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FINAL REPORT PROGRAM PLAN FOR SEARCH AND RESCUE ELECTRONICS ALERTING AND LOCATING SYSTEM

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16. Abstract

This study investigates the requirements that exist for electronic devices for alerting and locating distress incidents and presents a plan for acquiring an adequate capability. Data are provided that bound the problem. Possible alternatives are examined and compared. As a result, the GRAN-DILS concept is selected upon the basis of cost/benefits. A plan for acquiring the GRAN-DILS system is provided. Recommendations are made for the interim period prior to GRAN-DILS availability.

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PREFACE

This document presents a conceptual plan for development of an integrated electronic search and rescue alerting and locating system. The need for alerting and locating, the requirements which stem from these needs, and the possible alternatives which satisfy these requirements are presented as a basis for the plan.

The scope of the study was primarily limited to the civil user for downed aircraft and maritime accidents. It encompassed

- o developing requirements for civil users
- o surveying existing planned and potential equipments and systems both military and civil
- o reviewing status of existing programs and plans
- o selecting the best options from candidate alternatives
- o developing an integration plan
- o justifying the planned program

This program resulted from a series of ad hoc meetings that were held between NASA, DOT, DOD and other signators of the National SAR Plan to explore development of the Global Rescue Alarm Network (GRAN) and other related distress alerting and locating problems. As a result of these meetings it became apparent that although many efforts were in progress to provide electronic equipment for distress alert and location, there did not appear to be adequate coordination of activities concerning systems for civil use. The Office of Safety Affairs in DOT requested TSC to review activities in progress and recommend an integrated approach to the problem.

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GLOSSARY OF TERMS

AATMS	Advanced Air Traffic Management System
AGL	Above Ground Level
AM	Amplitude Modulation
AMVER	Automated Mutual Assistance Merchant Vessel Reports - A Coast Guard System that tracks Merchant Vessels at sea to support rescue activities
AOPA	Aircraft Owners & Pilots Association - An organization representing general aviation.
ARRS	Aerospace Rescue & Recovery Service - An organization within the U.S. Air Force that has among other responsibilities been assigned that of coordinating and participating inland rescues within the U.S. and its territories.
ASAP	Advanced Survival Avionics Program - An Air Force managed DOD Development program and has under development SLG and DILG equipments to be used for rescue of military personnel from distress situations.
ATC	Air Traffic Control
ATV	All Terrain Vehicle
CAP	Civil Air Patrol - A civilian volunteer air rescue organization
DALS	Distress Alerting Locating System - A USCG Development Program for a coastal distress alerting system.
DILG	Distress Incident Locator Group - The Equipment of the DILS System
DILS	Distress Incident Locator System - The part of ASAP system that will alert rescue headquarters to the fact that a distress incident has occurred.
DOD	Department of Defense
DOT	Department of Transportation
ELT	Emergency Locater Transmitter - A VHF Radio beacon that

	GA aircraft are required to carry which is activated when a crash occurs and indicate the position of the crash.
EPIRB	Emergency Position Indicating Radio Beacon - A VHF radio beacon that is prepared for use by survival craft to indicate location (maritime)
FAA	Federal Aviation Agency
FLIR	Forward Looking IR Sensors
FM	Frequency Modulation
GAMA	General Aviation Manufacturers Association
GRAN	Global Rescue Alarm Network
ICAO	International Civil Aviation Organization
IMCO	International Maritime Consultative Organization
IR	Infrared
LLTV	Low Light Level TV
KHz	Kilo Hertz
MHz	Mega Hertz
NATC	National Air Transport Conference - An Organization of air taxis and commuter air carriers
NTSB	National Transportation Safety Board
OMEGA	A Hyperbolic World Wide Navigation System operating at VLF
OPLE	The Relay of Omega Signals via Satellite to a remote computing center where position of receiver is determined
OTH	Over the Horizon
RCC	Recovery Coordination Center - operational command centers of AARS (USAF)
RCC	Rescue Coordination Center - USCG
SLG	Survivor Locator Group - Component of ASAP Program
SAR	Search and Rescue

1. INTRODUCTION

This study was initiated to develop a conceptual plan for integration of search and rescue telecommunications alerting and locating devices and systems currently in existence or under development, and for establishment of the directions that are needed to provide an adequate system to support civil needs.

The scope of the study was limited to the consideration of the civil user needs, in particular, alert and location for general aviation and maritime search and rescue. Highway and rail needs were considered but were not found to be completely compatible with the aircraft and maritime problem. This study did encompass:

- Developing requirements for civil users
- Surveying equipment and systems
- Reviewing status of existing programs
- Selecting the best options for development
- Developing an integrated plan
- Justifying the planned program.

The Department of Transportation (DOT) is one of the five signers of the National SAR Plan, an interagency agreement on general responsibilities and functions in SAR. The DOT has played a prominent role in search and rescue activities through the USCG as well as the FAA. However, no one Government department has been designated to lead or assure coordination of system development plans. Consequently, there is a lack of continuity that could be provided by an established entity associated with SAR alert and location system development. Efforts to develop a new civil system have met with limited interagency actions because the signators of plans do not effectively follow through. Long range funding for the development of new or improved systems has been uncoordinated and has suffered from the lack of unified goals within the several agencies.

A need exists to develop a plan for integration electronic telecommunications systems to be employed in the alert and in location of distress incidents. Effective and timely location of aircraft, ships and other transport vehicle emergencies in remote and unpopulated areas is contingent upon such integrated SAR telecommunication planning.

Although the Department of Defense has allocated approximately $6 million to the development of an advanced survival avionics system and the NASA has supported this with technical development engineering, the Department of Transportation and the other signatory agencies have not heretofore complemented these efforts with long-range planning for implementation by non-military users of the system. The DOT responsibilities for all modes of transportation safety indicated a need to develop an integrated plan for application of advanced telecommunication and satellite technology to transportation search and rescue.

From the analysis of alert and location requirements that has been made for this study, it is apparent that a significant fraction of the 3700 lives that are lost because of the limitations of our alert and location capabilities could be saved. The loss of Congressmen Boggs and Begich in Alaska is a case in point. Had they carried an ELT as required by law, their chance of rescue could have been greatly enhanced and the cost of search would have been greatly reduced.

The framework of the present communication system for alerting and localization, in the main, either dates back to World War II or even in parts to twenty years before that. There are many technical developments that have fallen out of the age of aerospace which can serve to improve the tele-communications aspect of SAR. These improvements, if applied, could result in improved reliability across the board and lower the cost, size and weight for life raft and small aircraft alert and location equipment. In particular these improvements would stem from:

a. Satellite Communications Technology

b. Omega Navigation Technology

c. Integrated Circuit Technology.

The alerting of SAR forces to the fact that a distress incident has taken place must be accomplished, in general, by wireless communications. The only reliable communication bands that are not beset with propagation difficulties are at VLF and line-of-sight frequencies. VLF requires vast antenna systems and power, therefore, it is not suitable for mobile users. The line of site communications, in general, are limited to short ranges and therefore, provide inadequate coverage. However, communications satellites greatly enhance the coverage that can be achieved at line of sight frequencies. Three geosynchronous satellites can provide world-wide line of sight coverage to 70° latitudes.

The Maritime Satellite (MARISAT) that is currently under development will afford this communication capability to ships. Unfortunately, the Maritime Satellite will operate at L-band and therefore, require excessive power or a directive antenna for survivor communication. These options are not practical for survivor craft or small aircraft so a VHS satellite must be used.

Part of the process of alerting is notifying the SAR forces approximately where to look. Although satellites can be used to determine where the distress is located, such satellite systems are orders of magnitude more expensive than simple satellites for communication. The simple relay satellite can be used if the position of the distress could be determined locally and relayed via the satellite. The Omega VLF Radio navigation system provides the basis for such a system at the lower cost of a simple satellite communications system. Integrated circuit technology can bring the cost of user units to a reasonable level.

The Omega SAR-COM approach is a long range solution that could be implemented by 1978. Two systems of this type have been proposed: Global Rescue Alarm Net (GRAN) and Distress Incident Locator System (DILS).

For present coverage, Congress has passed legislation that required general aviation aircraft to carry Emergency Locator Transmitters (ELT). Monitoring of these transmitters by commercial air transport aircraft can provide improved coverage in regions of high air traffic density. It is apparent that steps should be taken to have the air carriers monitor the ELT frequencies and report emergencies to provide an interim solution.

A summary of areas that have been studied and those still open to further examination is present in Figure 1-1. The modes of transportation form a matrix with possible environments. The systems that are appropriate for the mode and the environment are the elements of the matrix. The cases where further study is needed are also identified.

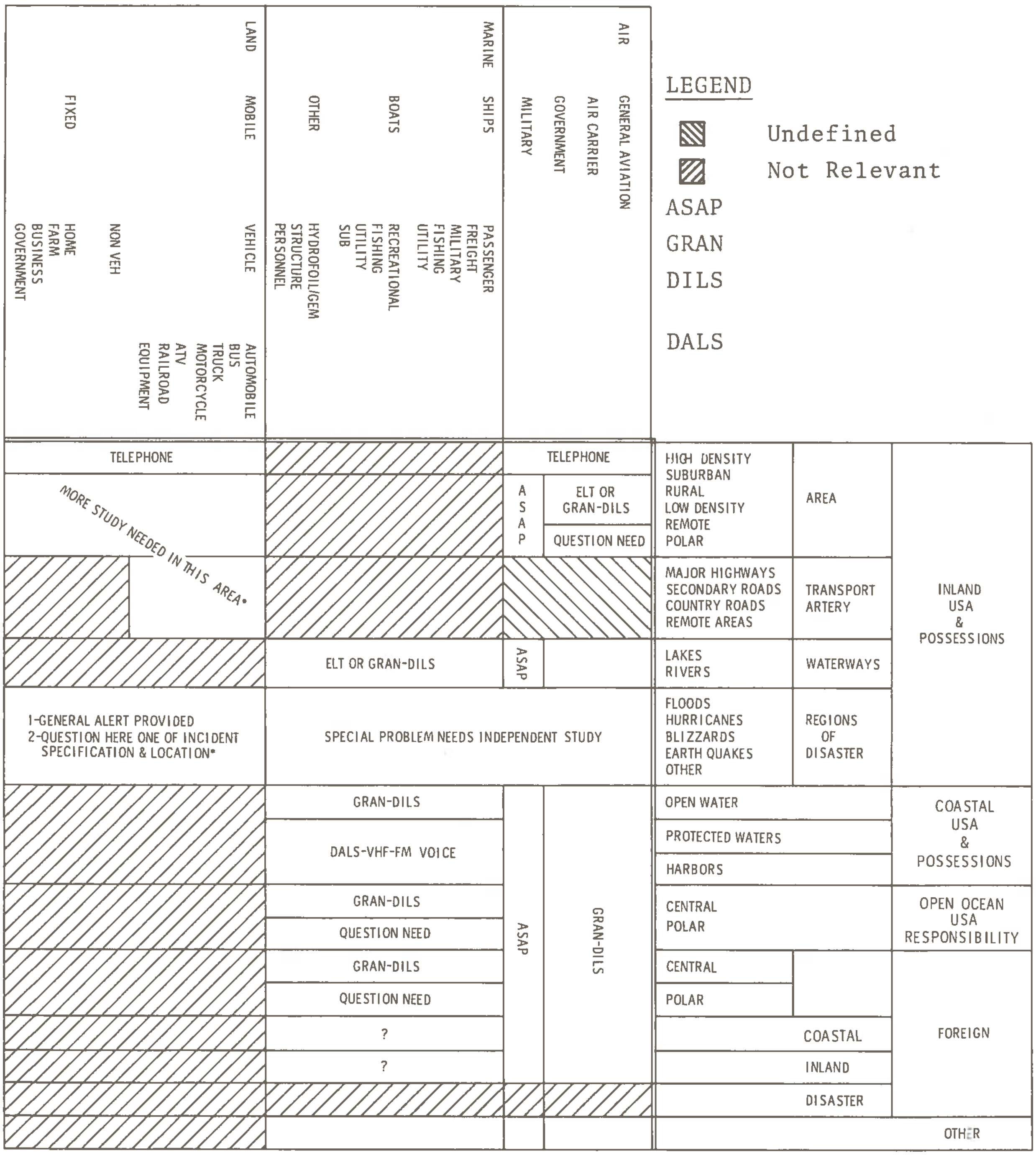


Figure 1-1. Summary of Prospectives for SAR-TELE-COM System Applications

2. REQUIREMENTS

An unfulfilled need exists for a timely alert and location capability to support SAR activities. Although certain alert and locating equipments are now in operation, they do not satisfactorily fulfill this need for a comprehensive capability. To develop an understanding of what the requirements for alert and location are, we must first investigate the current status of SAR activities that require alert and location communications and where communications limits these capabilities. Finally we will establish what features need to be incorporated in future systems.

2.1 SCOPE OF PROBLEM

National policy defined in terms of past practice and agreements through ICAO and IMCO commit the U.S. Federal Government to search and rescue of persons involved in air and marine distress situations. Through these international agreements, we have assumed the responsibility for coordinating and participating in search and rescue for our own inland and coastal areas in addition to large areas of the North Atlantic, Pacific, and Carribean. These areas are shown in Appendix A. Through the Coast Guard and the Aerospace Rescue & Recovery Service (ARRS), supported by CAP, state and local units, an organization is provided to support this commitment. However, because of the lack of communications suitable to alert SAR activities and locate the incident, many of the distress incidents lead to a higher level of fatalities and more costly operations that would be expected if suitable communications were available.

The loss of Congressmen Boggs and Begich in Alaska has triggered extensive Congressional interest in the SAR alert and location problem. Interestingly enough, if the pilot of that aircraft had conformed to Alaska state law, a successful rescue might have been achieved. Evidence indicates that SAR location equipment, required by Alaska law, was not carried on this flight. This incident represents search at its extreme in financial outlay.

More than 3500 hours of aircraft flying were expended which cost from 3 to 6 million dollars for the flying time alone. Over and above this aerial search, surface searches on land and at sea were carried out for which no cost estimates have been included. With SAR alert and location equipment, properly monitored, the Congressmen might have been quickly located and expenditure reduced to a few thousand dollars. While specific accidents highlight the problem, general statistics are more indicative of what the real needs are to provide alert and location communications for SAR.

Reported marine and air accidents for 1969 were at a rate just under 50,000 per year and involved 170,000 people, 2,000 of whom were classified as saves, (that is people who would have been fatalities, if no rescue had been carried out). The fatalities amounted to 3700 and seriously injured 1,800.

The breakdown of these SAR activities is presented in Table 2-1. Beyond these reported accidents are an unknown number of unreported accidents. The relatively large number of saves in relation to the number of deaths is in a large measure the result of the outstanding performance of our rescue services when they are properly informed. However, the 5,500 seriously injured and dead (1969) do represent a serious loss. Not that one can put a value on life, but Massachusetts law awards $200,000 for each life lost in careless accidents. By this criteria, we are currently involved in a billion dollar loss in life.

Our investigation in this section illustrates that delay in rescue seriously decreases the probability of survival. Such a delay stems from two sources:

- o Excessive delay in alert notification or no notification at all.
- o Long search time caused by poor alert position information.

Let us now consider the marine accidents in more detail. NTSB (Report NTSB-MSS-72-3 by National Transportation Safety Board Special Study Survival Locator Systems for Distressed Vessels, August 16, 1972) cites ten recent incidents in the North Atlantic

TABLE 2-1. SUMMARY SAR AIR AND OCEAN INCIDENT DATA (1969)

	Incidents or Missions	Rescue Sorties	Hours	HRS Per Mission	Saves	Fatal Accidents	Fatalities	Seriously Injured	Persons in Distress
TOTAL	46,922	77,340	180,826		2000		3704	1800	170,000
AIR	4641*					665*	1373*	750*	10,000+
ARRS F	425	1716	5943	14	~230		~450	NA	NA
CAP F	614	14584	27,626	45	FEW			NA	NA
OTHER F	?	6840		33.5				NA	NA
MARINE									
USCG	42,281	54,200	188,000	3.15	1700	NA	2114		160,000
Deep Ocean	2684	Δ	Δ	Δ			217	173	

* Air accidents are generally over land and frequently do not involve flight activity in Search and Rescue figures are totals from NTSB.

F Air Search and Rescue.

Δ Deep Ocean Rescue requires diverting nearby commercial ships to the rescue incident. A days delay will run from 5000 to 200,000 dollars.

\+ Based upon 2.2 occupancy for typical GA aircraft.

involving the loss of 243 lives, where there is no record of successful transmission of a radio alert message. These sinkings represent only a few of such incidents where records were available. An analysis made by the Coast Guard of data taken from their marine incident reporting system (Table 2-1) shows the cumulative distribution of delay in notification as a function of distance off-shore. For accidents in mid-ocean, not within 300 miles of shore, (35% of the time) it took more than nine hours from the time of first sending of a distress message for the SAR system to become aware of the accident. Only 46% of the alerting were received in the first hour. That is to say, if alert notification was not achieved in the first hour the chances were 2 out of 3 that it would take more than 9 hours.

As a result of the long delay in the alert notification the loss of ships is unduly high. One quarter of all ships in the category over 300 miles were never located.

In addition to the direct loss associated with unduly long delays, there are also search costs which are significantly increased when the specific location of the incident is not known. When a search is in progress, ships are frequently delayed in their transit to look for and pick up survivors. Delay of a single ship may cost as much as $200,000 per day.

The poor alert performance can be attributed to communications failures. The principal systems involved for at sea alerting are HF and MF radio. The over-the-horizon performance of such systems is well understood and known to be sporadic in nature. As a result it can be concluded that while SAR in support of Coastal Boating is adequate, serious difficulties exists in providing adequate communications for deep ocean shipping.

Turning to aviation, certificated air carriers in the zone of the interior have no alert problem because of the close control exercised by the Air Traffic Control System. However, General Aviation and in particular VFR flights that do not fly under IFR control have <u>not</u> experienced an impressive record in rapid location and recovery of victims of crashes.

Currently, General Aviation aircraft usually file VFR flight plans with expected times of arrival. When an aircraft does not arrive at its planned destination on time, a communication check is made of other airports in the vicinity and if it is not found, search and rescue is initiated. The search is frequently delayed until the next day because of night fall.

A sample of one hundred ninety one air accidents where Search and Rescue was involved were analyzed. It was found: 7% were located the same day and 34% one day later. Of these only 5% of the accidents had any survivors.

From Table 2-2 one can see the search times required to locate lost aircraft. CAP on the average expend 44 hours/search. An alert device that located the aircraft would result in saving 5000 hours of ARRS flying time in addition to another 40,000 hours of CAP and other civil units. If one evaluates the ARRS flying time at $500/hr and civil time at $50/hr, this could easily result in a $4,000,000 per year saving. With the legistative requirement for ELT, there should be a reduction in this search cost as well as improvement on alert times and consequently a higher percentage of lives saved. This can only be verified in 1974 after ELT have been universally installed.

In summary there are three areas of concern relative to communications for SAR: Coastal Boating, Deep Ocean, and inland General Aviation.

- The capabilities of the coastal boating system have evolved from a self-help attitude among recreational boaters and strategically located rescue facilities. Current programs are underway to increase effectiveness in coastal regions.
- Deep Ocean Rescue presents a serious problem in the reliable and timely alerting of distress incidents and further in locating the survivors in the region of the incident.
- Inland General Aviation SAR has similar difficulties to the deep ocean case.

TABLE 2-2. CUMULATIVE DISTRIBUTION OF DELAY IN ALERT AS A FUNCTION OF THE DISTANCE OFFSHORE

	distance offshore								
	0-3	3-10	10-25	25-50	50-100	100-150	150-300	>300	Unknown
0	35.2%	39.3	36.2	34.6	43.6	32.1	20.4	31.6	31.4
≤ 1/2	82.2	78.3	73.8	72.2	72.0	64.3	44.4	42.8	52.5
≤1	90.0	85.7	82.9	79.0	78.8	76.8	51.8	46.0	55.6
≤1-1/2	90.9	87.7	86.3	82.7	82.7	76.8	57.4	49.3	58.3
≤2	92.7	90.0	89.0	84.2	87.2	80.4	66.7	53.3	62.3
≤3	94.3	91.9	91.3	86.7	90.5	83.9	68.5	58.6	67.3
≤4	95.2	92.1	92.6	89.5	95.0	85.7	74.1	59.9	71.3
≤6	96.3	94.8	94.1	92.3	96.6	89.3	75.9	63.8	75.8
≤8	96.7	95.6	94.5	94.1	97.2	91.1	79.6	65.8	77.6
≤9	96.9	95.6	94.9	94.1	97.2	91.1	79.6	65.8	77.6
	19253	2344	911	324	193	56	54	152	223

records counted 25,262

total cases ~42.000

no time available 217,000

Having established the general need for SAR alert and location capability, let us next turn to the specific properties that such systems should have. Finally a management structure will be required to implement the system that fulfills their requirements.

2.2 SPECIFIC TECHNICAL REQUIREMENTS

To design a SAR electronic alerting and location system, it is necessary to define the specific properties that the system must provide, such as: coverage, alert warning, time, alert location accuracy, traffic capacity, localization capability, and expected radiation life of the system. To determine what these parameters should be, we have examined a number of accident reports and reviewed with the organizations that are responsible for SAR, such as the Coast Guard, the Aerospace Rescue and Recovery Service and the Civil Air Patrol for their understanding of the needs. Some of the design parameters are readily improved beyond the point of any real utility at little or no extra expenditure such as alert time for satellites. Other parameters require extensive investment to improve beyond an initial capability, such as extending satellite coverage to the polar region. This study has balanced the requirements against the cost of achieving the result in the light of possible design alternatives. However, parametric cost design tradeoffs should be made before finalizing on any design specification. To summarize the results of our requirements studies, we present the parameters that have been selected in Table 2-3.

2.2.1 Coverage

A comprehensive SAR electronic alerting and locating system should provide global coverage both from the requirements of our own national maritime and air interests and also from the point of view of the multi-national interests. From the point of view of density of expected SAR events, this means coverage from 70° North Latitude to 60° South Latitude. Figure 2-1 shows the density of shipping for ships over 100 tons GWT. Figure 2-2 shows the shipping density plus fishing trawler density. Except for limited coastal

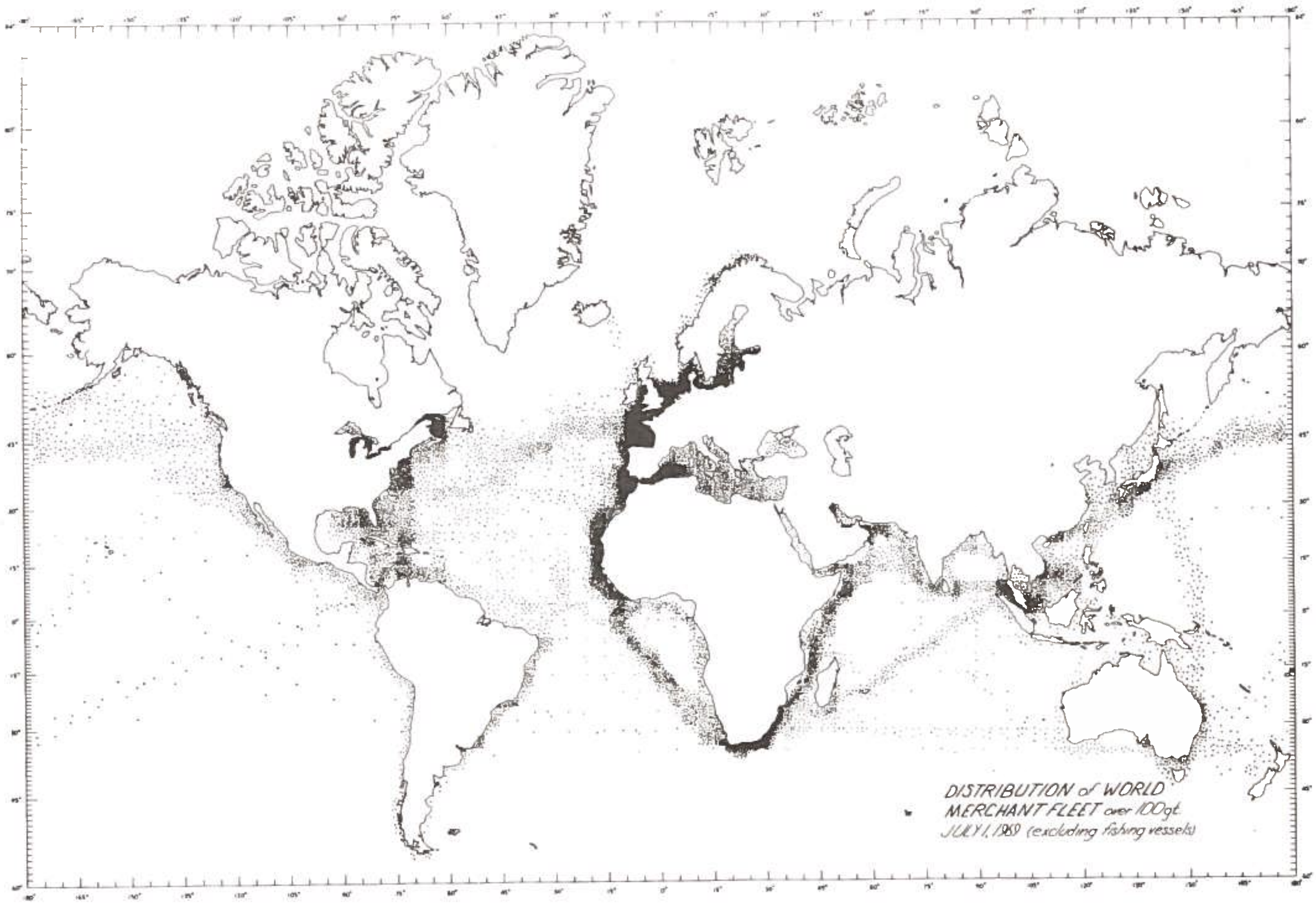


Figure 2-1. Distribution of World Merchant Fleet Over 100GWT July 1, 1969

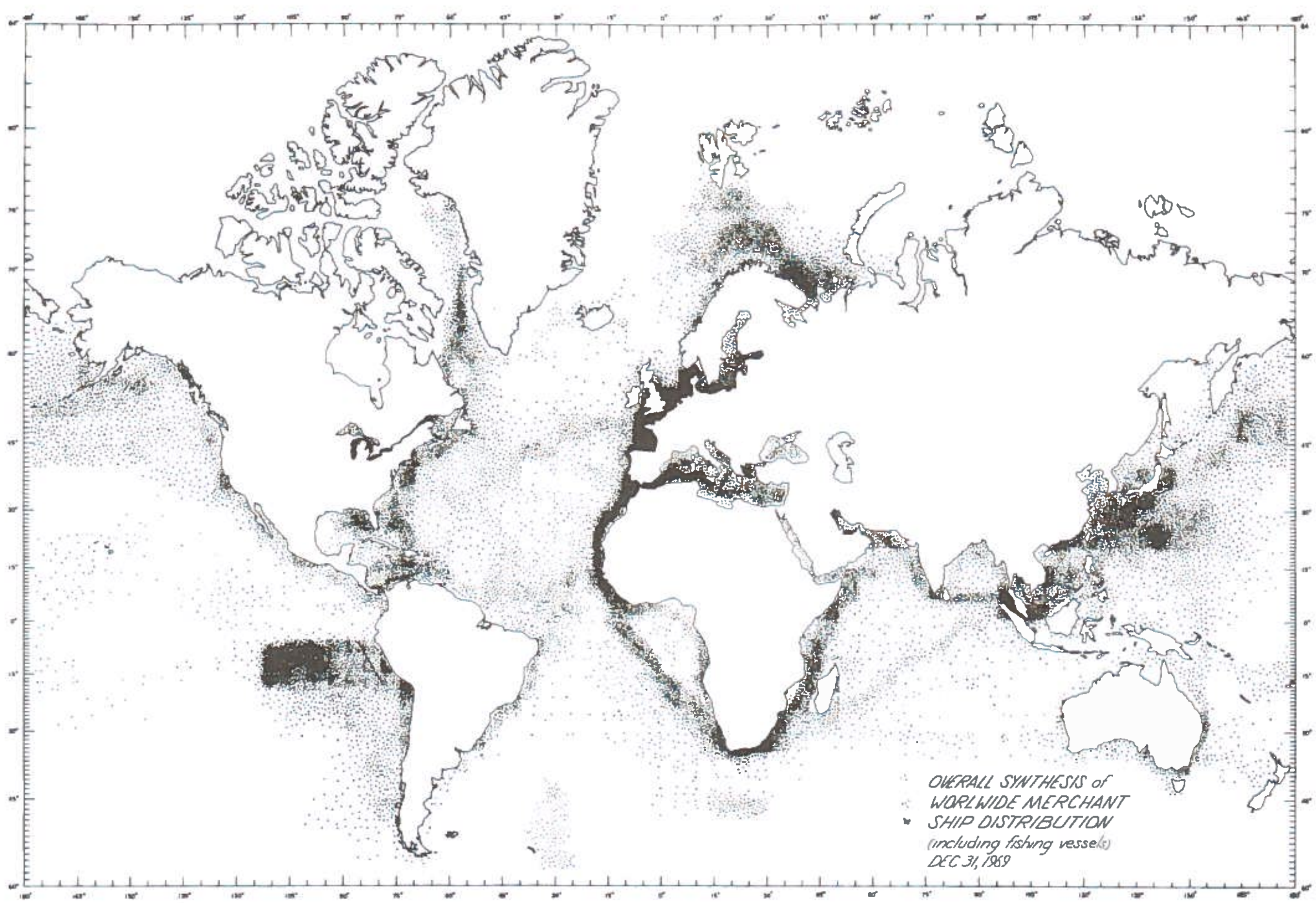


Figure 2-2. Synthesis of World Merchant & Fishing Ship Distribution

TABLE 2-3. SUMMARY OF REQUIREMENTS

Parameter	Performance	Conditions
Coverage	70° N to 65° S*	
	90° N&S	Would require 4 additional dedicated satellites costing $40 million (including launch cost)
Alert Warning	3 minutes*	easily obtained for satellite systems infrequently needed
	30 minutes	might increase loss of life 5% but more realistic
	300 minutes	could result in serious increase in loss of life
Alert-Location	1-3 miles*	would minimize search time and simplify RCC resource allocation
	3-10 miles	upper limits for circumstances where surface ships are used for search
	10-75 miles	upper limits where search performed by aircraft other than over rain forest
Traffic Capacity	Channel free 95% of time	
Seriousness notification	4 levels- automatic; high priority, mod. priority, nonpriority (manual)	
Operational Life	50 hours	Although environmental conditions may not permit rescue, it would be possible to establish a position fix for later rescue.
	100 hours*	90% of time weather conditions can be expected to change
Distress Surviv-ability	Must be capable of radiation after accident independent of severity	

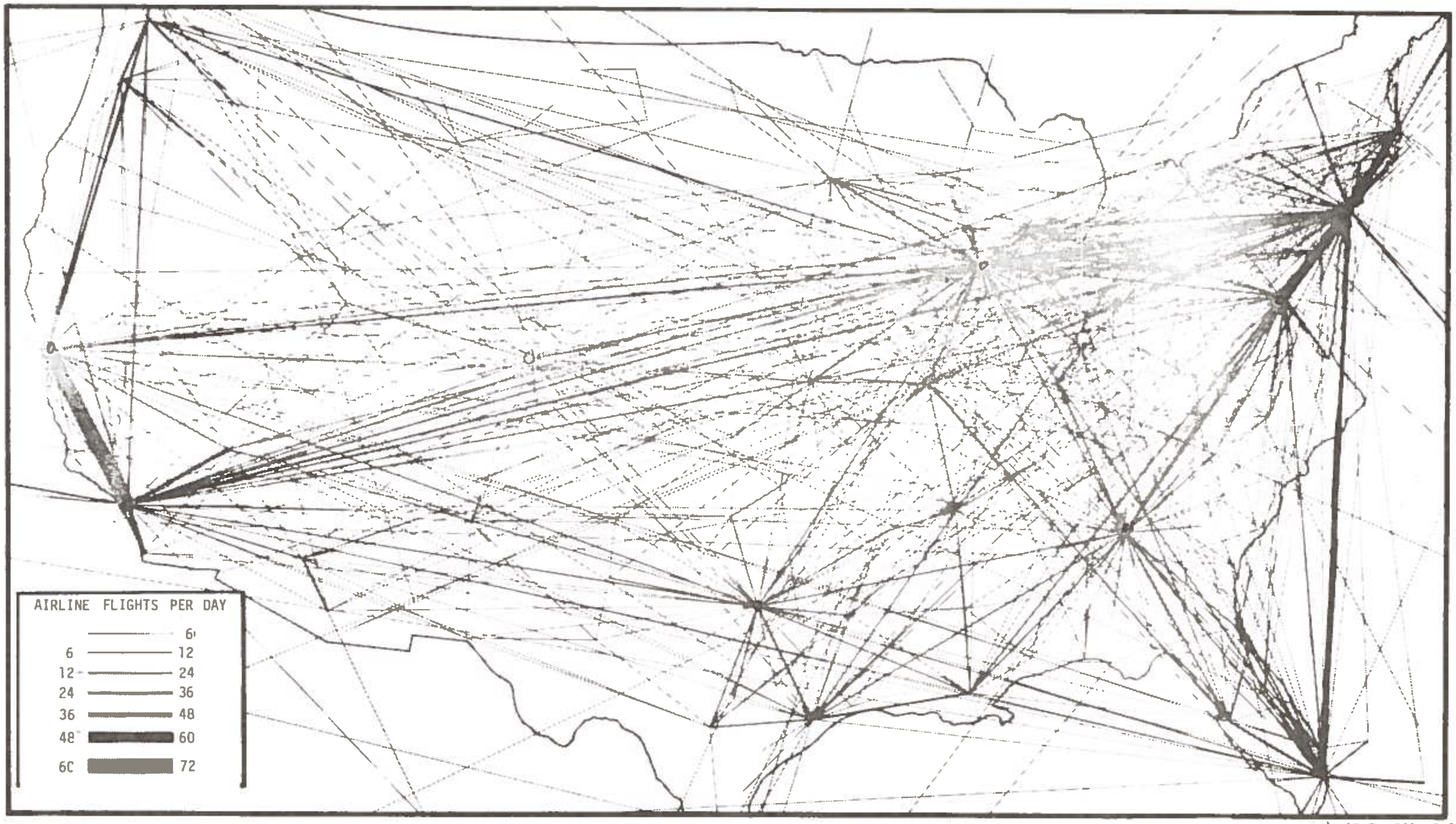
*Recommended

shipping on the Norway coast, there is no shipping north of 70° or south of 60° latitude; also, less than 1% of the fishing is done in these areas.

In addition, essentially all of the Continental air transportation would be covered within these limits. From Figure 2-4, it is apparent that a geosyncronous satellite could provide such coverage on a continuous basis. A system of three such satellites would provide 90% coverage at 70° and could be low in cost if it could go piggy-back on other communications satellites. A fourth satellite could increase this coverage at 70° to 100%. To provide total coverage, including the polar regions, would require additional polar orbiting satellites. The additional satellites would be dedicated to this project and as such would add (substantial cost) to the project. Since coverage to 70° will cover better than 98% of our shipping concern, such coverage should prove adequate. The specific SAR area responsibilities of U.S. are given in Appendix A.

2.2.2 Alert Time

In SAR incidents, where suvivors are critically injured or where severe environments exist, the time that it takes to retrieve survivors is critical to their survival. Therefore, SAR electronic alert and location systems should be designed to minimize that part of time that it takes to alert the rescue forces. However, in view of the time it takes to mobilize the SAR effort, and transit to the accident, there does not appear to be much gain in reducing alert time below one minute. On the other hand, delay times of the order of an hour can result in unnecessary casualties. The penalty for delay when accident victims are seriously injured can be judged from data that the National Safety Council has generated on accidents in general. In Figure 2-5 probability of survival in a serious accident is shown as a function of time it takes to provide medical aid. Figure 2-6 shows survival and death statistics for military rescue incidents and again the penalty for delay is apparent. The National Transportation Safety Board, indicated results that agree with these findings.



a)-AC Traffic Only

Figure 2-3. Airline Traffic Density for U.S.

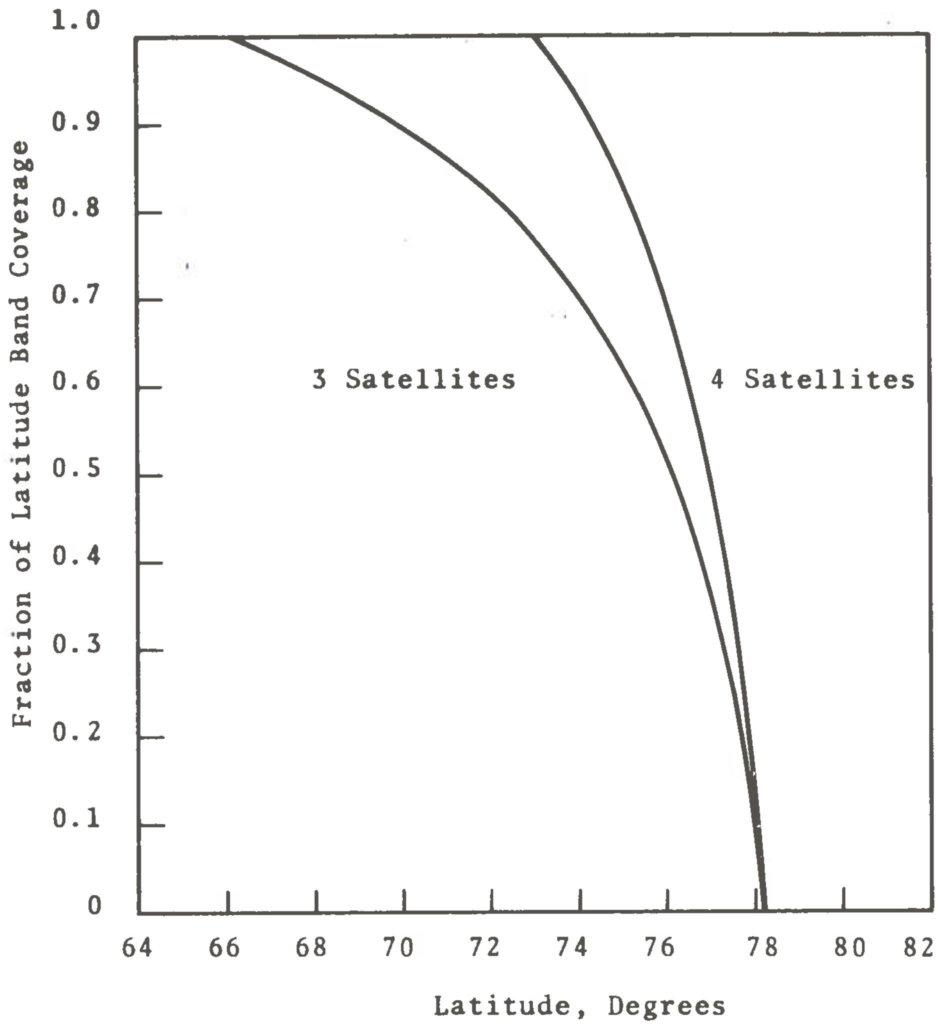


Figure 2-4. Geostationary Satellite Coverage

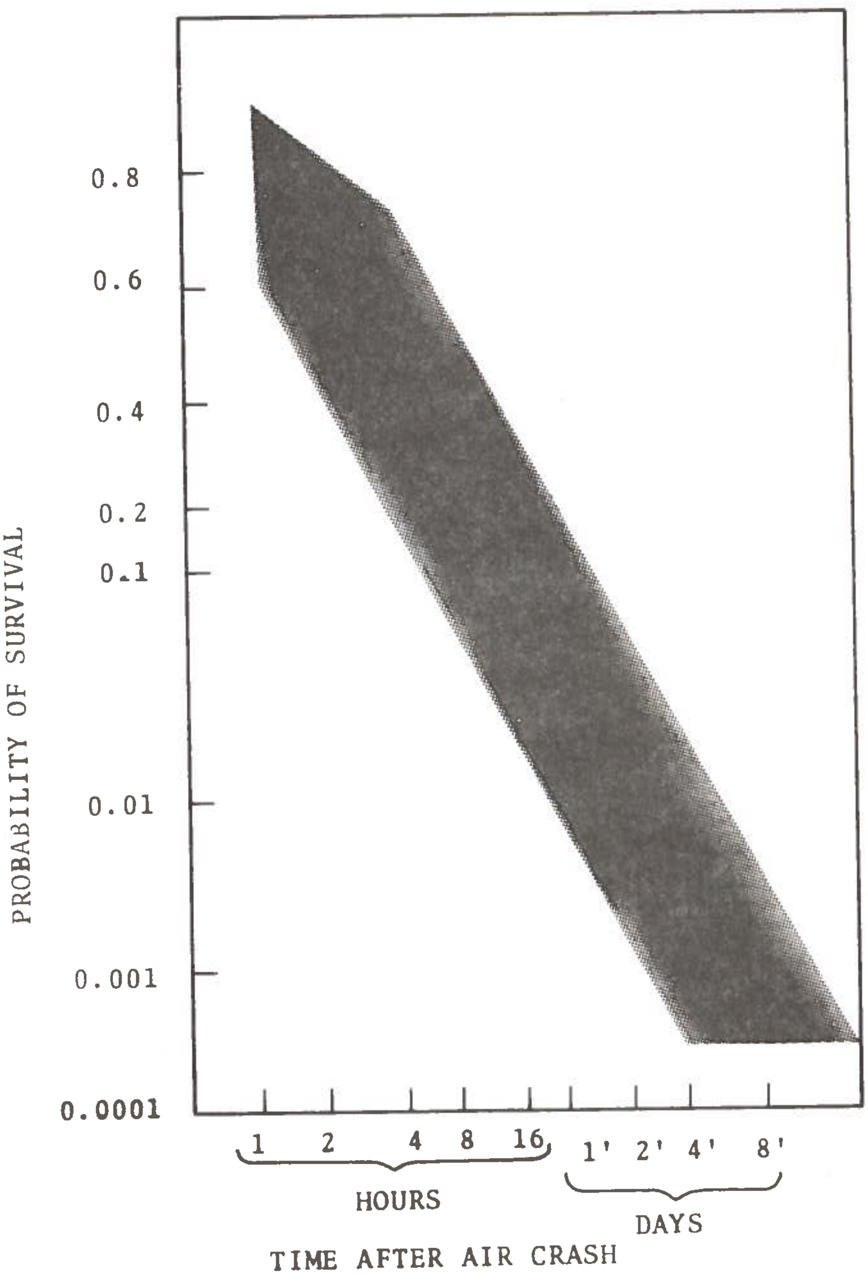


Figure 2-5. Survivability as a Function of Time after Crash

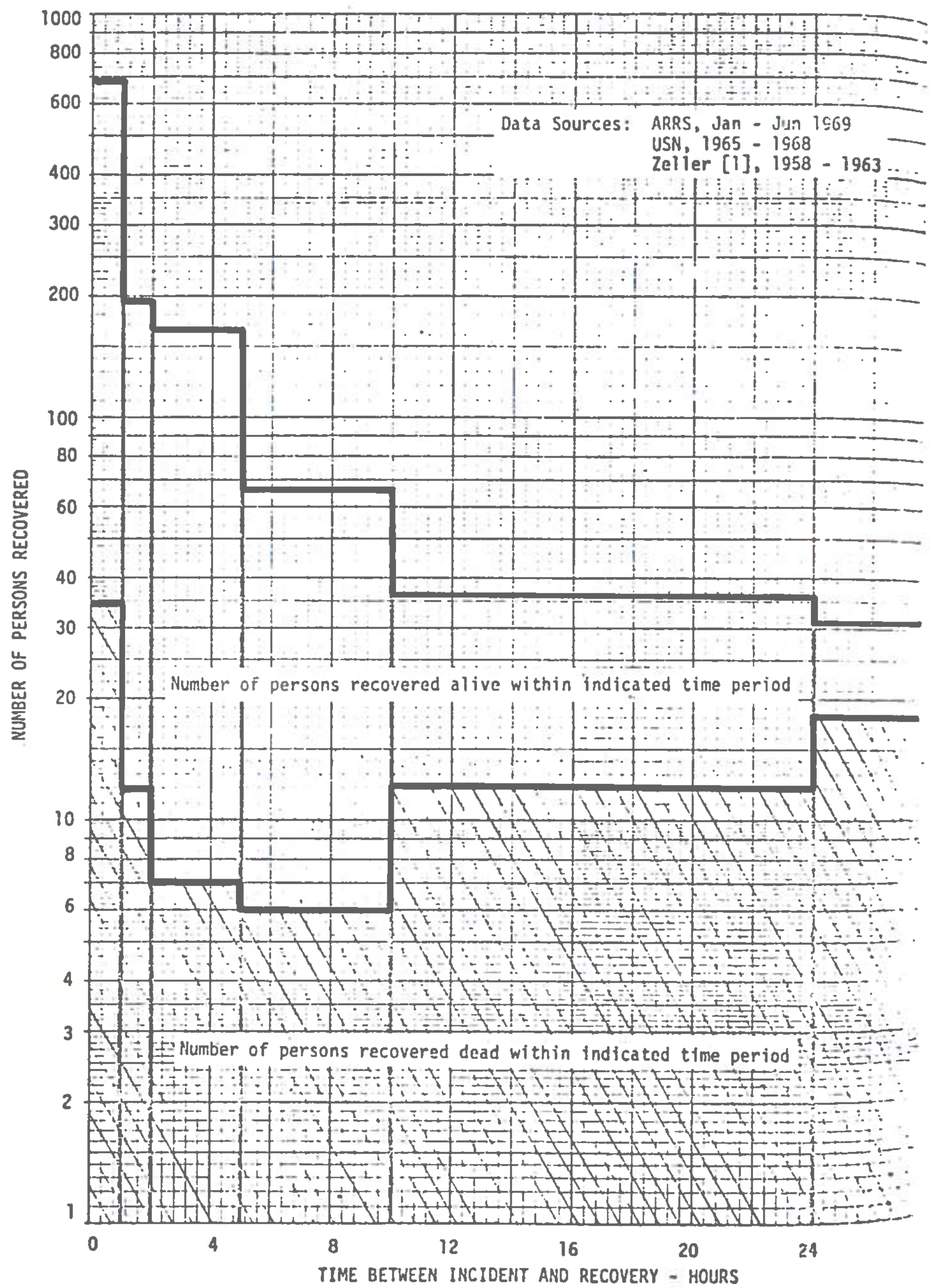


Figure 2-6. Recovery Status of Military SAR Victims

Severe environments even where accident victims are not seriously injured, also take a heavy toll of life. Table 2-4 shows the expected survival time of survivors in water as a function of temperature.

TABLE 2-4 SURVIVAL TIMES BY SEA SURFACE/TEMPERATURE RANGE

Sea Surface, %	Surface Temperature Range (February), °F	Maximum Range of Survival Time, Hrs
12.0	<35	0- 2.0
6.5	35-40	0.5- 3.0
8.5	40-50	0.5- 7.0
9.0	50-60	1.0-24.0
13.5	60-70	2.0-40.0
27.5	70-80	3.0-Indefinitely
23.0	>80	Indefinitely

We can translate these temperature survival statistics into its impact of overall probability of survival. The USCG accident data bank provides us with distribution curves of water temperature Figure 2-7. Combining these two sets of data we conclude that:

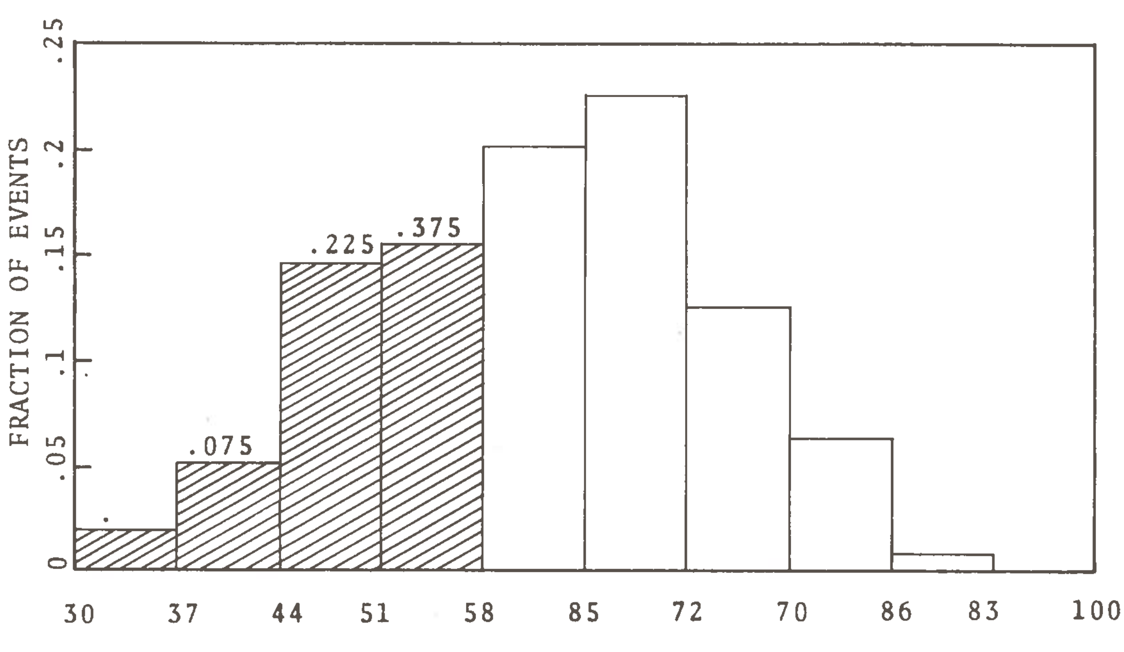


Figure 2-7. Distribution of Number of Sea Accidents as a Function of Temperature

forty percent of the victims would have survived less than a day. A quarter of the victims would have survived less than 8 hours and 2.5 percent less than 2 hours.

Fortunately, the rescue system in the coastal regions rescues 60 percent of the distress incidents in less than an hour. However, the results for incidents more than 100 miles off shore is much less favorable. Here it is found that 34 percent of the time alerts take 9 hours or more. This indicates that the LF, MF, HF radio systems which are used for deep ocean distress alerting are seriously inadequate.

Turning next to the question of survival of victims of aircraft accidents where severe environmental conditions exist. Humans can survive in environments ranging from Arctic cold to desert heat. However, there are certain extremes of temperature at which survival is difficult or impossible. In these cases, the critical variable is exposure time. Figure 2-8 shows the extremes of human temperature tolerance, determined experimentally, for resting men both nude and scientifically clothed for each zone of heat or cold.

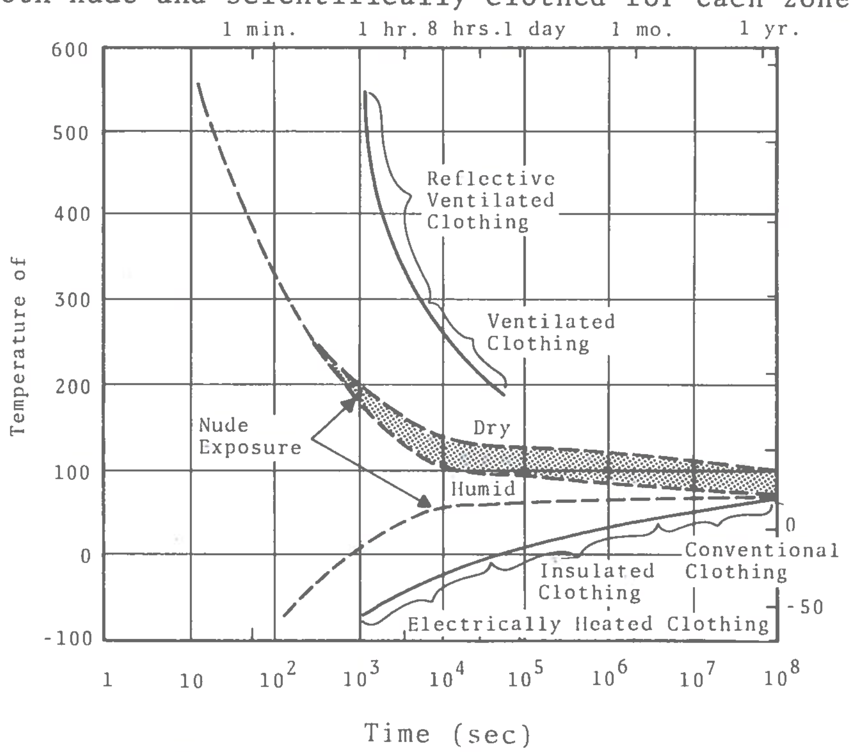


Figure 2-8. Survival of Air Victims in High and Low Temperature Environments

It should be noted that any movement of air passed by the body such as that generated by walking or running, has the same cooling effect as wind. Using the wind-chill index (Table 2-5), one must include speed of any movement in addition to natural wind speed.

In extremes of cold or heat, the body possesses more efficient, adaptive possibilities for heat stress than for cold.

Considering the survival time data under different environmental conditions it can be concluded that in a significant number of cases of cold weather, wind chill, and immersion in cold water that life expectancy is less than two hours. In the light of the fact that the rescuers will have to be mobilized, must transit to the region of the distress, and then search for the survivors, the time allowable for alerting must be made short compared to the other factors. If as much as 30 minutes were to be allowed for alerting, this could add materially to the mission time and in many cases might result in the loss of life. If on the other hand, the alert time were to be held to 3 minutes, it would always be small compared, to the other time factors and have little impact on the lives lost. Since the cost of improving from a 30 minute delay to a 3 minute delay in a satellite system is inconsequential, the shorter delay should be chosen. For air monitored systems the consequences of short delays are more sensitive to cost and the influences of environmental factors are less serious. The primary factor here is a question of survival after impact/injury in an air crash. Where general data indicates that time is critical, data specifically related to air crashes is needed to reach any decision. If such data were to indicate that an approximately 3 minute alert time is required, this would lead to the conclusion that a satellite monitoring system is needed for the Western U.S. and other remote areas. A program to collect the necessary medical data on aircraft accidents must be initiated if this question is to be answered.

In summary, an alert warning time of approximately 3 minutes is recommended for satellite monitored systems. For aircraft monitoring, a goal of 30 minutes alert time is more realistic.

TABLE 2-5. PROBABILITY OF SURVIVAL ACCORDING TO WIND-CHILL INDEX

Estimated Wind Speed (in mph)	Actual Thermometer Reading (°F)											
	50	40	30	20	10	0	-10	-20	-30	-40	-50	-60
	EQUIVALENT TEMPERATUE(°F)											
calm	50	40	30	20	10	0	-10	-20	-30	-40	-50	-60
5	48	37	27	16	6	-5	-15	-26	-36	-47	-57	-68
10	40	28	16	4	-9	-21	-33	-46	-58	-70	-83	-95
15	36	22	9	-5	-18	-36	-45	-58	-72	-85	-99	-112
20	32	18	4	-10	-25	-39	-53	-67	-82	-96	-110	-124
25	30	16	0	-15	-29	-44	-59	-74	-88	-104	-118	-133
30	28	13	-2	-18	-33	-48	-63	-79	-94	-109	-125	-140
35	27	11	-4	-20	-35	-49	-67	-82	-98	-113	-129	-145
40	26	10	-6	-21	-37	-53	-69	-85	-100	-116	-132	-148
(Wind Speeds greater than 40 mph have little additional effect.)	LITTLE DANGER (for properly clothed person)				INCREASING DANGER			GREAT DANGER				

Danger from freezing of exposed flesh

2.2.3 Location Information

The initial alert message must indicate where the distress incident is located. This information is required so that the appropriate Rescue Control Center (RCC) can assume the responsibility for the SAR activities and lay out its plan of action to effect a rescue. In planning and coordinating rescue activities the RCC must frequently allocate its resources against several different distress incidents. The better the accuracy the better this role can be fulfilled. The time involved in searching for survivors would be reduced and accurate position data may define the nature of rescue equipment so that the accident does not have to be reconnoitered before the actual rescue is started. As a consequence, the 1 to 3 mile accuracy that is achievable with the Omega-satellite type of system appears to be an attractive alternative. This order of accuracy will result in substantial savings in search time and costs as has already been indicated. Backing off to the minimum tolerable accuracies, 50 to 100 miles should be sufficient for air search in other than rain forest areas. For search by surface ships, this accuracy should be reduced to 10 to 15 miles. In inland cases where land parties are to perform the rescue, accuracies of 1 to 2 miles are required. Current data concerning the Coast Guard in its rescue activities, which are primarily along the U.S. coast, indicates that the position of an incident is known to better that a mile better than 90% of the time. (Figure 2-9). As a consequence, little time is spent in searching (Figure 2-10).

To repeat, a 1 to 3 mile accuracy is recommended for the alert phase information.

2.2.4 Traffic Capacity

Excess SAR-TEL-COM traffic may cause distress events to be lost by the system. Therefore, peak communications traffic loads must be determined for users; and then the system design made to accommodate for these loads, without saturating. Two kinds of traffic must be considered here: first, traffic arising directly

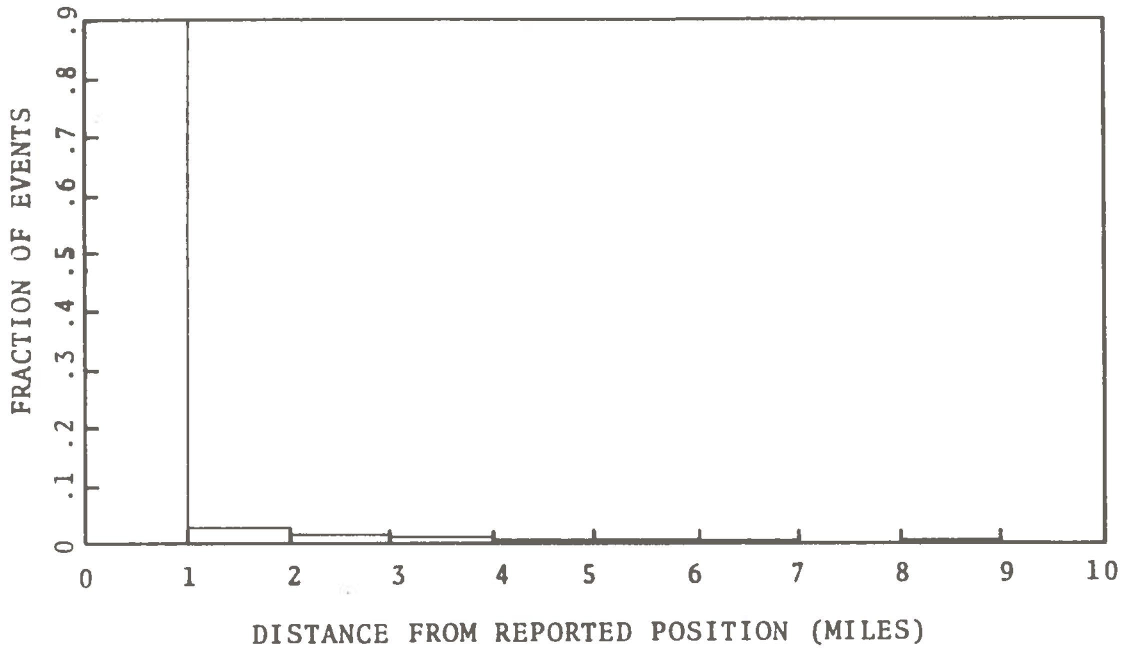


Figure 2-9. Distribution of Position Uncertainty for Ocean SAR Victims

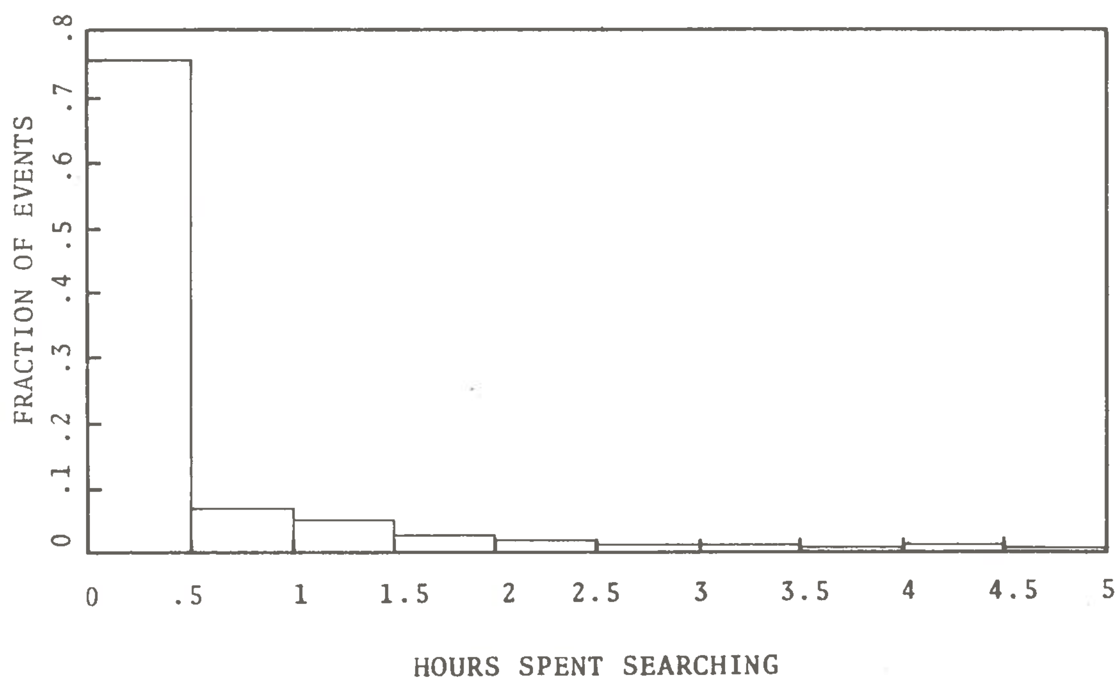


Figure 2-10. Distribution of Times Spent Searching for SAR Victims

from the expected frequency of distress events; secondly, traffic arising from false alarms which is related only to the number of vehicles. Table 2-6 shows hourly message frequency for aircraft, coastal boating and ocean ships. It also shows basic data for estimates. The aircraft and ocean shipping present few problems relevant to interferring using a single communication channel. However, coastal boating in all likelihood would have simultaneous messages if all traffic were on a common frequency. This indicates that the coastal boating problem is a different alert and location problem than for ships and aircraft and therefore, merits a solution that does not use a common channel with other users. Shore base line-of-sight receiving stations could reduce the traffic at each station to a reasonable operational level.

TABLE 2-6. COMMUNICATION TRAFFIC DENSITY AND FALSE ALARMS

	Max Hour Distress Events	Max Hour False Alarms	Yearly SAR Events	1 Peaking Factor	No. Craft
Coastal Boating	160	107[d]	36,000(1)	40[b]	4,000,000(4)
Aircraft	.696	4.0[d]	600(2)	10[b]	150,000
Oceanships	0.008	0.6[d]	70(3)	1	60,000

(1) USCG Data Bank
(2) CAP Civil Search Data
(3) Annual ships destroyed at sea
(4) Estimate number of boats over 20 feet
b Estimated traffic difference between peak and annual average
d Assumed 1 false alarm/32,000 craft/HR Based upon data from Elmendorf Air Force Base, 2 false alarms/day for 3,000 Alaskan Aircraft

An analysis of the channel capacity and preprocessing alternatives leads to the conclusion that better than 95% probability of achieving alert communications in the face of possible channel saturation can readily be achieved.

2.2.5 Seriousness of Incident

Past experience has indicated that the SAR-system cannot, within acceptable bugetary constraint, be supplied with adequare rescue craft to cope with peak load circumstances. As a consequence, priorities must be established between the incidents requiring service. To establish these priorities, the alert message must include priority information. Ideally, two way VOICE communication enables the RCC to evaluate the priority of candidates. But SAR coms designed for voice communication would be more expensive and have larger power and bandwidth requirements. Therefore, a coding for levels of emergency should be established and incorporated in the user equipment.

The levels of seriousness could be:

- o Automatic - operator incapacitated
- o High Priority } manual
- o Moderate Priority } manual
- o Low Priority } manual

2.2.6 Operational Life

The required operational radiation life of SAR electronic alert and location equipment should be much longer than the two days that is generally called for in current equipment. The life depends upon the time it takes to rescue the survivors; it consists of:

1. Alert Time
2. Mobilization and "Queing" Time
3. Transit Time
4. Localization Time
5. Delay in Pick-up Weather

The factor that calls for the long life is weather. Weather conditions can prevail for three or four days that make the retrival of survivors impossible. Heavy fog, high winds and severe icing are typical of such conditions. A review of weather statistics indicates that 90% of the time such conditions will pass in four days. The current requirements are in a large measure based upon capability of currently available equipment. These capabilities could be extended by increasing size and weight limitations so that more batteries could be included in the units, or providing better position information so that the searcher could start searching at a lesser range. The size and weight restraints on ELTs could easily be increased by a factor to two without detracting from the equipment either in the sense of portability or making it more difficult to incorporate in the vehicle. Providing better position data so that the searcher could start his search closer to the survivor is less tractable in that the survivor may move after the initial fix. A completely different look at the problem might offer a better solution: A reduction in the fraction of the time that the system radiates would result in an effective increase in the life of the system. There are two ways that this could be accomplished; the first is to make a unit that can be turned on and off by the searcher when he arrives at the scene of the incident. The second approach is to have a system that periodically transmits the position of the survivors with sufficient accuracy that the searcher could locate directly from this position data. In this type of system, it is important that the survivor and the search have a common coordinate reference frame. The differential Omega technique is typical of such a system.

The recommended radiation life for future SAR Alert and Location Equipment should be 100 hours. Such a life is compatible with the systems that can be developed; it will not materially add to the cost and will enhance the probability of rescue in severe weather conditions.

2.2.7 Distress Survivability

An obvious requirement of an SAR-COM user equipment is that it has the capability of surviving an accident. The accident that gives rise to the SAR-COM need should not prevent it from alerting the rescue forces. There are several things that must be taken into consideration to make the unit crash-proof:

- The unit must be sufficiently well constructed that it survives the shock, water immersion and other conditions that arise in an accident.
- The antenna must be so oriented after the accident that the monitor is not located in a nul of the antenna patterm.
- The unit will automatically start transmitting its alerting message independent of the condition of the survivors.

One problem that must be recognized is the overlap in conditions between normal operations and those conditions that prevail in a crash, which causes difficulty in distinguishing whether accident has occurred or not. This ambiguity results in an unduly high false alarm rate.

2.3 REQUIREMENT FOR SAR-TEL-COM MANAGEMENT

Responsibility for civil planning and development activities for SAR electronic alerting and location systems should be focused in a single office within DOT. On occasion differences in position will exist between the modal agencies within DOT relative to SAR alerting and location problems. Such matters should be resolved within the Department after consulting the various organizations involved rather than default to outside organizations actions. A recent example was the question of IPIRBS for recreational boating proposed by USCG and opposed by FAA. This question was resolved in FCC by a refusal to license small boats for use of 121.5 MHz frequency.

The responsibility for Civil SAR does not rest with DOT alone, but in conjunction with four other agencies that are signators to SAR interagency agreement: DOC, FCC, NASA and DOD. Therefore, if DOT is to be able to effectively negotiate with these other agencies, one civil SAR position should be developed: not each mode representing its own position in the interagency negotiations and discussions.

In few cases are SAR problems and their potential solutions unique to one agency. The coordination of requirements and investment must be made on department-wide basis to achieve best usage of the limited funds that are available for SAR. Let us point out a few examples of how problems run across modes.

The question of SAR electronic alerting and location for low traffic density regions is common to both USCG and FAA. In oceanic regions, Alaska and Western U.S., monitoring alert signals is found to be particularly difficult. On the other hand, in high traffic density areas such as coastal regions and highways the USCG and FHWA have common problems of false alarms and multiple simultaneous access.

Responsibility for providing a program for SAR electronic alerting and location system development exists between DOT and DOD. USCG shares operational and developmental responsibilities with DOD. FAA has no operational responsibility but shares development responsibility with DOD.

Another example of where split responsibility has resulted in a void in assumed responsibility is the question of monitoring ELTs. We have attempted without success to find within FAA or the air section of NTSB a clear position on just how successful the monitoring of ELTs is likely to be. Further, whether steps are necessary to improve this monitoring and, if so, who is responsible?

A single focus of responsibility within DOT would help to solve all of these problems.

3. DISTRESS ALERTING AND LOCATING SYSTEM ALTERNATIVES

3.1 GENERAL

It is doubtful that a universal SAR alerting and locating system can provide all the services desired by the diverse set of users. Rather, one can expect several systems that complement each other to evolve. The ELT monitored by air carriers will probably provide coverage for downed aircraft except over the oceans and in remote areas. A need exists to provide coverage for these last two cases; and it appears that only a satellite can provide such coverage reliably. There are two complementary programs that are under consideration that could meet this need. The first is a proposed maritime satellite and the second is the GRAN-DILS Program. GRAN and DILS are sufficiently close in concept that they have been viewed as one system. The proposed maritime satellite has the capability of sending extended messages which has obvious advantage; however, it requires power and antenna gain that are not compatible with survivor craft usage. Undoubtedly, the maritime satellite, if and when implemented, will be used by ships for emergency communications. To meet the SAR alerting and location needs for survivors on the oceans, and in remote areas, a GRAN-DILS type of system should be jointly developed by DOT and DOD. In this section of the report, the alternative systems that were considered will be described and the reasons that GRAN-DILS development was recommended will be examined.

Before attempting to make a comparison of the different systems, let us define what parts of the communications loop associated with SAR are under consideration. Figure 3-1 shows the communications that are associated with search and rescue. The distressed vehicle or survivor must send an alerting message to the rescue Coordination Center (RCC) to initiate the SAR activities. These messages are relayed by monitoring entities such as satellites, aircraft, ships or shore/ground stations. From the monitoring stations well defined reliable links exist to the RCC, such as private lines and commercial telephones. The RCC then mobilizes

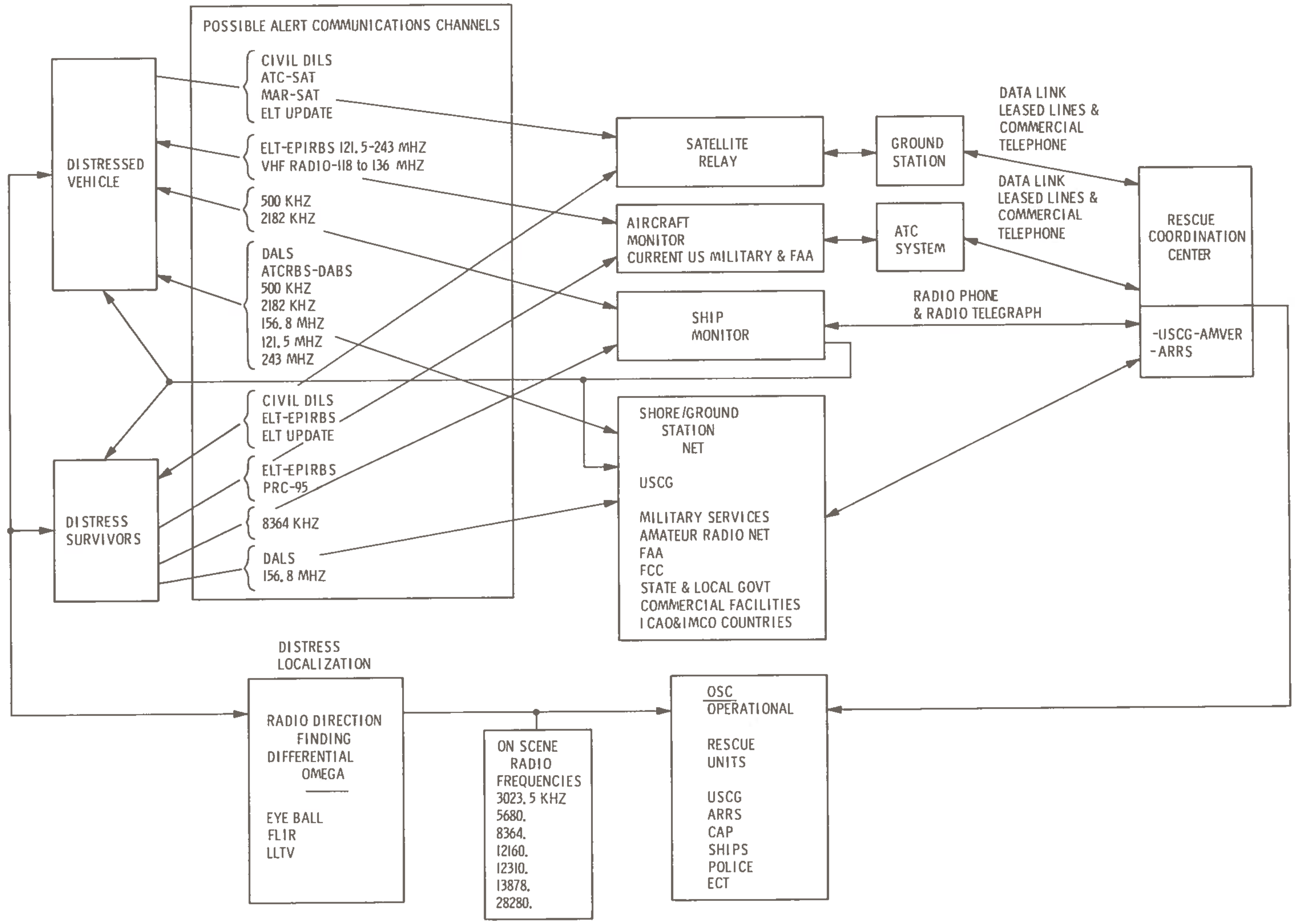


Figure 3-1. Data Flow SAR-TEL-COM Systems

the appropriate operational unit to search for the distress situation. The operational unit proceeds to the approximate location of the distress where it locks on to the distress signals and localizes to it by such techniques as Radio Direction Finding, Differential Omega, or more direct sensors (eyeball, LLTV [Low Light Level TV], and FLIR [Forward Looking IR sensors]. Of concern in this study is the first and last step in this loop. The first step establishes the link from the distress unit to a relay station. There are four possibilities:

- o Shore/Ground stations
- o Ships
- o Aircraft
- o Satellites

3.2 SHORE/GROUND MONITORING RELAY

3.2.1 SEA

First consider the Shore/Ground relay monitoring systems. SAR alert communications have been provided for the past 50 years by Over The Horizon (OTH) radio communications in the MF and HF bands to shore stations:

500KHZ - This frequency is the International Radiotelegraph distress safety and calling frequency and has been designated in the National Search and Rescue Plan as the CW distress and calling frequency. This frequency is monitored by automated equipment on on radiotelegraph equipped ships and at shore stations. This frequency is also recognized in International agreements through ICAO. In general, RT equipped ships beyond 300 miles at sea use this frequency for SAR.

2182KHZ - Is the International Radio telephone distress,safey and calling frequency and is used for RT equipped ships within 300 miles of shore.

8364KHZ - Has been designated as the International frequency for life boats, life rafts and survival craft.

Questions have been raised as to the utility of this frequency in the rescue picture.

SAR communications reliability at these frequencies is inadequate. Data generated by the USCG and presented in Table 2-2 shows that the probability of establishing communications within less than an hour is less than 50% and within 9 hours less than 65%. The long delays associated with establishing successful communications in the MF and HF bands have been traced to the loss of 10 ships with 243 lives in the past 10 years (NTSB Report NTSB-MSS-73-3, Aug. 16, 1972, Special Study Survivor Locator Systems for Distressed Vessels).

The U.S. Coast Guard has undertaken a major construction program for short range communications. The objective is to provide VHF-FM facilities for communications to a minimum of 20 nautical miles off-shore, along the major rivers and the Great Lakes. Coverage of the continental U.S. coastal waters is expected by the spring of 1974. Planning and construction is continuing in Hawaii, Puerto Rico and Alaska. Channel 16 (156.8 MHz) the National distress, safety and calling frequency in the maritime mobile VHF-FM band is used for this system. Coast Guard facilities provide continuous 24 hour watch on this frequency. Projected capability of the VHF-FM facilities expansion and a desire to avoid expenditure of funds for short range special purpose communications equipment has led the Coast Guard to evaluate electronic alerting and locating device (now under development) for operation in this VHF-FM band. The distress alerting and locating system (DALS) is currently configured to transmit Omega and Loran signals. The experimental system uses UHF frequencies around 350 and 400 MHz.

3.2.2 AIR

Aircraft communicate energy situations to FAA ground station facilities. The frequencies used are in the VHF 121.5 MHz, UHF and L-Band - thus line of site. Signals are generally only detected by ground stations when the aircraft is airborne. As a result, an aircraft might easily travel 100 miles after indicating an emergency before it crashes. The 121.5 MHz is voice AM radio and ground stations can DF to establish a LOP on the aircraft.

The L-Band System, ATCRBS (Air Traffic Control Radar Beacon System), is a coded Radar Transponder that has an emergency code. Range and azimuth of aircraft are established as long as the ground radar system has contact with the aircraft. The planned system calls for 99% coverage of U.S. over 6000'(Above Ground Level). In its current configuration, ATCRBS would be useless to locate the crash. However, the ATCRBS system could be modified to serve in the additional role of a crash position indicator. This requires developing new equipment for search aircraft and modification to current avionics. It would have the advantage of only transmitting when triggered and, therefore, achieve longer potential battery life than free running systems.

3.3 SHIP MONITORING RELAY

The next class of equipment are monitored by ocean going ships. These are the same as those monitored by shore stations. RT equipped ships monitor 500 KHz. A proposed ammendment to the IMCO Convention will require radio-telegraph equipped ships to monitor 2182 KHz when ratified by 2/3 of member countries. Monitoring may later be extended to 121.5 MHz if EPIRB, Emergency Position Indicating Radio Beacon, is proposed and approved in the future. The equipment for monitoring 500 KHz can employ automated alarm devices so that alerts are received whether the operator is on duty or not. One consideration that continues to make MF radio attractive for an emergency system at sea is that the range of the ground wave extend beyond the line of sight. So that nearby ships which are most likely to render assistance are alerted over a larger area than by VHF. At 300 miles the attenuation of 500 KHz would be only 30 dB less than at one mile, hence a relatively high probability of detection would result.

3.4 AIRCRAFT MONITORING RELAY

Aircraft monitoring of distress incidents is currently being carried out by the Air Force and other government aircraft which monitor 243 MHz one the the authorized ELT's emergency frequencies. Most general aviation aircraft will carry an ELT as required by law after Jan. 1, 1974. Air carrier monitoring as a possible means of alerting SAR forces would prove to be sufficient in regions of high traffic density - those regions are shown in Figure 3-2. However, more that 75% of A/C accidents in the Continental U.S. requiring search and rescue response occur in regions where alert monitoring on an hourly basis is open to question.

World wide monitoring by aircraft is not at all practical. More than 2/3 of the Earth's surface would not receive weekly coverage by ad hoc flying of aircraft involved in other missions. To provide twice daily coverage to these regions by aircraft dedicated to this mission would cost more than 1 billion dollars per year and a system investment of twice that amount. If air carriers monitor ELT frequencies and report distress alerts via the ATC system, this may provide sufficient coverage to alert 90% of the downed aircraft incidents within 12 hours of occurrence for the 48 states. This is based upon an analysis of airline coverage derived from plotting estimated positions of the U.S. air carrier fleet from the Official Airline Guide every 2 hours on a typical week day. See results in Appendix B.

A program should be initiated to evaluate the effectiveness of ELTS in alerting search and rescue organizations to the occurrence of aircraft accidents on the North American continent based upon operating experience.

This program should establish the level and adequacy of alert coverage that might be expected in the future. The Emergency Locator Transmitter (ELT) is a commercially available device (Appendix C) carried by aircraft, that when turned on, transmits a swept frequency radio signal on 121.5 MHz and 243 MHz (Appendix D). ELT's can be turned on either manually or automatically, SAR Aircraft can home on the transmitter to locate the lost aircraft. In 1974, most General Aviation aircraft will carry an ELT as a result of Public Law 91-596 passed by the 91st Congress.

In addition, the SAR system can get some measure of alert information from military and other government aircraft monitoring ELT frequencies on an ad hoc basis as they pursue their normal flight missions. The ELT was developed during World War II and

	SIGNAL FORMAT	SPECIFIC SYSTEMS	MONITOR	USER	FREQUENCY	YEARS TO AVAILABILITY	CAPACITY	COVERAGE/DELAY	LOCATION		SEVERITY DATA	VOICE	COST DATA: USER UNIT	COST DATA: PROCUREMENT	COST DATA: ANNUAL	REMARKS
DIRECT OVER THE HORIZON RADIO	CW	INT. CW DISTRESS F	SHIPS & SHORE	SHIPS	500KHZ	0	OK	GLOBAL-INRELIABLE	DF		YES	CW		0	?	IN SERVICE
	VOICE	INT. VOICE DISTRESS F		SHIPS AIRCRAFT	2182KHZ	0	NO	RELIABLE TO 300 MILES			YES	YES				
	?	INT SURVIVOR CRAFT DISTRESS FREQ.		SURVIVOR CRAFT	8364KHZ	0	OK	30 MILES NOT VERY USEFUL								
LINE OF SIGHT RADIO SYSTEMS	VOICE RADIO	INT. AERO EMERG. MILITARY EMERG.		DOWNED CRAFT	121.5KHZ	0	OK	LIMITED	DF	100'	YES	YES	$300	0	?	IN SERVICE
						0					YES	YES				
			SHORE	SURVIVOR		0					YES	YES				
	BEACONS	ATCRBS DABS	SURFACE	INFLIGHT AIRCRAFT	L BAND	0	OK	99% COVERAGE OVER 6000' ABOVE SURFACE INSTANTANEOUS	DF	?	NO	NO	$1200	0	0	IN SERVICE
		ATC SAT	SATELLITE	AIRCRAFT	L BAND	3	OK	NORTH AMERICA-INSTANTANEOUS	NONE	50'	YES	YES	$1200	NA	NA	DUBIOUS IT WILL BE IMPLEMENTED.
		ELT EPIRBS	SHIPS	DOWNED AIRCRAFT & SURVIVOR CRAFT	121.5KHZ & 243MHZ	?	OK	VERY LIMITED		100'	NO	NO	$100	?	—	
			AIRCRAFT			0	OK	EASTERN USA-INSTANTANEOUS WESTERN USA TWO HOURS TO NEVER		100'	NO	NO		$10M	$1M	PRESENTLY ONLY GOVT A/C MONITOR THEREFORE INADEQUATE
			HISAT			7	NO	GLOBAL INSTANTANEOUS			NO	NO		$80M	$8M	POWER MARGINAL.
			LOSAT			7	OK	GLOBAL 20 MIN.		5MI.	NO	NO		$80M	$8M	
		SLG	AIRCRAFT	DOWNED AIRCRAFT	243MHZ	3	OK	100 MILES FROM AIRCRAFT	DF	5'	YES	YES	$400	?	?	PLANNED 1978
	OPLEBASED SYSTEMS	GRAN-DILS	AIRCRAFT	DOWNED AIRCRAFT & SURVIVOR CRAFT	408.6MHZ	4	OK	LIMITED INSTANTANEOUS	Ω	5MI.	?	NO				PLANNED MID 1978
			HISAT			4		GLOBAL INSTANTANEOUS	ΔΩ	300'		NO	$200*	0	0	
			LOSAT			4		GLOBAL 20 MINUTES				NO		$80M	$8M	
		DALS	SHORE	COASTAL BOATING	156.8MHZ	4	OK	COSTAL USA	DF / ΔΩ	100' / 300'	YES	YES	$200*	$2M	?	POSSIBLE 1976

*COST OBJECTIVE

FUNDS TO BE EXPENDED BY THE MILITARY

Figure 3-2. Alternative SAR-TELE-COM Configurations has been used by the military with some degree of success ever since. Since then numerous incidents of both military and civil rescue have been recorded which attribute their success to ELT's both as an alert device and for incident localization. In phone discussions with Major Eldridge of the RCC at Elmendorf Air Force Base, in Alsaka, he reports quantitatively major savings in search time for rescue incidents where ELT are carried. They have not done any analysis of results. Further, in our pursuit of the subject through FAA, ARRS and NTSB we have been unable to unearth any creditable statistical analysis which lead to a quantitive evaluation of ELT alert performance.

We have reviewed flight densities over Northern Maine and certain areas of the Western U.S. (Appendix B). In light of the fact that 75% of the lost aircraft resulting in fatalities, crash in these regions, the alert capabilities of the ELT may be inadequate. Therefore, we have concluded that to understand the utility of ELT's for SAR activities, a data collection and measurements program should be carried out. This program should address the following questions:

- Quantatively, how will ELTs perform as an alerting system when they are fully deployed in 1974?
- Do the inadequacies arise because of lack of monitoring coverage or technical deficiencies in the ELT?
- What improvement in alerting would have been realized if air carrier coverage had been available?
- Are the uncorrectable deficiencies sufficient to justiry an alternative approach such as GRAN-DILS for inland applications?
- What is the false alarm rate with ELTs? What can be done about it?

This program should be carried out during 1974, the first year of complete ELT deployment.

Although we cannot say how ELTs will perform, the fact remains that they are the only airborne equipment with alerting and locating capability that will be installed in 1974. Every effort should be made to see that all the potential for alerting and localizing downed aircraft is realized and such deficiencies as exist in the system corrected. This system must provide the best possible alert capability until a new system is deployed.

There is a maritime counterpart to ELT called the Emergency Position Indicating Radio Beacon (EPIRB). This equipment is identical in its radio emergency signal to the ELT. The Coast Guard has proposed rule-making to require inspected vessels to carry EPIRBS units on their life boats.[1] Initially, it was also proposed to encompass recreational boating but the FAA and ARRS objected. FCC limited usage to registered vessels because of potential channel saturation by recreational boat users, which number about 8 million. Between the higher incidence of accidents, 10/hr and expected false alarm rate 40/hr, the channel would be saturated for air users. The EPIRB has utility for locating victims at the scene of an accident. This is sufficient justification for EPIRB, however, the probability of successful alert is much more limited than those of ELTs because, aircraft over flights are primarily limited to heavily used transoceanics routes.

In addition to the operational evaluation studies, we suggest that certain technical questions be evaluated to reduce the lead time in implementing a program for upgrading ELT-EPIRB performance. An investigation of air carrier monitoring of ELTs and EPIRBs to determine:

- Effect on crew work
- Possible automation of monitoring process
- Maintenance and cost problems associated with installing guard band receivers on air carrier aircraft
- Impact SAR monitoring would have upon the ATC System
- Mechanism which can be used to induce air carriers to monitor ELTs.
- The battery life and temperature problems

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[1] Department of Transportation, Coast Guard, Federal Communications Commission, Emergency Position Indicating Radiobeacons (Proposed Rule Making), Monday, March 5, 1973, Washington, D.C., Volume 38, Number 42, Part II

- Radiation problems associated with forest environments and antenna positions at time of accident.

3.5 SATELLITE MONITORING RELAY

Satellite monitored alerting and locating systems offer the lowest cost possibility for providing a reliable system with frequent access and global coverage. There are a number of possibilities that could work through a satellite:

GRAN/CIVIL DILS
ELT EPRIB
ATC SAT
MAR SAT

The ATC satellite, if implemented, would provide an ideal solution for monitoring aircraft emergencies. As proposed in the AATMS Program, the ATC satellite would provide surveillance, navigation and communication. This system would establish to within 100 feet, the position of a crash. Verification that the crash had occurred would require only a few seconds. There would be no additional cost to the user as the aircraft beacon would be in the aircraft for basic communications and air traffic control. It is unlikely that an air traffic control satellite will be operational before 1985, if then, it would only cover Continental North America.

3.5.1 Maritime Communications Satellite

The maritime communications satellite has progressed upon a predominant need for improved communications. Safety communications would coexist with operational traffic although there would necessarily have to be a priority interupt for distress communications. Alerting signals could be initiated through the shipboard satellite terminal. Location could be sent as a dead reckoned or known position, Loran or Omega signals for remote processing or if the capability exists in the satellite system through ranging signals from several visible satellites.

A MAR SAT communication chanel can be used to request support from ships which the AMVER system indicates are in the area of the distress. However, it is less suitable for circumstances where the alert message must be initiated from the survivor craft. The proposed maritime satellite uplink is 1636.5 - 1644 MHz Band. As opposed to 408 MHz proposed for GRAN DILS or 121.5, 243 MHz for ELT. As a consequence, the loop gain-power budget for the unit accessing a satellite would have to be increased by 12 dB to achieve comparable probability of successful alert notification at the higher frequency. This could be accomplished with increased power or antenna gain or a decrease in band width requirements by preprocessing of signals prior to transmission. The antenna gain option can be ruled out because the antenna would have to be aimed at the satellite. The possible options for such pointing are either costly or place unreasonable demand upon the survivors. The power option would demand larger, heavier and more expensive units. Preprocessing the received signals to narrow the bandwidth should be examined. However, providing for 400 MHz channels on MAR SAT would undoubtedly provide a less costly system option. When considered from an overall survivor system point of view, AERO SAT would have an advantage over MAR SAT because of spot beam antennas on the satellite reducing the power gain requirements of the ground systems. This option should be investigated.

3.5.2 ELT & EPIRB Satellite

ELTs and EPIRB can be detected from satellites, however, locating them on the surface of the earth with sufficient accuracy to initiate a search involves dedicated satellites. This would make such a system more costly than a system that could use a relatively small amount of channel capacity on a satellite that was servicing other functions. Traffic capacity is another difficulty for satellite monitored ELT's. ELT's signal format is already established so that separating signals to increase traffic capacity will involve either modifying or replacing units that are in the field.

The ELT signal format does not provide position information, so that the satellite system must itself make measurements to determine where the ELT is located. There are several possible options for making such a measurement. If a syncronous satellite monitoring system is used, either a set of three satellites must observe the ELT or a single satellite with three antennae more than 30 feet apart. If a low altitude satellite is used, the range rate (doppler shift) principle could be used to locate the ELT. In either case the satellite system is sufficiently complicated to require a dedicated system.

The fact ramins that the ELT will be required equipment on GA aircraft, probably an investment of 15 to 20 million dollars. This results in substantial pressure from the GA community (AOPA, NPA, GAMMA & NATC) to provide adequate monitoring. However, the development time required to implement satellite monitoring is so long, that other alternatives already under development could be available two to three years earlier. The development, implementation and operational cost of these other systems would be much less because:

- o They would be (shared with) the military
- o The satellite equipment could be piggy-back on multi-mission satellites.

The question of user investment is one of timing. If ELT were to be satellite monitored, it is unlikely that this could occur before 1981. By this time, users would be purchasing replacement equipment. We have compared replacing ELTs with GRAN DILS at this transition point and find that the total direct and allocable cost to the user is 3 million dollars less per year for the GRAN DILS alternative.

3.5.3 GRAN DILS

A promising alternative to satellite monitoring of ELT's could be developed by joining of two programs that are currently in progress: The GRAN system, an experimental system developed jointly by the Naval Air Test Center at Patuxent, and NASA Goddard with the DILS concept that is currently being developed by Cincinati Electronics for the USAF Wright Air Development Center's Life Support Group. The latter has program responsibility for Tri-service SAR Development. (We will refer to this combined program as GRAN DILS.) Both of these programs are in the conceptual phase of advanced development. These two programs are based upon the OPLE concept of relaying OMEGA signals and from a local device via satellite to a processing center. However, the predevelopment units are not interchangable.

3.5.3.1 GRAN - Any discussion of GRAN should start with a predecessor system called OPLE (OMEGA Position Location Experiment). OPLE equipment was developed by Texas Instruments under NASA contract and was not intended primarily for Search and Rescue operations. The requirement established was for the simultaneous tracking of up to 40 floating platforms by means of satellite relay of OMEGA signals. GRAN adapted these concepts for a SAR application.

Since the total bandwidth allocation for OPLE was 100 KHz, this value was divided by 40 to arrive at bandwidth for each Platform Electronic Package of 2.5 KHz with the intention of using a frequency multiplex scheme for multiple access to the ground station.

The VLF signal-to-noise ratios specified for the OPLE system were extremely poor (zero dB in a one Hz bandwidth), which necessarily led to a high degree of complexity and sophistication in the design of ground equipment and long processing times on received data in order to determine platform position.

The 2.5 kHz bandwidth requirement was carried forward into the present General Instruments, Inc. preprototype SAR COM transmitter which accomplishes this by means of a folded spectrum technique.

The total double-sided bandwidth of the OMEGA spectrum is 27.2 kHz. However, the band actually occupied by the three OMEGA signals encompasses only 3.4 kHz. (This bandwidth could be achieved directly by suppressed carrier SSB.). If the signals are to be altered in frequency (as in the SARCOM), it would be possible to coherently side-step them to a bandwidth of only a few hundred Hz. With digital preprocessing, even smaller bandwidth requirements could be achieved. Naturally, bandwidth will have a direct bearing on required transmitter powers and antenna gains and a wide bandwidth will, therefore, have an adverse effect on battery life. It can, therefore, be assumed that the GRAN SARCOM is really satisfying an earlier requirement and is a less than optimum design for the GRAN application.

On technical grounds, such as these, we can discount reports that GRAN hardware already exists and conclude that GRAN is still in the conceptual stage. The hardware used for GRAN experiments is really OPLE hardware.

These objections not withstanding, a partially successful GRAN test of OMEGA satellite retransmission was conducted (under idealized conditions) late in 1970. A van was equipped with OMEGA receivers, satellite transmitters and a portable power generator and used to retransmit OMEGA signals via satellite to the Texas site. In a sense the entire van can be considered a hand held SARCOM for purposes of this test. An up-looking antenna was mounted on a mast above the van to minimize ground problems.

Transmitter output power was set at 4 watts during satellite/ground station acquisition and then dropped to 900 milliwatts for OMEGA retransmission after acquisition was achieved. This procedure has been termed the "exalted acquisition reference" scheme.

Operation during the tests was apparently quite reliable, although consistent errors of about 27 miles in position determination were noted at certain times of the day. These errors were attributed to faulty correction of variations in OMEGA propagation velocities.

Tests were also performed utilizing Differential OMEGA techniques with much improved accuracy. Differential OMEGA has not been seriously considered for GRAN or any other rescue system in the alert phase of the operation, since it requires a separate retransmitter at a precisely known location in the immediate vicinity of the retransmitter at the unknown location.

In spite of the deficiencies noted and the idealized test conditions, we can conclude from the GRAN tests that position location by means of a satellite retransmission of OMEGA signals is possible.

Since GRAN has not reached the stage of having its own optimized hardware, the system must be discussed in conceptual terms.

GRAN is planned to consist of hand-held retransmitters, which communicate directly with synchronous satellites. The satellite will, in turn, retransmit these signals to a ground station for processing to determine the position of the hand-held retransmitter (SARCOM).

Although the operating principles are quite different from those of the ELT, several of the problems associated with the ELT will also affect the SARCOM. In particular, if the SARCOM is to be hand-portable, antenna orientation may prevent satellite access. Also, it is doubtful that a user in a distress situation can always be expected to carefully position his antenna. Deployable antennas can probably be designed to minimize the orientation problem, but such antennas would necessarily have negative gain (this would be acceptable with high gain antennas on the satellite and relatively high transmitter powers).

If the SARCOM is to be small and lightweight like the ELT, batteries must also be small, but transmitter power necessary to access a satellite may be considerably higher than the power output of an ELT. Therefore, battery life is again expected to be a serious problem. (The SARCOM might be operated with a low duty cycle to alleviate but not eliminate this problem.)

Because a very large number of SARCOMS would be in the hands of private users on a worldwide basis, simultaneous multiple access on a large scale must be provided.

This seems to imply SAR electronics package on a multifunction satellite. GRAN advocates have recommended dedicated satellites called SARSATS.

Satellite link calculations must be somewhat arbitrary at this point in time because all system parameters are still variable. However, a sample calculation directed at determining required minimum transmitter power is provided below.

For purposes of this calculation, we will assume that the present SARCOM bandwidth of 2.5 KHz is used, that a special non-orientation-sensative transmitting antenna has a minimum gain of -3dB, that an acquisition reference signal-to-noise is required in order to access within the 2.5 KHz bandwidth (will improve acquisition), and that the satellite has a minimum receive antenna gain of 15 dB to 8 dB for antenna pointing and station keeping errors on a synchronous satellite. This implies a 12 ft. dish which in turn, leaves no further question that the satellite be dedicated exclusively to this application. For ZERO dB S/N, signal must be KTB. Assuming a noise temperature of 600 degrees

$$KTB = 2.06 \times 10^{-14} \text{ milliwatts}$$
$$= 137 \text{ dBm}$$

For synchronous orbit of 20,000 nautical miles or 3.7×10^{7} meters, path loss will be 176 dB at 400 MHz.

Therefore:	Required Signal	-137 dBm
	Plus Path Loss	176 dB
	Less Receive Ant. Gain	-15 dB
	Less Transmit Ant. Gain	-(-3dB)
	Transmitter Output Power Required	+27 dBm

This analysis shows that acquisition can be achieved with a transmitter power of 1/2 watt and since processing can be performed at lower signal-to-noise ratios after acquisition, transmitter power could then be reduced to conserve battery life. However, no consideration has been given for ground effects. If we assume that vertical attenuation due to foliage is 2 dB for light cover, 8 dB for medium cover, and 22 dB for dense foliage, the required initial transmitter powers become 0.8 watts, 3.2 watts and 80 watts.
We can conclude from this, that SARCOM transmitter power should be greater than 1/2 watt for improved operational reliability but that there will still be some conditions under which the GRAN system can not work.

Another major problem of the GRAN concept is that of basic OMEGA accuracy. Even when corrected for propagation variations by presently known techniques, position determinations will have errors of one or two nautcial miles. Further, knowledge of a performance at high latitudes has not been developed.

GRAN presents a problem in the localization phase of an operation because it transmitts intermitently, so that the signal may be in an off state when the searcher arrives on the scene. This is not an overwhelming difficulty in that the SAR-COM can be designed to go into a transmit mode based upon a signal from the searcher or the searcher can localize on the basis of differential Omega.

Differential OMEGA based upon survivors GRAN and searcher GRAN units could be used to vector searches to within 300 feet of survivors. The final problem is OMEGA ambiguity resolution as discussed on page 53. However, the problem seems to be one of selecting the optimum solution from several known approaches rather than lack of a solution. Cincinnati Electronics Corporation has suggested a combination of approaches of ambiguity resolution for its ASAP/DIL and is still investigating methodology. The problem is common to both systems and any method selected for ASAP will also work for GRAN.

GRAN does show considerable promise as a worldwide SAR system because of the simplicity of its retransmitter and the fact that a single SAR center can serve very large areas. However, considerable additional work must be done in the areas of bandwidth reduction, transmitting antennas and improved battery life.

3.5.3.2 ASAP - The ASAP uses two major groups of subsystems to accomplish the SAR objectives. These are:

Distress Incident Locator Group (DILG)
Survivor Locator Group (SLG)

These subsystems are further divided into operational components as follows:

DILG

- Distress Incident Locator (DIL)
- Satellite Link
- SAR Ground Sation

SLG

- Survivor Locator Device (SLD)
- Tone Ranging/Pulse Coded Interrogation Equipment (TR/PCI)
- Director Finding/Exact Position Designation Equipment (DF/EPD)
- Airborne Multiple Target TR/DF/EPD Display

In operation, the DILG provides the distress alert and a crude position of the distress incidents on a worldwide basis. The SLG provides the exact position within the zone of errors of the DILG and the method of homing on that position to within ± 10 feet.

Because the SLG has a minimum range of 10 nautical miles over a dense jungle environment (and a maximum range of 100 nm under ideal conditions) the DILG can tolerate errors in position of at least 10 natuical miles. The function of the DIL is somewhat similar to that of the SARCOM of GRAN. However, because the performance requirements imposed on DIL are far less stringent than those of GRAN, the actual electrical and mechanical designs of the two subsystems are expected to be considerably different. DIL is intended primarily for distress incidents involving military aircraft. Its package configuration is an airfoil which is recessed into the skin of the aircraft. If the aircraft is seriously damaged either in flight or on crash, the DIL is deployed automatically. A gas bottle within the DIL then inflates a balloon which holds the electronics canister aloft for a period of a few minutes to a few hours. The satellite uplink antenna is formed of metallized mesh which is carried inside the inflated balloon.

OMEGA signals are received by the DIL, processed, combined with a digital code which identifies the aircraft, mission, etc., and transmitted via a satellite relay to a SAR center for further processing position determination. Cincinnati Electronics is presently performing trade-off studies on preprocessing techniques for bandwidth reduction. Since a sample link calculation has already been included in this report for the GRAN, the DIL will be evaluated here in the same frame of reference. Because the DIL antenna is a crossed dipole above a ground plane, it has gain rather than loss. Further, the balloon will orient this antenna in a nearly ideal position for satellite access. These factors will give the DIL an immediate advantage of up to 10 dB over the GRAN SARCOM. The balloon holds the DIL well above ground effects and foliage providing an additional advantage of 2 dB to more than 20 dB.

A bandwidth reduction of at least 10 to 1 will provide an advantage of 10 dB or more. The DIL does not need to continue to operate until rescue is completed, only in the alerting phase. Therefore, batteries can be drained at much higher rates and larger batteries can be carried so much higher transmitter powers are possible (but not needed).

For the exact example, (neglecting foliage) in which the GRAN required 1/2 watt for access, the DIL could perform with only five milliwatts of transmitter power. In practice, the DIL will not require dedicated satellites with high gain antennas, so this apparent advantage disappears. Actual recommendations for the DIL are 5 to 10 watts of output power which will provide a significant safety margin.

DILG also has a multiple access problem, but since there will be far fewer DILS in a worldwide network than there would be SARCOMS, again the problem is far less severe.

The SLG might be considered a special class of ELT system without most of the disadvantages discussed previously. The SLD is a very small (approximately one pound) package that has an output power of 250 milliwatts. However, this device is not a beacon transmitter but rather is a special type of transponder which is turned on remotely by the search aircraft. Since it does not transmit until the search party is actually in the immediate vicinity, battery life can be extended for many days.

The SLG is interrogated on a randomly assigned address code and the code is also established from the search aircraft so that each SLG can be interrogated independently. This feature eliminates the problem of self-jamming and also provides a means of displaying the bearing to many target SLG's simultaneously in the search aircraft.

There appear to be no disadvantages with the SLG that are not also disadvantages of the ELT and, as pointed out above, there are many advantages over the ELT.

There is no commonality between the SLG and the other systems discussed but the SLG would be an excellent companion system for GRAN (as it is for DILG).

The ground frequency selection problem is summarized in Figure 3-3. Since 243 MHz is an existing emergency frequency which happens to fall in a zone of minimum propagation loss, the data has been normalized to 243 MHz. Thus, the curves plot losses (above those anticipated at 243 MHz) as a function of frequency. Losses due to foliage will vary from 2 to 22 dB at 243 MHz as mentioned previously.

3.5.3.3 GRAN-DILS Development - Admitting differences that exist between GRAN and DILS the commonalities that exist are more significant in trying to shape a system. Both systems communicate OMEGA position data via satellite to a ground facility for processing; and a common joint rescue force is used to recover survivors.

A joint DOT-DOD study should be initiated to evolve a joint system with a set of user equipments that meet the needs of the different users, but can be handled through a common communications satellite link. This study should incorporate such questions as:

- The degree to which commonality in the equipments of different users can be made to produce economies of scale?

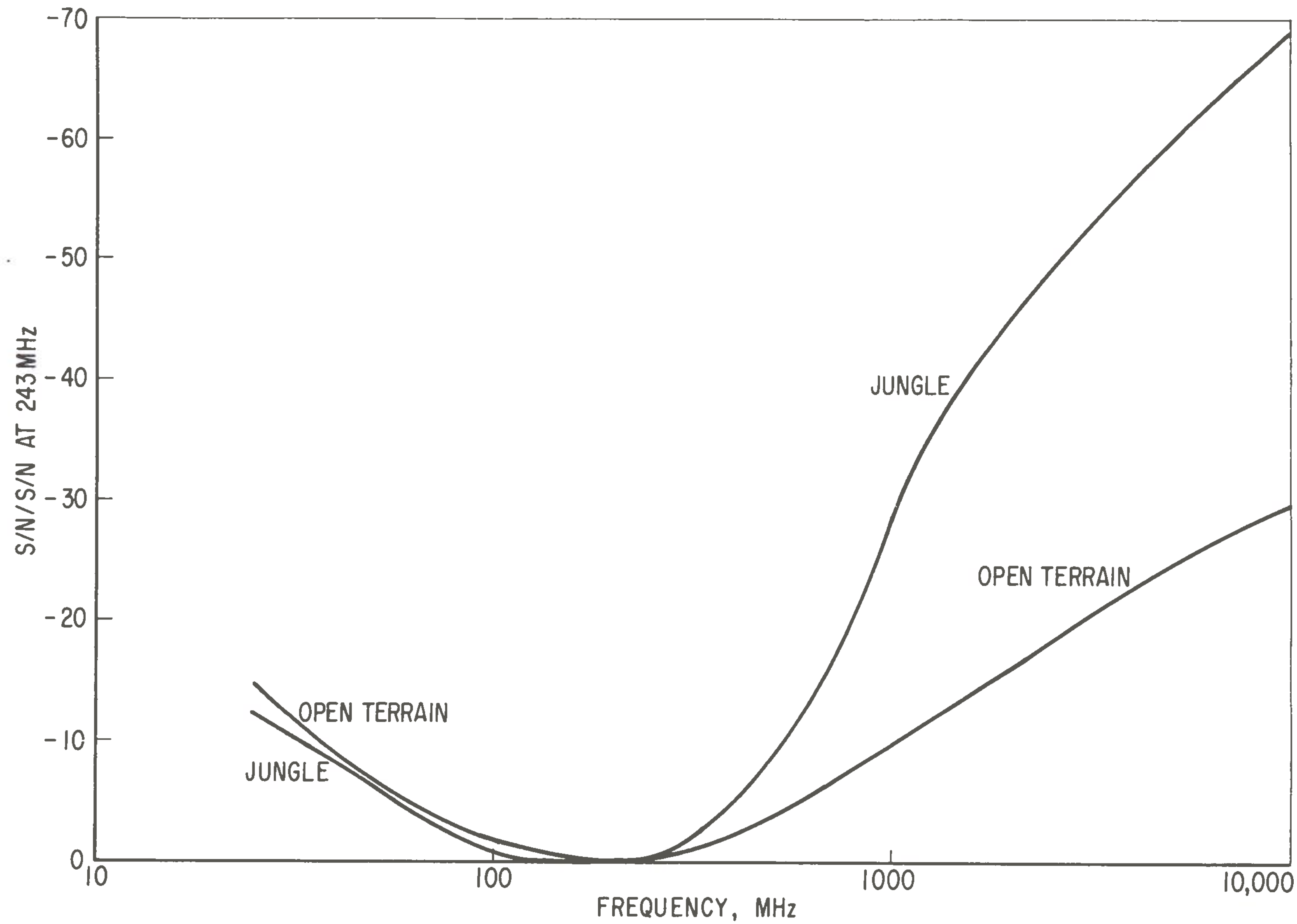

Figure 3-3. Propagation Losses Normalized to 243 MHz

- o What preprocessing of OMEGA signals should be used to reduce system bandwidth and as a consequence reduce power requirements and affords more multiple access capability for frequency division multiplexing?
- o How to achieve proper antenna orientation for units that are automatically activated?
- o Should localization of survivors be accomplished on the basis of Differential OMEGA, Direction Finding, and whether the latter should use the 400 MHz signal.
- o How can the localization signal be remotely activated?
- o Suitable batteries for range of environments to be encountered?

There are two problems that must be adressed if OMEGA is to provide a basis for search and rescue alerting.

- o Lane Ambiguity
- o Basic Accuracy

The OMEGA System has lines of position signals that repeat every 72 miles, so that the navigator cannot identify which 72 mile wide lane he is in. This ambiguity is not a problem for usual navigational situations where the navigator starts with a position fix and keeps track of the lanes that he has crossed. In the GRAN-DIL case the OMEGA receiver has no initialization data so that there is no way of knowing which lane the distress signal originated from. The only thing that is known is the relative position in some unspecified lane. There are two approaches that appear to offer partial solutions to this problem:

- o Add fourth frequency to OMEGA
- o Time of arrival of signals

This part of the program will be investigated in military contracts.

3.6 LOCALIZING DISTRESS INCIDENTS

Let us next turn to the question of localizing the distress incident once the SAR craft arrives at the site. Poor weather conditions may make this task extremely difficult-high winds, dense fog, heavy rain etc. The difficulties may impair the operational safety of the search vehicle as well as limit visual capabilities. Accurate position data from the alert channel reduces these difficulties by starting the search nearer to the target. Search time is reduced roughly as the inverse square of the position uncertainty.

One approach to locating targets is direction finding. The USCG already has such equipment in operational usage for the MF and HF radio signals. The primary systems for future SAR are most likely to be in the VHF, UHF, frequency region. So we will only comment on these DF systems. DF equipment that locates target to accuracy of 3-5° is available. Radair manufacturers such equipment that costs about $3000/unit. This equipment is currently being procured for CAP. The equipment is frame mounted which results in errors when the search aircraft is maneuvering, but should still be more than adequate for homing at low altitudes to within 100 feet of the target. Cubic Corp. produces precision equipments called ELF that measures in pitch as well as the direction plane. The Coast Guard and ARRS have installed and tested this equipment on their SAR Helicopters. It achieves an accuracy of 5-10 feet and costs $35,000 per unit. In the case of GRAN an added possibility is using differential Omega for the localization of survivors.

The differential Omega technique has been tested for surface craft by the Navy. At differential distances of 22 miles they achieved accuracy of 300 feet. It is doubtful that even in the immediate vicinity of a rescue accuracy much better than 100 feet could be achieved. The basic cycle length of Omega Signal is about 100,000 feet. Phase measurements to better than 1 part in 1000 are not practical. Beyond the question of accuracy, limitations of air vehicle motion may cause trouble unless an inertial sensor is included to compensate for aircraft or helicopter dynamics.

The SAR-TEL-COM may be supplemented in the localization phase by other equipment. The final specification of localization accuracy must take into consideration the systems that will be used to supplement it.

A detailed comparison of the potential SAR-TEL-COM alternatives is presented in Figure 3-2.

4. DEVELOPMENT PROGRAM FOR ALERTING AND LOCATING SYSTEMS

4.1 GENERAL

In this section a development program is described which will provide an integrated SAR Alerting and Locating system that will significantly reduce loss of life and property that can be attributed to limitations in distress communications capability. There are four programs that are of concern: Maritime satellite, GRAN, ELT-EPIRB, and DALS. The GRAN-DILS program is already under way with triservice support under the direction of the Life Support Division of Wright Air Development Center. DOT is a participant in this program through USCG. Beyond the efforts already underway DOT participation should involve coordination studies (as will be outlined) and investigation of special problems that are unique to the civil requirements. DOT is already heavily involved in the Maritime Satellite activities through TSC and the USCG. The impact of SAR on this program is primarily one of liason with the safety office. The ELT is currently operational; the problems here are primarily those of establishing how well it operates and determining what can be done to upgrade its performance. Finally, DALS is a Coast Guard R&D program that will be undergoing test and evaluation. The proposed program has been reviewed and approved within DOT and can be assumed to satisfy the needs of the Department in this area. The one item that might be profitably added to this program is to compare it on a system cost basis to shore D-Fing in the VHF FM-Band on voice radio.

4.2 MARITIME SATELLITE

The Maritime Satellite will provide immediate access for ship-to-shore and ship-to-ship communications. There will be channels available for communicating the ships position to AMVER. The DOT Safety Affairs Office should maintain liaison with the MAR SAT Program to insure that safety functions are adequate.

This program should be supported by a traffic analysis of safety functions. This work should require 1 man quarter time over life of MAR SAT development, $10,000/year.

4.3 GRAN-DILS

The GRAN-DILS System appears to be the best approach for providing a satellite monitored alert and location system for civil search and rescue. The system is currently being developed by DOD with plans to complete a system specification by April, 1974. If DOT is to influence that specification, it should establish an agreement with the triservice SAR Committee to this effect and initiate technical cost trade-off studies that identify design options that are suitable to satisfying the needs of the civil users, as well as the military. These studies should be completed to phase into the military specification.

The military DILS system has already completed requirements studies and Cincinnati Electronics is currently involved in conceptual design studies. These studies include work on how the Omega signals are processed to narrow the bandwidth of the user signal that is retransmitted to the satellite and methods for resolving the lane ambiguity problem. The Omega signal processing studies will in particular have a major impact on the cost of units for civil users and therefore should be of concern to DOT. A system study should be initiated that investigates the trade-offs between the following set of parameters.

- Cost Reduction thru Commonality
- Power Output
- Processing Gain
- Signal Bandwidth
- User Interference

Developing such curves will provide a basis for selecting a solution that is compatible with both civil and military users.

The civil system should provide both alert and localization in a common unit to meet the established cost objectives. As a result, the design must provide for localization. As the military uses a separate unit for localization DOT should make a design trade-off study between the possible options. This study should investigate:

- o Need and methods for searcher activiation of user unit.
- o DF solutions versus Differential Omega
- o Providing signal at current DF-ing frequencies as opposed to using 408.6 MHz that is used for SAR satellite communications.

The civil requirement for user SAR-COMs in the GRAN system will differ materially from the military system. Therefore, DOT should provide for establishing a design and test specification that commercial SAR-COMs can be designed to satisfy. Such a design and test specification will insure reliable SAR communications to the user, noninterference with other users, and compatibility with military users. To develop the data for such a specification requires that DOT design build and test and evaluate 20 SAR-COM preprototype units. This program must wait for the completion of civil systems studies. The program must be completed 1 year prior to the start of GRAN service to allow vendors sufficient time to develop units and put them on the market by July of 1978.

4.4 ELT's

The ELT will be in universal usage for GA aircraft during 1974. It will be timely to gather data pertaining to the field performance of ELT and their impact on reducing fatalities in air accidents. These data should be analyzed to determine what measures should be taken to upgrade the performance of the system. An analysis of OAG Official Airline Guide air carrier position plots should be made to establish what improvement in rescue time could be achieved by monitoring and in turn what impact this would have on reducing fatalities. These results should be compared with what would happen if satellite monitoring were to be implemented.

Data should be gathered on false alarms as to frequency, location and conditions under which it happened. This data can be used to evaluate impact false alarms on all systems under consideration and establish means for counteracting false alarms. A study should be conducted to evaluate the impact of airline monitoring

ELT's. This study should consider: crew work load requirements, maintenance and cost to the airlines, the impact on the ATC system, and means that can be used to make it attractive for airlines to perform this function. Finally, a series of technical studies to upgrade ELT performance should be conducted. These should include battery life studies and guard-band monitoring systems.

The capacity of homing equipments to localize ELT is a subject that has been operational for a number of years and ample data and analyses should be available from the services.

4.5 DALS

The DALS Program Plan is included in Appendix E. It is recommended that a study be performed to evaluate the relative cost of DALS as against shore DF-ing on VHF-FM signals from voice radios. Such a program could be carried out for $10,000.

4.6 PROGRAM PLAN

4.6.1 DOT Work

4.6.1.1	Marine Satellite Monitoring & Support Studies	5K
4.6.1.2	GRAN-DILS Signal Processing Trade-Off	100K
4.6.1.3	GRAN & DILS-Localization Study	20K
4.6.1.4	ELT Evaluation Analysis	60K
4.6.1.5	ELT Performance Upgrading Analysis	30K
4.6.1.6	Impact of Airline Monitoring ELT's	20K
4.6.1.7	ELT Technical Studies	30K
4.6.1.8	Currently Programmed DALS	
4.6.1.10	Civil SAR-COM Development Program	280K

4.6.2 DOD Planned Work

4.6.2.1 Detailed Technical Analysis
4.6.2.2 Four Frequency Station Mod.
4.6.2.3 Operate Station (Forrestport N.Y.)
4.6.2.4 Procure and Modify Receiver
4.6.2.5 Modify Preprototype DIL Unit

4.6.2.6 Collect Data

4.6.2.7 Data Analysis

4.6.2.8 DIL Specification

4.6.3 Schedule

The proposed schedule for suggested work efforts is shown in Figure 4-1.

4.7 PROGRAM INTEGRATION

The proposed program for developing a SAR electronic alert and location capability aims at providing an effective ELT monitoring capability at the earliest possible date. Following this and closely keyed to the military development of GRAN to provide the more universal coverage of the satellite monitored system. In parallel with this the Coast Guard will independently develop the DALS system. The close similarity regarding the Omega system between GRAN and DILS should lend itself to maximizing cross fertilization between the two programs.

The item that is critical in the ELT Program to providing an early alert capability is the Performance Evaluation Analysis. This item defines what new work is required to attain the best performance from the ELT system that is inherent in the system. Although this program will undoubtedly take two years to complete, the critical performance information that is needed to provide a basis for new development work should be available at a much earlier date. The air carrier impact analysis can be initiated at the beginning of the program and carried on in parallel with other development work. The same applies to the required technical studies.

The GRAN development work is keyed to the military development. The primary item that appears to be time critical in the civil development are the initial studies that will define a compatible satellite communications link for the civil and the military system. The military program has already initiated studies to define DILS. These studies are to be completed in December of 1973. A problem exists to complete a parallel civil effort to a time scale that

WORK ITEMS	COST	AGENCY
1.1 MAR-SAT monitoring and support.	5 K	DOT TSC
1.2 GRAN civil system tradeoff studies.	100 K	TSC
1.3 GRAN system localization study.	20 K	TSC
1.4 ELT evaluation analysis.	60 K	TSC
1.5 ELT performance upgrade analysis.	30 K	TSC
1.6 ELT air carrier monitoring impact st.		FAA
1.7 ELT technical studies.		FAA
1.8 DALS research and development.		USCG
1.9 DALS comparison with VHF-FM dfing.		USCG
1.10 Civil SAR-COM development test and evaluation.	250K	NASA
2.1 DILS technical analysis.		WADC
2.2 Omega four frequency tests.		(USN) NATC
2.3 Operate Omega stations.		NATC
2.4 Procure and modify Omega receivers.		WADC
2.5 Fabricate preprototype DILG.		WADC
2.6 Collect data.		WADC
2.7 Data analysis.		WADC
2.8 DILG specification		WADC
Transition to the GRAN system.		

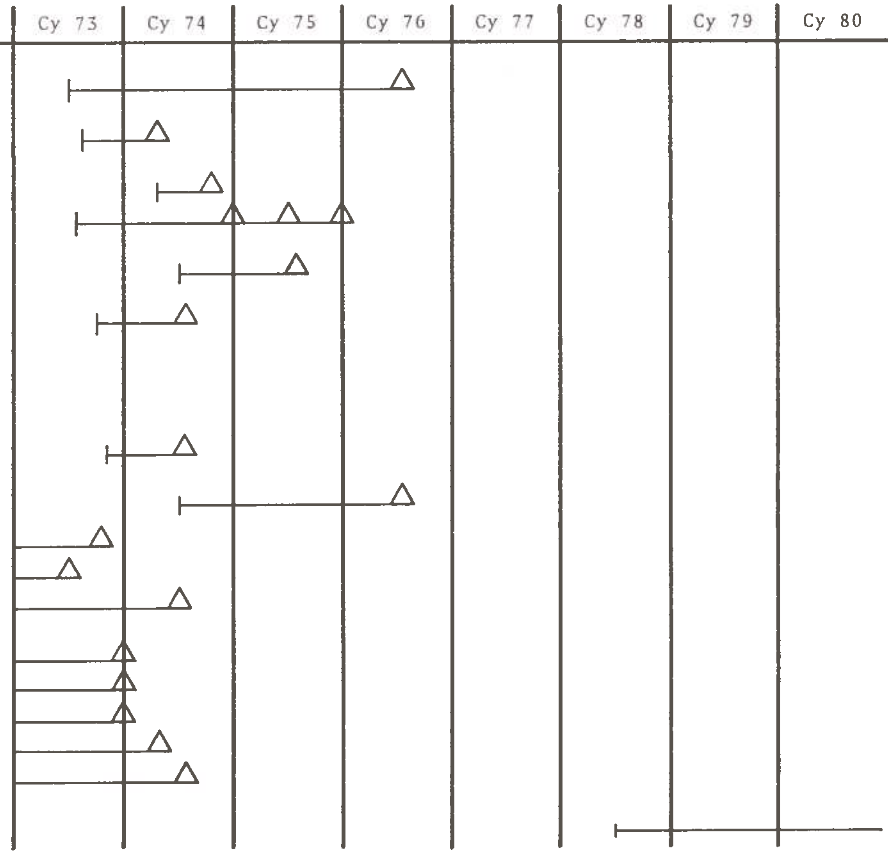

Figure 4.1. Budgetary and Schedule Estimates for SAR Alerting and Locating Integrated System Development

will permit the civil system to inject any significant inputs into the military program. As a result the civil system design will probably be comprised to meet the military needs without due consideration of its own priorities. Hence, the military needs will call out the specifications of the satellite communications channel which will be common to both users.

The next critical item in the schedule is the availability of GRAN user prototype hardware for tests with the Navy GAP-SAT in '76. A program plan provided by NASA indicates that such prototype hardware could be developed and delivered in less than 18 months. To meet such a schedule the GRAN system trade-off studies must be completed by mid 1974 as shown on the schedule Figure 4-1. As these studies will require at least nine months to complete, it is important that they be initiated forthwith. (If the civil system proposes to else but make the best of a system that is primarily designed to meet the military requirements.) The GRAN localization studies are less critical in their timing. If they were to be completed by the end of 1974 they could be incorporated in the Satellite SAR-COM development and testing program and would result in a reduction in the civil costs for developing the system. Completion of a testing program in parallel with the military during 1976 will allow nine months to provide a specification to the manufacturers to develop and get SAR-COMS into production to have civil units on the market when Navy SAR SAT is launched in mid 1978 to service the GRAN system.

5. CONCLUSIONS

5.1 NEED FOR SAR

An unfullfilled need exists for a timely electronic distress alerting and locating capability:

- o Survivability of downed aviators and distressed mariners diminishes rapidly with time. (the probability of survival is less than 50% if the search exceeds four hours.
- o Time required to locate aircraft survivors where SAR is involved now exceeds twenty-four hours, 93% of the time.
- o Four million dollars potential annual saving in expenditures on Search would result if adequate alert and location systems were available.
- o Six million dollars was spent in an unsuccessful search for Congressmen Boggs and Begich.

5.2 ELT

A program should be initiated to evaluate the effectiveness of ELTs in alerting the Search and Rescue organization to the occurrence of aircraft accidents on the North American continent, based on actual field experience:

- o ELTs are now required by law for general aviation.
- o Current very limited monitoring by military and government aircraft only provides inadequate and random coverage.
- o If aircarriers were properly equipped for monitoring ELTs, their coverage would be orderly. Exact predictions could be made of the coverage that they provided, so that complimentary monitoring needs could be defined.

5.3 COORDINATION

Search and Rescue development programs require a coordination function within DOT for all modes of transportation:

- Emergency Alert and location problems are common to several phases of transportation.
- Particular systems find application in several modal administrations.
- SAR alert and location systems can be best designed to a commonality of requirements which do not necessarily restrict themselves to lines of modal interface.
- Lack of clear responsibility has resulted in inadequate monitoring for ELTs.
- Operational SAR responsibility is shared with components of DOD as outlined in the National Search and Rescue Plan.
- New Equipment development coordination is needed.

5.4 COASTAL ALARM

Coastal regions present special problems that appear best handled by means of the coastal VHF-FM network.

- High traffic density within the coastal confluence region could lead to a saturation of a satellite System.
- False alarm rate for coastal boating is likely to be very high.
- VHF-FM NETWORK breaks the message traffic down into limited regions so that saturation is not a problem.
- Comparative studies of the Coast Guard's Distress Alerting and Location System with DFing on voice communication EPIRBs should be made to determine which is more suitable for this application.

5.5 HIGHWAYS

A study is needed that addresses an associated but different problem the distress alert question for highways.

- Highway deaths are an order of magnitude higher than all others modes.

- o Rural area death rate is double the metropolitan.

5.6 SATELLITE MONITORING

A satellite monitored SAR alert and locating system is needed for global civil aviation and ocean maritime traffic.

- o 75% of inland United States accidents involving SAR occur where aerial monitoring is minimal.
- o Canada and Alaska present coverage problems for aerial monitoring.
- o Ocean coverage by aircraft monitoring is highly unrealiable
- o Satellites provide least expensive total coverage.

5.7 GRAN

GRAN a civil version for the military Distress Incident Locator Group (DILG) will provide the most cost effective system of alerting and locating for maritime traffic and civil aviation in remote areas.

- o The major federal cost elements of the system R&D will be furnished by DOD in support of military requirements
- o Available 2 years earlier than satellite monitoring of ELTs
- o Satellite monitoring of ELTs as opposed to GRAN would not provide instantaneous alert.

5.8 DEVELOPMENT PLAN

This initial study has identified several deficiencies in the methods presently employed to alert federal and local agencies of transportation distresses. Evolving methods of locating the scene of the accident have also been investigated. The following recommended actions constitute an integrated plan that will lead to the correction of many of the deficiencies that appear in the systems.

- o GRAN-DILS trade-off study.
- o GRAN-DILS localization study.

- o ELT evaluation analysis
- o ELT performance upgrade analysis.
- o ELT air carrier monitoring impact study.
- o ELT technical studies
- o Retranmitted Navigational position vs direction finding for coastal confluence areas.
- o Monitor the developments in maritime satellites.
- o Civil search and rescue emergency alerting and locating device development test and evaluation.

REFERENCES

1. Whistler, Charles F., et al. Advanced Survival Avionics Development Study. Texas Instruments, Inc., Technical Report ASD-TR-70-27. September 1970.
2. The Utility of High-Performance Watercraft for Selected Missions of the United States Coast Guard, Center for Naval Analyses, University of Rochester, Arlington Va., Final Report, November 1972, contract DOT-CG-21941-A.
3. Analytic Methodology for Determining Gross Operational Parameters and System Performance Requirements relating to Air Force Search Equipment, Planning Research Corporation, ASD-TR-70-24, Ocotber 1970, Mitchell, T.R., Cohan, R.S., Heidey, C.H.
4. A Study of Maritime Mobile Satellites, Automated Marine International, Newport Beach, California, Final Report, Report No. DOT-CG-00505A, November 1970.

APPENDIX A
U.S. SEARCH AND RESCUE RESPONSIBILITY

The National SAR Plan, provides an overall plan for the control and coordination of all available facilities for all types of search and rescue operations. A single federal agency, through an appropriate Rescue Coordination Center, coordinates all SAR operations in any one area. The plan establishes three SAR Regions and designates Regional SAR Coordinators as follows:

The Inland Region:	The Air Force
The Maritime Region:	The Coast Guard
The Overseas Region:	Overseas unified commanders

Regional SAR Coordinators are responsible for organizing existing agencies and their facilities, through suitable agreements in a basic network for rendering assistance both to the military and non-military persons and property in distress and to carry out the United States' ICAO obligations within their specific SAR regions. The specific responsibilities are defined in Figures A-1 and A-2.

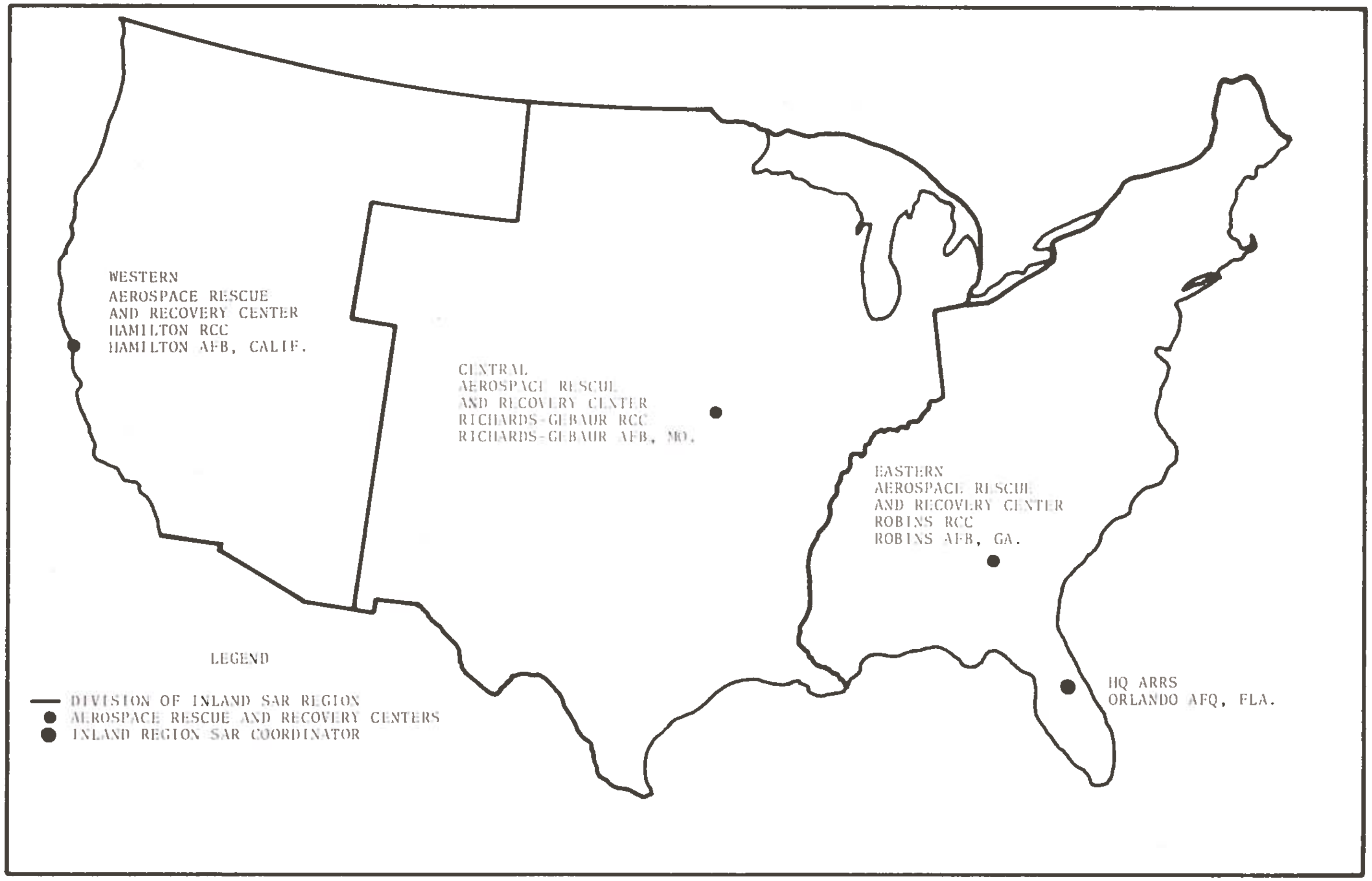

Figure A-1. SAR Areas & Coordinators Inland Region

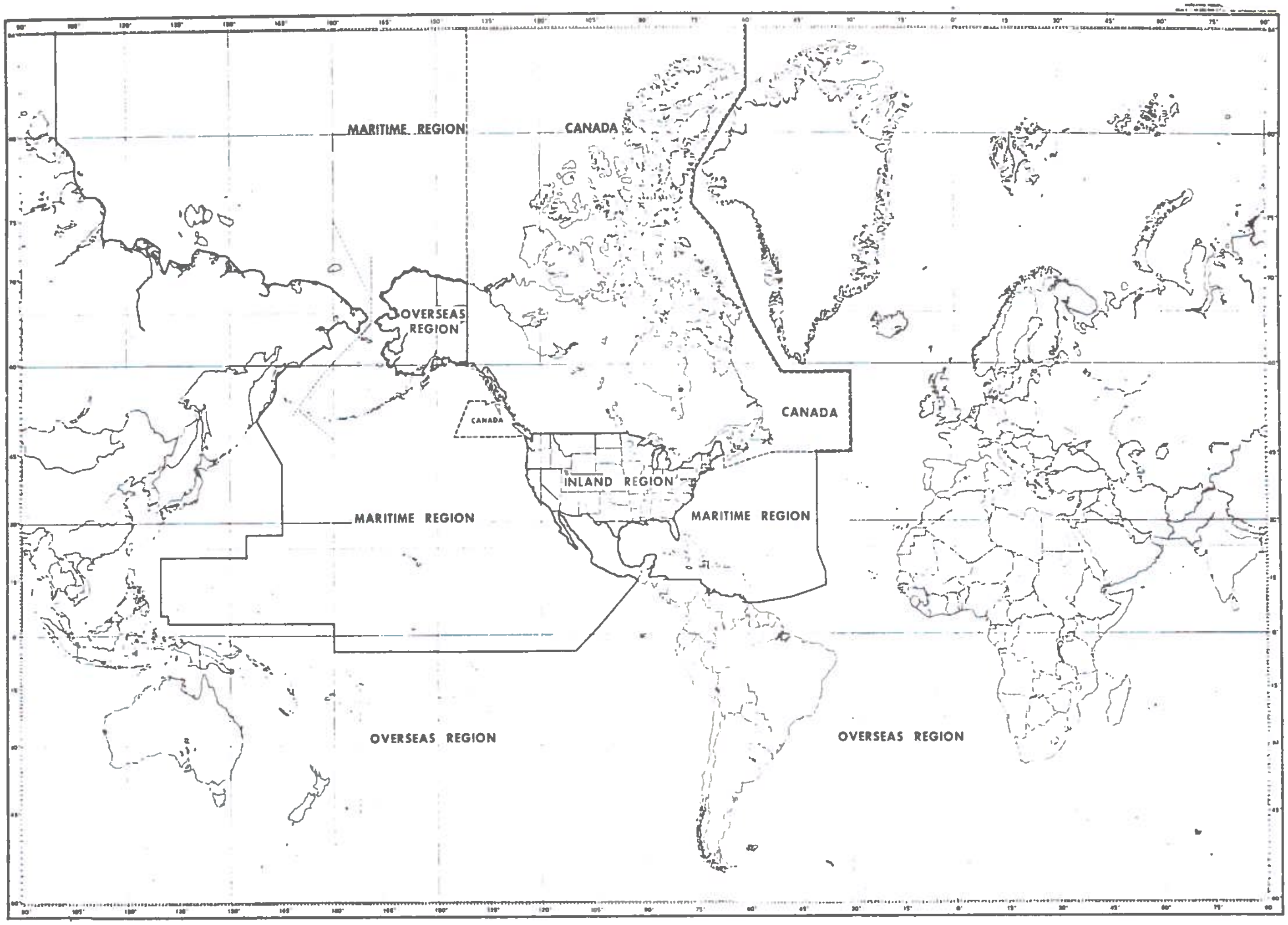

Figure A-2. Proposed Chart-National Search and Rescue Plan

APPENDIX B

AIR CARRIER COVERAGE OF CONTINENTAL UNITED STATES

An investigation was made to determine the air carrier coverage of continental U.S.

The first step was to produce a three-dimensional computer model of the air user population. This was accomplished by using Official Airline Guide schedule data to compute the instantaneous location of U.S. certified scheduled aircarrier aircraft within the CONUS (48) for selected times of days of the week. For each aircraft, latitude, longitude and altitude is computed based on scheduled departure/arrival times and specific performance characteristics of the aircraft type, such as climb rate, cruise altitude, etc. The output results of this model are shown in Figures 1 through 13. Figures 1-12 show hourly distribution and Figure 13 indicates that this population does not vary materially on a day to day basis. One can expect once per day coverage over 90% of Continental U.S. Those areas not covered are:

- o West Texas
- o Northern Maine
- o U.S. Canadian Border
- o Northern Nevada and East Oregon

The areas of high air traffic density will provide essentially continuous coverage. The Great Plains will have coverage on once hourly basis during daylight hours but not at night.

To complete this picture military, Government and GA flying should also be plotted. Military flying will in all probability complement the air carrier coverage.

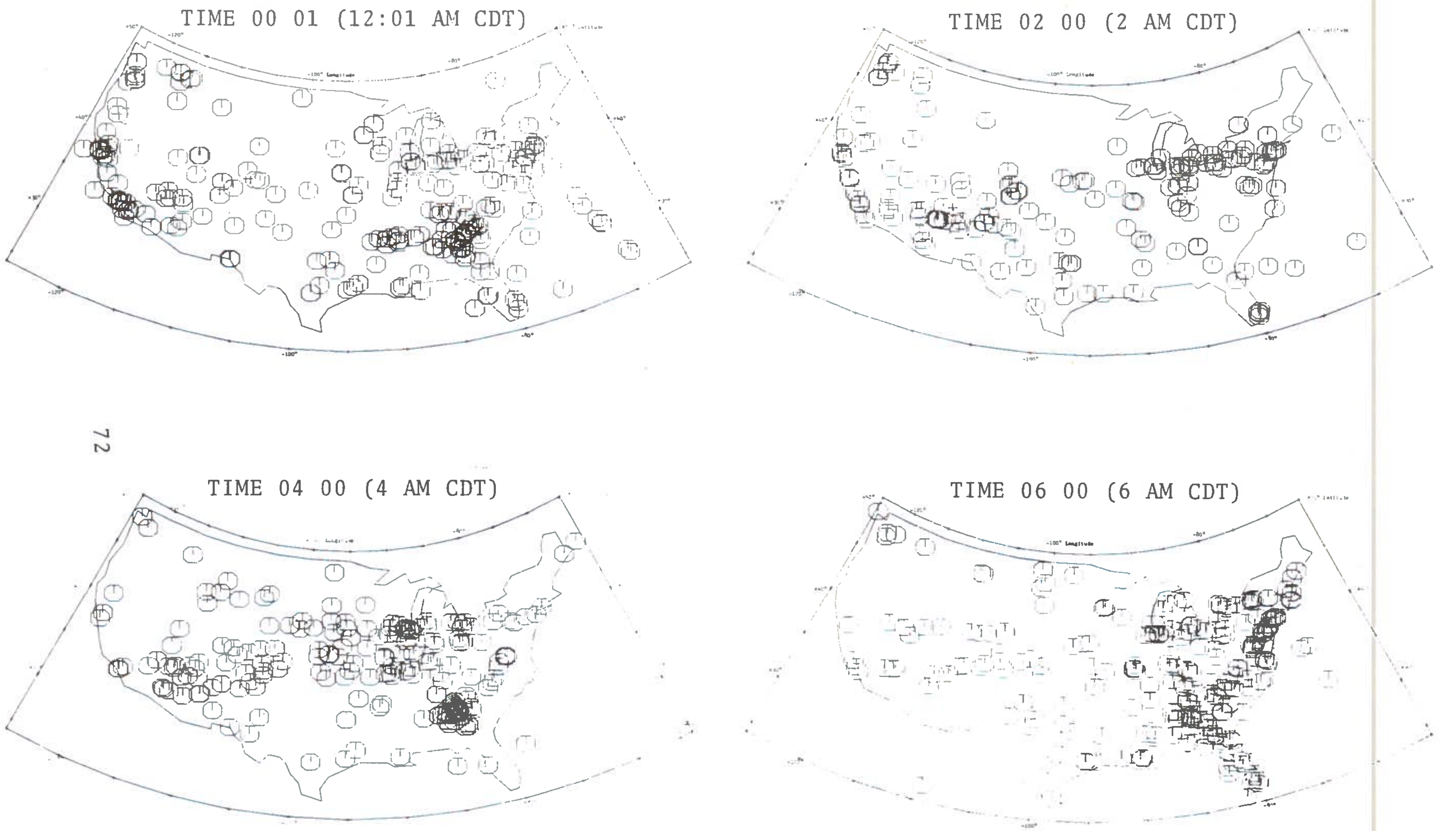

Figure B-1. Location of Air Carrier Aircraft Throughout Day

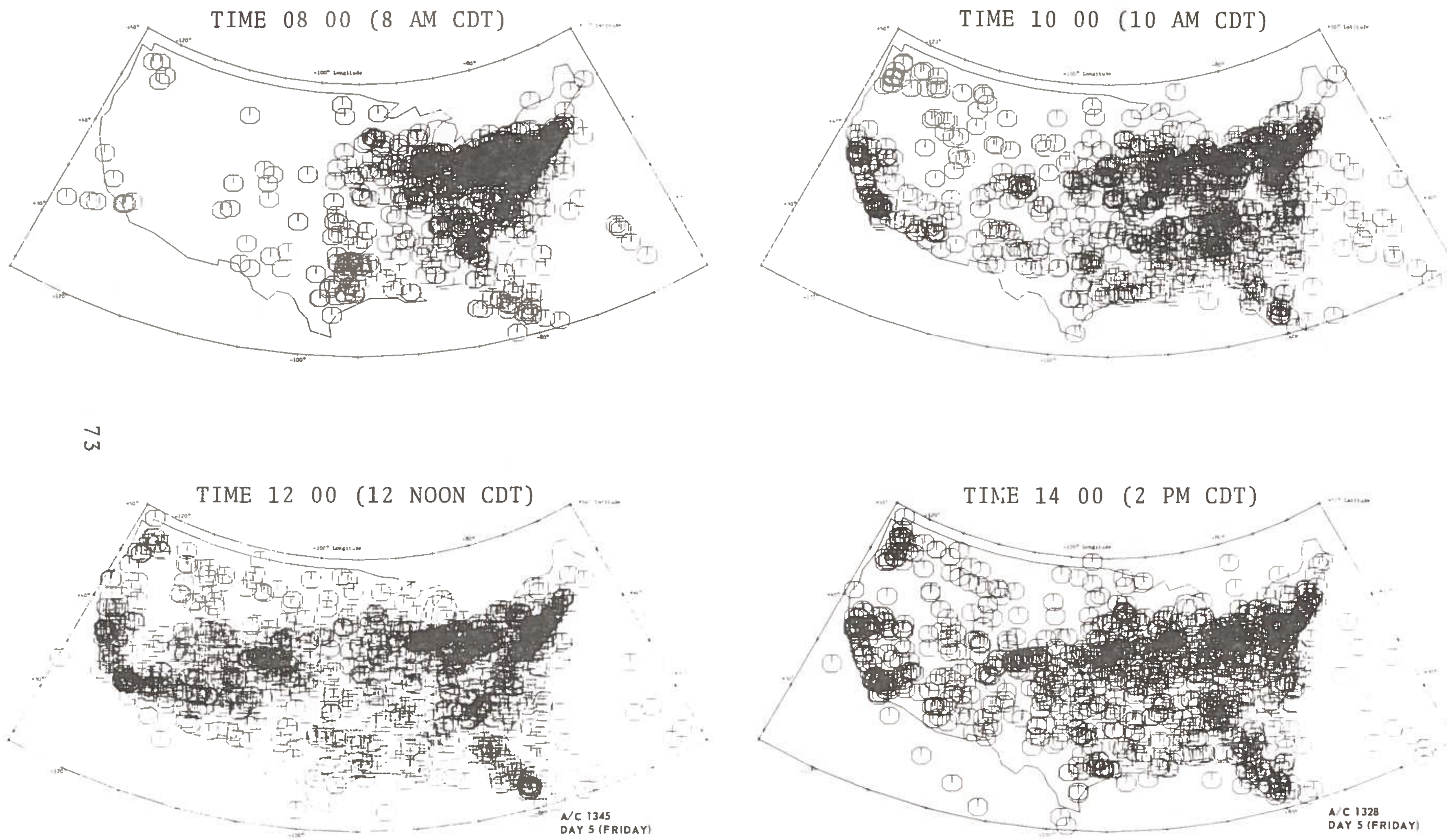

Figure B-1. Location of Air Carrier Aircraft Throughout Day (Continued)

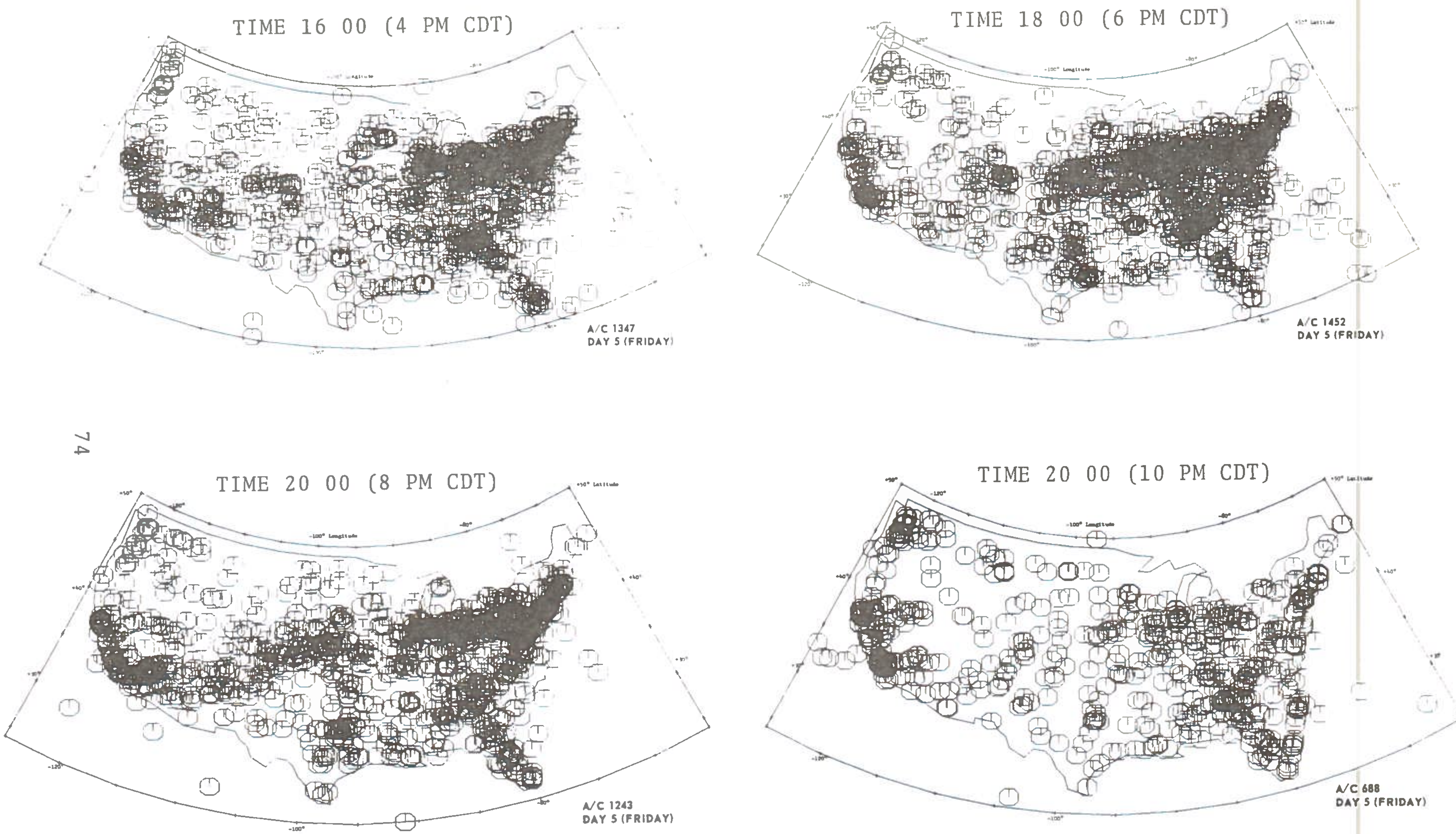

Figure B-1. Location of Air Carrier Aircraft Throughout Day (Continued)

APPENDIX C

SUMMARY OF AVAILABLE EMERGENCY LOCATION TRANSMITTER

UNIT	PRICE	POUNDS WEIGHT	MAX POWER	POWER AFTER 48 HRS	SIZE	AUTO ACTIVATE	ANTENNA
NARCO ELT-10	$149.	3.5	300	75	2-1/2x3x3/4	Yes	INTERNAL
LEIGH SYSTEMS SHARC-7	$160-185	2.3	400	75	4.4x3.2x2.6	Yes	REMOTE
EMERGENCY BEACON CORP.							
EBC102A	120	1.21	150	95	2-1/2x1-1/4x6-1/2	Yes	INTEGRAL
EBC202B	190	1.21	200	150	SAME	Yes	"
EBC302V	230	1.9	300	250	SAME	MULTI AXIS	"
MARTECH EB-2BCD							
EAGLE	195	3	300	150	6-1/4x3"d	Yes	INTERNAL
DOLPHIN	·250	3-1/4	600	100	15-3/8"x3"d	WATER ACT.	INTERNAL
GARRETT PAL							
RESCUE 99	320	5.4	200	75	8-1/2x8x3	Yes	REMOTE
RESCUE 88 (PIPER)	185	1.6	100	75	8-1/2x1-1/4x2-1/4	Yes	EXTERNAL
DORNE & MARGOLIN							
DMELT 1-3	200	5	300	175	9.0x7.5x3.9	None	REMOTE
COMMUNICATIONS COMP CORP							
CIR-10 ELT	230	2.5	225	75	7-1/2x3x2-1/4	Yes	REMOTE
AERO PRODUCTS DEVELOPMENT							
POINTER PORTABLE	145	1.7	150	90	7.6x3.4x3.2	Yes	REMOTE
POINTER II	250	3.7	250	75	13"x2-1/2d	Yes	INTEGRAL

APPENDIX D

MINIMUM PERFORMANCE STANDARDS - PERSONNEL TYPE EMERGENCY LOCATOR TRANSMITTERS ELT(P), OPERATING ON 121.5 AND 243.0 MEGAHERTZ

D.1 GENERAL STANDARDS

D.1.1 RATING OF COMPONENTS

The equipment shall not incorporate any vacuum tubes in its design. All components shall be so rated that, when the equipment is operated within the range of environments specified, its performance will not degrade. In addition, components shall be so rated that the equipment will function within the limits of these standards after extended periods of inaction while carried or installed in the aircraft and subjected to the environmental conditions prescribed. Operation into any load likely to occur in service, from open to short, shall not cause continuing degradation in performance.

D.1.2 CONTROLS AND THEIR OPERATION

The operation of control intended for use during normal operation in all possible position combinations or sequences shall not result in a condition whose presence or continuation would be detrimental to the continued performance of the equipment. The number of controls shall be kept to a minimum to permit ease of operation of the equipment. As a minimum, a positive means of turning the equipment "ON" and "OFF" shall be provided for the use of the operator.

D.1.3 EFFECT OF TESTS

Unless otherwise provided, the application of the specified tests shall produce no subsequently discernible condition which would be detrimental to the continued performance of the equipment.

D.1.4 POWER SUPPLY

The equipment shall have its own power supply and shall not be dependent upon the aircraft power supply for its operation. The power supply furnished shall be designed as an integral part of the equipment or be securely attached thereto. Replacement of the power supply shall not require any special tools or fixtures, and any interface connections required shall be accomplished in a manner to avoid reversed polarity or incorrect installation. The manufacturer may provide for use of the aircraft battery or any other supplemental supply or remote controls, provided that such provision does not compromise any other requirement of these standards.

D.1.5 WATERPROOFNESS

The equipment, exclusive of water activated batteries, shall be waterproof. The effects of standing water on the outer surface of the equipment shall have no significant adverse effect upon the performance of the equipment.

D.1.6 OPERATING INSTRUCTIONS

Concise, unambiguous operating instructions, understandable by untrained personnel, shall be conspicuously and permanently displayed on the equipment. The display shall be weather resistant, waterproof, and abrasion resistant.

D.1.7 EQUIPMENT EXTERIOR DESIGN

The exterior of the equipment shall have no sharp edges or projections which could easily damage inflatable survival equipment, injure personnel or damage their clothing. Means shall be provided to secure the equipment to a survival craft or person.

D.1.8 ANTENNA

If the antenna is not designed to be stowed in its normal operating position, the antenna shall be deployable to the designed length and operating position in a foolproof manner. If the antenna or sections thereof are demountable, the antenna or sections shall be secured against loss. The antenna shall provide optimum performance at 121.5 and 243.0 MHz and its radiation pattern in the horizontal plane shall be essentially omindirectional.

D.1.9 EQUIPMENT DEPLOYMENT

The equipment shall be so designed that it may be deployed, its controls actuated, or the antenna erected, each by a single action task which can be performed with either hand.

D.1.10 EQUIPMENT PERFORMANCE

Certain of the minimum performance standards specified in Section 2 are required to be demonstrated under certain environmental conditions, as specified in Section 3. The required environmental tests are limited to those so specified; however, the equipment shall be designed to meet all of the performance standards of Section 2 under all conditions within the specific envelopes defined by the environmental categories declared by the manufacturer. (See RTCA DO-138 for explanation of categories.)

D.2 MINIMUM PERFORMANCE STANDARDS UNDER STANDARD TEST CONDITIONS[1]

The test procedures applicable to a determination of the performance of personnel type emergency locator transmitters ELT(P) operating on the frequencies of 121.5 and 243.0 MHz under standard test conditions are set forth in Appendix A of this Paper.

D.2.1 OPERATING LIFE

The capacity of the power supply shall be sufficient to provide continuous operation for at least forty-eight (48) hours under the condition of maximum power consumption. During and at the end of the 48-hour period, and without interruption of operation, the peak effective radiated power shall be not less than that specified in Paragraph 2.2.5.

D.2.2 TRANSMITTER

D.2.2.1 Operating Frequencies

The transmitter shall operate simultaneously on 121.5 and 243.0 MHz ± .005%.

D.2.2.2 Modulation Characteristics

The type of emission shall be A9 and shall have a distinctive audio characteristic achieved by amplitude modulating the carrier with an audio frequency sweeping downward over a range of not less than 700 Hz, within the range 1600 to 300 Hz, and with a sweep repetition rate of between 2 and 4 Hz.

The modulation may be essentially or entirely negative going, and the modulation envelope may be essentially rectangular.

The modulation factor shall be at least 0.85.

---

[1] In addition to the standards specified herein, all of the requirements of Part 87 of the FCC Rules and Regulations, including Section 87.77(b), which requires transmitter type acceptance, shall apply.

D.2.2.3 Modulation Duty Cycle

The modulation applied to the carriers shall have a minimum duty cycle of 33% and a maximum duty cycle of 55%.

D.2.2.4 Transmitter Duty Cycle

The carrier shall not be interrupted, except as allowed in Paragraph 2.2.3, above.

D.2.2.5 Peak Effective Radiated Power

The peak effective radiated power (PERP) shall be at least 75 milliwatts on each frequency.

D.3 MINIMUM PERFORMANCE STANDARDS UNDER ENVIRONMENTAL TEST CONDITIONS

Unless otherwise specified, the test procedures applicable to a determination of the performance of the radio equipment under environmental test conditions are set forth in RTCA Document DO-138 - "Environmental Conditions and Test Procedures for Airborne Electronic/Electrical Equipment and Instruments," dated June 27, 1968

Tests that cannot be performed on the operating frequencies within a shielded room or other suitable shielded enclosure shall be performed on any frequency which is within 1% of the nominal frequencies of 121.5 and 243.0 MHz, and in accordance with applicable FCC Rules and Regulations.

D.3.1 TEMPERATURE AND ALTITUDE TESTS

NOTE: In conducting the Temperature-Altitude Tests, the test procedures of DO-138 shall apply except where noted and except that the temperature indicated below shall be used instead of those specified in Table I of DO-138:

The Low Not Operating Temperature shall be -65°C, the Low Operating Temperature shall be 0° C, the High Not Operating Temperature shall be +71° C, and the High Operating Temperature shall be +55° C.

D.3.1.1 Low Temperature Test

When the equipment is subjected to this test:

a) All mechanical devices shall operate satisfactorily.

b) The requirements of Paragraphs 2.1, 2.2.1, 2.2.2, 2.2.3 and 2.2.4 shall be met.

D.3.1.2 High Temperature Test

NOTE: No High Short-Time Operating Temperature Test is required

a) Immediately after exposure to the High Not Operating Temperature:

   1) All mechanical devices shall operate satisfactorily.

   2) There shall be no evidence of materials, such as grease or potting and sealing compounds, exuding or dripping from the equipment components.

b) When the equipment is operated at the High Operating Temperature, the requirements of Paragraphs 2.1, 2.2.1, 2.2.2, 2.2.3 and 2.2.4 shall be met.

D.3.1.3 Altitude Test

NOTE: The following test procedure is in lieu of that specified in DO-138.

Subject the equipment (not operating) to an atmospheric pressure equivalent to 50,000 feet for a period of not less than 15 minutes. Increase the pressure to ambient atmospheric pressure at a rate equivalent to at least 10,000 feet perminute. Within three minutes after reaching ambient atmospheric pressure, the requirements of Paragraphs 2.2.2, 2.2.3, 2.2.4 and 2.2.5 shall be met.

D.3.1.4 Decompression Test

NOTE: This test is applicable to equipment which is intended to be carried or installed in a pressurized area of an aircraft. The following test procedure is in lieu of that specified in DO-138.

With the equipment not operating, adjust the atmospheric pressure to that equivalent to an altitude of 8200 feet. Maintain this pressure for at least five minutes. Reduce the atmospheric pressure to that equivalent to an altitude of 40,000 feet.

This reduction in pressure shall be effected within a time period not to exceed 15 seconds. Maintain this reduced pressure for at least 10 minutes than increase the pressure to ambient atmospheric pressure. Within three minutes after ambient atmospheric pressure is reached, the requirements of Paragraphs 2.2.2, 2.2.3, 2.2.4 and 2.2.5 shall be met.

D.3.1.5 Over-pressure Test

NOTE: This test is applicable to equipment intended to be installed, or stored in pressurized areas of an aircraft.

When the equipment is subjected to this test:

a) All mechanical devices shall operate satisfactorily.

b) The requirements of Paragraphs 2.2.2, 2.2.3, 2.2.4 and 2.2.5 shall be met.

D.3.2 HUMIDITY TEST

NOTES: 1) The DO-138 Test Procedure for Standard Humidity Environment shall be used.

2) The humidity test shall be conducted after the Temperature and Altitude Tests, the Vibration Test and the Shock Test.

a) After being subjected to this test and within 15 minutes after power is applied, the transmitter's peak effective radiated power shall be not more that 3 dB below that specified in Paragraph 2.2.5 and the modulation capability shall be essentially that required by Paragraphs 2.2.2, 2.2.3 and 2.2.4.

b) Within four (4) hours of the time primary power is applied, the requirements of Paragraphs 2.2.2, 2.2.3, 2.2.4 and 2.2.5 shall be met.

c) Operate the equipment beginning immediately after being subjected to this test continuously for a period of 48 hours after which all of the requirements of Paragraph 2.2 shall be met.

D.3.3 SHOCK TEST

NOTE: The following test procedure is in lieu of that specified in DO-138.

Secure the equipment (not operating) to a shock table by the mounting means intended for use in service installations. With the equipment mounted in each of the below-stated six positions, apply one shock having the characteristics stated below. The mounting of the equipment should include those non-structural connections which are a normal part of the installation.

Adjust the shock table to deliver a shock pulse having a half sine wave with a duration of 11±2 milliseconds and an amplitude of 50G. The instrumentation to demonstrate compliance shall have a 3 dB response over the range of at least 5 - 250 Hertz.

A. Normal upright.

B. Suspended upside down.

C. At positions such that the first major orthogonal axis of the equipment successively forms angles of plus 90° and minus 90° (two positions) with the plane of the table.

D. At positions such that the second major orthogonal axis of the equipment successively forms angles of plus 90° and minus 90° (two positions) with the plane of the table.

Following application of the shocks, all of the requirements of Paragraphs 2.1 and 2.2 shall be met.

D.3.4 VIBRATION TEST

NOTE: The following test procedure is in lieu of that specified in DO-138

a) So secure the equipment (not operating) to a vibration table that sinusoidal vibratory motion is exerted parallel to one of the three major orthogonal axes of the equipment. The equipment shall be affixed to the vibration table by the means specified by the equipment manufacturer for service installations. Vary the vibration frequency over the range and amplitude specified below at a rate not to exceed 1.0 octave per minute. Continue the vibration for a minimum of one hour.

   <u>Vibration Characteristics</u>

   Constant total excursion of 0.100" from 5 Hertz to that frequency where an acceleration of 10G is reached and from that frequency to 2,000 Hertz a constant acceleration of 10G.

b) Repeat the procedure specified in (a) above with the vibratory motion applied along the second major orthogonal axis of the equipment.

c) Repeat the procedure specified in (a) above with the vibratory motion applied along the third major orthogonal axis of the equipment.

d) Subsequent to exposure to vibration, all of the requirements of Paragraphs 2.1 and 2.2 shall be met and all mechanical devices shall operate satisfactorily.

   NOTES: 1) The test fixture used shall be as rigid and symmetrical as practicable.

   2) The control accelerometer shall be mounted on the test fixture as near as possible to the equipment mounting location.

D.3.5 TEMPERATURE VARIATION TEST

NOTE: The following test procedure is in lieu of that specified in DO-138.

Stabilize the equipment temperature at 0° C at ambient room atmospheric pressure with the equipment not operating. Operate the equipment at maximum power consumption. Increase the temperature of the air in the test chamber to +55° C at a rate not exceeding 1° per minute. In the interval between the time that the equipment temperature stabilizes at 0° C and the time it stabilizes at +55° C, determine that the frequency of the rf carrier is within .005% of the assigned frequency.

D.3.6 IMMERSION TEST

NOTES: 1) This test is additional to the environmental tests specified in DO-138.

2) This test shall be conducted after the vibration Test and the Shock Test.

The equipment, including power supply, with the power off, shall be completely immersed in salt water for a period of at least 15 hours. Immediately upon removal of the equipment from the salt water:

a) All mechanical devices shall operate satisfactorily.

b) The standards of Section 2.0 shall be met, except that equipment designed to be operated from water activated batteries need (with respect to Paragraph 2.1) operate only 33 hours.

D.3.7 WATERPROOFNESS TEST

NOTE: The test procedures contained in DO-138 shall apply, except that compliance with the required standards shall be determined while being subjected to this test instead of after the 15-minute period.

While being subjected to this test, the requirements of Paragraph 1.5 shall be met.

APPENDIX E - DALS PROJECT 731140

E.1 OBJECTIVE

The Distress Alerting and Locating System (DALS) will provide the Coast Guard SAR personnel with the capability of locating a distressed vessel or person within 1/2 mile after a initial distress alerting signal has been received. Vessel or personal identification will be included as well as emergency status. In a very short period of time after the Coast Guard SAR forces have been automatically alerted of an emergency, the Rescue Coordinator will be told who is in distress, the extent of the emergency, how many persons involved as well as where the emergency took place. Therefore, the DAL system will eliminate all of the unknowns from SAR and only rescue will be involved thus reducing time and expense of SAR operations. The DAL system is based on coorperative and/or mandatory carriage of the distress device by maritime and boating personnel.

E.2 BACKGROUND

Under contract CWB-11187, the Department of Commerce (ESSA-Weather Bureau) provided some original development for weather balloon tracking to determine wind direction and velocity by utilizing remotely retransmitted LORAN/OMEGA signals. NASA initiated an experiment in June 1967 called OMEGA Position Location Equipment (OPLE) whereby the splash down point of Apollo spacecraft could be determined remotely. These two previous efforts are the basis for this development of a SAR Distress Alerting and Locating System (DALS) utilizing retransmitted LORAN/OMEGA signals to remotely determine the location of a distressed vessel or person.

E.3 APPROACH

General: Since a very high percentage (90%) of Coast Guard SAR cases involve recreational boaters in Coastal waters (within 20 nautical miles), this zone becomes of primary interest for coverage by DALS. Secondary area for SAR coverage will be the open Ocean zones thus extending DALS to a world-wide system. Within these guidelines, DALS will be designed to utilize a position location system and coded information for line of sight operation (coastal coverage to 20n miles) and evenutally will expand to world-wide coverage with a relay link via satellites. The distress device will be designed for simple operation, long shelf life, compact, easily tested, very reliable and low user cost.

Specific: The approach to be taken will provide for a prototype DALS for test and evaluation as a pre-operational system within a four (4) year period.

Initially, a modified LOCATE system developed by Beuker's Lab. was procured to provide for distressed vessel (person) position as well as identification. Field testing of this experimental DALS commenced in 4th Qrt. of FY73 in Coastal/Inland waters utilizing the CG R&D Center and continue through FY74. During FY73 the following efforts were initiated:

a. Investigate multiple access and false Alarms in an attempt to prevent system saturation.

b. Investigate feasibility of using DALS as a Harbor Traffic Control system and a Buoy Position monitoring system.

c. Investigate automatic deployment techniques for user device (hand-held unit), and re-packing techniques to prevent damages.

d. Investigate feasibility of a frequency modification to the Experimental DALS for operation on an allocated Safety and Distress frequency.

e. Situation code modification; upon completion of these investigations, the Experimental DALS transmitters (hand-held) would be re-packed to incorporate; long shelf life batteries, non-destruct antenna, and a sealed (environmentally protected) case, followed by:

   1. Modifications necessary to incorporate the Safety and Distress frequency change to provide for a Pre-Operational DALS.

   2. Field testing under pre-operational conditions.

   3. Provide design specifications for an Operational DALS.

E.4 BENEFITS

Since DALS will eliminate the need to search for cooperative individuals, the following benefits will be realized:

a. Reduced SAR expenses.

b. Reduced time to effect a rescue.

c. Reduced loss of life (increase probability of survival).

d. Reduced property loss.

e. Reduced injuries.

f. Reduced dangers to SAR personnel extended searches.

g. Improve total SAR efficiency.

E.5 RISKS

No technical risks are envisioned. Primarily the basic system has been proven feasible by NASA (OPLE), US Navy (GRAN) and the National Weather Service. System application problems of concern are:

Use of alerting and locating devices by large numbers of the maritime and boating populations can result in multiple access and false alarm problems thus saturating DALS and straining the present SAR capabilities. Also, the DALS requires the availability of a NAVAID signal without ambiguities. Presently, OMEGA possesses lane ambiguities. Cost of the user device unit must be in reasonable proportion to that of other safety devices and the overall investment in boat, motor, and miscellaneous equipment.

WORK PLAN AND SCHEDULE

Project Distress Alerting & Locating System Number 731140

	TASK No.	PLANNED COMPLETION			1977	Total Funds[1]
Develop Experimental DALS	1143.2					*283K
Exp. DALS Training		COMPLETED	COMPLETED	INITIATED		
Delivered		COMPLETED	COMPLETED	INITIATED		
Installed		COMPLETED	COMPLETED	INITIATED		
Commence Coastal/Inland Waters/T&D Harbor	1143					
Develop Test Plan	1143.1	COMPLETED	COMPLETED	INITIATED		7K
SAR Testing		MID FY74		INITIATED		8K
Vessel Tracking Tests		MID FY74		INITIATED		10K
Buoy Positioning Tests		MID FY74		INITIATED		10K
Ice Breaker/Helo Tests		MID FY74		INITIATED		20K
Prototype Development	1140.3					
(Exp. DALS Modification)						
Investigate Freq. Change to Operation	1141.1	MID FY74		INITIATED		25K
Investigate Emergency Status Implementation	1141.2	MID FY74		INITIATED		10K
Investigate Repackaging User Device	1142					
Battery	1142.1	MID FY74		INITIATED		65K
Antennas	1142.2	MID FY74		INITIATED		65K
Reduction in Size/Cost	1142.3	MID FY74		INITIATED		60K
Complete Prototype Developments	1140.3	END FY75		INITIATED		680K
Prototype Test & Evaluation	1140.2	END FY76	END FY75			
Modifications	1140.1	END FY76	1ST QUARTER FY76			
Design Specifications	1140	END FY76	1ST QUARTER FY76			--
Funds[1] Allocated/Required						1255K
Funds[1] Expended		283K	7K 8K			298K

[1]Funds in Thousands of Dollars *Already Expended

Date 15 March 1973 By J.R. CARROS

F I N A N C I A L   P L A N   E L E M E N T   Distress Alerting and Locating System

PROJECT NO. 731140

DATE 15 March 1973

TITLE	J	A	S	O	N	D	J	F	M	A	M	J	REMARKS
Change Exp. Fre. to Operational Freq.									△1	△2		△3	Contract Mod. (100K)
Investigation of Distress Status (person/craft)									△1	△2		△3	Contract Mod. (50K)
Repackage hand-held Device (Battery, Antenna, Case)									△1	△2		△3	Contract Mod. (105K)
Develop prototype specifications										△1	△2	△3	BOA Task (50K)
Test Planning		△3											MIPR to NAVY (7K)
Test and Evaluation		△3											R&D Center Task (38K)

MILESTONE

△1 Complete RFP or other obligation

△2 Initiate FSP Contracting Services

△3 Award Contract