AD-A052 003 COMPUTER SCIENCES CORP ARLINGTON VA F/G 13/12
STUDY OF ALERTING AND LOCATING TECHNIQUES AND THEIR IMPACT (SAL--ETC(U)
SEP 75 DOT-CG-52032-A

UNCLASSIFIED NL

1 OF 2
AD A
052003

AD A052003

DDC FILE COPY

AD No.

17

STUDY OF ALERTING AND LOCATING TECHNIQUES AND THEIR IMPACT (SALTTI)

(6)

DDC
RECEIVED
APR 3 1978
F

Prepared for

UNITED STATES COAST GUARD
400 7th Street, S. W.
Washington, D. C. 20591

(15) DOT-CG-52032-A

by

COMPUTER SCIENCES CORPORATION

(11) 18 SEPTEMBER 1975

(12) 125p.

DEPARTMENT OF TRANSPORTATION ● UNITED STATES COAST GUARD

COST-BENEFIT ANALYSES

(COASTAL AREA)

403978

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd)

Section 2 - SALTTI Cost-Benefit Model Continued

TABLE OF CONTENTS (Cont'd)

TABLE OF CONTENTS (Cont'd)

LIST OF ILLUSTRATIONS

Figure

LIST OF TABLES

SECTION 1 - INTRODUCTION AND SUMMARY

1.1 Purpose. This report examines the cost-benefit ratios of electronic alerting and locating configurations considered by the Study of Alerting and Locating Techniques and Their Impact (SALTTI) for the coastal area. These analyses considered approximately 108 candidate systems under voluntary or mandatory carriage, with or without SAR impact, and by year through ten years. The geographical area includes the Great Lakes and coastal area extending 20 miles off shore, and a user population of commercial, fishing, and recreational boats.

1.2 Study Organization

1.2.1 Coast Guard Staff. SALTTI for the coastal area was conducted by the Coast Guard staff with a lead staff role assigned to the Telecommunications Management Division. This was in consonance with direction of the Chief of Staff on 21 December 1973. The SALTTI Group compiled related data, identified candidate systems, and performed the overall investigation except for cost-benefit aspects. The report of the SALTTI Group is contained in a Coast Guard publication, dated 18 September 1975.

1.2.2 Contract Support. Cost-benefit methodology and analyses were provided to SALTTI through contractor participation (DOT-CG-52032-A). The numerous configurations and conditions represented by candidate systems required computer assistance for analysis, rank order, and sensitivity. As a prerequisite, the cost-benefit model required determination of individual and combined system effectiveness. In providing responsive support, analyses by the contractor were delivered in informal and computer printout formats as needed in the SALTTI deliberations. These reports and the methodology applied are formally consolidated herein for reference.

1.3 Methodology

1.3.1 Modeling. The cost-benefit model is detailed separately. In order to evaluate benefits, it is necessary to determine effectiveness of various radio techniques in the environment addressed. Effectiveness comparisons utilized a model representing a 40-mile section of coastline extending 20 miles off shore. Representative populations and SAR deployment factors were applied to the model except for geographical transpositions in certain specialized cases. These exceptions included positioning the model in an area of high density coastal aircraft movement in one instance, and assuming commercial ship movement along the Florida coast as being representative of commercial population in the model. Actual radio propagation, electrical noise levels, emission characteristics, and transmission data were utilized. The cost-benefits were determined for each candidate system by year, by carriage and by SAR impact. These were tabulated and ranked by benefit:cost ratio and by benefit less cost. These were further ranked by commercial, commercial fishing, and recreational boat categories.

1.3.2 Simulation. The effect of signal congestion on the successful receipt of an emergency message was developed by computer simulation using a Monte Carlo approach. The program was run through at least 18,000 distress calls for the sampling base.

1.3.3 Significant Terminology. The term cost-benefit is used in its generic sense, whereas the term benefit:cost is used herein to identify specific benefits per unit dollar of cost applied. If the benefit:cost is greater than 1.000, the candidate system is favorable in that potential benefits exceed the user and Government costs. The term benefit less cost is the total dollar value of benefits less the dollar costs to implement that candidate system. Each candidate system is considered as an independent case for comparison reasons. Effectiveness in the model and computer analyses is expressed as the probability of success where 1.000 is maximum.

1.4 Significant Findings of Sensitivity

1.4.1 Unit Cost to the User. Benefit:cost and overall effectiveness under a voluntary carriage approach is most affected by the cost to participate regardless of technical attributes of a system. This is demonstrated by numerous candidate systems. Using one system (identified as 3A5B) which utilized an EPIRB with shore alerting and locating, the given unit cost of $200 was progressively reduced to compare participation and benefit:cost ratios. These results illustrate the effect of unit cost as follows:

Unit Cost	Percent Participation	Benefit:Cost
$200	10.9%	1.620
$150	13.8%	1.715
$100	19.4%	1.814
$ 75	24.7%	1.857
$ 50	28.8%	1.992

1.4.2 Aircraft Overflight Alerting. The effectiveness of emergency beacons dependent upon aircraft overflight in the coastal areas is highly sensitive to variations in commercial aircraft density along the coastal area. The benefit: cost conditions used in the analysis are not applicable to all U.S. coastal areas. The analysis purposely selected the highest density found along the East Coast and transposed the model to this area for this specific examination. The air traffic over Wilmington VOR, a mandatory reporting point, totals 540 aircraft a day and was used in the analysis. From midnight to 0800, air traffic is 2.8% of the daily total. The significance of lower densities of air traffic is illustrated for case 3A7A, Serial 79 (alerted by aircraft overflight, located by aircraft DF/Homing):

Aircraft Per Day In Radio Range	Probability of Alerting	Benefit: Cost
540	.751	1.344
32	.666	1.287
28	.584	1.231
20	.417	1.111
16	.333	1.048
10	.209	.951
5	.104	.866

1.4.3 Systems Using 2182 kHz. All candidate systems based on 2182 kHz in the coastal area had a benefit:cost ratio of less than 1, and ranked no higher than 49th among 108 systems. The lowest ranking group was 2182 kHz EPIRBs with a benefit:cost ratio of 0.403. With the exception of limited seasonal hours and Northern geography, atmospheric noise seriously impaired the effectiveness and benefit:cost ratio of 2182 kHz systems. The radiated power possible with EPIRBs and recreational boat antenna installations provide a signal-to-noise level that is too marginal. Further, the replacement costs of new mandatory SSB installed equipment seriously reduced the voluntary participation of recreational boats. The sensitivity of radio detection and location ranges to atmospheric noise seriously limits the value of 2182 kHz in U.S. coastal areas except for users having space for effective antennas.

1.4.4 Use of 500 kHz. Although highly effective in commercial application, the predominant recreation and fishing boat environment in the coastal area resulted in unfavorable benefit:cost ratios for 500 kHz systems except for survival (SOLAS) equipment. The feasibility of this equipment in the coastal area is an unacceptable solution for small craft because of size, weight, and operational complexity.

1.4.5 Radio Line-of-Sight (LOS) Candidates. A total of 32 candidate systems for alerting and/or locating were found to have favorable benefit:cost ratios, that is, the benefits were greater than the costs.* If the six candidates involving 500 kHz are disregarded for the coastal area (Paragraph 1.4.4), all remaining candidates having favorable benefit:costs are LOS systems. This collective categorization includes 121.5/243 MHz, 156.8 MHz, VHF-AM, VHF-FM, and 406 MHz. Because of coverage capabilities already engineered in selecting remote communications monitoring sites, the U.S. coastal area is within transmission capabilities of all one-watt or conventionally powered LOS equipment. The slight effectiveness advantages of VHF-AM or UHF-AM over 156.8 MHz merely reflect potentially reduced congestion. Otherwise, this collective group is most affected by user costs, acceptability, and Government costs for satellites. Of the 26 LOS candidates with favorable benefit:cost ratios, 16 were various EPIRB/ELT/Beacon concepts using terrestrial alerting and locating, seven utilized satellites for alerting and terrestrial (shore, aircraft or ship DF) techniques in locating, and three utilized 156.8 MHz installed or handheld equipment.

1.4.6 Single or Two Line-of-Positions (LOP) in SAR Station Configuration. Because the DF capabilities associated with each CG Station are spaced 30 to 40 miles along the coast, a geometric dilution in DF locating occurs for boats within approximately five miles of shore. However, statistical distribution of recreational boats place 90% in this zone. This would suggest that some areas of recreational boat activity should include a supplemental DF facility remotely-controlled by the CG Station and positioned a few miles distant. Because the supplemental station does not require the range or sensitivity, its technical performance may be reduced in antenna gain and height. The sensitivity in overall alerting and locating and in benefit:cost ratio was examined. For this purpose, a 75-milliwatt distress signal was assumed and the supplemental site

*Voluntary with SAR impact.

afforded a 0-dB gain antenna whereas the CG Station utilizes a higher performance antenna with 12-dB gain. The results are:

Case	Success Probability	Benefit:Cost Ratio
Single CG Station	.731	1.342
Supplemental DF Plus CG Station	.788	1.299

1.4.7 EPIRB/Beacon Duty Cycles. Existing system concepts have the automated beacon (EPIRB/ELT) transmitting continuously once activated. In event of a storm front or emergency affecting multiple incidents, the radio interference among simultaneous emitters seriously restricts alerting and locating success. An on-off sequence of individual emitters would alleviate this threat. Analytical techniques are available to define the duration of transmission and silent intervals to optimize the individual probability of success in a multiple emitter environment. In order to fix the ideal cycle, it is necessary to establish the maximum emitters to be considered by the SAR system. If four simultaneous emergencies are assumed as a design objective, the following table shows the probability of separating and locating the multiple emitters:

Cyclic Parameters (In Seconds)	Time to Sort (In Minutes)	Probability
10 on, 102 off	20	.999
15 on, 160 off	20	.997
10 on, 102 off	10	.987
15 on, 160 off	10	.942
10 on, 102 off	5	.870
15 on, 160 off	5	.730

1.4.8 Communications Congestion. For voice distress alerting systems on radio frequency channels also utilized for voice calling and short messages, the recognition of a distress call may be degraded by increased communication calls. This sensitivity to congestion was examined by computer simulation using the Monte Carlo techniques. Although the third attempt success probability is degraded in projections to 1990, the impact of time in ensuring receipt in the worst case does not exceed ten minutes. This sensitivity is illustrated by the following data which utilized the New York area:

Situation	Probability of Success (Third Call or Less)
1974 Density	.976
1985 Density	.943
1990 Density	.907

1.5 Alerting and Locating Functions

1.5.1 Alerting. For alerting purposes only, the highest benefit:cost ratios were for beacons (EPIRB) and handheld LOS units (excludes 500 kHz consideration). The LOS units are 156.8 MHz, VHF or UHF devices.

1.5.2 Locating. For location in the coastal area, the highest benefit:cost ratios were for configurations using shore and aircraft DF. Although the aircraft lacks the accuracy of shore and ship DF (because of receiver sensitivity), its mobility offsets this by permitting an indefinite baseline of bearings and homing in time. The next favorable group in descending order included ship DF and retransmission of NAVAID data to shore.

1.5.3 Alerting and Locating. Twenty-three candidate systems have favorable benefit:cost ratios for providing alert and location functions. Except for three systems using installed 156.8-MHz equipment, all favorable systems utilized survival or beacon configurations in which location was provided by shore DF, aircraft DF, ship DF or retransmission of NAVAID data.

1.6 Report Presentation. The report is contained in two volumes. This volume describes methodology and data base. Cost-benefit computations are contained in a separate volume.

SECTION 2 - SALTTI COST-BENEFIT MODEL

2.1 Introduction. The SALTTI Cost-Benefit Model develops an estimated ten-year life cycle system cost and estimates the benefits in dollars over the same ten-year period. The ten-year life cycle cost includes an estimate of the Government and user costs as well as costs due to SAR caseload impact required by Task 5 of the Statement of Work. The user costs will reflect both voluntary and proposed mandatory carriage of the alerting and/or locating (A/L) devices by commercial, fishing, and recreational boats. The benefits model will estimate benefits measured in dollars for each of the three categories: commercial, fishing, and recreational boating. The estimate of benefits will reflect the fatalities and property damage prevented by the exclusive use of each of the A/L devices without considering the capabilities of the current system. The benefit:cost ratio is determined by dividing the present value of the benefits for the ten-year period by the present value of the costs for the same period. The present values are derived by discounting the annual costs at a 10-percent interest rate.

2.2 Government Costs. The estimated cost for Government electronic equipment was furnished by the Government and includes initial cost, R&D as appropriate, Acquisition and Installation Costs (AC&I), and recurring Operation and Maintenance Costs (O&M) for a 10-year period. The estimated costs will be in terms of constant 1974 dollars and the present value will be determined using an interest rate of 10 percent. For those candidate systems for which Government equipment has already been procured, the initial costs which are normally considered as sunk costs will be included for the purpose of this Benefit:Cost analysis. For those candidate systems for which Government equipment must be procured, it will be assumed that the equipment will be procured and installed during the base year. For systems in which the equipment is leased, there is no AC&I cost and it will be assumed that the equipment will be installed during the first year. The recurring costs include estimated cost of leasing equipment and lines, and/or an annual maintenance cost determined as 10 percent of installed equipment cost for equipment which has been procured. Operations personnel cost of $10,200 per annum is based on enlisted personnel costs budgeted for FY-76. This cost includes basic pay, BAQ, Incentive and Special Pay, and miscellaneous expenses such as subsistence, uniform and clothing allowances, FICA, etc. Retirement entitlements (17%), leave and holiday (20%) and other personnel costs (23%) such as medical, quarter and subsistence are not included.[1]

In accordance with Task 5, the cost impact due to an increased SAR caseload will be estimated. This cost is also a Government cost and is the cost of acquiring and operating additional search and rescue assets due to the expected SAR caseload increase resulting from the use of the A/L device. These Government costs will be separated from the Government costs of acquiring and operating the electronic equipment required for the alerting and locating functions; benefit:cost ratios will be developed both with and without SAR Impact Costs included. The basic data for the cost of the SAR impact was provided by the Government using the SARSIM. The SAR impact costs include both the added annual O&M and the added acquisition and installation costs of servicing excess SAR caseloads. The AC&I cost is incremented on an annual basis to cover the acquisition of additional assets required.

2.3 User Costs. The estimated user costs will address both mandatory and voluntary carriage of A/L devices by commercial, fishing and recreational boats. The user cost model for both voluntary and mandatory carriage will consider the user population, estimated increases in boating population, and learning curves for estimating unit cost based on potential market. In addition, the voluntary carriage user cost model will consider the recreational boating user acceptability of A/L devices based on cost. The present value of the cost

---

[1] Department of Defense Instructions 7220.25 June. 15, 1972

to users of the A/L devices will also be determined using an interest rate of 10 percent and computed in terms of constant 1974 dollars.

2.3.1 User Population. The major factor in determining the user cost is the size of the user population. The user cost model considers the total recreational boating population, the voluntary carriage population and a population which reflects a proposed mandatory carriage (PMC).

2.3.1.1 Total Population. The total recreational boating population is the total population against which the safety equipment tabulation of the national boating survey[(1)] was examined. This total population is the total number of boats determined by the survey except those which are located in the East Central and Midwest/Mountain Region.

	Total Boats[(2)]	Equipped with Distress Signals[(3)]
Total	8,336,343	2,954,695
Less East Central	543,161	173,454
Less Midwest/Mountain	684,213	192,551
Total Population (1973)	7,108,969	2,588,690
Percent equipped = 36.4		

2.3.1.2 Mandatory Carriage Population. The mandatory population reflects a logically derived set of users in each of the three classes of boating. The definition of the set of users includes characteristics of the boat as well as characteristics of the A/L device, and expected area of operation. The set of users includes those for which carriage is mandatory under existing statutory provisions as well as those for which statutory provision for mandatory carriage

---

(1) Wulfsberg and Lang, "Recreational Boating in the Continental United States in 1973: The Nationwide Boating Survey", October 1974

(2) Wulfsberg and Lang, op. cit., Table 10

(3) Wulfsberg and Lang, op. cit., Table 19

may be logically proposed. A full description of the PMC for each class of the boating population is contained in Section 3.

2.3.1.3 Voluntary Carriage Population. The voluntary population for commercial and fishing boats is estimated from current usage based on type of equipment and is discussed in greater detail in Section 3 in conjunction with the development of the PMC. The voluntary recreational boating population is derived from a demand curve provided by SALTTI 54-4 and is based on the results of the Nationwide Boating Survey. The methodology for estimating the population of recreational boating which voluntarily carries an A/L device depends on both the demand curve and the learning curve.

2.3.2 Estimation Methodology for Recreational Boating Voluntary Carriage Population

2.3.2.1 Demand Curve. For the recreational boating population, the voluntary carriage of A/L devices will be based on user acceptability of the A/L devices. The acceptability of the devices is measured by the percent of participation and this percentage can be expressed in terms of cost of the device. Generally, the lower the cost, the greater the acceptance. The acceptability of the A/L devices for recreational boaters was furnished by the Government in the form of the linear demand curves shown in Figure 2-1. These linear demand curves can be very closely approximated by the continuous curve also shown in Figure 2-1. The equation for this curve is:

$$\text{Percent Participation } PA = \frac{P_{vr}}{P_t} = 3.2586\, C_v^{-0.7262} \times 100 \qquad (1.1)$$

Where: P_{vr} = voluntary population, recreational boating

P_t = total population (7,108,969 in 1973)

C_v = cost, if carriage is voluntary

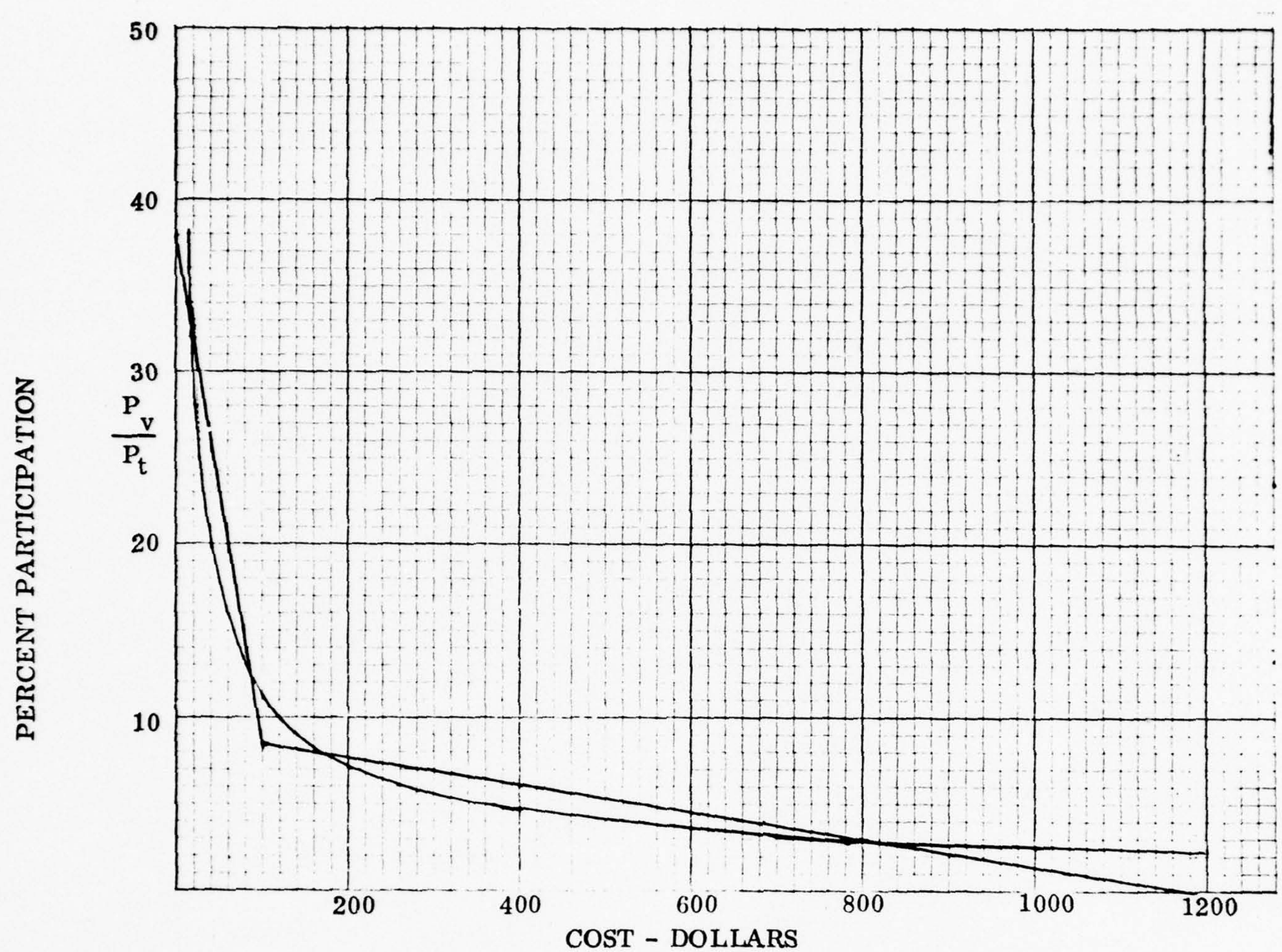


Figure 2-1. User Acceptability of A&L Devices, Recreational Boating

By using equation (1.1), it is possible to estimate the voluntary population from the cost of the A/L device. However, it is generally accepted that when a large number of units are manufactured, the cost per unit decreases. Thus, as the cost decreases, the participation will increase and the cost will be expected to decrease further. The average unit cost, based on the number of units produced can be estimated by what is known as the "Learning Curve".

2.3.2.2 Learning Curve. Producing units in larger quantities enables the average cost per unit to be significantly reduced. This reduction in the average unit cost is due to an increase in worker efficiency resulting from the learning process. The learning process is due to a number of factors. In the narrow sense, a learning curve considers only the individual operator learning the sequence and technique of his job and making improvements over time and quantity on those sequences and techniques. In a broader sense, this type of learning accounts for the cost reduction for only a single manufacturer and not for the industry as a whole. The learning factor is the percent reduction in cost when the production is doubled. Thus, if the cost of the first unit is $100 and the average cost of the first two units is $90, then the learning factor is 0.9. The average unit cost of the first four units would be $81.

The principal applications of the learning curve assumption appear in those processes that include assembly operations or a mix of assembly and machining operations. In general, production runs which are more labor intensive would correspond to the lower values of the learning factor. The value of the learning factors recommended for the several different types of equipment is given in Table 2-1, Learning Factor Values. Each of these factors represents a degree of labor intensity. The 500-kHz installed transmitter and receiver are the most labor intensive while the EPIRBs and other portable units with solid state components and printed circuitry are the least labor intensive.

TABLE 2-1. LEARNING FACTOR VALUES

EQUIPMENT	LEARNING FACTOR
500 kHz Installed	0.82
2128 kHz Installed	0.85
156.8 MHz Installed	0.85
500-kHz Portable Survivor Craft Xmitter	0.85
EPIRBs and other portable units	0.88[1]

In using the learning curve for estimating the costs of larger quantities, the average unit cost, C(N), for N units is given by the expression:

$$C(N) = C(B)\left(\frac{N}{B}\right)^{LnLF/Ln2} \quad (1.2)$$

where:

B = base number of units

C(B) = average unit cost of B number of units

N = number of units for which average unit cost is desired

LF = learning factor

2.3.2.3 Voluntary Carriage Projection. The Demand Curve, equation (1.1), furnished an estimate of the percent of participation based on the cost of the A/L device. The Learning Curve, equation (1.2), furnishes an estimate of the cost based on the number of units to be manufactured. It is apparent that as more units are manufactured, the lower the cost will be and the greater the voluntary participation. To determine the estimated cost and voluntary carriage population, equations (1.1) and (1.2) may be solved simultaneously.

---

[1] Data Collection Platform Study for the Synchronous Meteorological Satellite System (Appendices), Vol. II Final Report: July-November, 1970, The Magnavox Company, Government and Industrial Division Advanced Systems Analysis Office

Substituting (1.2) into (1.1) and solving for the voluntary recreational boating population, P_{vr}, the equation (1.3) is obtained.

$$P_{vr} = \left[\frac{Pt \times 3.2586 \times C(B)^{-0.7262}}{B^{-0.7262 \times \text{Ln } LF/\text{Ln}2}}\right]^{1/(1+0.7262 x \text{Ln} LF/\text{Ln}2)} \qquad (1.3)$$

where N in (1.2) represents P_{vr} in (1.1) and the other variables are the same as defined for equations (1.1) and (1.2). Using equation (1.3) it is possible to estimate the number of A/L device acquisitions for recreational boating under voluntary carriage, P_{vr}, based on the total recreational boating population. P_t defined in Paragraph 1.3.1.1, for this specific demand curve.

To determine the estimated cost of the A/L device, it is necessary to add the estimated number of boats/vessels equipped with the equipment in the fishing boat and commercial fleet P_{vf} and P_{vc} respectively. The estimated average unit cost for the A/L device is predicted by equation (1.2). Based on this average unit cost, the percent participation PA(i) and the estimated recreational boating population which will acquire this device under voluntary carriage is estimated from the demand curve, equation (1.1). These results are illustrated graphically in Figure 2-2.

For example, if the demand curve for an A/L device is as shown in Figure 2-1, the average retail cost from a single manufacturer is $1500 and there are 14 manufacturers, the learning factor is 0.85 and the total population in 1975, the base year is:

$$P_t = 7,108,969 \times 1.0375^2$$

$$= 7,652,139, \qquad (1.4)$$

where annual rate of increase of recreational boats is 3.75 percent. Using equation (1.3), the first estimate of recreational boating voluntary population P_{vr} is obtained:

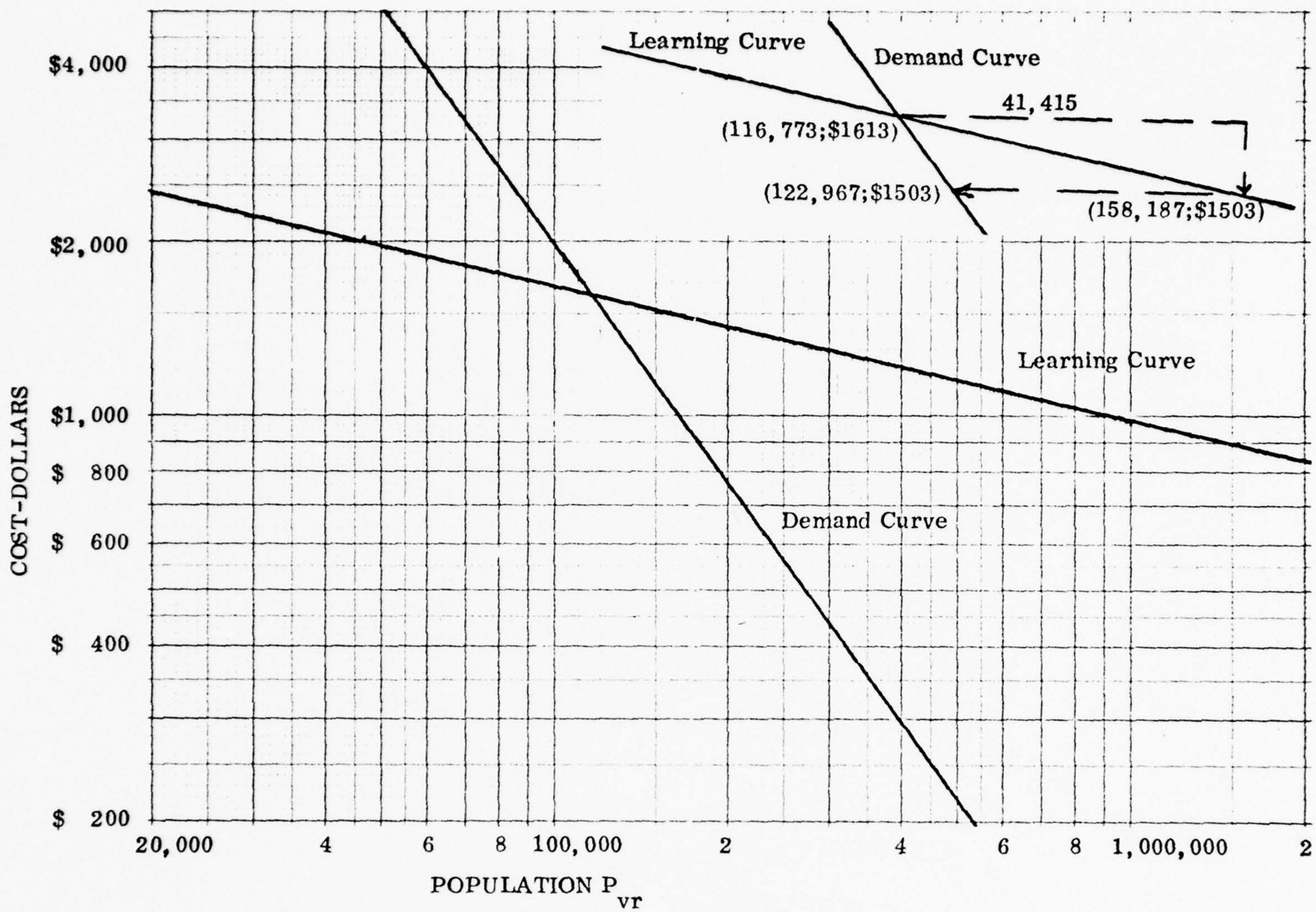


Figure 2-2. Demand and Learning Curves

$$P_{vr} = \left[\frac{7,652,138 \times 3.2586 \times 1500^{-0.7262}}{(11,383 \times 14)^{-0.7262 \times Ln0.85/Ln2}}\right]^{1/(1+0.7262 \times Ln0.85/Ln2)} \qquad (1.5)$$

$$= 116,773$$

Then, if there are 5,938 commercial vessels (P_{vc}) and 34,714 fishing vessels (P_{vf}) which carry the A/L device voluntarily in 1973 and the annual rate of increase of commercial and fishing vessels is 4 percent and 0.4 percent respectively, the estimated cost of the A/L device, as determined by equation (1.2) is:

$$C(N) = \$1500 \left(\frac{5,938 \times 1.04^2 + 34,714 \times 1.004^2 \times 116,773}{11,383 \times 14}\right)^{Ln0.85/Ln2} \qquad (1.6)$$

$$= \$1503$$

where $N = P_{vc} + P_{vf} + P_{vr}$.

Using this cost for the second iteration, the final estimate for the recreational boating population, P'_{vr}, and the percent participation, PA, is obtained by using equation (1.1):

$$P'_{vr} = 7.652,138 \times 3.2586 \times 1503^{-0.2345} \qquad (1.7)$$

$$= 122,967$$

$$PA = 122,967/7,652,138 = 0.0161 \qquad (1.7')$$

The base number of units is derived from the number of licenses (159,356) reported by FCC for the 2-MHz installations which is used as the illustrative example. Assuming 14 manufacturers, each manufacturers 11,383 units. Therefore, in this example the base point for the Learning Curve is 159,362 units at $1500 each.

The data for other types of sets are as follows:

Total licenses reported by FCC

VHF - FM Installations	121,600	14 manufacturers
2 MHz	159,356	14 manufacturers
500 kHz	970	5 manufacturers

For all other A/L devices the average unit cost is based on 3000 units for each by an assumed 14 manufacturers.

In the event that the computed first estimate of the recreational boating voluntary population exceeds the recreational boating PMC population, the value of the PMC population will be used to compute the cost, C_v, as in equation (1.6).

2.3.3 User Cost Estimation Methodology. To more realistically estimate the user cost of the A/L devices, it is necessary to consider the annual increase in boating population. The base populations and the estimated annual rate of increase are shown in Table 2-2.

TABLE 2-2. BOATING POPULATION REFERENCE DATA

	Commercial	Fishing	Recreation	
Total Population (1973)	5,938	84,812	7,108,969	Fishery Data, Boating Survey Commercial Count (Para. 3.3)
Annual Rate of Increase %	2.5 - 5.5	.4	2.5 - 5	SALTTI 54
Assumed in Model (%)	4	4	3.75	

The estimated annual user costs are based on an initial buy of the A/L device in the first year with a user O&M cost of 10 percent per year and yearly acquisition due to the increase in the boating population. Using only the first two years of the 10-year life cycle period, Table 2-3 illustrates the computational procedure for determining the present value of the annual users' cost. Continuing with the previous example, the projected number of equipped commercial, fishing and recreational boats are shown in row (1). Row (2) shows the number of newly acquired units each year and is the difference between the respective annual totals, row (1). The estimated unit cost is shown in row (3). Row (4) represents the users annual investment and is the product of rows (2) and (3). Row (6) derives the annual O&M cost which is estimated at ten percent of the cumulative investment cost, row (5). Row (7) contains the values of the present worth factors at ten percent interest rate. The values in rows (8) and (9) represent the present value of the users annual investment cost and O&M cost,respectively. The sum of the respective annual entries in Rows (8) and (9) are shown in rows (10) and (11) and represent the present value of the ten-year users'investment and annual operating cost with the present value of the total costs shown in row (12) of the final year.

The computation of the present value of the users cost for mandatory carriage follows the same procedure as described in Table 2-3, except that the PMC for recreational boating is supplied as input in place of the computational procedure for recreational boating voluntary population, P_{vr}.

2.4 Effectiveness Model. The unit effectiveness of the A/L Device is the product of a number of component effectiveness factors which are discussed in detail in Section 3 . These factors are described briefly in this section together with the procedures used to derive the unit effectiveness from the factors for the cases of "alerting only" "locating only" and "alerting and locating". The unit effectiveness is one of the factors used in deriving the SAR Impact Costs and the estimated benefits.

TABLE 2-3. PRESENT VALUE COMPUTATIONAL PROCEDURE

YEAR	1975			1976		
CATEGORY	C	F	R	C	F	R
(1) PV	6,422	34,992	122,967	6,679	35,132	128,349
(2) NEW	6,422	34,992	122,967	257	140	5,382
(3) CV ($)	1,503	1,503	1,503	1,490	1,490	1,490
(4) UIN ($K)	9,652	52,593	184,819	383	209	8,019
(5) SUM ($K)	9,652	52,593	184,819	10,035	52,802	192,839
(6) AOM ($K)	965	5,259	18,482	1,004	5,280	19,284
(7) PWF	0.9091	0.9091	0.9091	0.8264	0.8264	0.8264
(8) PVIN ($K)	8,775	47,812	168,018	316	172	6,627
(9) PVOM ($K)	877	4,781	16,802	829	4,364	15,937
(10) SPVIN ($K)	8,775	47,812	168,018	9,091	47,984	174,645
(11) SPVOM ($K)	877	4,781	16,802	1,707	9,145	32,739
(12) PCOST ($K)	-	-	-	10,798	57,129	207,384

2.4.1 Effectiveness Factors. EP describes the propagational capability to provide adequate signal throughout the geographical zone and is a measure of the percentage of geography afforded adequate coverage.

ET describes the time availability of the detecting facility/platform and is measured by the available minutes per day divided by 1440.

EA describes the equipment availability in the detecting facility/platform and is 0.995 for all systems.

ES describes the probability of success for voice/record communication alerting message within signal environment and the EPIRB success probability within environment of multiple EPIRB signals and is measured by success probability within three calls or less times probability of success within ten minutes of initiating alerting message.

EL describes the probability of providing adequate location for SAR and is measured by probability of successful location to result in two mile sighting distance or less within 30 minutes of emergency message, or homing directly by DF equipment. (The value of 1.000 is used for "alerting only" cases.)

2.4.2 Unit Effectiveness. The unit effectiveness, EV, is dependent not only on the system effectiveness factors, but also of the function of the system, alerting only, locating only, and alerting and locating. In search and rescue missions, alerting and locating are functions which are considered of equal importance. Therefore, in determining the EV value, the product of the system effectivness factors is multiplied by 0.5 for alerting only and locating only A/L systems.

2.4.2.1 Alerting Only. The EV value, for the j th alerting only A/L systems is given by:

$$EV_{ao}(j) = 0.5 \times EP \times ET \times EA \times ES \times EL \qquad (1.8)$$

where $EL = 1.0$ for alerting only systems

2.4.2.2 Locating Only. The EV value, for the k th locating only A/L system is given by:

$$EV_{lo}(k) = 0.5 \times EP \times ET \times EA \times ES \times EL \quad (1.9)$$

2.4.2.3 Alerting and Locating. The EV value, for a given alerting and locating system, the components of which are the j th alerting system and the k th locating system, is given by:

$$EV_{al} = EV_{ao}(j) + EV_{lo}(k) \quad (1.10)$$

2.4.3 Impact Probability. To determine an equivalent number of units which would contribute to an increase in the SAR caseload, the impact probability, PI(i), is defined as:

$$PI(i) = EV \times PA(i) \quad (1.11)$$

where PA(i) is the percent participation defined by equation (1.1)

2.4.4 Fraction of Loss. The actual value of the fraction, f(i), of lives lost that could be saved is given by

$$f(i) = F \times PA(i) \times EV \quad (1.12)$$

where F is the maximum value of the fraction of lines lost and/or property damage that could be prevented by a completely effective A/L device as described in Paragraph 2.6.1.

2.4.5 Effectiveness Example. Assume that the A/L systems have the following system effectiveness

	j th Alerting Only	k th Locating Only	j th Alerting and k th Locating
EP	0.950	0.950	0.950
ET	0.996	0.996	0.996
EA	0.995	0.995	0.995
ES	0.907	0.907	0.907
EL	1.000	0.880	0.751

The EV values are computed as follows:

$$EV_{ao} = 0.950 \times 0.996 \times 0.995 \times 0.907 \times 1.0 \times 0.5 = 0.4270$$

$$EV_{lo} = 0.950 \times 0.996 \times 0.995 \times 0.907 \times 0.880 \times 0.5 = 0.3757$$

and therefore

$$EV_{al} = 0.4270 + 0.3757 = 0.8027$$

However, for computational purposes:

$$EL_{al} = EP(k) \times ET(k) \times EA(k) \times ES(k) \times EL(k) = 2 \times EV_{lo}(k)$$

and $EP_{al} = EP(j)$

$$ET_{al} = ET(j)$$

$$EA_{al} = EA(j) = 0.995$$

$$ES_{al} = ES(j)$$

and therefore from (1.10)

$$EV_{al} = EV_{ao}(j) + EV_{lo}(k)$$

$$= 0.5 \times EP_{al} \times ET_{al} \times EA_{al} \times ES_{al} + 0.5\ EL_{al}$$

$$= 0.5 \times (EP \times ET \times EA \times ES + EL)_{al}$$

Continuing with the example

$$EV_{al} = 0.5 \times (0.950 \times 0.996 \times 0.995 \times 0.907 + 0.751)$$

$$= 0.8025.$$

(The difference between 0.8027 and 0.8025 is caused by rounding off EL_{al} to three significant places.)

The EV values are used in equations (1.11) and (1.12) to derive SAR Impact costs and benefits respectively.

2.5 SAR Impact Costs. The basic procedures and data for determining cost increases due to increased SAR caseload is furnished in SALTTI/54, 54-3, and 54-4. Since the major customer of the Coast Guard's SAR service in the coastal environment is the recreational boater, the cost increase due to increased SAR caseload is driven by the recreational boater. However, the SAR caseload for both commercial and fishing as well as other causes are included in the computations.

2.5.1 SAR Caseload Reference Data. The SAR impact costs are based on an expected annual SAR caseload, which, in turn, is based on the expected number of recreational boating incidents in which the A/L device is used. This relationship, described in SALTTI/54-4, is based on the total caseload for 1980. To predict the caseload on an annual basis, analytic expressions are required. The SAR caseload reference data shown in Table 2-4 was derived from SALTTI/54, Table 5 and includes the base number of SAR cases, expected annual rate of increase, and expected percent which occur within 25 miles of shore. This data is the basis for determining the annual caseload as explained in the following paragraph.

The user acceptability is also a factor used to determine the expected annual SAR caseload, The recreational boating user acceptability of device is measured by percent participation and is based on user's cost from Figure 8, SALTTI/54-4 or from equation (1.1). The probability of acceptance is multiplied by an effectiveness factor to obtain an impact probability which is used to determine the the anticipated caseload from Figure 9, SALTTI/54-4. Thus, continuing with our previous example, the percent participation, PA(i), is 1.61 percent (from equation 1.7'), the probability of being able to alert the Coast Guard is EV_{ao} = 0.4270 (from Paragraph 1.4.5). The impact probability, PI, is:

$$PI(i) = PA(i) \times EV = 0.0161 \times 0.4270 = 0.0069 \qquad (1.13)$$

2.5.2 SAR Caseload Increase. Analytical expressions in terms of annual increases for the linear relationships shown in Figure 9, SALTTI/54-4, using the notation of SALTTI/54-4, are developed with reference to the SAR Caseload Reference Data of Table 2-4.

TABLE 2-4. SAR CASELOAD REFERENCE DATA

REFERENCE		USER GROUP					SOURCE
		Commercial C	Fishing F	Recreational R	Misc. M	Total * T	
SAR Caseload (1974)	B	2,240	5,750	40,260	9,240	260,300	SALTTI 54
Annual Rate of Increase	R	-1.87%	2,06%	5.97%	2.15%	4.96%	SALTTI 54
Percent within 25 Miles	PC	80.00%	89.23%	99.12%	N/A	99.12%	SALTTI 54

*Total Recreational Boating incidents which occurred off-shore in waters within the Coast Guards jurisdiction.

$$C_t = 348{,}000 \times PI + 57{,}000\ (1-PI) \tag{1.14}$$

and in terms of reference data for computing C_t on an annual basis, i:

$$C_t(i) = BT \times (1+RT)^i \times PI(i) + BR \times (1+RR)^i \times (1-PI(i)) \tag{1.14'}$$

$$= PI(i)\,[BT \times (1+RT)^i - BR\ (1+RR)^i] + BR \times (1+RR)^i$$

$$C_\Delta = C_t - 57{,}000 \tag{1.15}$$

$$C_\Delta(i) = PI(i)\,[BT \times (1+RT)^i - BR \times (1+RR)^i] \tag{1.15'}$$

and the overall total CG caseload, CT, for all categories equals:

$$CT = 19{,}000 + C_t \tag{1.16}$$

$$CT(i) = BC \times (1+RC)^i + BF \times (1+RF)^i + BM \times (1+RM)^i + BR\ (1+RR)^i + PI(i)\,[BT \times (1+RT)^i - BR\ (1+RR)^i] \tag{1.16'}$$

$$= A(i) \times PI(i) + B(i) \tag{1.16''}$$

where

$$A(i) = BT \times (1+RT)^i - BR \times (1+RR)^i$$

and

$$B(i) = BC \times (1+RC)^i + BF\ (1+RF)^i + BR\ (1+RR)^i + BM \times (1+RM)^i$$

2.5.3 O&M Cost of Excess Caseloads. Figure 10 of SALTTI/54-4 represents the linear relationships for determining annual direct operating cost for different search reduction percentages as a function of Total Caseload, CT. The equation for the zero percent search reduction is:

$$CDZ\$ = 488.88 \times CT - 24{,}915 \tag{1.17}$$

where CT is total caseload (thousands) and CDZ$ is direct cost zero percent search reduction (thousands of dollars).

For the 100-percent search reduction, the equation is:

$$CDH\$ = 360.61 \times CT - 24{,}799 \tag{1.18}$$

2.5.3.1 Alerting Only. For those A/L devices whose function is alerting only the added annual SAR operating cost, (S$), is determined by the following expression:

$$S\$ = CDZ\$(CT) - CDZ\$(B(i))$$

$$= 488.88\ PI(i) \times A(i) \qquad (1.19)$$

This is depicted graphically in Figure 2-3, and is reduced to the following expressing using equations (1.16") and (1.15')

$$S\$ = 488.88\ C_{\Delta} \qquad (1.19')$$

which is the equation of the "Alerting Only" line on Figure 12 of SALTTI/54-4.

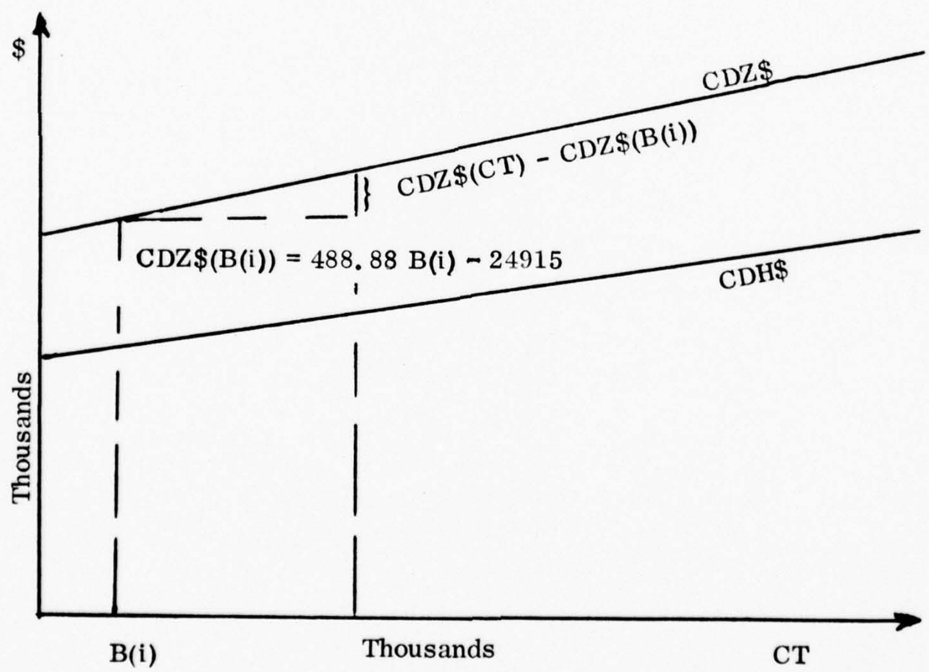


Figure 2-3. Added Annual Operating Cost, Alerting Only

2.5.3.2 Locating Only. For those A/L devices whose function is locating only the annual SAR saving (negative costs), S$, is determined by the following expression:

$$S\$ = PI(i) \times [CDZ\$ \ (B(i)) - CDH\$ \ (B(i))] \qquad (1.20)$$

This is depicted graphically in Figure 2-4 and reduces to the following expression:

$$S\$ = PI(i) \ (128.27 \times B(i) - 116) \qquad (1.20')$$

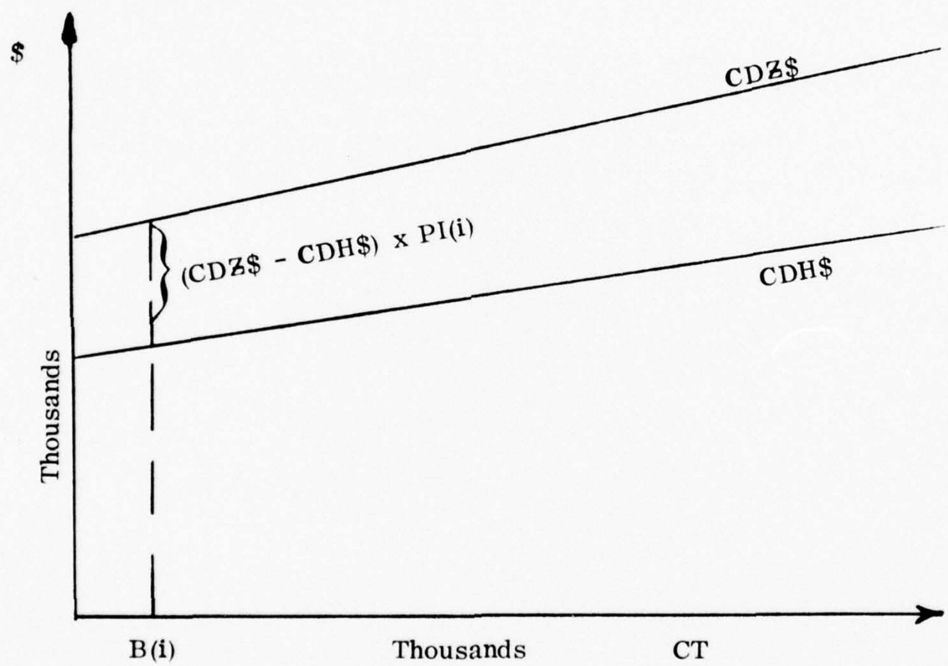


Figure 2-4. Added Annual Operating Cost, Locating Only

2.5.3.3 Alerting and Locating. For those A/L devices/systems which combine the function of alerting and locating, the manual SAR costs, S$, is determined by the following expression:

$$S\$ = (1-PI(i)) \times [CDZ\$ \ (B(i)) - CDH\$ \ (B(i))] + CDH\$ - CDZ \ (B(i)) \qquad (1.21)$$

This is depicted graphically in Figure 2-5 and reduces to the following expression:

$$S\$ = PI(i) \times (360.61 \times A(i) - 128.27 \times B(i) + 116) \qquad (1.21')$$

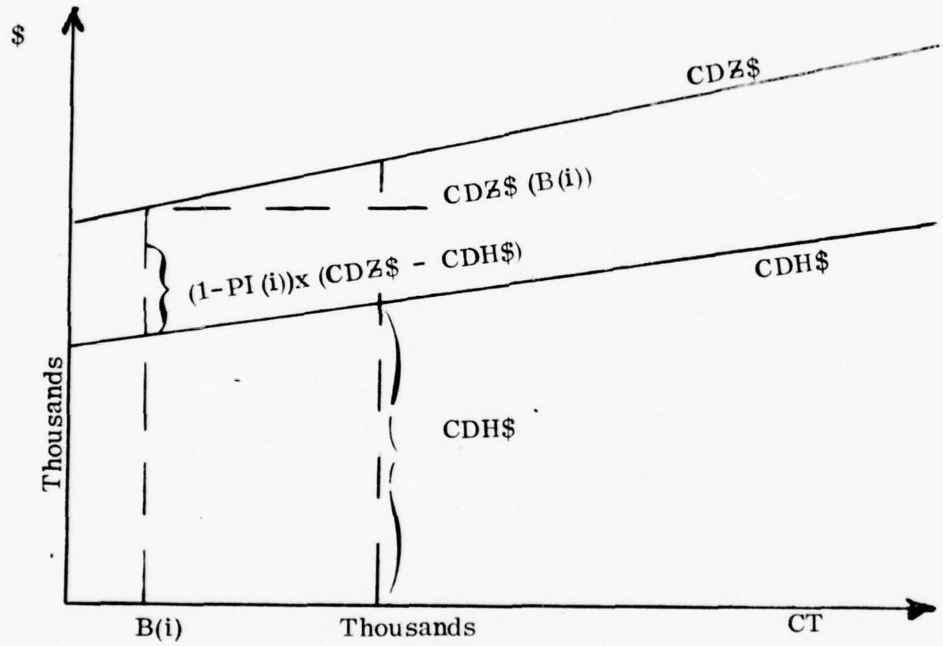


Figure 2-5. Added Annual Operating Cost, Alerting and Locating

This equation may also be transformed by using the relationships (1.15') (1.16'') to obtain:

$$S\$ = C_{\Delta} \left(360.61 \quad \frac{128.27\ B(i) - 116}{A(i)}\right) \qquad (1.21'')$$

$$= 327.51\ C_{\Delta} \quad (\text{for } i = 6 \text{ , CY } 1980)$$

which is the "With Locating" line on Figure 12 of SALTTI/54-4.

2.5.4 <u>AC&I Cost of Excess Caseloads.</u> Figure 11 of SALTTI/54-4 represents the linear relationships for determining the added AC&I cost of servicing the excess caseloads for different search reduction percentages as a function of the Total Caseload, CT. The added annual cost, SAA$(i), is the difference between added AC&I cost for the current year and the added AC&I cost for the preceding year. This implies the assumption that the acquisition of resources required to service the excess caseloads will be acquired incrementally on an annual basis. The equation for the zero percent search reduction is:

CAZ$ = 2,056.64 CT - 100,076 (1.22)

and for the 100 percent search reduction

CAH$ = 1,429.85 CT - 98,600 (1.23)

Following the same procedures for determining the added cost due to the functions of alerting, locating and alerting and locating, the following equations are obtained.

Alerting Only (Cost)

SA$ = 2,056.64 x PI(i) x A(i) (1.24)

Locating Only

The procedure for computing the cost of increased SAR caseload for "Locating Only" A/L devices results in a negative value (savings). The interpretation, when applied to AC&I, is that there is no decrease or disposal of SAR assets. Therefore, the value of SA$ for "Locating Only" is zero.

Alerting and Locating Cost

SA$ = PI(i) (1429.85 x A(i) - 626.79 x B(i) + 1476) (1.25)

2.6 Benefits. The benefits will be measured in dollars and will consider the savings which may accrue from prevention of fatalities and property damage. For loss of life, it is estimated that one quarter to one third of the lives lost could not be saved by the use of any A/L devices. It is from those lives which could be saved, or property damage prevented, that the benefits for A/L devices will be derived. The present value of the benefits will be determined on an annual basis over the ten-year period. Benefits will be computed for prevention of fatalities and property damage for commercial vessels, fishing and recreational boats.

2.6.1 Benefit Model. The computational procedure explained in this paragraph will be the same for determining the benefits due to prevention of fatalities and property damage for each of the boating categories, commercial, fishing, and recreational. The value of the benefits for each case will be different because different values of input parameters will be used. These values are given in Table 2-5.

TABLE 2-5 BENEFIT PARAMETER VALUES

Reference	Commercial C	Fishing F	Recreational R	Symbol
Rate of Fatalities, Fatalities/SAR Case	0.085159	0.022086	-	RF
Fatalities/Incident	-	-	0.006474	RF
Savings, Property Damage, $/SAR Case	26,415	8,612	-	SP
$/Incident	-	-	$37.91	SP
Savings, Fatalities, $/Fatality	250,000			SF

The derivation of the values displayed in Table 2-5 will be explained in the paragraphs which follow. The benefit model will be derived using the symbols shown in Table 2-5.

The loss, L, is the expected number of lives lost or value of property damage and is determined by multiplying the expected number of cases, C, by the expected rate of loss, R, (deaths per SAR case, RF; property damage per incident, RP).

$$L = C \times R \quad (1.26)$$

The SAR effectiveness, e, is given by:

$$\text{SAR effectiveness} = \frac{\text{(Deaths, damage) prevented (P)}}{\text{(Deaths, damage) prevented (P)} + \text{Loss (L)}}$$

$$\text{or} \qquad e = \frac{P}{P + L} \quad (1.27)$$

Solving equation (1.27) for P gives:

$$P = L \times (e/(1-e) \quad (1.28)$$

and substituting in for L from equation (1.26),the estimated loss prevented by the system is expressed in terms of system effectiveness, number of cases and losses per case

$$P = C \times R \times (e/(1-e)) \quad (1.29)$$

The losses prevented by the present system, Po, may be expressed as

$$Po = C \times R \times (e/(1-e)) \quad (1.30)$$

The losses that would be prevented by a new improved system is Po plus some fraction, f, of the loss that could be prevented by the new system. Since it has been determined that in two-thirds of the cases, fatalities and/or property damage could be prevented and that,of these cases,another two-thirds can be affected by the use of A/L devices, the assumption is made that the maximum value of the fraction, f, of lives lost and/or property damaged that could be prevented by a completely effective A/L device is $F = 2/3 \times 2/3 = 4/9$. If the system is not fully effective, in that it will not contribute to the saving of all lives that could be saved, the value of the fraction f is less than F and will vary over the range

$$0 \leq f \leq F \qquad (1.31)$$

Thus, under the new system exclusively the loss prevented, P, may be expressed as:

$$P = f \times L \qquad (1.32)$$

$$= f \times C \times R \qquad (1.32')$$

The value of the benefit, B, can then be expressed as

$$B = S \times P \qquad (1.33)$$

$$= S \times f \times C \times R \qquad (1.33')$$

The projected number of cases, in the ith year, C (i), is given by:

$$C = p * base * (1+r)^i \qquad (1.34)$$

where:

p = percent of SAR cases or recreational boating incidents that occur within 25 miles of shore (Table 1-4)

base = base number of SAR cases or total recreational boating incidents (Table 1-4)

r = annual rate of increase of SAR cases or total recreational boating incidents (Table 1-4)

i = number of years from base year (Table 1-4)

The value of the fraction, f, is equal to:

$$f(i) = F \times PA(i) \times EV \qquad (1.35)$$

Thus, the annual value of the benefits may be expressed as a function of relevant factors:

$$B(i) = p \times base \times (1+r)^i \times S \times R \times F \times PA(i) \times EV \qquad (1.36)$$

The present value of the annual benefits derived from prevention of fatalities and property damage for commercial, fishing, and recreational boating will then be summed over the ten-year period.

$$B = \sum_{i=1}^{10} \frac{B(i)}{(1+INT)^i} \qquad (1.37)$$

2.6.2 Expected Savings. The benefits which are measured in dollars are derived from the expected number of fatalities, injuries, and property damage per incident. The value of the savings given in Table 2-5 are:

SF = $250,000 per fatality

SPC = $ 26,415 per commercial property damage SAR incident

SPF = $ 8,612 per fishing property damage SAR incident

SPR = $ 37.91 damage per recreational boating incident

The estimated savings in dollars per fatality is derived by compounding the $200,000 value given in SALTTI-22 from 1972 data to 1974 data. This value is from a 1973 report and is assumed to be based on 1972 data. Table C-12 of the U.S. Department of Labor, Bureau of Labor Statistics publication "Employment and Earning" lists employee compensation data in current dollars as follows:

1972	137.8
1973	146.6
1974	158.3

These values result in a 6.5 percent annual increase in compensation which, when compounded for three years, yields 23.13 percent increase and raises the $200,000 in 1972 dollars to $246,251 in 1974 dollars.

The CPI increased 26.7 percent from January 1972 (123.2) to January 1975 (156.1) and would raise the $200,000 in 1972 dollars to $253,409 in 1974 dollars. It is therefore reasonable to use a value of $250,000 as the estimated savings per fatality.

2.6.3 Expected Rate of Loss. The values for the expected rates of loss were derived from SAR report printouts for FY 1972.

2.6.3.1 Expected Fatality Rate

Commercial:	RFC	=	Lives Lost ÷ Commercial SAR Cases	(1.38)
		=	171 ÷ 2008 = 0.085159	
Fishing:	RFF	=	Lives Lost ÷ Fishing SAR Cases	(1.39)
		=	126 ÷ 5705 = 0.022086	
Recreational:	RFR	=	Occurrence Rate	(1.40)
		=	0.006474 fatalities per incident	

2.6.3.2 Expected Property Damage Rate. The expected property damage is measured in dollars per SAR incident for commercial and fishing categories. From the SAR reports, the value of the property assisted is recorded by usage. By assuming that the SAR effectiveness is the same for property damage as it is for fatalities, the expected loss is estimated by solving equation (1.27) for L:

$$L = P\,((1-e)/e) \qquad (1.41)$$

Then, if Sp is the expected value of property damage loss per SAR case when there is property damage

$$Sp = L/C_p = \frac{P\,((1-e)/e)}{C_p} \qquad (1.42)$$

where C_p is number of SAR cases which involve property damage, and from equation (1.26)

$$R_p = L/C_p \qquad (1.43)$$

where R_p is number of property damage cases per SAR case or

$$R_p = \frac{C_p}{C} \qquad (1.44)$$

Then the value of the benefits for property damage cases can be expressed as follows using equations (1.29) and (1.32).

$$B = C \times (f + e/(1-e)) \times S_p \times R_p \qquad (1.45)$$

$$= C \times (f + e/(1-e)) \times \frac{P((1-e)/e)}{C_p} \times \frac{C_p}{C} \qquad (1.45')$$

Since the value of C_p is not available from the SAR reports, the value of the benefits is:

$$B = C \times (f + e/(1-e)) \times \frac{P}{C}((1-e)/e) \qquad (1.45'')$$

where from the notation of equation 1.29

$$S \times R = P/C\ ((1-e)/e) \qquad (1.46)$$

Hence, from the SAR reports, the following data is derived.

Commercial:

$$SPC \times RPC = \frac{P_c}{C_c}((1-e_c)/e_c) \qquad (1.46')$$

$$= \frac{\$57,462,500}{2008}((1-0.52)/0.52)$$

$$= \$26,415$$

$$\text{or } SPC = \$26,415$$

$$\text{and } RPC = 1.0$$

where 0.52 is computed SAR effectiveness for commercial category

Fishing:

$$SPF \times RPF = \frac{P_f}{C_f}((1-e_f)/e_f) \qquad (1.46'')$$

$$= \frac{\$114,641,300}{5705}((1-0.7)/0.7)$$

$$= \$8,612$$

or SPF = \$8,612

and RFP = 1.0

where 0.70 is SAR effectiveness for fishing category

Recreational:

$$SPR \times RPR = \$37.91 \times 1.0 \qquad (1.46''')$$

where the notation follows from above but the values are based on property damage per recreational boating incidents and were furnished by the USCG.

2.6.4 Benefit Example. For example, the estimate of benefits to be realized from preventing fatalities in recreational boating activities by use of an "alerting only" A/L device in 1975 will be computed. Using equation (1.32), i = 1 and

$B(1) = p \times base \times (1+r) \times S \times R \times F \times PA(1) \times EV$

p = 0.9912 percent (decimal equivalent) of recreational boating incidents that occur within 25 miles of shore (Table 1-4)

base = 260,300 total number of recreational boating incidents (Table 1-4)

r = 0.0496 annual rate of increase (Table 1-4)

s = \$250,000/fatality (Table 1-5)

R = 0.006474 fatalities/incident (Table 1-5)

F = 4/9 (Paragraph 1.5.1)

PA(1) = 0.0161 (equation (1.7'))

EV = 0.4270 (Paragraph 1.5.4.4)

$B(1) = 0.9912 \times 260{,}300 \times 1.0496 \times 250{,}000 \times 0.006474 \times (4/9) \times 0.0161 \times 0.4270$

= \$1,339.193 thousand

2.7 Benefit Cost Ratio Analysis. The ratio is simple to calculate once the proper benefits and costs are estimated. The costs and benefits have been estimated in future dollars for the ten-year life cycle. The future costs and benefits dollar values have been expressed in 1974 dollars and the effects of inflation ignored. The future costs and benefits have been multiplied by a present value factor to transform them to annual present values. The annual present values have been summed to give the present value of the costs and benefits for the ten-year period. The benefit:cost ratio is obtained by dividing the summed present value benefits by the summed present value costs.

When comparing multiple alternatives, it is not sufficient to compare the benefit:cost ratio alone without a consideration of the magnitude of the benefits and the costs. When comparing multiple alternatives, it is necessary to examine the value of the net gain of the system which is the value of benefits less the cost of the system.

2.8 Benefit-Cost Model Summary. Figure 2-6 shows the relationship of the component models and the data inputs required to compute the system estimated costs and benefits. The same basic procedure is followed to compute each of the four cases of output data: I Voluntary Carriage, without SAR impact; II Voluntary Carriage, with SAR impact; III Mandatory Carriage without SAR impact; and IV Mandatory Carriage with SAR impact.

2.8.1 Input Data

2.8.1.1 Government Costs. The present value of Government cost for each system is derived from:

- Acquisition and Installation (AC&I) cost of electronic equipment for each of the systems. This cost is furnished by the Government.

- Annual Operating and Maintenance (OE) cost for personnel and operation of the electronic equipment for each of the systems. This cost is furnished by the Government.

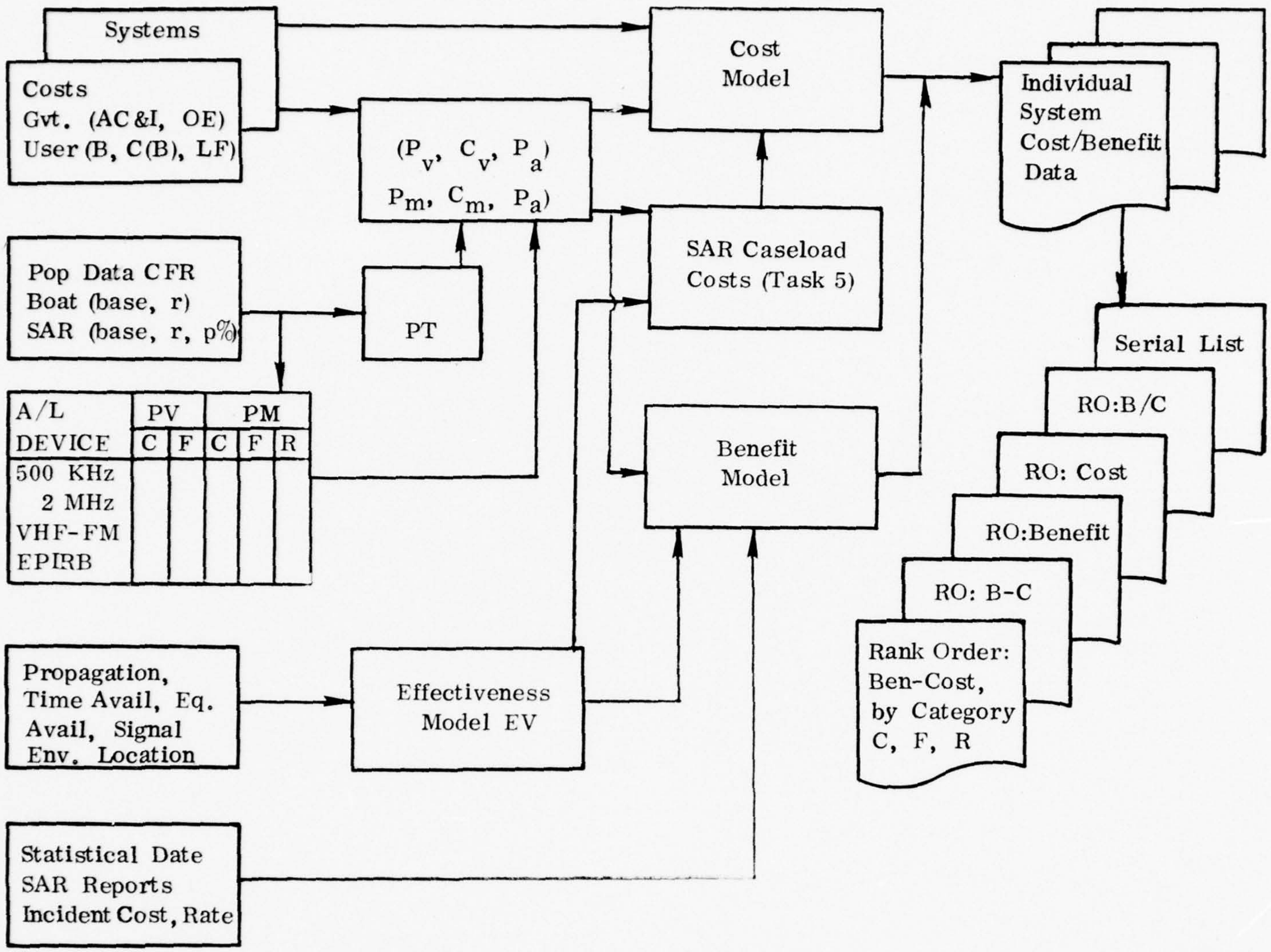


Figure 2-6. Benefit:Cost Analysis Model

2.8.1.2 User Costs. The present value of the cost to users is derived from:

- The average unit cost C(B) for a given number of units. This cost is furnished by the Government.
- The given number of units (B) upon which the average cost is based. This value is given by the Government for projected systems and is estimated from the number of licenses reported by the FCC for existing 500 kHz, 2182 kHz, and 156.8 MHz systems.
- The learning factor (LF) estimated for each system as given in Table 2-1.

2.8.1.3 Boating/Vessel Population Data. The time-series analysis for determining user cost by category on an annual basis requires the base number of vessels/boats and the estimated annual rate of increases (r) for each category. This data and the sources of the data are given in Table 2-2.

2.8.1.4 SAR Incident Data. The time-series analysis for determining SAR impact costs and estimated benefits by category requires the base number of SAR cases/recreational boating incidents, the annual rate of increase (r) and the percentage of cases/incidents (p%) that occur within 25 miles of shore. This data and the sources of the data are given in Table 2-4.

2.8.1.5 Statistical Data, SAR Reports. This data is required to estimate the expected benefits provided by each system, is furnished by the Government, and is contained in Table 2-5.

2.8.1.6 Projected Carriage. The number of vessels/boats by category that would be equipped with each type of A/L devices is required to determine the present value of the user cost for both voluntary and mandatory carriage. Section 3 is devoted to the development of these values and presents the rationale for the values developed.

2.8.1.7 Effectiveness Factors. The effectiveness model impacts the estimated benefits expected by each system as well as the SAR impact costs for excess SAR caseload. The effectiveness factors which are input to the effectiveness model are listed and described in Paragraph 2.4.1 and the development of the value of the effectiveness factors and the rationale is presented in Section 4. The benefit-cost model is programmed in FORTRAN IV and computes the estimated costs and benefits for each system using the input data described and produces data sheets for each system and then sorts and lists the systems by benefit:cost ratio, cost/benefits and benefits less cost.

2.8.2 Model Methodology

2.8.2.1 Cost Model. The cost model has two distinct parts, Government cost and user cost.

2.8.2.1.1 Government Cost. The present value of the Government cost for each system is computed by the equation

$$PV = \frac{GACI}{1 + INT} + \sum_{i=1}^{N} \frac{GAOM}{(1 + INT)i}$$

where: INT = Interest factor (10 percent)

GACI = Government AC&I Cost

GAOM = Government Annual O&M Cost

N = Period of the analysis (10 years)

The Government cost is the same for Cases I-IV.

2.8.2.1.2 User Cost. The present value of the user cost for each category of use is computed by using the procedure described in Paragraph 2.3.3. The average unit cost and the estimated recreational boating voluntary carriage population are the major inputs and are derived by the procedures described in Paragraph 2.3.2.3. One set of user costs are derived for Cases I and II, Voluntary Carriage; another set is derived for Cases III and IV, Mandatory Carriage.

2.8.2.2 SAR Caseload Cost Model. Annual added costs for servicing excess case loads are computed in accordance with the procedures described in Paragraph 2.5. The present value is determined by multiplying each annual cost by the respective present worth factor and summing over the 10-year period. The percent participation determined in the user cost model and the system effectiveness determined in the effectiveness model are used to determine the impact probability which is a major input to the SAR Caseload Cost Model. A different set of results is computed for each of Cases II and IV. SAR Impact Costs are not included in Cases I and III.

2.8.2.3 Benefit Model. The present value of the estimated benefits for fatalities and property damage for each category, commercial, fishing, and recreational boating are computed using the procedures described in Paragraph 2.6. Inputs from the user cost model and effectiveness models are the percent participation and the unit effectiveness respectively. One set of benefit values are computed for Voluntary Carriage, Cases I and II, and another set of values is computed for Mandatory Carriage, Cases III and IV.

2.8.3 Output Data. The output data is of two types. The first type is a printout of cost-benefit tabulations by individual systems and the second type is a series of rank orderings by a figure of merit for each of the four cases. The figures of merit which are the basis of the system rank orderings are: Benefit: Cost Ratio, Total Cost, Total Benefit, Total Benefit less Total Cost, Benefits less Cost for Commercial Category, Benefits less Cost for Fishing Category, and Benefits less Cost for Recreational Boating. For the last three rank orderings, the sorts are for Voluntary and Mandatory Carriage only, since SAR Impact Costs are not included in the cost of each of the three categories.

A key for the values contained in the print-out of the Cost-Benefit Tabulations by Individual Systems is contained in Table 2-6.

TABLE 2-6. COST-BENEFIT TABULATION KEY

I. Cost Data and Effectiveness

```
  #1      #2                                              #3
                                                            ALERTING AND LOCATING
GOVT COS AC+I $    #4                   ANNUAL O+M $     #5
USER COS UNIT COST $   #6                QUANTITY OF      #7        LEARNING FACTOR   #8
            VOL CAR $   #10          TO $  #10          NUMBER OF MANUFACTURERS   #9
            MAND CAR$   #11          TO $  #11
EP=  #12        ET=  #12          EA=  #12          ES=  #12          EL=  #12
POPULATION  TOTAL  #13        M.BASE 1975.RECREATIONAL BOATS EXCEPT EC + M/M REG.
```

#1 Number indicating serial listing of all systems.

#2 SALTTI Number; the first digit indicates function:

1 Alerting only

2 Locating only

3 Alerting and Locating

#3 System function.

#4 Government acquisition and installation cost for electronic equipment.

#5 Government annual operation and maintenance cost.

#6 Average unit cost of device based on number produced. (#7 times #9).

#7 Estimated number of units upon which a manufacturer bases his cost.

#8 Value used in learning curve.

#9 Estimated number of manufacturers which will produce A/L device for sale.

#10 Range of average unit cost for device based on use of learning curve for cost projections under voluntary carriage. First value is average unit cost in first year; second value is average unit cost in last year of study.

TABLE 2-6. COST-BENEFIT TABULATION KEY (Cont'd)

#11 Range of average unit cost for device based on use of learning curve for cost projections under mandatory carriage. First value is average unit cost in first year; second value is average unit cost of device in last year of study.

#12 Values of effectiveness factors.

#13 Total recreational boating population used as base for determining percent participation using demand curve.

II. Voluntary Carriage

```
                                        VOLUNTARY CARRIAGE
EQUIPPED HULL                               PERCENT PARTIC  IMPACT PROBABILITY
COMM   #14       TO      #14                COMM   #15         #20    TO   #20
FISH   #16       TO      #16                FISH   #17
RECB   #18       TO      #18                RECB   #19            EFF: EV=   #21
                                              TO   #19
NOTE: EQUIP RECB HULLS VOL CARR                   #22A    EXCEEDS PMC        #22B
```

#14 Range of commercial vessels equipped with A/L device under voluntary carriage. First value is number of equipped vessels during first year; second figure is number of vessels equipped during last year of study.

#15 Percent of participation of commercial vessels expressed as a decimal instead of percent. (Entry 0.1000 indicates 10 percent; 0.0010 indicates one tenth of 1 percent). This value is assumed constant over study period.

#16 Range of fishing vessels equipped with A/L Device under voluntary carriage. First value is number of equipped boats during the first year and second figure is number of boats equipped during last year.

#17 Percent of participation of fishing boats expressed as a decimal instead of percent. This value is assumed constant over study period.

TABLE 2-6. COST-BENEFIT TABULATION KEY (Cont'd)

#18 Range of recreational boats equipped with A/L device under voluntary carriage. First value is number of equipped boats during first year; second figure is number of recreational boats equipped during last year.

#19 Range of percent participation of recreational boating as determined from demand curve on an annual basis. Value is expressed as a decimal instead of percent. This value is not constant and first value is percent participation during first year, second value is percent participation during last year.

#20 Range of values of impact probability used to determine SAR impact costs. Values represent first and last year and are product of system effectiveness, EV #21, and respective value of percent participation recreational boating #19.

#21 System effectivness value.

#22 Note: Following this section there is a line which appears only on certain tabulations. This line will appear only when number of recreational boats "A" computed by demand curve exceeds number of botas considered as Proposed Mandatory Carriage (PMC) "B". Program then computes user cost based on fewer number proposed mandatory carriage.

III. Mandatory Carriage

```
                                          MANDATORY CARRIAGE
EQUIPPED HULL                                 PERCENT PARTIC   IMPACT PROBABILITY
COMM )               TO )                     COMM )               #25   TO   #25
FISH } #23           TO }   #23               FISH } #24
RECB )               TO )                     RECB )                 EFF: EV=  #21
```

#23 Range of values for number of vessels of each category equipped with A/L Device under PMC. Values are number of equipped vessels in first and last years, respectively.

TABLE 2-6. COST-BENEFIT TABULATION KEY (Cont'd)

#24 Percent of participation of vessels of each category equipped with A/L Device under PMC. This value is expressed as a decimal instead of true percent. (Entry 0.9999 indicates 99.99 percent and rounds off to 100 percent). These values are assumed to be constant for study duration.

#25 Value of impact probability used to determine SAR impact costs under PMS. Value represents product of system effectiveness #21 and percent participation for recreational boating, #24.

IV. Cost-Benefits Voluntary Carriage Without SAR Impact

COST-BENEFIT (\$K)		VOLUNTARY CARRIAGE WITHOUT SAR IMPACT		
COST	A C + I	O + M	TOTAL	
GOV	\$ #26	\$ #27	\$ #28	
COMM	\$ #29	\$ #30	\$ #31	
FISH	\$ #32	\$ #33	\$ #34	
RECB	\$ #35	\$ #36	\$ #37	
TOTA	\$ #38	\$ #39	\$ #40	
BENEFIT	FATALITIES	PROP DAM	TOTAL	CATEGORY B:C
COM	\$ #41	\$ #42	\$ #43	#44
FIS	\$ #45	\$ #46	\$ #47	#48
REC	\$ #49	\$ #50	\$ #51	#52
TOTA	\$ #53	\$ #54	\$ #55	
			BENEFIT COST RATIO	#56 :1

This section shows estimated costs and benefits measured in thousands of dollars.

#26 Present value of Government acquisition and installation costs for electronic equipment.

#27 Present value of Government annual operations and maintenance costs.

#28 Present value of total Government cost (does not include SAR impact costs).

#29 Present value of costs for acquisition and installation of A/L Devices on commercial vessels.

TABLE 2-6. COST-BENEFIT TABULATION KEY (Cont'd)

#30	Present value of operation and maintenance costs for A/L Device on commercial vessels.
#31	Present value of total cost of A/L Device for commercial category.
#32	Present value of costs for acquisition and installation of A/L Devices on fishing boats.
#33	Present value of operations and maintenance costs for A/L Devices on fishing boats.
#34	Present value of total cost of A/L Device for fishing category.
#35	Present value of costs for acquisition and installation of A/L Devices on recreational boats.
#36	Present value of operations and maintenance costs for A/L Devices on recreational boats.
#37	Present value of total cost of A/L Device for recreational boating.
#38	Total present value for acquisition and installation.
#39	Total present value for annual operation and maintenance.
#40	Total present value for system tabulation.
#41	Present value of benefits due to reduced fatalities for commercial vessels.
#42	Present value of benefits due to reduced property damage for commercial vessels.
#43	Total present value of benefits for commercial vessels.
#44	Benefit:cost ratio for commercial category. Value of item #13 divided by value of item #31.
#45	Present value of benefits due to reduced fatalities for fishing boats.
#46	Present value of benefits due to reduced property damage for fishing boats.

TABLE 2-6. COST-BENEFIT TABULATION KEY (Cont'd)

#47 Total present value of benefits for fishing boats.

#48 Benefit:cost ratio for fishing category. Value of item #47 divided by value of itme #34.

#49 Present value of benefits due to reduced fatalities for recreational boating.

#50 Present value of benefits due to reduced property damage for recreational boating.

#51 Total present value of benefits for recreational boating.

#52 Benefit:cost ratio for recreational boating category. Value of item #51 divided by value of item #37.

#53 Total present value for benefits due to reduction of fatalities.

#54 Total present value for benefits due to reduction of property damage.

#55 Total present value for benefits.

#56 Benefit:cost ratio of present value of total benefits item #55 divided by present value of total costs item #40.

V. Cost-Benefits Voluntary Carriage With SAR Impact

COST-BENEFIT ($K)		VOLUNTARY CARRIAGE WITH SAR IMPACT		SAR CASELOAD (K)
COST	A C + I	O + M	TOTAL	
SARIM	$ #57	$ #58	$ #59	#60 TO #60
GOV	$ #26	$ #27	$ #28	
COMM	$ #29	$ #30	$ #31	
FISH	$ #32	$ #33	$ #34	
RECB	$ #35	$ #36	$ #37	
TOTA	$ #61	$ #62	$ #63	
BENEFIT	FATALITIES	PROP DAM	TOTAL	CATEGORY B:C
COM	$ #41	$ #42	$ #43	#44
FIS	$ #45	$ #46	$ #47	#48
REC	$ #49	$ #50	$ #51	#52
TOTA	$ #53	$ #54	$ #55	
			BENEFIT COST RATIO	#64 :1

#57 Present value of added acquisition and installation cost of servicing excess SAR caseloads.

TABLE 2-6. COST-BENEFIT TABULATION KEY (Cont'd)

#58	Present value of the added direct annual cost of servicing excess SAR caseloads.
#59	Present value of total SAR impact cost.
#60	Range of values for increased SAR caseload in thousands of SAR cases. Values shown are for first and last year of study, respectively.
#61	Total present value for AC&I includes SAR impact costs.
#62	Total present value for annual O&M includes SAR impact cost.
#63	Total present value includes SAR impact cost.
#64	Benefit:cost ratio of present value of total benefits, item #55, divided by present value of total costs, item #64.

VI. Cost-Benefits Mandatory Carriage Without SAR Impact

The values under this part follow the same format as under Part IV except that they are developed under the proposed mandatory carriage (PMC).

VII. Cost-Benefits Mandatory Carriage With SAR Impact

The values under this part follow the same format as under Part V except that they are developed under the proposed mandatory carriage (PMC).

SECTION 3 - MANDATORY CARRIAGE

3.1 General. The cost-benefit analysis includes a mandatory and a voluntary situation. The mandatory concept requires determination of the maximum potential installations as a reference noting utilization, location, and physical limitations. The mandatory carriage population also provides a comparison to evaluate participating coverage under a voluntary concept. Further, analysis under a voluntary concept requires establishing the present user population for existing systems. This section examines the mandatory and starting voluntary base for the three user categories in the Great Lakes and coastal area.

3.2 Recreational Boating. Although maritime radio communication installations are encouraged for recreational boating through educational and some organizational groups, there are no regulatory requirements in this respect for mandatory carriage. In most cases, this decision is one of judgement as to exposure and economics. Any future proposed mandatory carriage (PMC) involves determination of the size and purpose of the recreational boat, and is a policy decision at National level. For this investigation, the PMC population is assumed based upon the size, primary power generation, and area of exposure. This approach acknowledges that canoes, kayaks and inflatable boats, as well as other small boats upon many small ponds, rivers and quarries are not logical candidates for proposed mandatory carriage. Further, some communication systems are impracticable of serious installation where either antenna space or power generation are obvious handicaps. Accordingly, different mandatory levels exist if realistic installation capabilities are considered. Table 43 of the 1973 Boating Survey established that 31 percent of rescue situations occurred on the oceans and Great Lakes.

The population of recreational boating for proposed mandatory carriage of ASL devices was derived from the data contained in the 1973 boating survey and is 31 percent of the number of all boats except:

- Canoes, kayaks, and inflatable boats
- Any boats used in the East Central and Midwest/Mountain region.

This number is derived as follows:

Total number of recreational boats		8,336,343
Less:	All boats in East Central Region	543,161
	All boats in Midwest/Mountain Region	684,213
Less:	All canoes	495,535
	All kayaks	37,481
	All inflatable boats	51,192
Plus:	Canoes in East Central Region	12,790
	Canoes in Midwest/Mountain Region	50,118
	Inflatable boats in Midwest/Mountain Region	15,330
	Kayaks in Midwest/Mountain Region	843
Total		6,603,842
31 percent of total		2,047,191

3.2.1 Handheld VHF-FM (1 Watt) Recreational Boat. This potential mandatory base assumes all inboards, inboard/outboard, auxiliary sail, houseboats, twin outboards, and all outboards over 36 HP. Selection of outboards over 36 HP is a judgment factor in examination of 1973 Boating Survey tabulations. This engine power rating suggests a statistical point for separating numerous small fishing craft used in local ponds or tributaries. If this criteria is applied, the totals from the 1973 Boating Survey are:

Coastal states	=	1,956,744
Great Lakes	=	664,382
Subtotal		2,621,126

To reduce this total (by category) to geographical users in coastal or Great Lakes waters, a percentage reduction is applied. This data was not included in the 1973 survey, but may be estimated on the basis of relative locations of situations (Table 43, Page 96, Boating Survey). On a National basis, this indicates 31% of rescues were beyond the immediate coastline or beach. In the Great Lakes region, this factor is 33% based upon tabulated data of SAR locations. The base for the estimated annual number of recreational boats for mandatory carriage is designated as PMRI. For handheld VHF-FM equipment, the mandatory base is:

Coastal Zone = 606,591
Great Lakes = 219,246
Total PMRI = 825,837

3.2.2 VHF-FM Installed Capabilities. The potential mandatory base for installed units considers sufficient physical facilities for the antenna and set plus a means of storage battery/engine generator power. The estimated mandatory base for handheld VHF-FM in the previous paragraph are reduced by judgment of boat sizes and their electrical capacity to operate installed VHF-FM equipment. It is assumed that the major difference will occur among the 36-HP group, and that of this power rating 50% would have the antenna mounting and power capability. Under this condition, the totals are as follows:

Region	Total Meeting Criteria	Estimated Actual Coastal
National Coastal States	1,424,959	441,737
Great Lakes Region	440,472	145,355
Total PMRI		587,092

The existing voluntary base for installed VHF-FM equipment is derived from current FCC licenses which indicates 121,600 installations.

3.2.3 <u>2-MHz Radiotelephone Installations</u>. The mandatory base for recreational boats capable of 2-MHz installations considers those boats having supports for necessary antennas and electrical power generation for approximately 200 watts. This includes all inboards, inboard/outboard, and auxiliary sailboats. Using data in the 1973 Boating Survey, these categories of recreational boats are:

Region	Total Meeting Criteria	Estimated Actual Coastal
National Coastal States	813,185	252,087
Great Lakes	171,777	56,686
Total PMRI		308,773

The total voluntarily installed are determined from FCC licenses as 159,356 installations.

3.3 <u>Commercial Fishing Boats</u>. Fishing boat statistics are from Fishery Statistics of the U.S. (1969) and Fisheries of the U.S. (1973) published by The National Marine Fisheries Service. The distribution of fishing activity is obtained from statistics of annual catch. The total is 84,812 commercial fishing boats.

Commercial fishing vessels over 500 tons and having mandatory radio telephone licensed by the FCC totals 55. These vessels enter the coastal zone for menhaden but generally are in offshore lobster and tuna fishing.

Documented vessels over 5 tons total 13,187 vessels and all are considered to have radiotelephones.

An additional 71,570 boats are listed in Fishery Statistics of the U.S. as less than 5 tons. These commercial fishing boats are generally over 25 feet in length to approximately 40 feet. Based upon statistics of operating area and catch reported by these commercial boats, approximately 30% of the 71,570 may be assumed to be logical candidates for radiotelephones (21,471 boats). An approximate additional 30% are on bays and beaches where the risk and economics may not justify individual radiotelephones but an EPIRB is justified. Accordingly, 60% of 71,570 are considered for EPIRB capabilities. The total mandatory carriage base for commercial fishing boats is:

Region	Total Vessels	Total Boats	Total (2 & 156 MHz)	Total (EPIRBS)
National Radiotelephones	13,187	21,471#	34,713	
National EPIRBS	13,187	42,942*		56,184
# 30% of 71,570				
* 60% of 71,570				

FCC license data does not provide means to identify commercial fishing authorizations beyond 13,242. That is, that portion of boats less than 5 tons within the estimated 21,471 who in fact have voluntary installations. In sampling six fishing cooperatives on the East Coast, all indicated that no boat of less than 5 tons fishes offshore without some form of radio communication.

3.4 Commercial Ships

3.4.1 Radiotelegraph Mandatory. Radiotelegraph installations are mandatory aboard defined categories of users. Ships in this category under U.S. Flag operation total 970. Ships owned and operated by U.S.-based corporations but registered under foreign flags-of-convenience total 552. While foreign registered, it is observed that operators of these ships follow U.S. radio installation requirements and practices. The flags-of-convenience ships transit the 20-mile coastal zone and are accordingly included for a total radiotelegraph user population subject to U.S. control or influence of 1522 ships. The total mandatory carriage base is 970 for 500-kHz operation.

3.4.2 Radiotelephone Mandatory. Mandatory radiotelephone installations are in ships between 500 and 1600 tons pursuant to Part II of Title III, Communications Act. These coastal transportation vessels licensed by the FCC total 233 ships.

3.4.3 Radiotelephone, Non-Mandatory. Ships in this category are non-mandatory in terms of regulatory aspects except for vessel traffic systems and bridge-to-bridge requirements. In addition, all commercial ships in this category have operational coordination or control requirements. The result is that radiotelephone installations exist in all commercial ships in the coastal zone. In most cases, and assumed as all cases in this examination, both 2-MHz and VHF-FM facilities exist. These are further described as follows:

All ships having mandatory radiotelegraph installations also have radiotelephone installations. This totals 970 ships.

Tugs engaged in coastwise transportation roles along the Atlantic, Pacific and Gulf coasts are reported by the American Waterways Operators, Inc. as 1,630.

Tugs that enter the coastal zone to escort arriving or departing ships are estimated as 812.

Self-propelled vessels or tugs engaged in intercoastal waterways total 2,293. Since intercoastal waterways include segments of coastal open water, these vessels and tugs are included in the coastal population.

3.4.4 Radiotelephones Aboard Commercial Ships. Total ships are 233 in the mandatory category and 5,705 in the obligatory category pursuant to existing regulatory aspects. The total mandatory carriage base is 5,938.

3.5 Summary. The summary totals are shown in Table 3-1.

TABLE 3-1. CATEGORIZATION OF USER POPULATIONS

	Mandatory (Part II Title III Comm Act)	Obligatory or High Probable (VTS, B to B) Commercial Practice, etc.	Presently Non-Mandatory but Considered as Mandatory for SALTTI		
			Coastal	Great Lakes	Total
Recreational					
EPIRB			1,429,077	618,114	2,047,191
VHF-FM Handheld			606,591	219,246	825,837
VHF-FM Installed			441,737	145,355	587,092
2 MHz Installed			252,087	56,686	308,773
Commercial Fishing					
EPIRB			56,184		56,184
Radiotelephones	55	13,187	34,713		34,713
Commercial Ships					
EPIRB			5,938		5,938
Radiotelephone	233	5,705	5,938		5,938
Radiotelegraph	970*		970		970
Recapitulation					
Total EPIRBS			1,491,199	618,114	2,109,313
Total Radiotelephones			647,242	219,146	866,488
Total Radiotelegraph			970		970

*U.S. Flag

SECTION 4 - EFFECTIVENESS METHODOLOGY

4.1 Introduction. Measures of effectiveness define those attributes of a system, and permit comparisons among alternative approaches. By selecting parameters that are common among most or all systems, a comparative effectiveness score may be established. Where the problem is complicated by large magnitudes and many variables, a useful analytical tool is a representative but reduced scale model. The model permits manipulation of variables so as to define impacts and sensitivity, and permits a grasp of the total behavior. The systems to be examined are coastal alerting and locating systems described in various configurations by the Coast Guard SALTTI Group. This section describes the methodology, assumptions, and characteristics pertinent to measuring effectiveness. The effectiveness of each system is an input to the Cost-Benefit Model described in Paragraph 2.4.

4.2 Parameters Evaluated for Effectiveness. The parameters selected are generally common to all alternatives, and those that most influence performance of the alerting and locating telecommunication objectives. The individual scoring of each parameter is expressed from 0.000 to 1.000 in terms of success; 1.000 representing a fully satisfied parameter. Where computations of a specific system are related to probability of failure or area of uncertainty, the positive or success attribute is used in scoring by subtracting the failure probability from 1.000. The final effectiveness of the system or configuration examined is the product of all attributes considered. In this methodology, parameters not pertinent to a particular configuration are scored 1.000. It is acknowledged that some scorings are judgements based upon experience factors and telecommunications practices; however, the rationale is presented in such cases. The methodology avoids using typical SAR stations of the Coast Guard, but assumes a representative station in which all current programs have been accomplished. Otherwise, the analysis results in an engineering evaluation of present stations rather than the objective of assessing system effectiveness in a representative case.

4.2.1 Geographical Coverage (EP). This parameter is the degree to which radio coverage achieved by the system satisfies the desired coverage objectives. It is determined by the transmitted power of the A/L device, the receiving sensitivity of the receiving system, the appropriate radio propagation losses, and the electrical noise level in which the system is expected to operate. In the case of the coastal VHF-FM system, the Coast Guard program is based upon fully covering the area to 20 miles offshore. In this instance, the geographical coverage (EP) is 1.000. Where the coverage is subject to high electrical noise on a diurnal or seasonal basis, the worst-case situations are examined to establish the expected geographical coverage.

4.2.2 Time Availability (ET). The availability of the facility serving in the alert detection process is normally 1.000 for Coast Guard watches at all stations. However, this factor is less than one for some systems. For example, detection of the alerting signal by aircraft overflights depends upon the presence of an aircraft within radio range and availability of an aircraft receiver tuned to the emergency alerting frequency.

4.2.3 Equipment Availability (EA). This parameter concerns the technical standard of Coast Guard equipment dedicated to alerting or direction finding. Its value as established by the Coast Guard is 0.995, and is programmed as a fixed value in computing overall system effectiveness (E).

4.2.4 Signal Effectiveness in the Operating Environment (ES). This parameter addresses the probability of the alerting communications message or EPIRB signal being detected promptly among all other signals. In the case of communication systems, the model determines probable activity based upon monitoring experience and simulates recognition of an emergency call among those random background signals. The background signal environment is composed of random individual callers whose call durations are distributed about an assumed average, and whose signal strengths by distance is related to geographical distribution. The multiple EPIRB effectiveness concerns the probability of failure in detecting or locating an individual EPIRB signal among several. This probability is related to the time domain and duty cycles regardless of the radio frequency. It is therefore pertinent to all EPIRB type systems. The hypothesis is that an EPIRB system can cope with individual cases separated in time, but its real test is a capability to cope with several that may result from a widespread storm-front.

4.2.5 Location Effectiveness (EL). This parameter is 1.000 for all alerting situations. For systems assigned a location mission, the value of ELO is related to the area of uncertainty which must be searched. The relationship of varied areas of uncertainty to effectiveness involves subjective judgement, and the time limits that is assigned to accomplish a successful location. If a location is defined within one square mile, the rescue means should attain visual upon arrival and a location effectiveness of 0.999 is assumed. That is, search time within the location area represents no significant delay. Location effectiveness accordingly is the degree of delay in finding the emergency site, and this is assumed to be proportional to the area of uncertainty; or in positive terms, the saving of time to the victim and search team resources. The decision to search by air or water is assumed to be related to the area of uncertainty, and the significance of time in the situation.

4.2.6 Installation Capability to Participate (EIN). The effectiveness of any A/L system is first controlled by the number of participants having capabilities for access. The number of users from voluntary or mandatory carriage define an effectiveness regardless of other attributes. The value of EIN is the percent of carriage as compared to the total that may be potentially mandatory. On a voluntary approach, the number of equipped vessels varies with total population, price per unit, and the number of users willing to buy at that price and as stimulated by educational or operational risk. The mandatory carriage base varies with the vessel/boat capabilities to install or carry the system. Where the particular system (i. e., 500-kHz radiotelegraph) is mandatory for specific users, the value of EIN is 1,000. Because installation parameters vary with time and system, EIN is computed in the program and recalled for effectiveness evaluation.

4.2.7 General. Some parameters are developed to support effectiveness analyses, but are not individually tabulated. An example is the determination of activity factors and the number of active platforms in the model. Only active platforms with the candidate system installed represent the base per signal environment in simulation techniques. Other considerations are the contributions of instrumental error or geometric dilution in locating systems. Although these are important considerations, the assumption in the model is to avoid specific design deficiencies and assume that D/F stations are properly spaced, geometrically deployed and operated to desired specifications. The aircraft antennas are also assumed as omni-directional, a situation which differs among specific aircraft and antenna installations.

4.2.8 Overall System Effectiveness (EV). This value is determined by the product of all effectiveness values in a specific system (EV = (EIN)(EP)(ET)(EA)(ES)(EL)). (See Paragraph 2.4.2)

4.3 Geographical Model. In order to provide a manageable analysis tool, a model is utilized with representative populations and deployments. This permits various effectiveness parameters to be examined in a controlled environment, and the means to ensure a standard reference in comparing candidate systems. The model size should be sufficient to permit application of radio propagation and noise, and the variation of signal performance with distance. The geographical model used in this analysis is selected to represent typical geometry of a Coast Guard Station and its SAR coverage. As shown in Figure 4-1, the model is 40 miles in length along the coast, and extends 20 miles from the coast. Because the coverage between the model's Coast Guard Station and adjacent stations is to extend 20 miles to sea and 20 miles along the coast in both directions, the maximum radio path is 28.2 miles.

The same geographical zone is applied to location techniques, and which are primarily direction finding as fixes or lines-of-position. As previously mentioned in the discussion of evaluation parameters, the significant location problem is to control the area of uncertainty. This is illustrated in Figure 4-2.

The geographical model for aircraft overflights (required as one of the system alternatives in 121.5/243 MHz EPIRBs) is to assume a reference passage line that coincides with the Coast Guard station and extends inland perpendicular to the coast for approximately 100 miles. The actual model available is a mandatory reporting point on active airways through the Wilmington area (VOR ILM) as shown in Figure 4-3.

4.4 User Population and Distribution. The population in the 20 by 40 mile model was derived from 1973 coastal totals as reduced proportionally to the model size. Growth factors were applied to project these to 1975 levels as the base year of study. The distribution relates to the number of boats by incremental mileage strata offshore. The New England coast was used for population estimates because of its high density compared to other areas.

4.4.1 Recreational Boating. The New England region was found to have the highest density. Boating data was available to tabulate Atlantic Coast boating populations. These totals were divided by 587 miles of New England coastline, and multiplied by 40 to fit the model's coast. This resulted in 8003 recreational boats. The distribution is assumed to be identical to SAR statistics for recreational boat incidents.

4.4.2 Commercial Fishing. Fishing statistics of the U.S. published by the National Marine Fisheries Service provided the user base for commercial

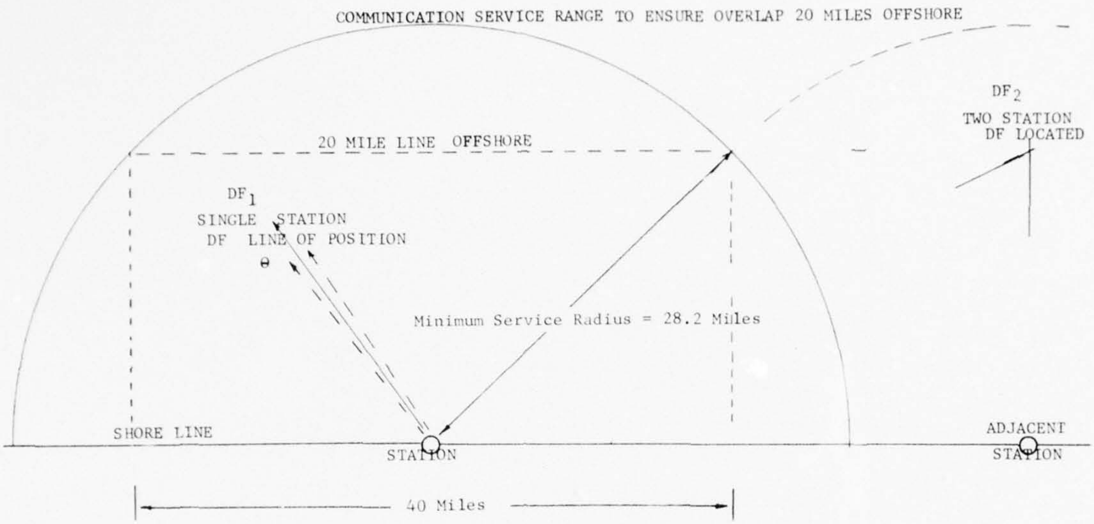
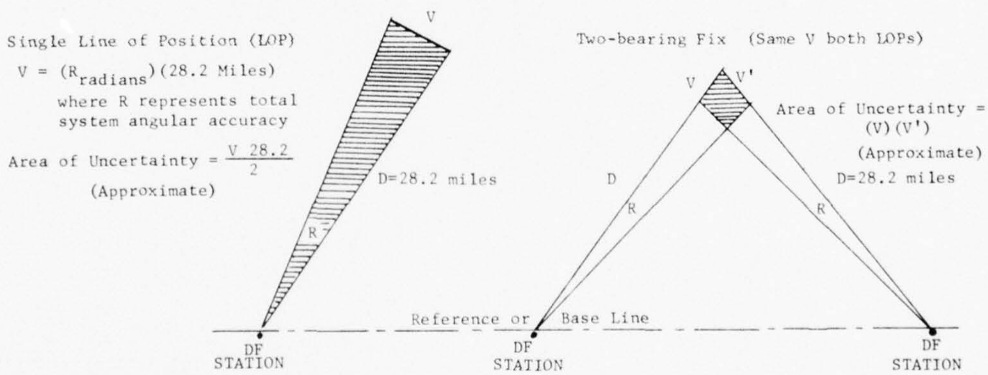
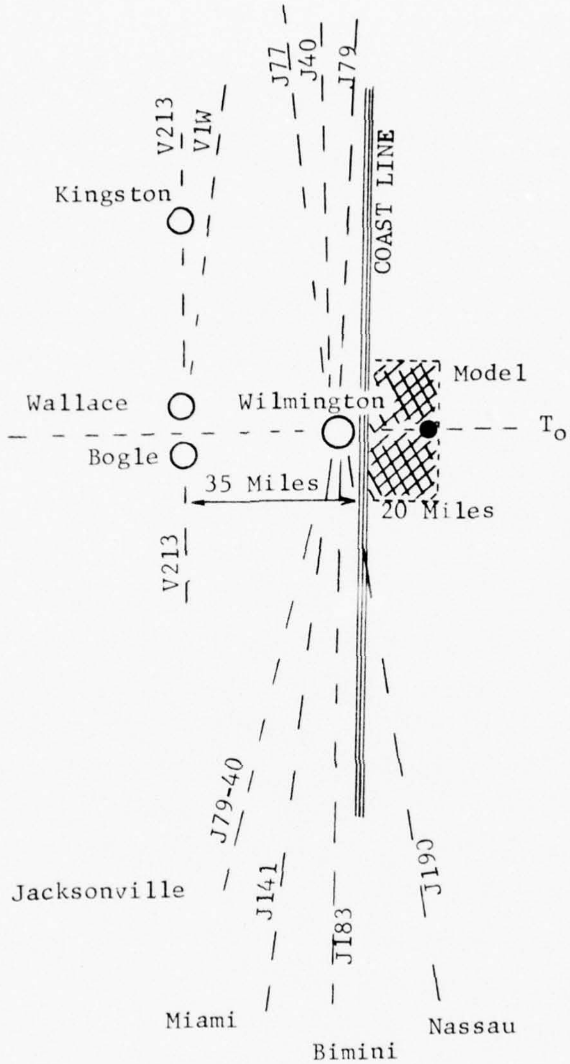


Figure 4-1. Geographical Model



SYSTEM ACCURACY (± Degrees)	V and V' (Miles)	AREA OF UNCERTAINTY (Square Miles)	
		SINGLE LOP	TWO-BEARING FIX
1	.98	13.8	.96
2	1.96	27.6	3.76
3	2.95	41.6	8.7
4	3.93	55.4	15.4
5	4.92	69.3	24.2
6	5.90	83.1	34.8
7	6.89	97.1	47.4
8	7.87	110.0	61.9

Figure 4-2. Direction Finding Areas of Uncertainty in Model



LEGEND

O	Aeronautical VOR Station
T_o	Time abeam of emergency site
●	Emergency site
J190 etc	Enroute Designations

Figure 4-3. Aeronautical Overflight Model

fishing vessels and boats. This was examined nationally and for the New England area, and a fishing population of 268 boats was in the model area. The New England population was higher than the national average. The distribution of commercial fishing boats required additional computations because of the format in which the only pertinent data was available. The National Marine Fisheries Service reports the total product by mile offshore for various types of fishing. By comparing the total landings by boat size and tons caught at various distances offshore, a distribution of boats in a statistical day was obtained.

4.4.3 Commercial Ships. The commercial ships in the outer edges of the model considered two approaches. One approach examined Commerce Department reports of tons transported coastwise and sizes of ships involved. This provided a daily throughput and means to describe a probable density in a 40-mile segment. The second approach was to divide all commercial ships engaged in transportation by the 4003-mile coastline. The two approaches generally validated an estimate of 38 ships as the model population. The distribution of these ships are in the outer edges of the model, i.e., 18, 19, and 20 miles.

4.4.4 Activity. The at-sea activity of platforms affects the signal environment. The highest activity of recreational boats was on summer Sundays, and the SAR incident rates suggest an activity factor of 31 percent. The fishing fleet averages 15% at sea based on fishing statistics, and which was used in the model. Exceptions were factory, tuna, freezers and super-seiners which averaged 78%. Commercial ships averaged 51% based upon maritime communication studies.

4.4.5 User Population and Distribution Summary. The model population is shown in Table 4-1. The distribution is shown graphically in Figure 4-4. The population distribution in terms of 100 units is shown in Table 4-2.

TABLE 4-1. MODEL POPULATION

YEAR	TOTAL PLATFORMS IN MODEL AREA			ACTIVE PLATFORMS IN MODEL AREA		
	COMMERCIAL	FISHING	RECREATION	COMMERCIAL	FISHING	RECREATION
1973	38	268	8003	19	56	2480
1974	39	269	8303	19	56	2573
1975	41	270	8614	20	56	2670
1976	42	271	8937	21	56	2770
1977	44	272	9272	22	57	2874
1978	46	273	9619	23	57	2981
1979	47	274	9979	23	57	3093
1980	48	275	10353	24	57	3209
1981	50	276	10741	25	57	3329
1982	52	277	11143	26	58	3454
1983	54	278	11560	27	58	3583
1984	56	279	11993	28	58	3717
1985	59	280	12442	29	58	3857

EXPLANATION: Total platforms in the model are commensurate proportions of total coastal populations and coastline as scaled for each category. A percentage factor at sea for each category is applied to determine the active population. Commercial and fishing activities are based upon statistical averages. The recreational boat population is based on the activity representative of a summer Sunday. The basis for Sunday peaks is from "A Design for Coastal Search and Rescue Communications System for the Third Coast Guard District" by Robert H. Cassis, Jr., LCDR, 1971.

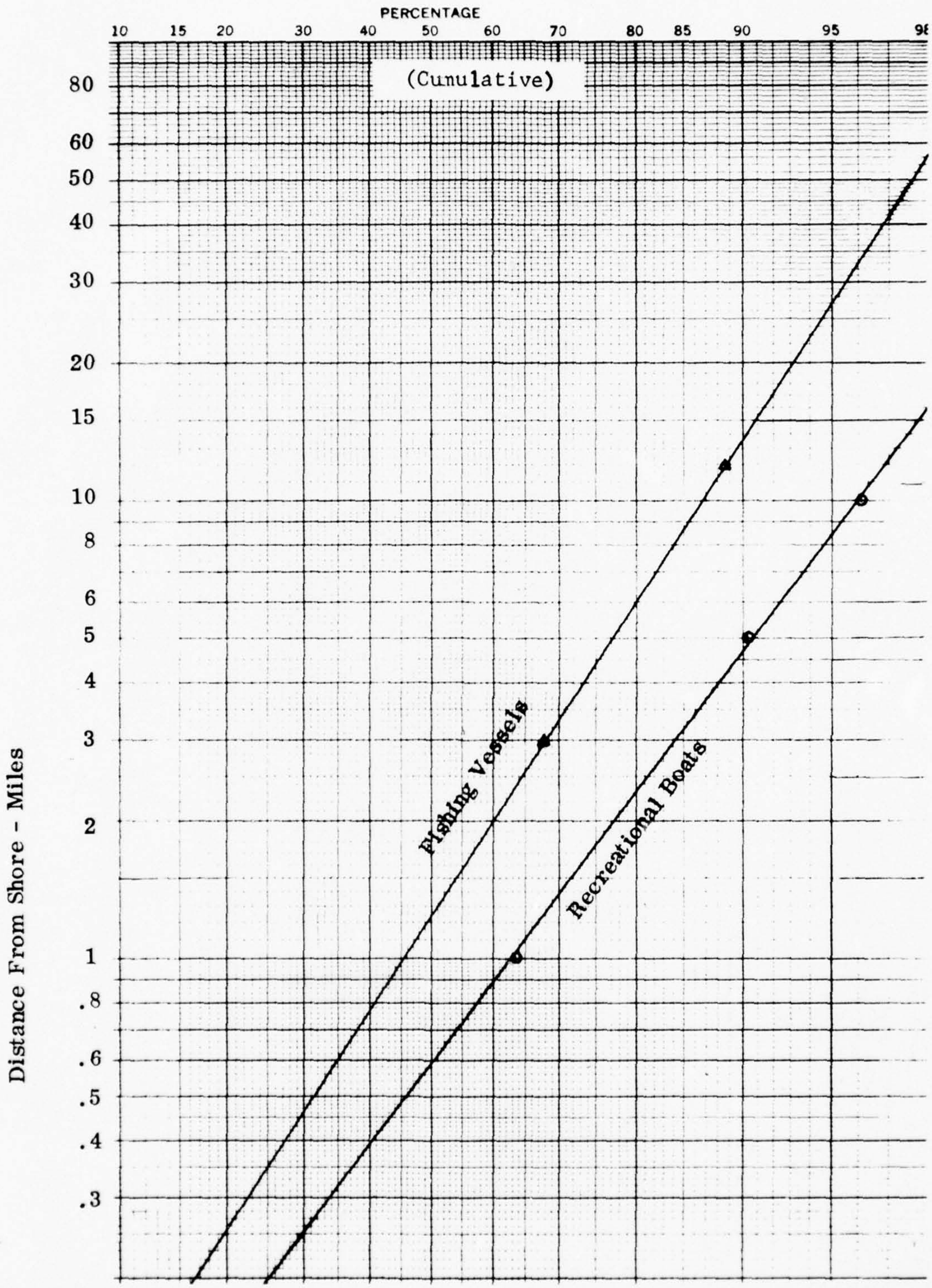


Figure 4-4. Distribution of Operation of Fishing Vessels and Recreational Boats

TABLE 4-2. RANDOM DISTRIBUTION ON BASIS OF 100 UNITS

MILES FROM SHORE *	RECREATIONAL BOATS (Basis of 100)	FISHING BOATS (Basis of 100)
1	63	45
2	14	15
3	7	8
4	4	6
5	2.5	3
6	1.8	3
7	1.3	2
8	.9	2
9	.8	1.5
10	.7	1.5
11	.5	1.5
12	.5	1
13	.2	1
14	.2	1
15	.1	1
16	.09	0.75
17		0.75
18		0.75
19		0.5
20		0.5
Mean Distance	2.2 Miles	7.4 Miles

* Considers population contours per mile from shore at indicated distance

4.5 Aeronautical Overflights. The detailed recording of air traffic for flights of civilian air carriers and military aircraft on domestic airways provides a data base for aeronautical overflights. Because the range of the 121.5/243-MHz EPIRB is approximately 80 miles in a future concept, a reference site was selected that included a relatively high density of flights along the coast. The VOR station at Wilmington ILM provided this reference since it was a mandatory reporting site (either by aircrew or radar - following). The data sampled is shown in Table 4-3. Additional records were examined for tracks beyond 80 miles inland, and tabulated for potential improvement to time of availability. The characteristics of various aircraft receivers and their ranges in detecting a 75-milliwatt EPIRB are shown in Table 4-4. The methodology of coverage effectiveness is to relate the total period of coverage based on range in terms of minutes before and beyond the passage reference. This is shown for the FAA automated alert receiver in Table 4-5. The total minutes of coverage (aircraft times duration in range) divided by 1440 minutes provides the effectiveness of passing aircraft.

4.6 Communication Duty Cycles and Transmission Characteristics. In the situations where a communications calling frequency may also be the emergency or distress frequency, some indication of communications activity is required. The most recent data and fully representative is the Coast Guard's examination of the New York area and approaches conducted on 156.8 MHz in 1974.

New York sampling indicated peak transmissions of 190 per hour, and peak average transmission durations of 11.65 seconds as a maximum observed in any hour. The average overall duration of transmissions was 4.2 seconds. A direct relationship exists between maximum transmissions, transmission times, and inactive periods between transmissions. If the maximum observed transmission duration of 11.6 seconds and the minimum averaged interval of 17 seconds resulting from this sampling are accepted, a total of 125

TABLE 4-3. AERONAUTICAL OVERFLIGHTS

HOUR OF THE DAY		AIRCRAFT PASSING REFERENCE LINE IN EACH HOUR (Count beginning with indicated hour)	PERCENT OF TOTAL BY HOUR	MAXIMUM INTERVAL BETWEEN AIRCRAFT PASSAGES IN THE HOUR OR CONSECUTIVE HOUR (In Minutes)
Z	EDST			
00	8 PM	18	3	17
01	9 PM	2	0.3	40
02	10 PM	5	0.9	26
03	11 PM	1	0.1	68
04	Midnight	5	0.9	28
05	1 AM	2	0.3	41
06	2 AM	2	0.3	73
07	3 AM	1	0.1	76
08	4 AM	0		
09	5 AM	0		
10	6 AM	5	0.9	132
11	7 AM	7	1.2	37
12	8 AM	3	0.5	27
13	9 AM	9	1.6	77
14	10 AM	52	9.6	7
15	11 AM	40	7.4	6
16	Noon	40	7.4	6
17	1 PM	42	7.7	7
18	2 PM	67	12.4	4
19	3 PM	33	6.1	15
20	4 PM	56	10	6
21	5 PM	46	8.5	5
22	6 PM	49	9	5
23	7 PM	55	10	5

Source: Analysis of Air Traffic Control records, Sunday, 2 March 1975, North-South over mandatory reporting site on the coast, VOR Wilmington (ILM). Data courtesy of Washington Air Route Traffic Control Center, Leesburg.

TABLE 4-4. AIRCRAFT ELT DETECTION CHARACTERISTICS

CHARACTERISTIC	TYPE AERONAUTICAL RECEIVER SYSTEM			
	ARINC 546/566 RECEIVER	ICAO (Annex 10) RECEIVER	FAA AUTO ALERT A/C RECEIVER	MILITARY UHF RECEIVER
Radiated Power ELT/EPIRB (dBm)	18.75	18.75	18.75	18.75
Receiver System Sensitivity in dBm	-107.7	- 98.7	- 98.0	-104.7
Allowance for variation in Antenna gain over field of view	6 dB	6 dB	6 dB	6 dB
Miscellaneous Propagation Loss Allowance	3 dB	3 dB	3 dB	3 dB
Allowable Path Loss in dB Worst case (1)	117.4	108.4	107.7	114.4
Minimum Slant Range, Miles (1)	91.1	32.3	29.8	32.1
Allowable Path Loss in dB Best case (2)	126.4	117.4	116.7	123.4
Maximum Slant Range, Miles (2)	256.8	91.1	84.1	90.6

(1) Includes total link variation of 9 dB for variation of the aircraft antenna gain over field of view and other miscellaneous propagation allowances.

(2) Best case link performance without allowance for antenna gain variations or miscellaneous propagation allowances.

Assumes: ELT/EPIRB signal distinguishable at 3 dB S/N
Modulation of ELT/EPIRB is not less than 85%

TABLE 4-5. ALERTING AVAILABILITY OF TRANSIT AIRCRAFT

FLIGHT LEVEL (In Feet)	RADIO HORIZON	RANGE TO SENSITIVITY LIMITS OF AUTO ELT RECEIVER (Miles)	TOTAL DURATION OF TIME THAT AN ASSUMED SURVIVAL CRAFT IS WITHIN RADIO RANGE BASED ON A GROUND SPEED OF 420 MILES PER HOUR (In Minutes)		
			OVERFLIGHT	35 MILES OFFSET	70 MILES OFFSET
32,000	256	84	24	21.8	13.6
25,000	224	84	24	21.8	13.6
20,000	200	84	24	21.8	13.6
10,000	141	84	24	21.8	13.6
6,000	109	84	24	21.8	13.6
3,528	84	84	24	21.8	13.6

Assumes: ELT/EPIRB signal distinguishable at 3 dB S/N
Radiated power = 75 Milliwatts 121.5 MHz
Modulation = 85 % or better

Note: The range of 256 miles at 32,000 feet also represents the maximum possible sensitivity for the ARINC Specification 546/566, optimum propagation, and assumed conditions.

transmissions are feasible each hour. Based on distribution of transmissions accomplished per hour, 95% of hourly transmissions for all periods sampled were approximately 127 transmissions or less. However, in considering the distribution of transmission durations for the total hours sampled, 95% were approximately 600 seconds or less per hour. Under this assumed loading, each active transmission averaged 4.7 seconds and the interval periods between calls averaged 23.6 seconds. This is rounded to 5 seconds active, 23 seconds inactive for the 1973 model.

A similar duty cycle was assumed for 2182 kHz but with a longer transmission duration. This is based upon the increased use by commercial fishing vessels in offshore operations.

In order to estimate possible blocking on 500 kHz, an activity factor of 36 transmissions per hour was assumed in or adjacent to the model area. Each call was assumed to be 10 seconds in duration.

4.7 Radio Propagation and Path Loss. The effectiveness of A/L devices are constrained by transmission capabilities for any given radiated power, path loss, electrical noise, and receiver sensitivity. Direction finders using the null of amplitude variations require stronger signals than the alert receiver, and their accuracy deteriorates as the signal level decreases. The characteristics of typical transmitters and sensitivities of receivers establish specific signal levels. Path loss for any frequency range and noise level is a function of distance. The analytical approach is to determine the ranges that each system provides, and the extent that this satisfies the coastal zone requirement. When coverage is conditioned upon electrical noise, the percentage of time that the noise level permits coverage becomes the approximate effectiveness for the conditions assumed.

A summary of radiated powers and receiver sensitivities is shown in Table 4-6. The ranges involved in the model permit application of transmission formulas without serious regard to ground wave attenuation except for 500

TABLE 4-6. RADIATED POWERS AND RECEIVER SENSITIVITIES

EMERGENCY FUNCTION	TYPICAL RADIATED POWER	RECEIVER SENSITIVITY IN UV/M			
		COAST STATION		SHIP	AIRCRAFT
		COMMO	DF		
500 kHz					
Communications	50 watts	10	50	50	100
Survival Craft (26-foot antenna)	250 milliwatts				
Auto Alarm Receiver				100	
2182 kHz					
Communications		5	10	25	50
20-foot whip	0.2 watts				
75-foot antenna	2 watts				
Survival Craft	38 milliwatts				
EPIRB	0.55 milliwatts				
8364 kHz Survival	6 milliwatts				
121.5 MHz					
ELT/EPIRB	75 milliwatts*				
ARINC 546/566					3
ICAO Annex 10					7
ELT AUTO ALERT					9
156.8 MHz					
Communications		0.35	0.35	3	50
Installed	15 watts				
Handheld	1 watt				
EPIRB	75 milliwatts				
243 MHz					
ELT/EPIRB	75 milliwatts				3

*225 for oceanic

kHz. Accordingly, skywave computations are not considered. SALTTI/86 contains the computational approaches that apply to this assumption. The limits of the radio horizon control feasible VHF and UHF terrestrial transmissions, and are established by

$$D_{miles} = \sqrt{2h_t} + \sqrt{2h_r}$$

where h is the height in feet for the transmitter and receiver antennas

The computations applied within the above limits are to determine the range at which the receiving system sensitivity is exceeded, and the range at which the noise (signal-to-noise) limits the system. The lesser range is limiting but the basis for this limit is identified by this process. These computations are illustrated in basic computer language in Figure 4-5. The basic formula is:

$$D = \frac{\sqrt{(1.2 \times 10^{-5})\, P_r}}{E}$$

where D = distance in statute miles

P_r = radiated power

E = field strength in volts per meter (E_N + S/N) or (receiver sensitivity)

$$E_n = F_a - 95.5 + 20 \log F + 10 \log b$$

where F = frequency (MHz)

b = bandwidth (Hz)

F_a = noise factor at operating frequency

```
5   ON ERROR GO TO 10
10  PRINT "MAN-MADE NOISE (DB)";
20  INPUT N1
25  IF N1 = 99.99 GO TO 360
30  PRINT "NATURAL NOISE (DB)";
40  INPUT N2
50  PRINT "ERP";
60  INPUT P
70  PRINT "WAS THAT IN (1)WATTS,(2)MILLIWATTS,(3)DBW,(4)DBM";
80  INPUT Z
90  IF Z=1 GO TO 190
100 IF Z=2 GO TO 180
110 IF Z=3 GO TO 160
120 IF Z=4 GO TO 140
130 GO TO 50
140 P=(10↑(P/10))/1000
150 GO TO 190
160 P=10↑(P/10)
170 GO TO 190
180 P=P/1000
190 CONTINUE
200 PRINT "REQUIRED SIGNAL TO NOISE RATIO (DB);
210 INPUT M
220 PRINT "MIN RECEIVER SENSITIVITY (UV/M)";
230 INPUT S
240 PRINT "BANDWIDTH (HZ)";
250 INPUT B
260 PRINT "FREQUENCY (MHZ)";
270 INPUT F
280 N0=10↑((N2+N1+M-95.5+8.686*LOG(F)+4.343*LOG(B))/20)
290 R1=(1E6*SQR(30*P)/S)/1609.344
300 R2=(1E6*SQR(30*P)/N0)/1609.344
310 PRINT USING 320,R1
320 :RANGE WHERE MIN. RCVR SENSITIVITY IS EXCEEDED = #####.## MILES
330 PRINT USING 340,R2
340 :RANGE WHERE REQ. S/N0 IS EXCEEDED = #####.## MILES
345 PRINT
346 PRINT
350 GO TO 10
360 END
```

Figure 4-5. Computer Program Used for Propagational Ranges

The noise factor is significant to 2- and 0.5-MHz systems, and varies diurnally, seasonally, and geographically. Data source is Report 322, CCIR, Xth Plenary. The noise levels for the Virginia-New York coast are used in the model as representative of most of the coastal areas. These are tabulated by hours per year in Table 4-7.

The sensitivities and ranges of various shore, surface,and aircraft are shown in Tables 4-8, 4-9, and 4-10, respectively.

4.8 Radio Location. The majority of alternate systems utilize the direction finder as the location device in this time frame and coastal zone. The effectiveness of location is related to search time and the capability to support prompt mission accomplishment. Because the locational fix of direction finders involve some degree of an area of uncertainty, a relationship has been assumed with effectiveness scoring. Because of the capability of search by helicopter, it has been used to define a 50% effectiveness point in searching an area of uncertainty in an hour. The major impact in keeping the area of uncertainty at a minimum is the accuracy to which the actual bearing or line-of-position may be established. This success is related to system instrumentation accuracy which requires a relatively strong signal to define the deepest null in amplitude measurement techniques. Unfortunately, most survival type devices are of low power which increases the error with distance from the emitter, and accordingly the area of uncertainty. However, the mobility of other air or surface craft may offset this problem if given the general direction of the target. Figure 4-6 shows the effectiveness assumed as a function of the area of uncertainty.

4.9 Signal Detection and Simulation. The probability of each system to recognize the emergency signal when using communication frequencies depends upon relative signal levels, user distributions in range who may be communicating, and a random distribution by events. In addition, the cyclic nature of representative communication durations represent windows through which the alerting

TABLE 4-7. NATURAL NOISE LEVELS

ATMOSPHERIC NOISE (2182 kHz)	HOURS PER YEAR AT THIS LEVEL OR LESS	PERCENT OF HOURS PER YEAR
68	8760	100
65	8030	91
62	6935	79
58	6570	75
56	6205	70
50	5475	62
48	4380	50
46	2920	33
32	2555	29
28	2190	25
24	1460	16
20	1095	12

Source: CCIR 322, World Distribution and Characteristics of Atmospheric Noise.

Area Examined: New Jersey - Cape Cod Coastal Area

TABLE 4-8. RANGES OF SHORE STATION BY SYSTEM

EMERGENCY SYSTEM	NOISE	ALERTING RANGE (Miles)	D/F RANGE (Miles)	LIMITING PARAMETER IN SITUATION	
				ALERTING	D/F
500 kHz Installed	70	323	270	Noise	Noise
500 kHz Survival	70	80	59	System	System
2182 kHz Installed					
	68	119	119	Noise	Noise
	65	168	152	Noise	System
	62	238	152	Noise	System
2182 kHz Survival	68	52	52	Noise	Noise
	62	103	66	Noise	System
	58	132	66	System	System
2182 kHz EPIRB	68	6	6	Noise	Noise
	65	9	8	Noise	System
	62	13	8	Noise	System
	58	16	8	System	System
121.5/243 MHz ELT/ EPIRB		RH	RH	Shore equipment specifications meet minimum signal requirements as limited only by radio horizon.	
156.8 MHz Installed		RH	RH		
156.8 MHz Handheld		RH	RH		
156.8 MHz EPIRB		RH	RH		
406 MHz UHF-AM		RH	RH		

Note: The VHF-FM program has installed adequate tower heights to provide radio coverage 20 miles to sea.

TABLE 4-9. RANGES OF SHIP RADIO FACILITIES (DIRECT WAVE)

EMERGENCY SYSTEM	ALERTING RANGE (Miles)	DIRECTION FINDING (Miles)
500 kHz, Installed	270	270
500 kHz, Survival	59	59
2182 kHz, Installed	60	60
2182 kHz, Survival	26	26
2182 kHz, EPIRB	3	3
121.5/243 MHz ELT/EPIRB	RH	RH
156.8 MHz, Installed	RH	RH
156.8 MHz, Portable	RH	RH
156.8 MHz EPIRB	RH	RH
406 MHz, UHF-AM	RH	RH

Notes:

Atmospheric noise conditions at 500 and 2182 kHz assumed at maximum of 68.

RH: Radio Horizon (Limiting Conditions)

Antenna Height above water (In Feet)	Representative Ship Type (Length in Feet)	Range (Miles)	
		Surface (3 Feet)	Small Boat (10 Feet)
75	210	14.6	16.6
30	40 Utility	10.1	12.1
10	44	6.8	8.8

TABLE 4-10. RADIO RANGES OF AIRCRAFT FACILITIES (DIRECT WAVE)

EMERGENCY SYSTEM	RANGE IN MILES				REMARKS
	COAST GUARD	AIR FORCE & NAVY	AIR CARRIER (Auto ELT Receiver)	AIR CARRIER (ARINC 546/566)	
500 kHz Installed	170*				
500 kHz Survival	20*				
2182 kHz Installed	30.4				
2182 kHz Survival	13.2				
2182 kHz EPIRB	1.6				
121.5/243 ELT			84.1 29.8	256 91	Probable Nulls
156.8 MHz Installed	RH				
156.8 MHz Portable	RH				
156.8 MHz EPIRB	18.6				
243 MHz EPIRB	18.6	90.6			
406 MHz UHF-AM #	18.6				

Notes:

* Equipment assumed as installed in aircraft.

\# UHF-AM equipment assumed to operate at 406 MHz.

The minimum range for 121.5/243 MHz indicated as nulls represents temporary worst case antenna shadows and propagational situations.

The range of Coast Guard aircraft for frequencies above 156.8 MHz results from direction finding receiver sensitivities.

RH Radio horizon range

Altitude	Miles to Radio Horizon
1000	44
2000	63
3000	77
4000	89
5000	100

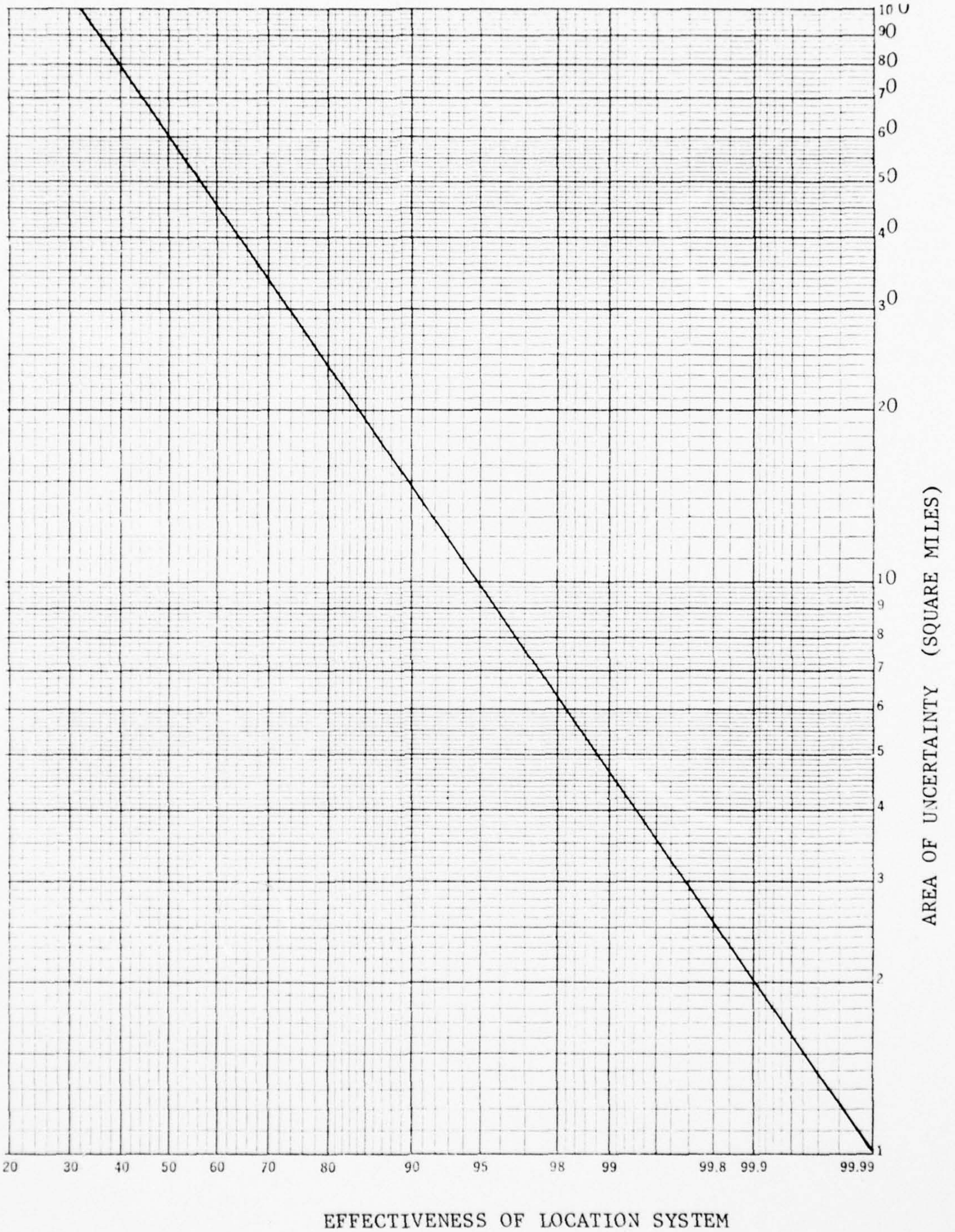


Figure 4-6. Assumed Relationship of Area of Uncertainty and Location Effectiveness

signal or device would be recognized. The factors involved are propagation and path length, radiated signals on the frequency, probability as a function of time and signal durations, and noise levels including that representing random signals in the background.

The simulation program for communication models was examined as shown in Figure 4-7 for VHF and Figure 4-8 for 2182 MHz.

4.10 Rescue Time Objectives. The consequences of delay in alerting and locating is a continuing consideration, and directly influences the SAR mission objectives. A determination of the target time, however, is difficult to establish other than being as prompt as possible. Review of experience reports and exposure studies suggest that one hour elapsed time is a desired target. In many systems, the effectiveness is related to time targets which are assumed on a case-by-case basis. Because the steps in a successful SAR mission are sequentially related, it is essential to expect the alerting and locating segments to be in terms of minutes. In considering effectiveness in this respect, the capability to influence decisions in the first 10 to 15 minutes is a major judgement factor. The summary of time delay impacts is shown in Table 4-11.

Emergency caller:

Subcase 1: 1 watt, 6 miles from station, signal level = - 96 dBw
Subcase 2: 1 watt, 28 miles from station, signal level = -109 dBw
Subcase 3: 15 watt, 28 miles from station, signal level = -97.6 dBw

3 seconds required to recognize emergency signal in a total transmission of 10 seconds.
10 seconds silent listening to possible response

Communication Stations: 15 watt, random distribution as below

Commications activity:

Case 10:	127 calls/hour,	10 second duration,	18.3 seconds silent
Case 20:	127	12	16.3
Case 30:	199	10	8
Case 40:	199	12	6
Case 50:	199	15	3

Random Communications Background, viewed from station

X = 1 to 20 miles,

Y =

Miles	Stations	dBw at shore antenna Maximum	Minimum
1	132	-68.7	-94.7
2	30	-74.7	-94.7
3	15	-78.2	-94.7
4	9	-80.7	-94.7
5	6	-82.6	-95.1
6	5	-84.2	-95.1
7	4	-85.6	-95.1
8	4	-86.7	-95.5
9	4	-87.7	-95.5
10	4	-88.7	-95.5
11	4	-89.5	-95.9
12	4	-90.2	-95.9
13	4	-90.9	-96.3
14	4	-91.6	-96.3
15	4	-92.2	-96.6
16	4	-92.7	-96.9
17	4	-93.3	-96.9
18	4	-93.8	-97.3
19	4	-94.2	-97.6
20	4	-94.7	-97.6

QUESTION: What is probability of emergency recognition: first or n^{th} call?

Figure 4-7. Simulation Model for VHF-FM

Emergency Caller:

Subcase 1: 100 watt PEP (25 watt) into 20' whip, 6 miles from station, - 66.9 dBw

Subcase 2: 100 watt PEP (25 watt) into 20' whip, 28 miles from station, -80.3 dBw

Emergency recognition contained in first 3 seconds of 10 second transmission. Caller silent for 10 seconds.

Communications Environment:

Channel activity: 200 calls/hour, 15 seconds duration with random plus or minus normal distribution.

Users and power distributed as viewed from shore station

X = random 1 to 20 miles

Y = random within population and power levels

Miles from station	Percent of users	Signal Level (at station) Nearest	Fartherest
1	52	-51.3 dBw	-77.3 dBw
2	12	-57.3	-77.3
3	6	-60.9	-77.3
4	4	-63.4	-77.3
5	4	-65.3	-77.3
6	3	-66.9	-77.8
7	2	-68.2	-77.8
8	2	-69.4	-78.0
9	2	-70.4	-78.2
10	2	-71.3	-78.3
11	2	-72.1	-78.6
12	1	-72.9	-78.6
13	1	-73.5	-78.7
14	1	-74.2	-78.7
15	1	-74.8	-79.3
16	1	-75.4	-79.6
17	1	-75.9	-79.6
18	1	-76.4	-79.9
19	1	-76.9	-79.9
20	1 *	-58.0	-61.0

* These users have 150 watt PEP and 75 foot antennas, all others similar to emergency caller.

Question: What is probability of emergency recognition, first or nth call, and assuming that an emergency caller 9 dB stronger will be recognized regardless of background?

Figure 4-8. Simulation Model for 2182 kHz Alerting Calls

TABLE 4-11. RESCUE TIME EXPERIENCE AND OBJECTIVES

TIME BETWEEN INCIDENT AND RECOVERY	NUMBER RECOVERED ALIVE	PERCENTAGE OF THOSE RECOVERED ALIVE TO TOTAL INVOLVED
Within 1st hour of incident	665	95
In the 2nd hour of incident	188	94
In the 3rd through 5th hour	155	91
In the 6th through 10th hour	58	85
In the 11th through 23rd hour	22	64
In the 24th hour or later	13	41

Data source: Final Report Program Plan for Search and Rescue Electronics Alerting and Locating System February, 1974, DOT-TSC-OST-73-42

WATER TEMPERATURE (^{o}F)	HOURS OF SURVIVAL	
	WITHOUT FLOTATION	WITH FLOTATION
40	1.46	1.96
50	1.69	2.62
60	3.07	4.11

Source: Proceedings of the Marine Safety Council, March 1975, "Hypothermia: What to do in and out of the water".

WATER TEMPERATURE (^{o}F)	SURVIVAL TIME IN THE WATER (HOURS)
Above 68	Not governed by water temperature
64.4	10
32	1

Source: Sir Eric Bradbury at the Royal Navy Symposium on Cold/Wet Survival, reported in SAIL Magazine, July 1973.

4.11 Retransmission of NAVAID. The navigational system assumed for retransmission in the coastal areas is LORAN-C. Accuracies of this system are better than 1500 feet with typical being 200 feet. The location effectiveness assigned is 0.999 where retransmission modes are used.

4.12 Satellite-Related Assumptions. The Doppler navigation accuracy is assumed as 0.2 nautical mile when the speed over the bottom is known. This accuracy is assigned a location effectiveness in the study of 0.998.

The orbiting satellites considered in certain A/L configurations are assumed to consist of two satellites reported to have a 40-minute visibility. If the visibility is limited to 8° above the horizon, the satellite is visible for 164° of arc in a 40-minute period or is moving 4.1° per minute. The satellite period accordingly is 87.8 minutes and accomplishes 16.4 revolutions of the earth per day. Two satellites therefore are assumed to provide a maximum of 1312 minutes per day radio visibility or an availability effectiveness of 0.910. The location capability, however, is restricted to periods of satellite zenith.

SECTION 5 - DISCUSSIONS OF SYSTEM EFFECTIVENESS

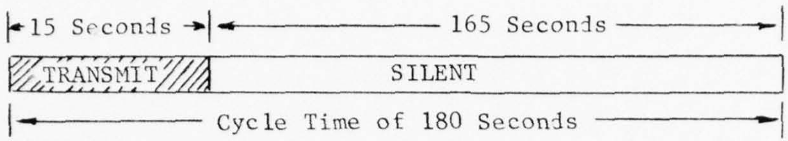
5.1 Emergency Position Indicating Radio Beacon Signals

5.1.1 Finding. The EPIRB and ELT devices are currently designed to operate with a continuously radiating signal,once activated. The multiple emitter environment potentially resulting from any widespread maritime situation degrades the performance of alerting and locating features. It is important to define the future design approaches that resolve this type performance limitation, and to do so prior to increasing the user population and inventory.

5.1.2 Approaches. The separation among users to increase interference-free operation and meet performance goals intended may take two basic forms. They may employ differences in random units of radio frequencies or through the time domain using various duty cycles. However, if units are distributed through the radio spectrum, their proper detection and location would require increased receivers and personnel. Further, the congested nature of the radio spectrum and the inability to optimize a responsive system would be impractical. A solution based upon random time intervals of transmission provides a practical approach which may use a standardized system and single frequency. This approach requires that each device have a generally specified transmission cycle of an active duration followed by an inactive period.

If the total simultaneous emergencies are assumed for which the system is designed to accept and a maximum target period for successful alert and location established, an optimum relationship exists for the duration of a cycle and the transmission period within each cycle. Because of the present minimum time required for a direction finding bearing, the transmission period must be approximately 15 seconds.

If the A/L shore system is based upon a designed capability of up to four simultaneous EPIRB emergencies, a target not to exceed 10 minutes, and a 15-second minimum transmission time, the optimum duty cycle is:



The analysis and graphs for various combinations follow.

5.1.3 Analysis

Each EPIRB transmission consists of a burst of duration τ. This quantity is chosen to be consistent with the time required to obtain a positional fix on the transmitter. For a coastal station, $\tau = 10$ seconds is probably sufficient and for a helicopter, $\tau = 15$ seconds might be required. Successive EPIRB transmissions are assumed to occur periodically with period T. Thus, each EPIRB transmitter is on for τ, off for $T - \tau$, on for τ; etc., repetitively, until silenced. While it is activated, the transmitter duty factor is τ/T, which, in general, will be found to be considerably less than one.

The probability that some specific EPIRB causes interference to a single burst of some other specific EPIRB is given by

$$P_1 = 2\tau/T \qquad (1)$$

and therefore, the probability that interference is not present is

$$Q_1 = 1 - P_1 = 1 - (2\tau/T) \quad . \qquad (2)$$

If a total of M EPIRBs are simultaneously active, M-1 of those are potential candidates which could cause interference to any one EPIRB transmission. The probability that a single burst from any one specific EPIRB is received free of interference is

$$Q = Q_1^{M-1} = \left[1 - (2\tau/T)\right]^{M-1} \tag{3}$$

so the probability of interference is

$$P = 1 - Q = 1 - \left[1 - (2\tau/T)\right]^{M-1} \quad . \tag{4}$$

It is not necessary that each and every burst be received free of interference. Rather, a realistic goal is to require the reception of at least one interference-free burst from a specific EPIRB within some time, ψ, starting from the initiation of that EPIRB activity. The probability that this goal is not met will be called the probability of failure, P(f). During the time interval ψ, approximately ψ/T bursts will be received from each EPIRB. Actually, the number of complete bursts must be an integer, but the quantity ψ/T, which generally is not an integer, represents a conservative (small) estimate of the number of bursts received from that specific EPIRB whose transmitter became active at the beginning of the interval ψ. The probability of failure is, therefore, conservatively estimated by

$$P(f) = P^{\psi/T} = \left\{1 - \left[1 - (2\tau/T)\right]^{M-1}\right\}^{\psi/T} \quad . \tag{5}$$

Upon choosing values for τ and M, it is possible to select a value for T which minimizes P(f). By taking the derivative of P(f) with respect to T and equating the result to zero, it was found that the system load factor, defined by

$$\lambda = M\tau/T \tag{6}$$

should be about 0.35 in order to minimize P(f). Thus, upon solving for the optimum value of T, one obtains

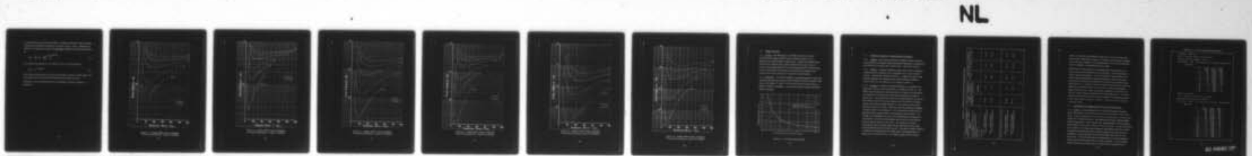
$$T = 2.857\, M\tau \quad . \tag{7}$$

Numerical results were obtained from equation 5 for τ = 10 and 15 seconds and ψ = 5, 10, and 20 minutes. Curves of P(f) versus T are included herein. It can easily

AD-A052 003 COMPUTER SCIENCES CORP ARLINGTON VA F/G 13/12
STUDY OF ALERTING AND LOCATING TECHNIQUES AND THEIR IMPACT (SAL--ETC(U)
SEP 75 DOT-CG-52032-A

UNCLASSIFIED NL

2 OF 2
AD A
052003



END
DATE
FILMED
4 -78
DDC

be verified from these curves that equation 7 accurately predicts the value of T, which minimizes the probability of failure for any choices of M, τ, and ψ. Substitution of equation 7 into equation 5 provides the minimized probability of failure which is given by

$$P_o(f) = \left\{1 - \left[1 - \frac{0.7}{M}\right]^{M-1}\right\}^{.35\psi/M\tau} \quad . \tag{8}$$

If one replaces the quantity M-1 in equation 8 by M, it can be shown that

$$P_o(f) \le 2^{-.35\psi/M\tau} \quad . \tag{9}$$

This simple result provides conservative performance estimates at small values of M but becomes very accurate when M becomes large (such that $M \approx M-1$).

Probability versus Transmission Period relationships are shown in Figures 5-1 through 5-6.

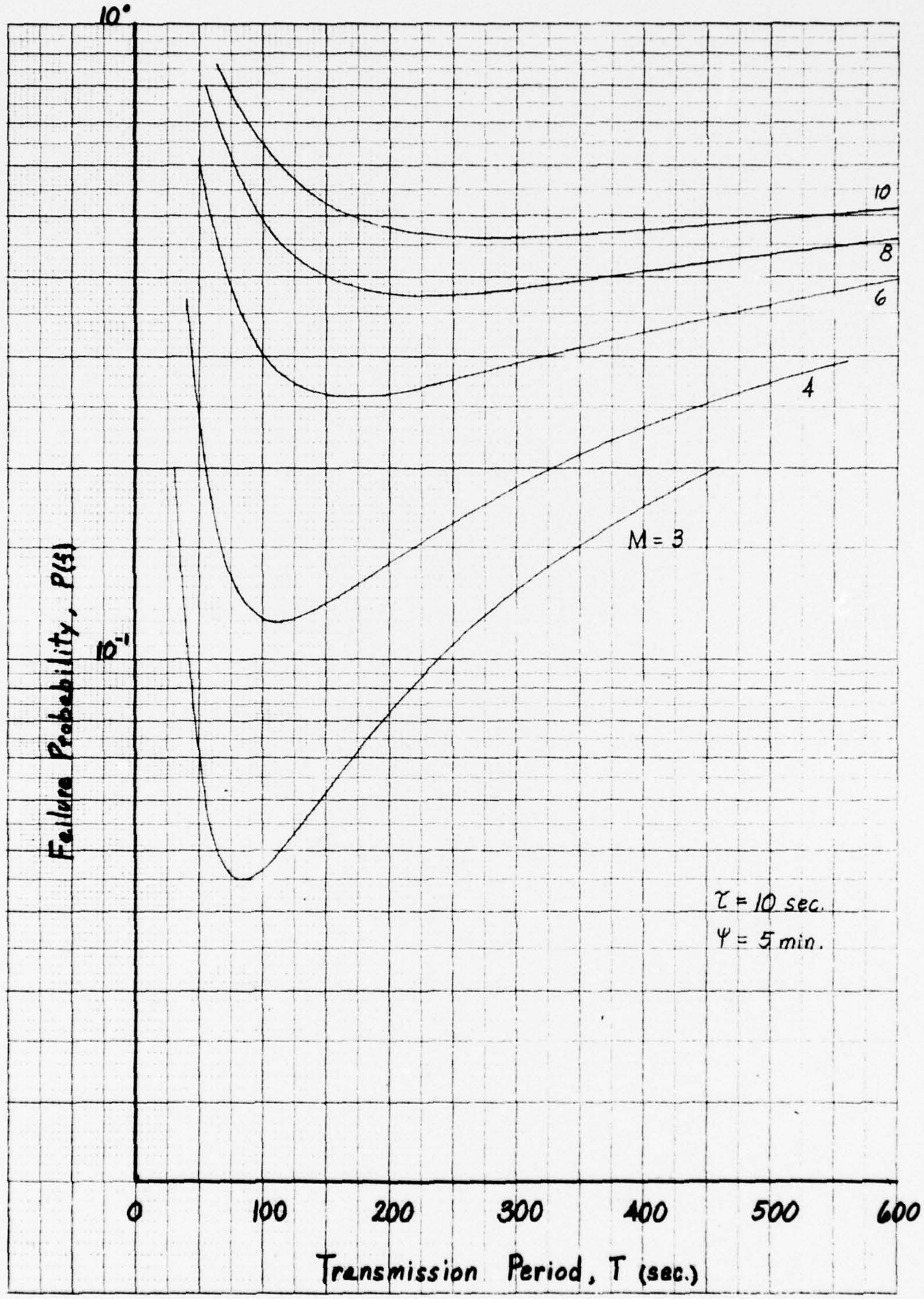


Figure 5-1. Multiple EPIRB Failure Probability
(10-second transmissions, target of 5 minutes)

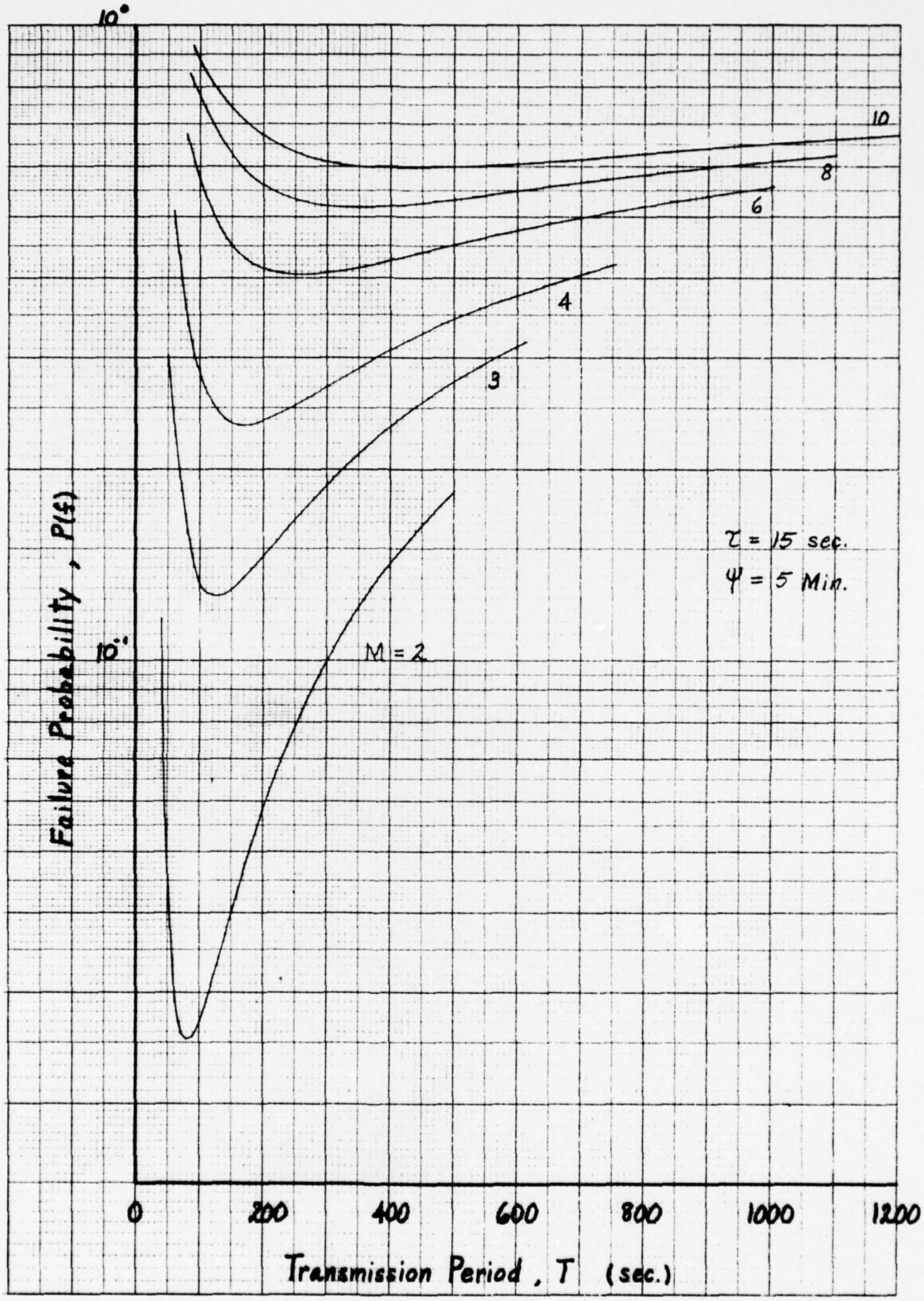


Figure 5-2. Multiple EPIRB Failure Probability
(15-second transmissions, target of 5 minutes)

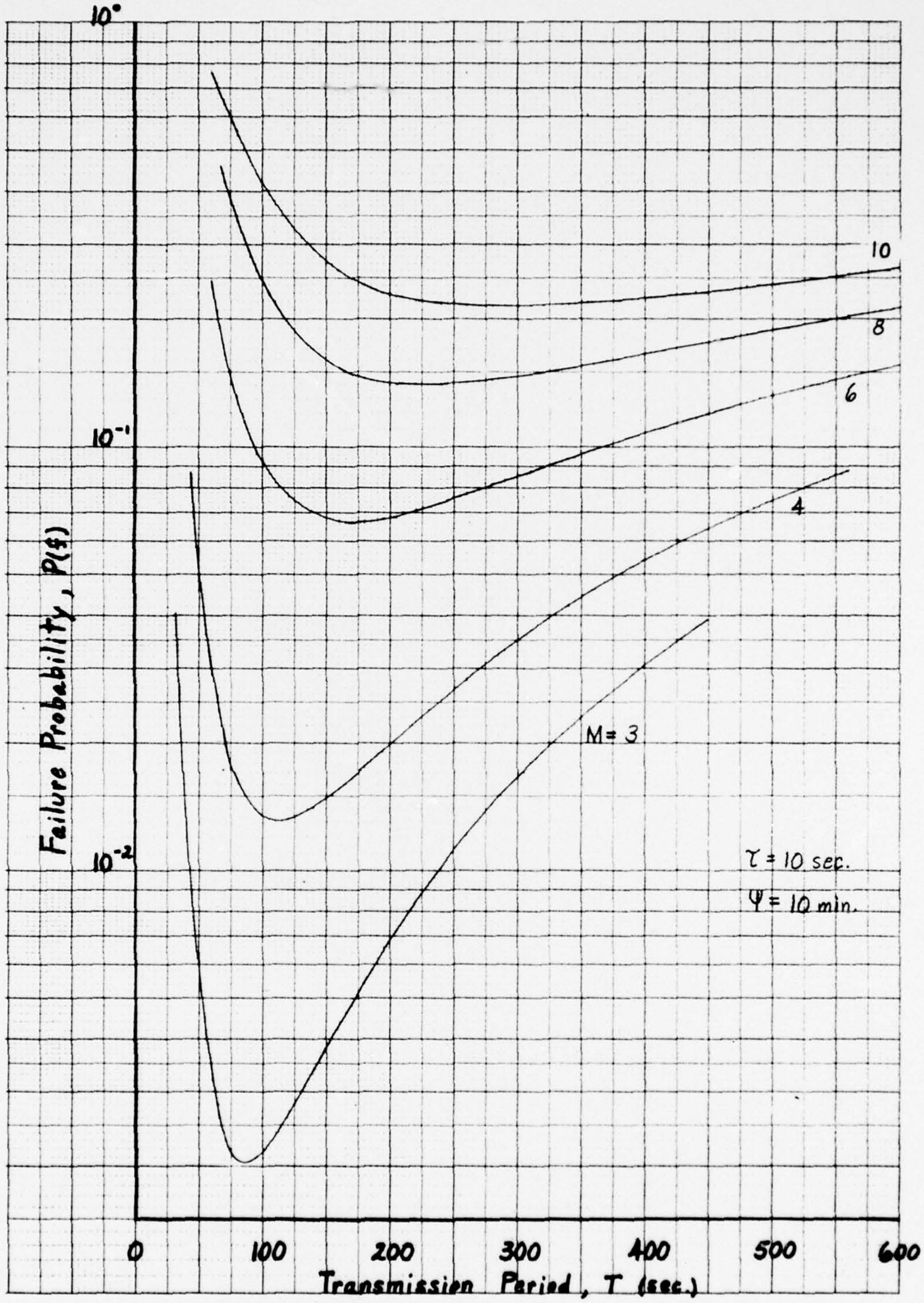


Figure 5-3. Multiple EPIRB Failure Probability (10-second transmissions, target of 10 minutes)

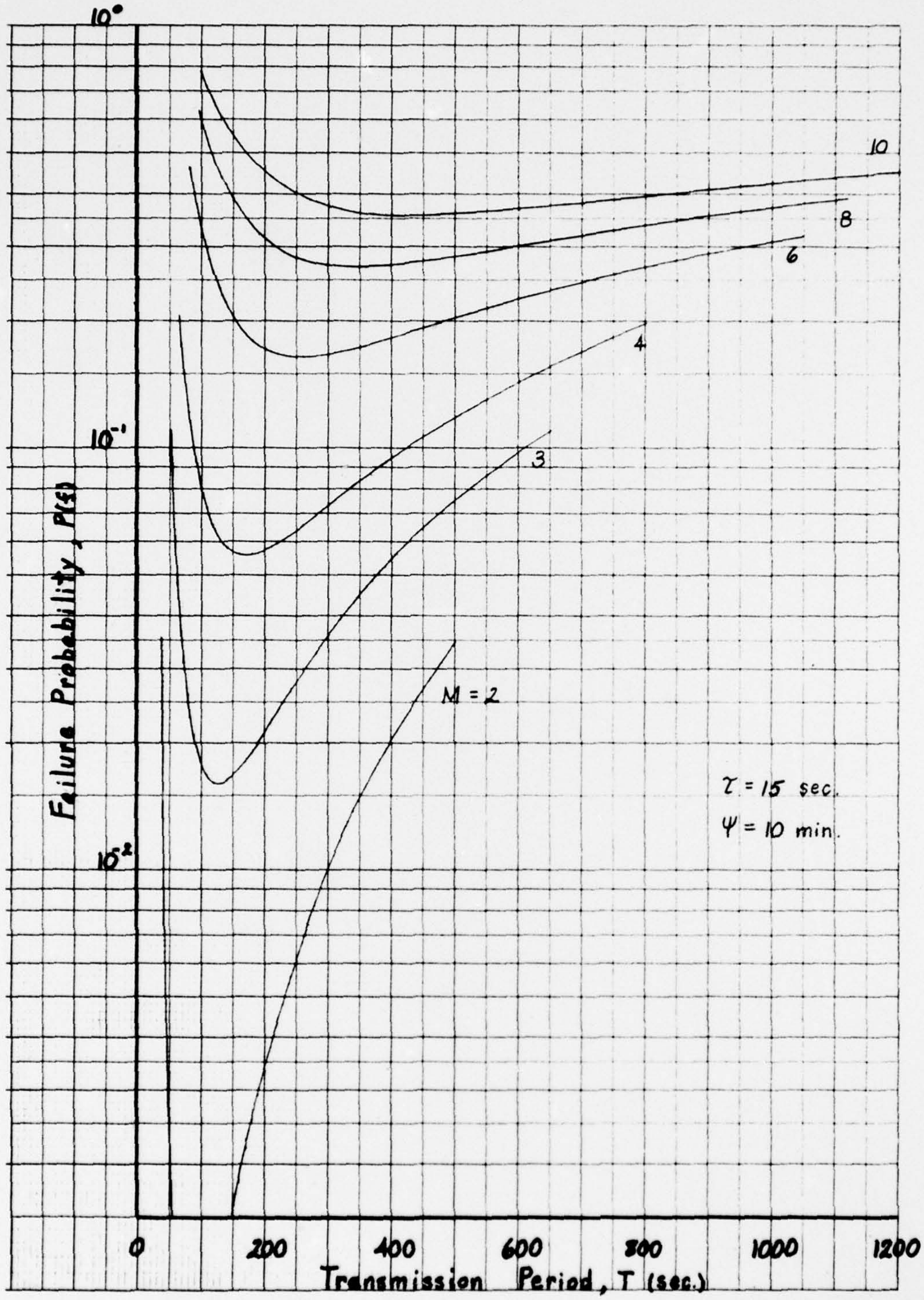


Figure 5-4. Multiple EPIRB Failure Probability (15-second transmissions, target of 10 minutes)

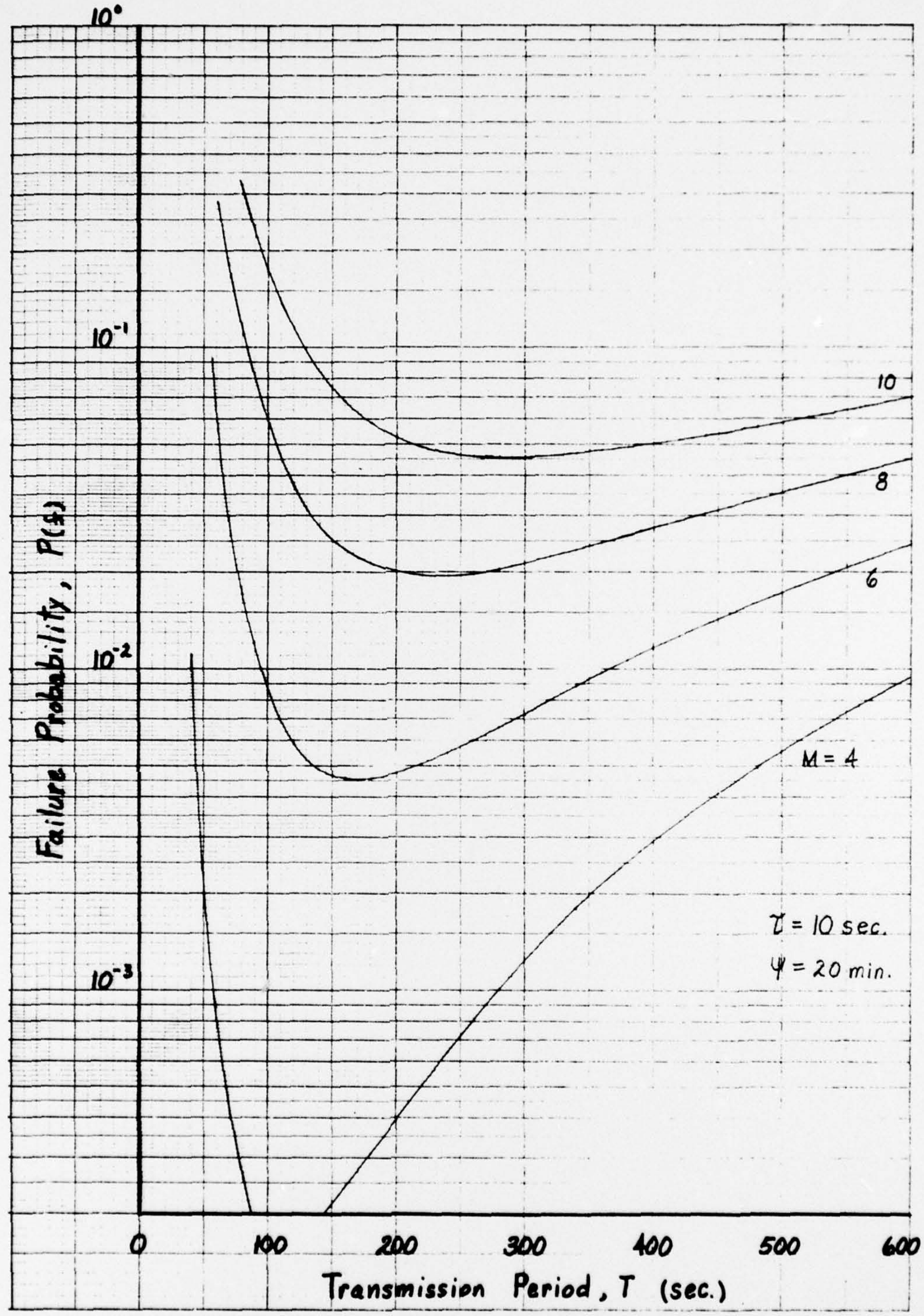


Figure 5-5. Multiple EPIRB Failure Probability (10-second transmissions, target of 20 minutes)

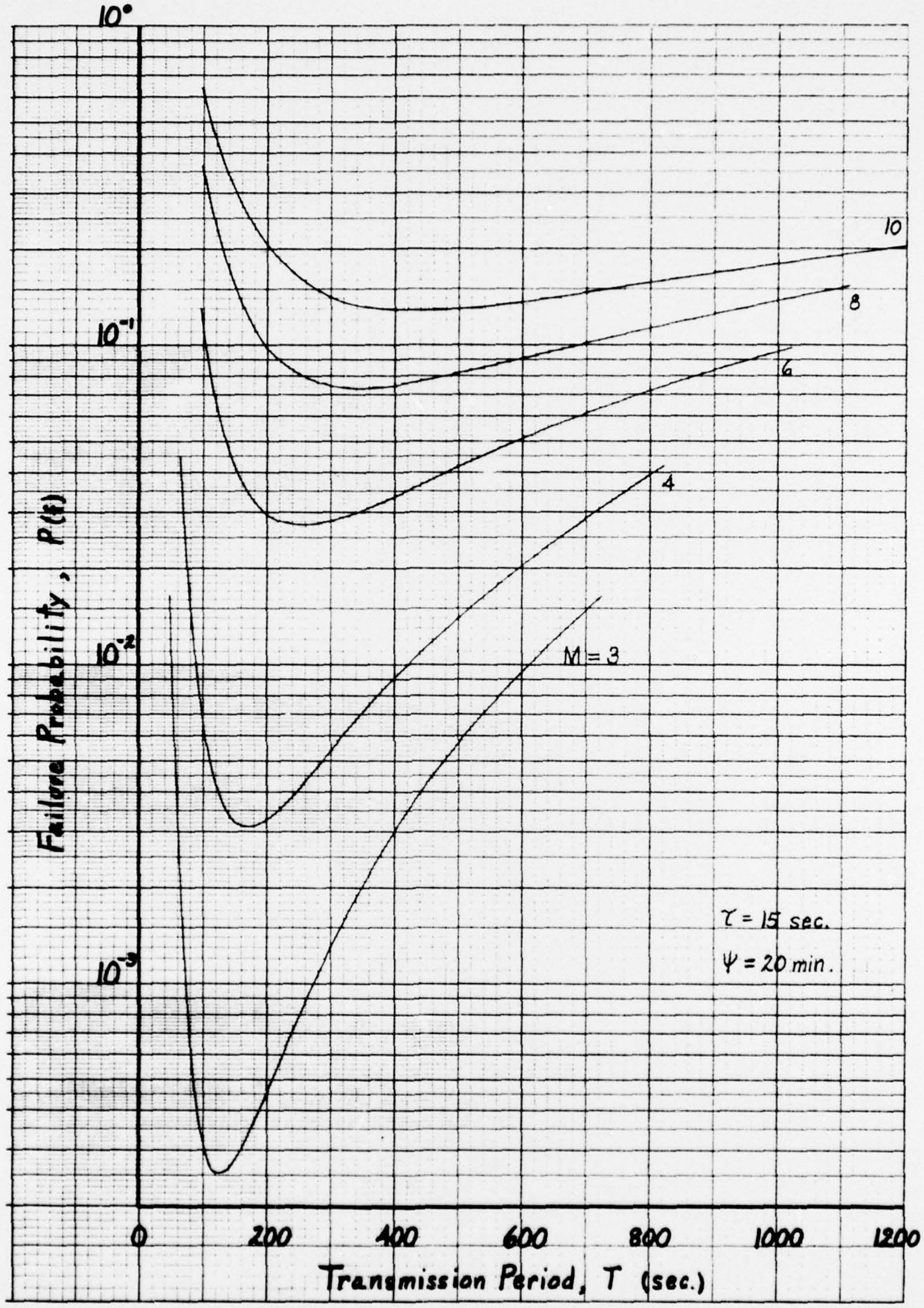


Figure 5-6. Multiple EPIRB Failure Probability
(15-second transmissions, target of 20 minutes)

5.2 EPIRB, 2182 kHz

5.2.1 Finding. The effectiveness of EPIRBS on 2182 kHz is greatly restricted by the power available and the inefficient antenna for this frequency and feasible physical configuration. SALTTI investigation shows that the actual radiated power, typical electrical noise levels, and the receiver sensitivity, particularly for aircraft, grossly limits its effectiveness. In fact, during higher noise periods the aircraft should establish visual contact almost at the same time it is capable of a radio bearing.

5.2.2 Discussion. The 2182-kHz EPIRB is severely limited for Coast Guard aircraft homing because of the sensitivity required by present receivers. This impact is illustrated in Figure 5-7 below which shows predicted range as a function of receiver sensitivity. This is prepared from analysis of 2182-kHz EPIRB capabilities.

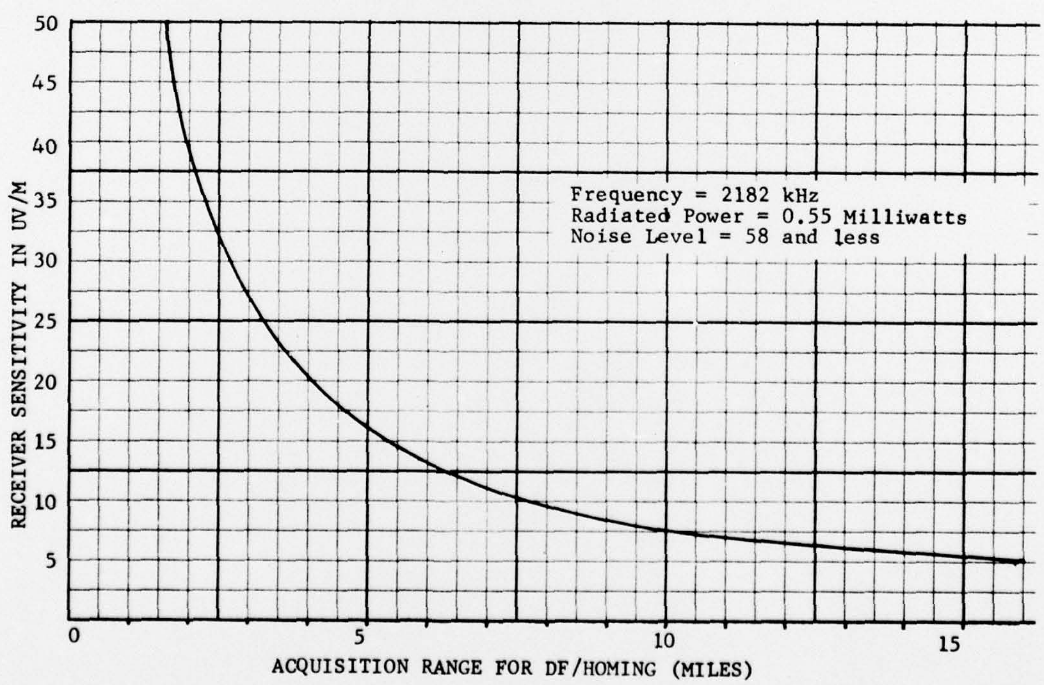


Figure 5-7. Aircraft Acquisition Range

5.3 Simulation Analysis of Communications Environment

5.3.1 Purpose. Effectiveness estimates of alerting systems using voice communications on maritime calling and distress frequencies are affected by the environment created by other transmissions. What is this impact?

5.3.2 Analysis. Analytical techniques using computer-driven simulation conditions permit examination of the probability for success by the alert message. Through the assistance of LCDR J. R. Offut of the Coast Guard, simulation analysis was conducted under several projected conditions. Program inputs for this purpose were as outlined in Section 4.

5.3.3 Findings. A summary of simulation findings for communications effectiveness for 156.8 MHz and 2182 kHz is contained in Table 5-1. The differences by frequency are relatively minor, and appear more affected by call density and call duration than transmission capabilities in the near coastal area. The assumed call rate for 1985 of approximately 200 calls per hour indicates need for increasing emphasis on call durations on common calling and emergency alerting frequencies. The analyses assumed call durations of 10 and 15 seconds, and that 3 seconds of emergency recognition is required within each alerting call. The communications effectiveness is degraded by the average duration of non-emergency transmissions. For example, the probability of success in the communications environment is decreased by 3.6% when the transmission time average of non-emergency callers increases from 10 to 15 seconds. The difference in distance of emergency callers between 6 miles and the model extreme of 28 miles decreases effectiveness of 2182 kHz by 2.6%. The effect of similar distances is slightly more pronounced on 156.8-MHz signal environment where the effectiveness is decreased 3.6%. The findings suggest that the distance

TABLE 5-1. SUMMARY OF COMMUNICATIONS SIMULATIONS

COMMUNICATION ENVIRONMENT AND DISTANCE ALERT CALLER IS FROM STATION (All emergency calls are of 10 second duration, background transmission durations as indicated.)	TOTAL ALERT CALLS CONSIDERED IN SIMULATION	MAXIMUM TIME TO ENSURE CLEARING ALL ALERT CALLS (MINUTES)	ALERT SUCCESS (IN PERCENT)		
			1st CALL	2nd CALL	3rd CALL
156.8 MHz					
1975, 6 MILES DISTANCE (10 Second Transmissions)	35,181	5.0	86.5	94.5	97.6
1985, 6 MILES DISTANCE (10 Second Transmissions)	25,426	5.6	80.6	89.9	91.4
2182 kHz (100 Watt PEP, 20' Whip)					
1985, 6 MILES DISTANCE (15 Second Transmissions)	23,009	7.6	82.4	89.5	93.3
1985, 28 MILES DISTANCE (15 Second Transmissions)	18,723	10.0	79.7	86.8	90.7

effects are identical with the effects created by a 15-second average transmission time compared to 10 seconds. Simulations using identical conditions, except call rates, indicate a 3.3% reduction from 1975 to 1985 alerting effectiveness created by user population increases alone.

Effectiveness of alerting devices on communication calling frequencies in coastal areas are most affected by system discipline and the importance of concise (short) transmissions. If it is not feasible to attain reduced transmission through educational or regulatory approaches, the alerting signal should differ in emission characteristics so as to favor shore station recognition of the alert. While the results are similar for interactions of communication users on either 2182 kHz or 156.8 MHz, it should be noted that the impacts of static bursts, noise, and skywave interference characteristic of 2182 kHz are not included in simulation of communication users. The atmospheric noise level effect for 2182 kHz would degrade communications alerting in the manner shown by Table 4-7, Section 4. Tables 5-2 and 5-3 show the simulation results.

5.4 Aeronautical ELT Applications to the Coastal Maritime Area

5.4.1 Finding. The aeronautical ELT as a form of emergency indicating beacon for maritime use is presently limited by flight schedules in the coastal areas. Based on samplings of a busy air route along the coast, an overall availability of 75.1% of the day exists. This pattern involves heavy daylight traffic but little night traffic. In the sampled zone, daylight traffic over the reporting point reached five aircraft per minute on several occasions. During daylight there was no absence of coverage based on passages and detection coverage. During the night, when commercial carriers within reception range of the coast were unavailable, records indicated several military flights paralelled the coast within range. These were included in determining total coverage although the military aircraft would detect only the 243-MHz radiations. If the sensitivity of the aircraft receiver is increased, or commercial aircraft utilize their

TABLE 5-2. 2182 kHz SIMULATION RESULTS

Frequency: 2182 kHz

Power: 100 Watts (PEP), 20-Foot Antenna

Emergency Caller Distance: 6 Miles

Environment: 1985 (200 calls/hour, 15-second transmissions)

DATA RUN:

QUEUE	MAXIMUM CONTENTS	AVERAGE CONTENTS	TOTAL ENTRIES
1	18980	9515.136	18980
2	1630	841.560	1630
3	862	423.945	862
4	465	235.267	465
5	334	171.181	334
6	238	120.562	238
7	156	78.664	156
8	100	49.620	100
9	73	36.121	73
10	50	24.202	50
11	33	14.128	33
12	20	10.003	20
13	25	10.837	25
14	12	5.481	12
15	12	6.285	12
16	4	1.635	4
17	3	1.539	3
18	3	1.151	3
19	4	1.339	4
20	2	1.014	2
23	3	2.276	3

Frequency: 2182 kHz

Power: 100 Watts (PEP), 20-Foot Antenna

Emergency Caller Distance: 28 Miles

Environment: 1985 (200 calls/hour, 15-second transmissions)

DATA RUN:

QUEUE	MAXIMUM CONTENTS	AVERAGE CONTENTS	TOTAL ENTRIES
1	14940	7485.730	14940
2	1321	645.118	1321
3	739	367.218	739
4	500	251.065	500
5	343	169.986	343
6	238	118.043	238
7	155	74.149	155
8	127	62.684	127
9	88	47.967	88
10	67	35.575	67
11	68	33.158	68
12	39	21.791	39
13	22	10.451	22
14	16	7.379	16
15	16	8.637	16
16	6	1.607	6
17	13	5.718	13
18	6	3.119	6
19	4	1.444	4
20	4	2.325	4
21	2	1.951	2
22	2	1.269	2
24	2	1.716	2
25	2	1.178	2
27	2	.418	2
30	1	.492	1

TABLE 5-3. 156.8 MHz SIMULATION RESULTS

Frequency: 156.8 MHz

Power: 1 Watt

Emergency Caller Distance: 6 Miles

Environment: 1975 (127 calls/hour, 10-second transmissions)

DATA RUN:

QUEUE	MAXIMUM CONTENTS	AVERAGE CONTENTS	TOTAL ENTRIES
1	30442	15154.519	30442
2	2834	1425.412	2834
3	1076	541.416	1076
4	429	214.184	429
5	223	114.720	223
6	90	42.402	90
7	42	20.596	42
8	28	14.121	28
9	9	4.008	9
10	2	1.152	2
11	2	1.654	2
12	2	.528	2
14	1	.247	1
15	1	.767	1

Frequency: 156.8 MHz

Power: 1 Watt

Emergency Caller Distance: 6 Miles

Environment: 1985 (200 calls/hour, 10-second transmissions)

DATA RUN:

QUEUE	MAXIMUM CONTENTS	AVERAGE CONTENTS	TOTAL ENTRIES
1	20512	10311.792	20512
2	2347	1173.252	2347
3	1119	559.094	1119
4	624	303.119	624
5	364	181.416	364
6	173	83.182	173
7	126	65.397	126
8	66	35.994	66
9	37	17.643	37
10	21	11.731	21
11	17	9.032	17
12	8	4.018	8
13	9	3.578	9
15	1	.796	1
16	1	.388	1
17	1	.076	1

communication receiver having ARINC 546/566 specifications, additional traffic approximately 250 miles inland would increase the available coverage. In the sample area, this increased range includes traffic over Raleigh and night flights from or to Atlanta. It is noted that domestic flight rules do not require commercial aircraft to monitor 121.5 MHz.

5.4.2 Discussion. A solution to improved aircraft guard of 121.5 MHz is through an automated receiver that provides a flight deck alarm upon reception of the distinctive audio sweep signal. The characteristic of the 4-sweep per second downward tone of the ELT permits electronic gates to easily recognize the signal. The FAA now has in advanced development a type receiver to accomplish this automated alarm, and expects to introduce these on civilian aircraft no later than 1977. The specifications proposed have been forwarded for concurrence of RTCA. The target cost is desired to be less than $50 per unit.

The sensitivity of the automated ELT receiver as presently proposed would result in a systems range of 84 miles for a 75-milliwatt signal. Increasing the sensitivity impacts upon operational considerations between minimum activation ranges and aircraft beyond ranges of land involvement. The need for maximum range over water is recognized by requiring the survival package for oceanic aircraft to be 225 milliwatts.

The gross location of an activated ELT by air route carriers is by midpoint of the route segment over which the signal is heard, and an assumed perpendicular line of position. Similar reports from other aircraft tracks provide a general fix. The final location is by homing by Air Force or Coast Guard aircraft. The difficulty in practice is that the ELT receiving antenna is not truly omni-directional, and the signal is not heard at equal detection ranges in regard to flight path. In fact, some data has shown sufficient nulls in some aircraft orientations as to create erroneous locations prior to a homing mission. The

ELTs experienced a high false alarm rate. This was caused by accidental errors in leaving the unit on after landing and airframe shocks from washing or towing. Fortunately, the trend of false alarms is decreasing as a result of educational programs.

The impact of multiple ELT signals has not been fully defined. Although an estimated location may be feasible with two emitters, this determination is very difficult if several are within the radio horizon. The solution to this type problem is to decrease altitude and thereby discriminate through progressive reduction of the radio horizon. As the population increases, the aeronautical ELT suffers degradation in a multiple ELT environment. A duty cycle should be optimized for ELT/EPIRB to improve performance in a multiple emitter environment.

5.5 Geographical Configurations for Improved Effectiveness of VHF/UHF Location

5.5.1 Observation. The model configuration with a single station capability for VHF/UHF DF in the 20 by 40 mile coastal area is representative; however, introduces some effectiveness questions in view of the high population near shore. This is a tradeoff between alerting and locating on the basis of installation costs and manning, and suggests further review.

5.5.2 Discussion. A single station in the model requires a 28-mile capability to ensure coverage to 20 miles offshore, and provides a single line-of-position (LOP). Scoring for location effectiveness at VHF/UHF considered this condition. If a two-station fix is obtained using an adjacent station 40 miles distant on the coast, the VHF/UHF range capability is 44.7 miles. The 28-mile capability requires an antenna height of 414 feet above sea level and the 44.7-mile capability requires 1000 feet. Except for limited instances of high terrain, this dictates expensive tower installation and maintenance.

Because approximately 90% of the user population is within 4 miles of shore, the system design efficiency must be diluted to also serve the remaining 10%

farther offshore. For location only, this design approach reduces the effectiveness for a majority of users nearer the shore. In the absence of available LOPs from aircraft or ships in proper position for a fix, the area of uncertainty may be large.

In order to obtain a fix using the adjacent shore station (assumed 40 miles distant), the two-station LOP intersection approaches 180° for the majority of users. Regardless of the higher instrumental accuracies possible at VHF/UHF, the geometric dilution results in slight improvement over a single LOP for most users. If the baseline serving the user group within 4 miles is decreased to 10 miles, the intersecting angle (θ) more closely approaches the optimum $\theta = 90°$ with a value of 102°. If the system accuracy is $\pm 1°$, the area of uncertainty is 0.04 square mile $(0.03 \text{ radian} \times 6.4 \text{ Miles})^2$ for a target 4 miles out and midway between the shore DF stations. The second site, being designed for locating in the 4-mile population strata, needs antenna heights of only 50 feet. This may be remote-controlled atop relatively inexpensive wooden poles.

Adaptation of model observations to real installations is in the form of guidelines. Where actual activity and geography permit, it appears that location requirements have greater impact on station sites/configurations than alerting alone. A single tall tower serves effectively for VHF/UHF alerting, but supplemental sites are required to improve the system for location by DF. On the basis of each 100 users, the thesis is to afford location accuracies of 0.99 to 90 users while accepting that 10 users may be located 0.50 effectively. However, improved capabilities to accurately fix the 90 in close range will, by elimination, reduce the LOP to be searched for the other 10.

5.6 Effectiveness Factors Applied

5.6.1 Summary. Effectiveness factors developed and applied are shown in Table 5-4.

TABLE 5-4. SUMMARY OF PARAMETER SCORING GUIDES

	PARAMETER	500 kHz Installed	500 kHz Survival	2182 kHz Installed	2182 kHz Survival	2182 kHz EPIRB [3]	121.5/243 EPIRB/ELT via Overflight	121.5/243 EPIRB/ELT via Shore [3]	VHF-AM (Other than 121.5)	VHF-FM Installed and Portable	VHF-FM EPIRB [3]	UHF-AM [4]
EP	PROPAGATIONAL COVERAGE	1.00	1.00	0.99	0.91	0.50	1.00	1.00	1.00	1.00	1.00	1.00
ET	TIME AVAILABILITY											
	TERRESTRIAL	0.996	0.996	0.996	0.996	0.996		0.996	0.996	0.996	0.996	0.996
	AIRCRAFT OVERFLIGHTS						0.751					
	ORBIT. SATELLITES							0.910	0.910	0.910	0.910	0.910
	GEOSTATIONARY SATELLITES							0.996	0.996	0.996	0.996	0.996
ES	SIGNAL ENVIRONMENT											
	COMMUNICATIONS	0.990	0.980	0.907	0.880	0.795[1]	0.980	0.75 Shore & Ship 0.80 Aircraft	0.990	0.914	0.862[2]	0.990
	EPIRB/ELT [3]					0.944					0.944	0.944
EL	LOCATION EFFECTIVENESS											
	SELF-DETERMINED	0.990	0.990	0.880	0.880				0.880	0.880	0.880	0.880
	SHORE LOP AND SIGNAL JUDGEMENT OR DF FIX	0.980	0.950	0.90	0.80	0.70		0.90	0.80	0.80	0.80	0.80
	SHIPBOARD DF AND HOMING	0.95	0.94	0.80	0.70	0.20		0.62	0.62	0.62	0.62	0.62
	AIRCRAFT DF AND HOMING	0.95	0.90	0.90	0.85	0.28	0.50[5]	0.95	0.95	0.95	0.95	0.95
	DOPPLER SATELLITE [6]								0.99	0.99	0.99	0.99
	NAVAID RETRANSMISSION (Assumed as LORAN-C)								0.999	0.999	0.999	0.999

Notes:
1. EPIRB on a communications calling frequency, 0.80 x 0.944 = 0.795
2. EPIRB on a communications calling frequency, 0.914 x 0.944 = 0.862
3. Specific EPIRB in a multiple EPIRB signal environment (4 emitters)
4. Assumed as an exclusive SAR frequency
5. Assumes aircraft in this case maintains flight path and does not home on ELT/EPIRB
6. Assumes multiple satellite availability and shore capability to receive and process

5.6.2 Propagational Coverage. The factor of 1.000 was applied to all subsystems except the 2182-kHz EPIRB. The coverage afforded by 0.55 milliwatt radiated resulted in coverage of 50% of the model area (20 by 40 miles).

5.6.3 Time Availability. Watch position availability was assumed as 0.996. Aircraft overflight for ELT/EPIRB coverage was computed as 0.751 for a high traffic zone. In the sample of a day's traffic, there were 359 minutes of the 1440-minute day that coverage was not afforded an assumed point in the model 20 miles offshore. The availability of an orbiting satellite is computed in Paragraph 4.12 of Section 4. The 0.98 value for 121.5 kHz was developed from call rate analysis.

5.6.4 Signal Environment. The effectiveness in view of telecommunications activity on the frequency was 99% for 500 kHz based on 36 calls per hour in the model area or immediately adjacent. The strict observance of radio silence on 500 kHz in event of an emergency was scored 0.998. The effectiveness of 2182 kHz and 156.8 MHz was determined by simulation explained separately. The weaker signal of the survival (SOLAS) radio on 2182 kHz was extrapolated as 0.88. The 0.944 effectiveness of EPIRB signals is from curves of failure probability and assumes a 15-second transmission and 165 seconds silence, a total of four simultaneous EPIRBs, and a successful alert not to exceed 10 minutes. The differences in radio silence effectiveness are relative to discipline observed in the bands.

5.6.5 Location Effectiveness. The coastal positions of commercial mandatory 500-kHz installations is assumed as being within 0.99 limits of the criteria used in Figure 4-6, Section 4. The running fix of recreational boats was estimated as within 3.5 miles accuracy. The DF accuracies were related to areas of uncertainty, specified accuracy for various signal levels and extrapolation of increasing inaccuracy with lower signal levels. The lower ship DF effectiveness at VHF or above stems from limitations of the radio horizon as a result of mast heights. The decreased capabilities of DF/Homing for 2182-kHz EPIRBs result from system sensitivities and the increased azimuthal null for the low power involved. The 0.50 for the ELT results from the area of uncertainty in the location approach used. Doppler and LORAN-C accuracies are from system evaluations as related to the area of uncertainty used in the methodology.