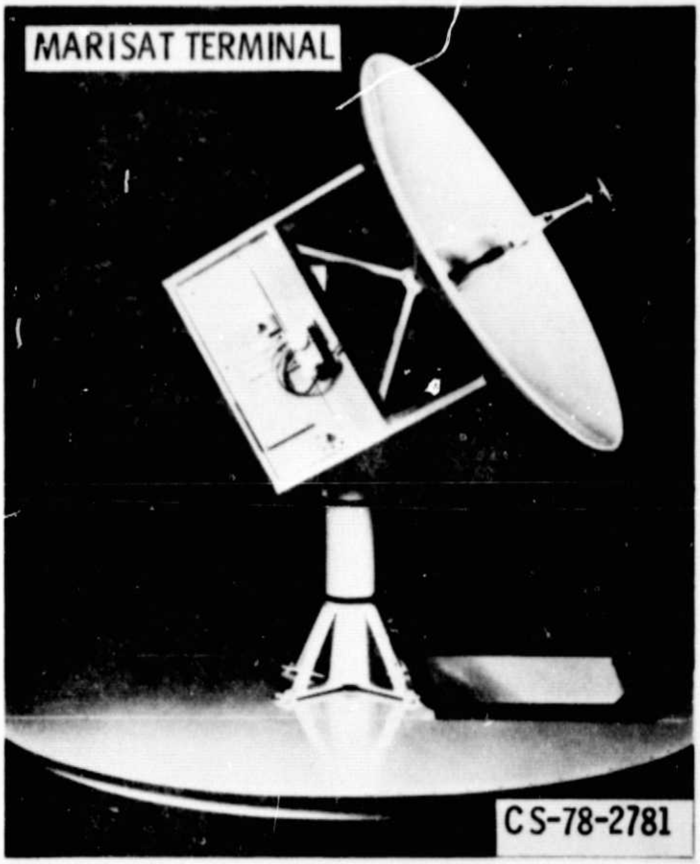

Fig. 6. MARISAT ship terminal

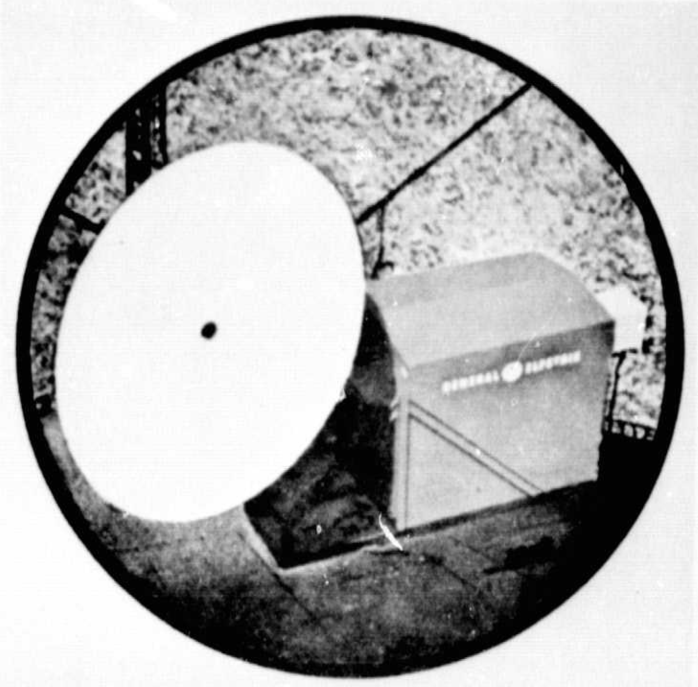

Fig. 7. MARISAT fixed site terminal

In the future INTELSAT will provide L-Band service to INMARSAT on the INTELSAT V satellite. As a consequence the potential exists for utilization of either INTELSAT or INMARSAT as the backbone system upon which to build a disaster communications network. One such communications satellite network is shown schematically in Fig. 8. This system would utilize the L-Band capability of INTELSAT V to provide one interactive voice channel using a highly transportable small (1.2 meter antenna) ground terminal.

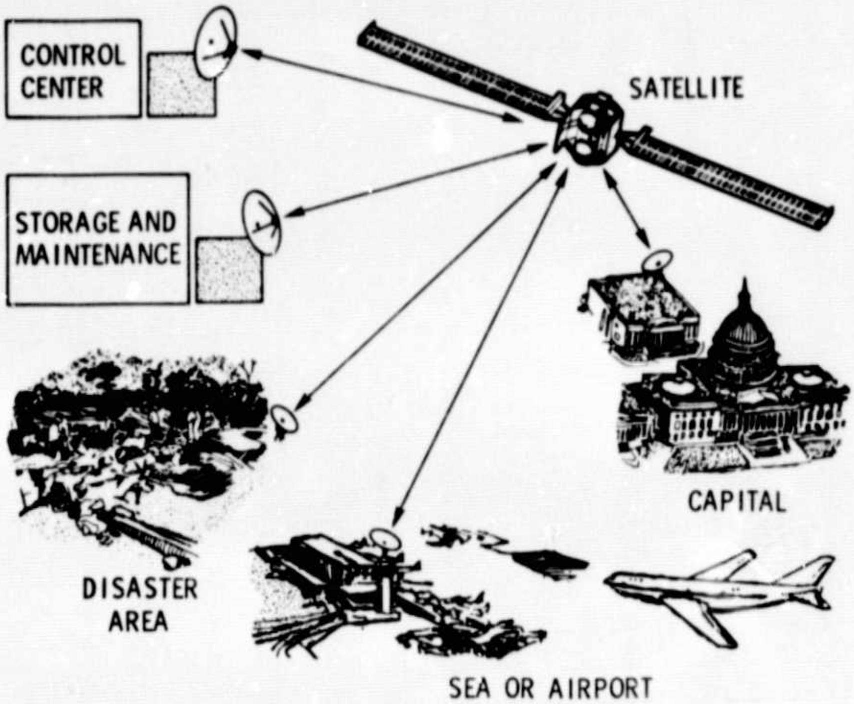

Fig. 8. Disaster communication network schematic

A schematic of a modified MARISAT terminal is shown in Fig. 9.

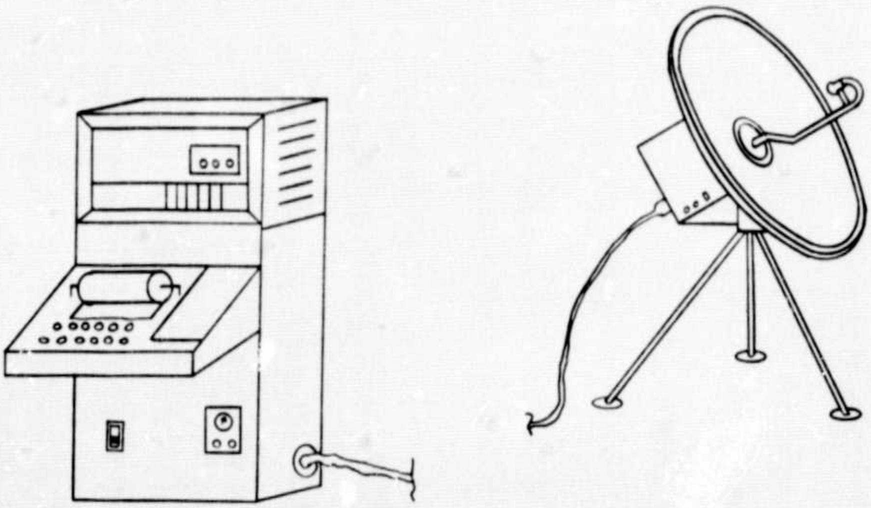

Fig. 9. Lightweight, portable MARISAT terminal

This terminal modified for use in a disaster situation would weight about 150 kilograms, require 700 watts of power and could be set up in about 2 to 4 hours by two field technicians.

A link would be established between the disaster scene and the capital of the effected country through the nearest INMARSAT terminal. Current plans for INMARSAT require patching through the INMARSAT main terminal to normal communication channels. Interconnects to the outside world would then be possible through the standard INTELSAT communications channels. Communications to and from the disaster scene would allow real time on-site assessment of the damage and type of relief supplies needed.

Coordination of the relief activities and the provision of general communications services on a temporary basis to augment or replace existing communications service disrupted by the disaster could be conducted close to but somewhat remote from the actual disaster site by a transportable medium size (5 meter) ground terminal which permits 10-100 channels of interactive voice channels using INTELSAT C-Band transponders. Both classes of transportable terminals would be moved from a general storage area in the region to the effected area as required. The Class B type terminals located in the capitals of the participating countries could be permanent installations and could serve other functions when not required for disaster communications.

The 5 meter receive only type terminals could be used in a predisaster situation to permit the distribution of video programming at the community level of educational material pertaining to disasters.

A satellite communications network similar to that just discussed could be implemented now. Since the satellites are already a part of existing systems, it remains only to establish the character of the ground systems and arrange for leasing of satellite transponder space. The system is evolutionary in nature and allows growth from demonstration projects to operational use depending on the political, institutional and economic arrangements that are made.

An assessment of the probable costs for such a system is reported in (LeRoy, 1979). It would appear that modest service costs are possible with a relatively flexible network system based on the L-Band and C-Band capabilities of the INTELSAT V system.

To determine an expected cost of system implementation and operation it is necessary to scope the requirements the system must meet. In (LeRoy, 1979) a range of capability was considered from low utilization of the system that is only a few of the approximately 45 disasters that occur yearly on a global basis require system support and high utilization where many of the disasters require communications system support. In order to scope the costs of systems and services a best guess average set of requirements was selected and is shown in Table 3.

TABLE 3 Average Annual Set of Global Disaster Occurrences with Expected Communication Requirements

Disasters Per Year	45
Activity Days/Disaster	60
Simultaneous Occurrences	7
Disasters Requiring Terminals (@ 25%)	11
Terminal Utilization, Days	5
Terminals/Disaster	2
Voice Channels/Terminal	3
Channel Usage/Day, Hours	4

The expected costs for this average case implementing an all L-Band system using MARISAT current costs as a basis results in a yearly cost for the average utilization case of about one million dollars and includes space segment costs $800K, ground terminal costs at $150K and transportation at $50K. If the INTELSAT system is used at C-Band on an "as needed" basis, lower yearly costs are possible; however, larger field terminals are required. It should be noted that a combination of L-Band and C-Band utilization have been postulated herein with expected costs in the same range as indicated in (LeRoy, 1979).

NASA DISASTER RELATED ACTIVITIES

As part of an extended evaluation of how future satellite technology might be used for the warning as well as interactive (two-way) communications functions, NASA conducted a series of systems studies for the National Oceanic and Atmospheric Administration, NOAA, (Spar, 1974; LeRoy, 1977; Hein, 1972) dealing with direct-to-home disaster warning. Consideration was given to potential disaster situations occurring within the 50 states. Disaster events ranged from tornadoes (see Table 4) with very short response times required to winter storms and general floods that had moderate response times required.

TABLE 4 Disaster Response Times

Disaster Type	Smallest Area Warned	Message On-Line Upper-Bound
Tornado or Severe Storm	Part of County	1-5 Minutes
Hurricane	Part of Coast	1-15 Minutes
River Flood	Part of State	15 Minutes - 1 Hour
Small Craft Warning	Part of Coast (Lake)	15 Minutes - 1 Hour
Winter Storm	Part of State	15 Minutes - 1 Hour
Others	Part of County	1 Minute - 1 Hour

The general set of communications services to be provided by the alternative systems are shown in Table 5.

TABLE 5 Disaster Warning System General Service Requirements

Delivery of Warnings to Public via Home Receivers
Spotter Alerting and Reporting
Data Collection
Coordination among National Weather Service Facilities
Broadcasting of Routine Weather Information

Alternative system solutions were evaluated and compared including dedicated satellite systems, hybrid satellite/terrestrial systems and all terrestrial systems. For the direct-to-home warning requirement, it was necessary to operate the broadcast channel at low frequency, approximately 1 GHz, and at relatively high transmit power coupled with a large spacecraft antenna to allow area selectivity. A sketch of the satellite is shown in Fig. 10.

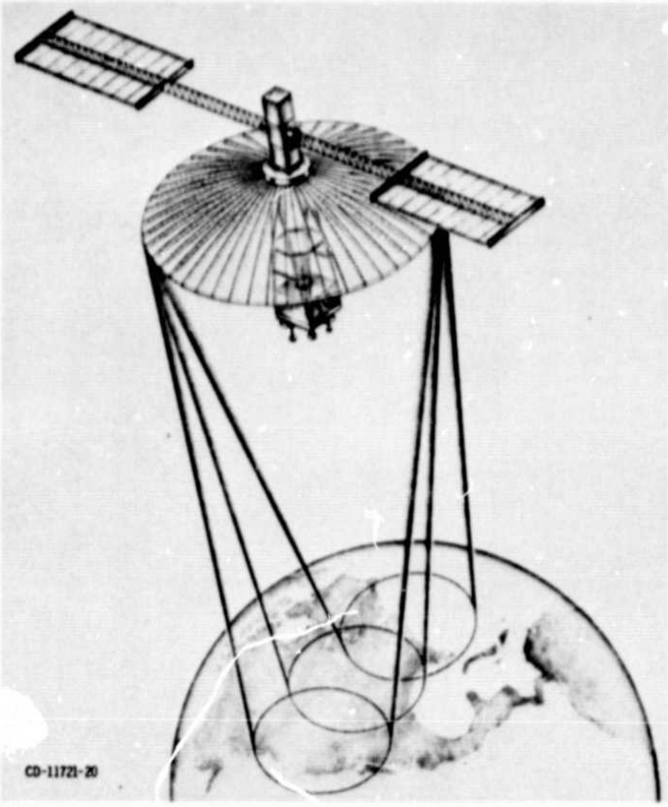

Fig. 10. Disaster warning broadcast satellite

The technology demonstrated in ATS-6 experimental satellite was applied in this case study. In this mode, this satellite system permitted broadcasting of a voice warning to selected areas of the country which could be received by a very small receive-only voice terminal shown in Fig. 11. The alternative all-terrestrial system utilized a large number of transmitting stations distributed around the country operating at VHF (about 150 MHz) frequency capable of broadcasting voice warnings to similar small receive-only voice terminals. About 750 VHF broadcasting transmitters would be required to provide complete coverage of the United States.

The conclusion of these studies indicated that for the United States all three system types could effectively provide warnings as well as interactive communications services to meet the overall requirements. However, the highly developed terrestrial networks already in place coupled with the U.S. domestic satellite services available precluded the option of a dedicated satellite system for disaster communications from being cost competitive. Although these studies did deal with the range of communication services needed for disaster communications on a global scale, the conclusion reached may not be applicable. The existence of two global satellite systems INTELSAT and INMARSAT do, however, offer the potential to provide needed services without requiring a dedicated satellite system. It should be noted that because of the very large geographical area to be served in any global system, a careful trade-off must be made of the minimum terminal size as a function of the overall cost of service taking into account the communication capacity needed, the flexibility required, the capability of existing systems and the timing of system operation.

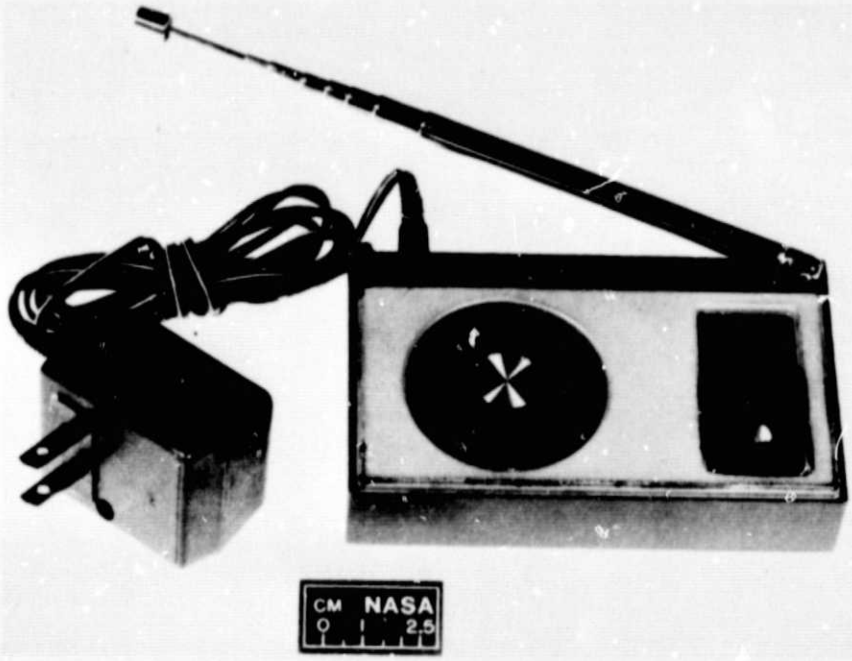

Fig. 11. Disaster warning receiver

As part of the overall study activity concurrent experiments related to disaster communications have been conducted to establish the feasibility of the advanced technology inherent in the NASA experimental satellites CTS and ATS-6.

Using the CTS satellite, experiments were conducted under both real and simulated disaster conditions using multichannel voice terminals with antennas of 1.2 meter diameter and are reported in (Donoughe, 1978; Kaiser, 1977; Edelman, 1977). Photographs of the terminals used are shown in Fig. 12, Fig. 13 and Fig. 14.

Fig. 12. Small CTS transportable terminal

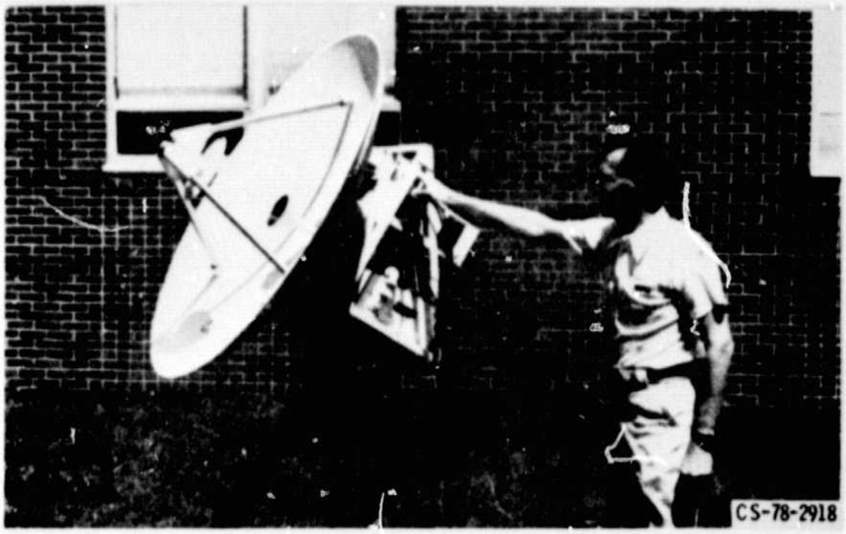

Fig. 13. Small CTS transportable terminal

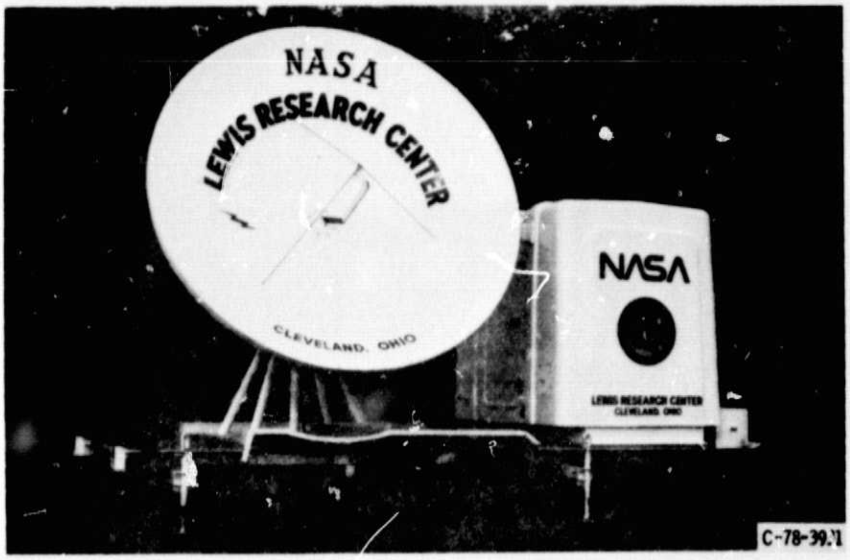

Fig. 14. Trailer mounted CTS terminal

Similar experiments have been conducted with ATS-6 as reported in (Anderson, 1976; Maruschak, 1978; Laurence, 1975; Baker, 1977). Because of the range of downlink frequencies possible with ATS-6, a variety of terminals as shown in Fig. 15, Fig. 16, Fig. 17 and Fig. 18 were used ranging from receive only video at UHF and S-Band frequencies to two-way voice to suitcase terminals at L-Band.

Fig. 15. Video receive only - SITE experiment

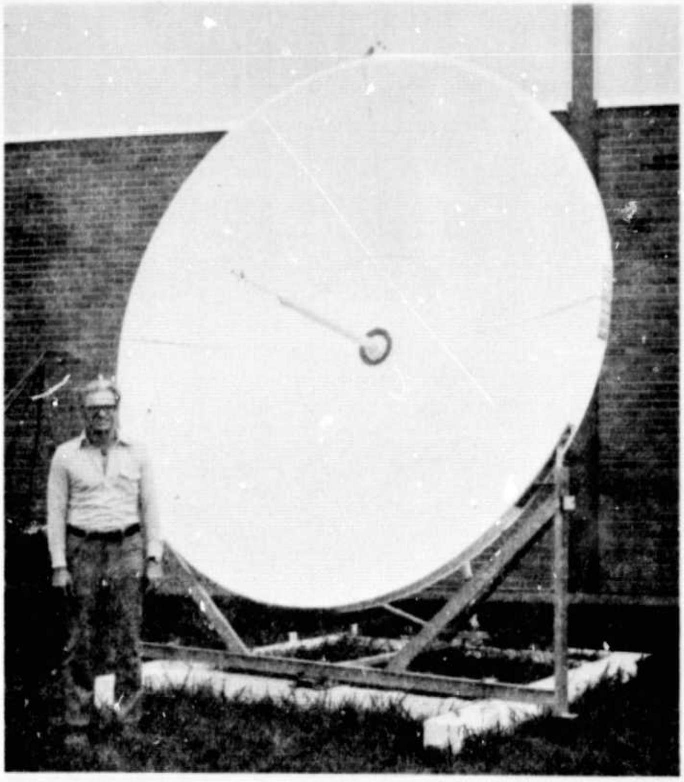

Fig. 16. Transportable two-way video terminal antenna

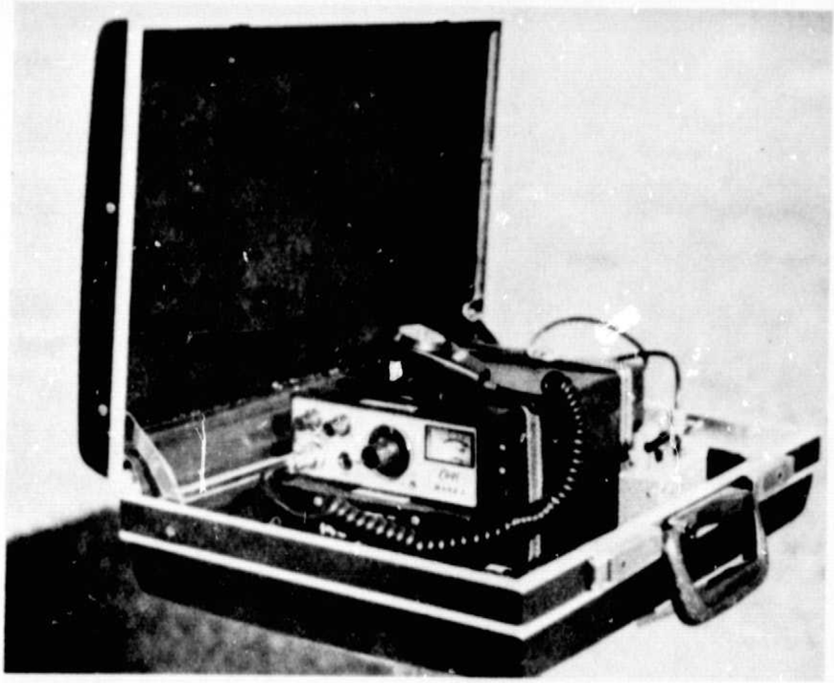

Fig. 17. Suitcase portable terminal

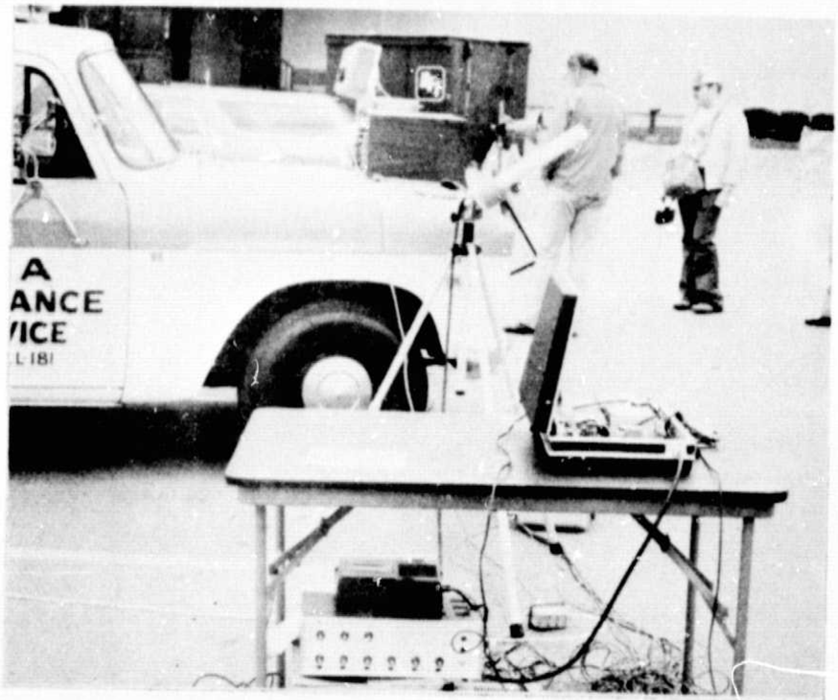

Fig. 18. Suitcase portable terminal and helix antenna

FUTURE SYSTEM POTENTIAL

The discussion to this point has centered on applying capability that either currently exists or is planned for the near future. No major advanced technology has been considered. Technology advances, however, will occur during the next decade that may permit application of complex spacecraft/ground system combinations that will offer increased flexibility in network organization. Steerable spacecraft spot beam antenna systems employing high frequency may allow higher effective power to be radiated to the disaster region. Satellite-to-satellite interconnection and on-board satellite switching will permit global links to be established without requiring multiple satellite hops. This will allow consideration of small terminals than described with existing satellite systems even to the utilization of manpack terminals. The technical feasibility of such small terminals was demonstrated with ATS-6 where suitcase size terminals as shown in Fig. 17 and Fig. 18 were used to implement two-way voice links.

Advanced satellite systems employing large spacecraft antennas and high frequencies as shown in Fig. 19 in an artist's concept, may generate high intensity spot beams for use in very localized regions to facilitate a wide range of communication services to support pre and post-disaster operations.

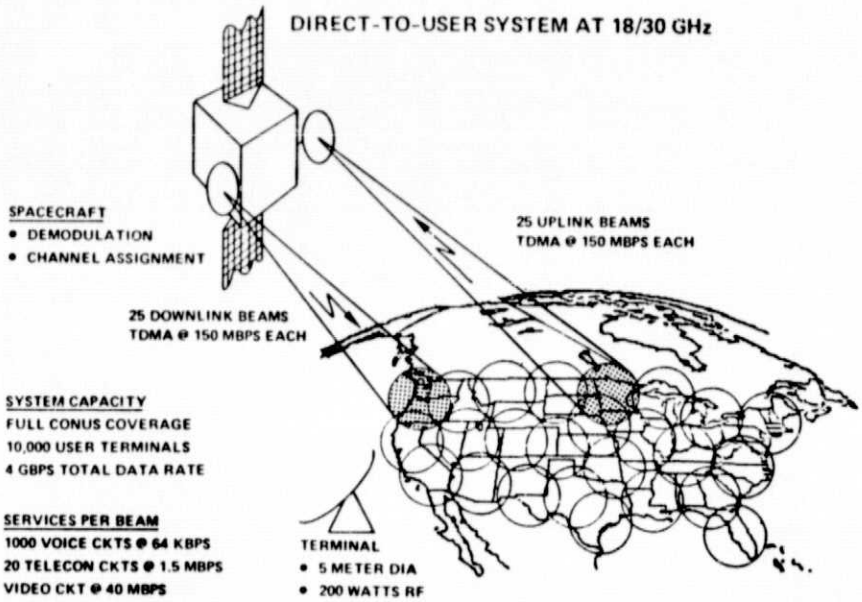

Fig. 19. Advanced K-band system

It should be noted that the cost of providing a communication service to a node in the network system is to first order dependent on the throughput of the node. That is to say high capacity nodes (multi-channel) costs-per-channel are much less than for low or single channel capacity nodes.

Providing very portable ground terminals may reduce the cost of individual terminals but the costs associated with establishing the channels through the satellite will most likely be commensurately higher. Even with the advanced technology systems, to determine the service rendered would require an overall systems analysis to establish the best fit between desired capability and service cost.

CONCLUDING REMARKS

Responding effectively to natural disaster situations depends to a large degree on the existence of a reliable and flexible communication network devoted to disaster related communication services. At the present time existing international satellite communication systems offer real potential for the establishment of an effective network in the near term. Experimentation with these systems is possible in order to define the real requirements of such a network.

Advances in technology in satellite systems may offer additional network flexibility in the future but costs of advanced systems if higher than current systems must be weighed against the added benefits that are derived. It will be necessary to periodically assess future options as technology advances in order to maintain a good balance between service rendered and costs incurred.

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