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GLOBAL DISASTER SATELLITE COMMUNICATIONS SYSTEM FOR DISASTER ASSESSMENT AND RELIEF COORDINATION

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ABSTRACT

Natural disasters which generate the need for assistance from the international community predominantly occur in developing countries with limited communications. Moreover, these disasters often destroy most or all of the communication links which previously existed in the disaster areas. This results in a lack of adequate information regarding the severity and extent of the disaster as well as the kinds and amount of assistance required in the recovery process. The sparcity of information greatly adds to the human suffering from the disaster. In order to significantly improve disaster assistance, it is reasonable to consider a disaster communication system that is capable of quickly providing reliable communications between a disaster site and disaster relief operational entities.

This paper analyzes the global communication requirements for disaster assistance and examines operationally feasible satellite system concepts and the associated system parameters. Both present and planned commercially available systems are considered and the associated global disaster communication yearly service costs are estimated.

INTRODUCTION

This paper presents a "broad brush" analysis of satellite communications systems for disaster assessment and relief coordination. The subject is not new and has been addressed in previous work (Ref. 1, 2, 3). Prior work has dealt largely with ground terminal technology for a disaster communications system. The basic conclusions have been that technology is not the major impediment to a global disaster communications system. Rather, it has been suggested that institutional barriers such as lack of specific frequency assignments and permission to use small transportable terminals provide the greatest hinderance to effective disaster communications. Both national and international groups have called upon the WARC '79 to address these questions. Once these questions are resolved, it becomes a matter of development and engineering to supply the necessary equipment.

The primary emphasis in the paper is economics. As background, we will briefly describe some potential problems associated with the current method of providing disaster assistance and a scenario for disaster assistance relying on satellite communications. Historical statistics will be used with the scenario to assess service requirements. From the plausible range of service requirements, we will estimate total systems service costs based on powsible methods of technical implementation. Current commercial systems and planned systems will be considered. A realistic planning horizon can be no more than 7 years for the data presented here.

DISASTER ASSISTANCE SCENARIO

To develop a plausible scenario, we must examine the stages and problems of disasters. There are, generally speaking, six stages to a disaster:

Prediction	- Analysis of in-situ or remote data leading to the conclusion that a disaster is imminent or possible in the near term.
Detection	- In-situ or remote sensing of the disaster agent.
ALERT	- Delivery of potential disaster information to appropriate entities (governments, general public, etc.)
Assessment	- Survey of the social and physical impact of the disaster agent to determine relief and rehabilitation requirements.
Relief	- Short term delivery of items to mitigate physical impact (food, shelter, etc.)
Rehabilitation	- Long term assistance directed toward restoring the impacted area and personnel to near pre-disaster state.

We will restrict our analysis to "post-disaster" communications for management of Assessment, Relief, and Rehabilitation activities.

An excellent report by the National Research Council (Ref. 4-5) details the following key problems centered on the delivery of goods to the affected country during the emergency period:

(1) goods irrelevant to needs arrive in large quantities.

(2) relevant goods arrive in insufficient quantities.

(3) relevant goods arrive in excessive quantities.

(4) unlabeled and unsorted goods arrive.

(5) concurrent arrivals of goods create transportation congestion.

(6) inadequate internal transportation for distribution.

(7) no systematic evaluation of logistics of the delivery or use of provided goods.

These problems arise, in part, due to inadequate communications capability. Major problems can be created because lack of disaster damage is seldom reported. An example[4] is that unneeded medical units were dispatched to Nicaragua in 1972 after the major earthquake that occurred in Managua. It was assumed that the medical units were needed when, in fact, there was no damage to the 16 hospitals within the community and injuries could be adequately handled by those facilities.

The scenario developed herein could be considered typical of a major disaster striking a country that requires outside assistance for relief activities. The scenario is schematically presented in Figure 1. We

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postulate the existence of some central "clearing house" for coordination and control of external assistance activities. The U.S. Office of Foreign Disaster Assistance, Washington, or UNDRO, Geneva, could possibly fill this role. In addition, we assume some storage and maintenance facilities exist from which small terminals are dispatched to the impacted country.

The small terminals provide temporary long distance communication for management of relief activities and are deployed upon the host country's invitation. Within the impacted country, three terminals might be deployed. One terminal located at the host country capital provides communications to government officials for the control and management of all disaster activities. A second terminal located at a port facility could communicate to the host country capital and the "clearing house" - providing current reports on the relief goods arriving in the country. A third terminal located at a local disaster control center within the impacted area could provide needs assessment reports, and relief and rehabilitation progress reports to the country capital and the "clearing house". If one or more of these locations are co-located, fewer terminals would be needed. The communications services that these terminals could provide are: voice, facsimile, teletype, data, or narrowband (freeze frame) video. No requirement for wideband service has yet been established. Since the earth terminals are for long distance communications, we can surmize that local communications might be accomplished by HF, VHF, or UHF radio. However, a truly mobile long distance link could be established by relay of VHF radio through one of the transportable earth terminals. It is assumed that, as relief activities transition to rehabilitation, the communications systems within the disaster area are restored and the need for small emergency earth terminals decreases.

Statistics and Systems Requirements

In Reference 4, it is shown that over the 10-year span from 1965 to 1975, the United States assisted in an average of 45 foreign disasters each year. The minimum was 20 and the maximum was 55 during this period. Externally-sponsored relief and rehabilitation activities generally last from 30 to 90 days from disaster on-set. From this, we can assume that there are from 2 to 14 simultaneous relief/rehabilitation activities worldwide at any instant, if the probability of a disaster is uniform in time.

Table 1 summarizes some pertinent parameters for the systems designer. We have not applied statistical modeling to determine worst case or maximum service requirements or to determine the probability of not being able to deploy a terminal when needed. Rather, we have adopted a "broad brush" approach to bound the needed parameters for further study. A low utilization case is postulated wherein few disasters occur and the terminals are deployed for only a few days. A high utilization case is considered wherein the maximum number of disasters occur and terminals are required for extended management operations. The average utilization case represents "best guesses" where hard data is not available.

In Table 1, items 1, 2, and 3 have been discussed above. Based on informal conversations with A.I.D./Office of Foreign Disaster Assistance (OFDA) personnel, only about 25% of all disasters would require emergency communications. Thus, from 5 to 14 deployments of disaster terminals can be expected (Item 4). The number of days that emergency terminal service is required (Item 5) is postulated from 2 days to 30 days per occurrance. The smaller value reflects the potential for quick restoration of local and international communications after a sudden disaster, while the larger value reflects a long-term communications need over a varying geographical area for disasters having a slow onset. The number of terminals deployed to any disaster ranges from 1 to 3 per the scenario (Item 6).

The average number of terminals deployed at any instant (Item 7) is estimated from Items 4, 5, and 6. Simultaneous channel requirements per terminal (Item 8) have been discussed in the literature and in References 1, 2, and 3 where the range is from 3 to 6. Since the type and quantities of services needed are uncertain, we considered a range of 1 to 10 channels per terminal, which results in a large range in the number of channels deployed at any instant (Item 9). Actual channel usage is probably inversely proportional to the length of terminal usage. Short-term deployments are assumed to use the channel 8 hours per day, while longer deployments would use each channel only 2 hours per day (Item 10). With the above assumptions, a range on yearly channel utilization can be obtained (Item 11).

SYSTEM DESIGN AND COST

Approximate system cost estimates can be obtained by considering only space segment, ground segment, and transportation costs. Costs not estimated are circuit tail end costs and additional manpower costs for terminal operations, if needed. A major question to be answered is whether it is cost-effective to lease complete or partial transponders or to pay for satellite time on an "as needed" basis. Figure 2 presents the break-even curves for space segment costing. From these curves, cost tradeoffs may be made for the various systems under consideration. For example, consider the \$10/min. curve which is typical of Marisat duplex voice channel charges. At low utilization - say $2x10^4$ channel minutes per year - the space segment charges would be \$200,000. Certainly, in this case, designing the global disaster system to operate at L-band with Marisat (or its successors) is financially sound, if the only alternative was to lease 3 dedicated transponders from Intelsat, since current Intelsat charges approximate \$1M/transponder per year. On the other hand, if satellite usage approaches $1x10^6$ channel minutes, then dedicated transponder leasing is cost-effective when compared to a \$10/minute charge.

Figure 3 shows the number of terminals versus the yearly operating costs with terminal acquisition cost as a parameter. We have assumed that the annual lease cost is 35% of acquisition cost. This factor is consistent with current carrier practices for terminals designed for largely unattended operation and includes storage, maintenance, depreciation, interest, and return on investment. Note from Table I that even for the highly active year, the average number of terminals deployed is only 4. Allowing a 2 to 1 redundancy brings the total to 8. Thus, if terminal acquisition costs are \$300K per unit, the yearly cost is about \$850K. In Reference 6, the costs for several small terminals for thin route communications are estimated. From these estimates, we assume that the likely disaster communication terminal cost range is from \$50K to \$300K.

Terminal size and weight has been a major concern to thos responsible for disaster assessment and relief, and rehabilitation activities. They perceive the necessity for highly portable, compact, lightweight units to be used by existing agency personnel. While satellite service using truly portable "hand-held" terminals may be technologically possible, it is not economically feasible within the planning horizon adopted in this report. For this reason, the scenario presented lends itself to strategically located satellite terminals with hand-held units providing communications to the terminals for relay as required. With terminal development for field operation, we could expect terminal weights in the range of 300-600 lbs. This does not include weight for terminal power generation or peripheral gear such as TV monitors, facsimile, test equipment, etc. However, we may estimate the economic impact of terminal weight with the aid of Figure 4. Here we have the yearly transportation cost as a function of number of terminal miles per year. Terminal weight is a parameter in Figure 4 and the assumed tariff is $\$5 \times 10^{-4}$/lb/mi. This tariff approximates air transportation costs for scheduled air routes. To estimate total terminal miles, we return to our scenario and Table I. We might expect in a typical year to deploy 2 terminals to 11 disasters for a total of 22 terminal deployments. To estimate the average round trip, we note that most major disasters occur between 40°N latitude and 40° south latitude. If storage and maintenance facilities were located near the equator, then the average round trip should be less than 5,000 miles. Thus, the total terminal miles expected would be 110, 000 miles. The likely range in transportation costs is approximately $20,000 to $200,000 per year.

We have in Figures 2, 3 and 4 sufficient information to establish reasonable estimates of yearly costs for a disaster communications systems of the type described in the scenario. We have not, however, indicated what terminal parameters are necessary. For the Marisat system operating at L-band, the antenna is small (∿ 4' diameter) and terminal G/T is ∿ -6 dB/°K. The current problem with this system is the number of available satellite voice channels. However, next generation satellites should provide from 30 to 100 voice channels per satellite - sufficient to handle average global disaster traffic requirements (Table I).

In contrast, the Intelsat system is designed to operate with large earth terminals. To date, operational service to earth terminals with antennas less than 6m has not been approved. Figure 5 represents the transponder half circuit capability of the Intelsat IV and V global and zone beams as a function of transponder backoff for earth station G/T of 0 dB/°K and 15 dB/°K. The assumptions for Figure 5 were: single channel per carrier operation (SCPC), C/N = 12 dB, receiver bandwidth = 20 KHz, no other margin, and a 40% activity factor.

It is apparent from Figure 5 that sufficient capacity exists as the emergency terminals G/T approaches 15 dB/°K. A G/T of 15 dB/°K could be easily attained with a 4.5m antenna and 300°K system temperature. Figure 5 also indirectly indicates the cost range one might expect from use of the Intelsat system. Assume an average of 1000 simplex circuits per Intelsat transponder, and a ground terminal G/T = 15 dB/°K. Then each simplex circuit established to a small emergency terminal displaces from 5 circuits for zone beam and 2 dB backoff to 90 circuits for global beam and 8 dB backoff. Given that the average simplex circuit cost is about $6,000 per year, then the circuit cost to small terminals should range from $30,000 to $540,000 per year. If the terms are on an "as use" basis, the charges are from $.06/minute to $1.03/minute for a simplex circuit and $.12/minute to $2.06/minute for a duplex circuit compared to the current Marisat charge of $10/ minute. For Intelsat "as use" costing, we will assume a charge of $.50/minute.

Tables II, III and IV summarize some system cost variations for the low utilization, high utilization and expected utilization cases detailed in Table I. In Table II, Case 1 indicates the costs we could expect in using a Marisat follow-on system. Case 2 allows for larger, more expensive terminals to be used with Intelsat. Note the difference in space segment cost between Cases 1 and 2. Case 3 allows for a 10-fold increase in channel minutes to indicate the impact of space segment costing with the Intelsat system. Table III clearly indicates the potential dominance of space segment costing if the utilization is high. System costing is minimized if Intelsat transponders are used "as needed". Table IV treats the expected average utilization. Case 1 indicates the costing of a Marisat (or follow-on) designed system. In Case 2, we have assumed full transponder leasing and larger terminals appropriate to Intelsat. In Case 3, we have assumed the Intelsat system is costed on an "as use" basis.

CONCLUDING REMARKS

In Reference 4, it is noted that worldwide expenditures for disaster assistance are currently in excess of $500M annually. The most costly system examined in this report does not exceed 1% of this figure; thus, the cost of a disaster communications system is well within the individual or combined resources of many nations.

It is clearly evident that a statistical traffic analysis is needed to better quantify the requirements for the system. The systems analysis presented tends to support the use of C-band for high traffic cases. For low utilization cases, terminal costs dominate and it is unclear whether C or L-band is to be preferred. Given the assumptions in this paper, it is the disaster assistance scenario which dictates the quantity of terminals purchased - not the amount of communications traffic. Since there is a tendency to increasingly use resources at hand, the system might be utilized more than anticipated in our assumptions. This factor has not and cannot be quantified at this stage of system development.

From the "broad brush" systems analysis presented, we can conclude that the likely number of terminals required is small (less than 10). Additionally, transportation costs are not likely to exceed 25% of the annual systems' cost. Thus, there is little economic justification for ground terminal development for the global disaster communications system. Currently, large transportable C-band terminals exist and relatively small portable (mobile) terminals are operating with Marisat at L-band. We can, however, envision repackaging C-band and/or L-band terminals to minimize weight and size, if this is shown to be necessary for timely deployment of terminals to the impacted area.

REFERENCES

(1) Helm, Neil, "Disaster Communications Via Satellite", International Astronautical Federation, XXVIIIth Congress, Prague, 25 Sept. - 1 Oct. 1977.

(2) Haviland, R.P., "On Satellites for Communications in Natural Disasters", Telecommunication Journal, Vol. 44-I/1977.

(3) Report 554, CCIF Volume IV, "The Use of Transportable Earth Stations With A Small Antenna For Relief Operation in the Event of Natural Disasters and Similar Emergencies", 1974.

(4) "The U.S. Government Foreign Disaster Assistance Program" - National Academy of Sciences, Washington, D.C., 1978.

(5) "The Role of Technology in International Disaster Assistance", National Academy of Sciences, Washington, D.C. 1978.

(6) Helm, N. and Kaiser, J., "Small Earth Terminals for Medical/Educational Applications", AIAA Conference on Communications Satellites for Health/Education Applications, No. 75-917.

TABLE I

SYSTEM STATISTICS

		LOW UTILIZATION RELIEF OPERATIONS ONLY	HIGH UTILIZATION EXTENDED OPERATIONS	EXPECTED AVERAGE
1.	Disasters Per Year	20	55	45
2.	Activity Days Per Disaster	30	90	60
3.	Number of Simultaneous Activities	2	14	7
4.	Disasters Requiring Terminals (@25%)	5	14	11
5.	Assumed Terminal-Days Per Disaster (Days)	2	30	5
6.	Number of Terminals Per Disaster	1	3	2
7.	Time Average Number of Terminals Deployed	.02	3.45	.30
8.	Number of Narrowband Channels Per Terminal	1	10	3
9.	Time Average Number of Channels Deployed	.03	34.5	.9
10.	Assumed Channel Usage Per Day (Hours)	8	2	4
11.	Channel Minutes Per Year	5.3×10^3	1.5×10^6	7.9×10^4

TABLE II

YEARLY SYSTEM COSTS
LOW UTILIZATION
20 DISASTERS PER YEAR

CASE 1 - L-BAND (MARISAT FOLLOW-ON)

	PARAMETER	COST ($K)	% OF TOTAL
SPACE SEGMENT	5.3×10^3 min. @ $10/min.	53	40
GROUND SEGMENT	2 Terminals @ $100K/Term.	70	53
TRANSPORTATION	20K Miles 1000 Lb.	10	7
TOTAL		133	100

CASE 2 - C-BAND (INTELSAT)

	PARAMETER	COST ($K)	% OF TOTAL
SPACE SEGMENT	5.3×10^3 @ $.5/min.	3	2
GROUND SEGMENT	2 Terminals @ $200K/Term.	140	86
TRANSPORTATION	20K Miles 2000 Lb.	20	12
TOTAL		163	100

CASE 3 - C-BAND HIGHER USE (INTELSAT)

	PARAMETER	COST ($K)	% OF TOTAL
SPACE SEGMENT	5.3×10^4 @ $.5/min.	26	14
GROUND SEGMENT	2 Terminals @ $200K/Term.	140	75
TRANSPORTATION	20K Miles 2000 Lb.	20	11
TOTAL		186	100

TABLE III

YEARLY SYSTEM COSTS
HIGH UTILIZATION
55 DISASTERS PER YEAR

CASE 1 - C-BAND TRANSPONDER RENTAL (INTELSAT)

	PARAMETER	COST ($K)	% OF TOTAL
SPACE SEGMENT	FIXED COST	3000	89
GROUND SEGMENT	8 Terminals @ $200K/Term.	280	8
TRANSPORTATION	210K Miles 1000 Lb.	105	3
		3385	100

CASE 2 - L-BAND (MARISAT)

SPACE SEGMENT	4×10^5 min. @ $10/min.	4000	91
GROUND SEGMENT	8 Terminals @ $100K/Term.	280	7
TRANSPORTATION	210K Miles 1000 Lb.	105	2
TOTAL		4385	100

CASE 3 - C-BAND "AS NEEDED" (INTELSAT)

SPACE SEGMENT	4×10^5 min. @ $.5/min.	200	20
GROUND SEGMENT	8 Terminals @ $200K/Term.	560	58
TRANSPORTATION	210K Miles 2000 Lb.	210	22
TOTAL		970	100

TABLE IV

YEARLY SYSTEM COSTS
AVERAGE UTILIZATION
45 DISASTERS PER YEAR

CASE 1 - L-BAND (MARISAT FOLLOW-ON)

	PARAMETER	COST ($K)	% OF TOTAL
SPACE SEGMENT	7.9×10^4 min. @ $10/min.	790	80
GROUND SEGMENT	4 Terminals @ $100K/Term.	140	14
TRANSPORTATION	110K Miles 1000 Lb.	55	6
TOTAL		985	100

CASE 2 - C-BAND TRANSPONDER RENTAL (INTELSAT)

	PARAMETER	COST ($K)	% OF TOTAL
SPACE SEGMENT	FIXED COST	3000	89
GROUND SEGMENT	4 Terminals @ $200K/Term.	280	8
TRANSPORTATION	110K Miles 2000 Lb.	110	3
TOTAL		3390	100

CASE 3 - C-BAND "AS NEEDED" (INTELSAT)

	PARAMETER	COST ($K)	% OF TOTAL
SPACE SEGMENT	7.9×10^4 min. @ $.5/min.	40	9
GROUND SEGMENT	4 Terminals @ $200K/Term.	280	65
TRANSPORTATION	110K Miles 2000 Lb.	110	26
TOTAL		430	100

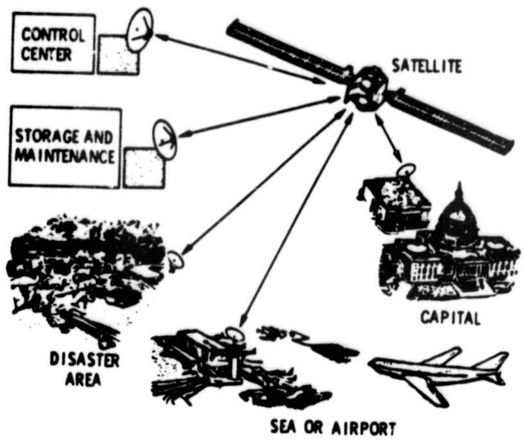

Figure 1. - Operational system schematic.

BREAKEVEN CURVES FOR SPACE SEGMENT COSTING

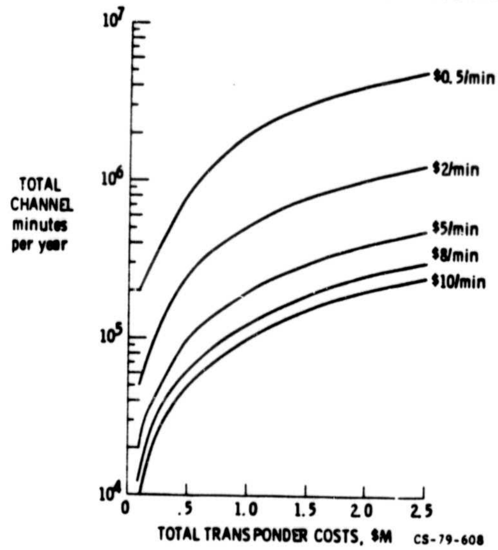

Figure 2

TERMINAL EQUIVALENT YEARLY COSTS

ANNUALIZATION FACTOR • 0.35

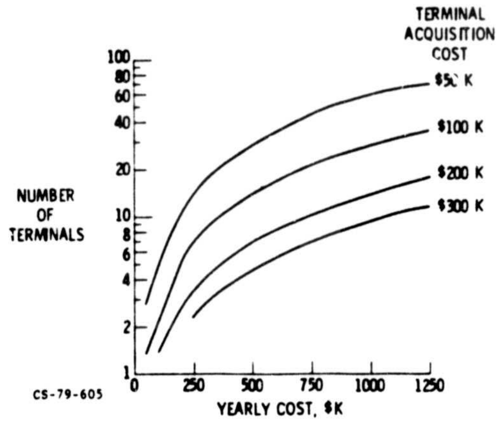

Figure 3

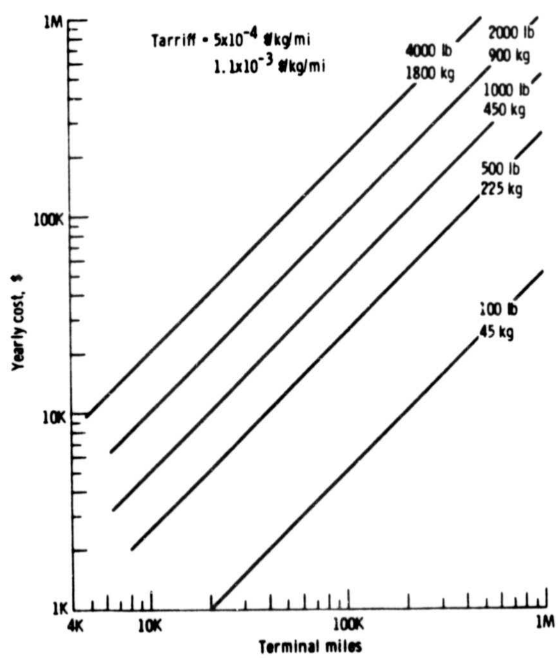

Figure 4. - Terminal transportation costs.

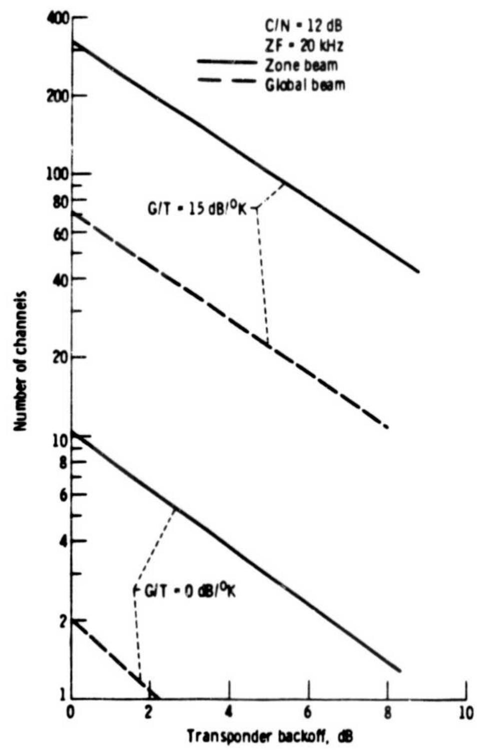

Figure 5. - Transponder capability.