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U.S. Coast Guard SARSAT Final Evaluation Report

Vol. I: Technical Evaluation

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16. Abstract

Volume I of this report, Technical Evaluation, presents the findings of the U.S. Coast Guard's two year demonstration and evaluation (D&E) of the COSPAS/SARSAT satellite-aided search and rescue system for locating distressed vessels and aircraft, a cooperative project of the US, USSR, France, and Canada. The report summarizes results of controlled tests and exercises; analyzes SARSAT's role in actual distress cases; discusses operations of the system's radio beacons, satellites, Coast Guard Rescue Coordination Centers, U.S. Mission Control Center, Local User Terminals, and ground communications; appraises the system's long-term economic costs and benefits; and assesses achievement of project objectives. Results indicate that the COSPAS/SARSAT system increased the role of radio beacons in search and rescue cases and provided key information in locating more than one-third of Coast Guard ELT/EPIRB distress cases during the D&E, resulting in the rescue of 74 persons.

Volume II consists of appendices that give detailed information and data in support of each section of the Technical Evaluation; Volume III contains programs and data listings.

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PREFACE

The COSPAS/SARSAT project is an international effort to develop and evaluate a global satellite-aided tracking system for search and rescue operations. This Search and Rescue Satellite-Aided Tracking System (SARSAT) and the parallel Soviet Space System for Search of Distressed Vessels (COSPAS) are intended to improve monitoring, alerting, and position locating of emergency beacons on distressed vessels and downed aircraft.

The partners in this joint venture are Canada's Department of Communications (DOC), France's Centre National D'Etudes Spatiales (CNES), the United States' National Aeronautics and Space Administration (NASA), and the USSR's Ministry of Merchant Marine (MORFLOT). Other nations are particpating as operators and as users of the system. The U.S. Coast Guard and the U.S. Air Force operated and exercised the COSPAS/SARSAT system in conjunction with NASA, NOAA, and the Canadian, French, Soviet and other participants during an international Demonstration and Evaluation of the system from February 1, 1983 through July 31, 1984. The first Search-and-Rescue instrumentation (COSPAS I) was launched by the Soviet Union in June 1982. The first U.S. instrumentation (SARSAT I) was launched in March 1983. As of September 1985, a total of three Soviet and two U.S. satellites were put into orbit, and over 470 persons had been rescued through the COSPAS/SARSAT system.

As part of its support of the U.S. Coast Guard in the SARSAT D&E, TSC conducted controlled tests and gathered data on real incidents and on the operation of the COSPAS/SARSAT system starting February 1983. Results of the tests and real incidents are reported here for the two years of the Coast Guard D&E period, February 1, 1983 through January 31, 1985.

This is the Final Report of a series of USCG/SARSAT planning, development and evaluation documents produced by the U.S. Coast Guard and TSC throughout the SARSAT project. The full list of USCG/TSC documents is shown in Figure I and listed in Table I.

This Final Evaluation Report is the result of the efforts of many contributors over a period of more than five years.

The extensive planning and direction required for the Coast Guard SARSAT Demonstration and Evaluation was carried out initially in the Coast Guard Office of Research and Development by R. Vollmers, under RADM K.G. Wiman, and at TSC by J. Gutwein, P. Engels, B. Goldstein and H. Hill. From 1982 to date the program has been

TABLE I. USCG SARSAT DOCUMENTATION LIST

1. Project Master Plan Narrative, U.S. Coast Guard, G-D 2000A (rev. 8-80), Project No. 8109.3, Nov. 1981.

2. Commandant Instruction 2840.1: Search and Rescue Satellite-Aided Tracking (SARSAT Project), U.S. Coast Guard, June 1981.

3. Hand-off Agreement for SARSAT; Memorandum, U.S. Coast Guard, 16575/2-1647P, Nov. 1983.

4. Search and Rescue Satellite System Development, Joseph M. Gutwein, Rev. No. 0-4, PPA No. CG-124, GWA No. 81-CG, September 1980.

5. United States Coast Guard SARSAT Demonstration and Evaluation Plan, Benjamin S. Goldstein and J. Harry Hill, Report No. CG-124-PM-81-48, April 1982.

6. Technical Memorandum I.B-United States Coast Guard SAR/SARSAT System Integration Description, B.S. Goldstein, Report No. DOT/TSC CG-224: TM-I.B, June 1982.

7. Technical Memorandum I.D.1-United States Coast Guard SARSAT Classification and Statistical Analysis of ELT/EPIRB Baesline Data, Part 1, U.S. Dept. of Transportation: Research and Special Programs Admin., TSC, Report No. DOT/TSC CG-224: TM.I.D.1, June 1982.

8. Technical Memorandum I.D.1 - United States Coast Guard SARSAT Classification and Statistical Analysis of ELT/EPRIB Baseline Data, Part II, J.F. Bellantoni, Report No. DOT/TSC CG-324: TM I.D.1, Nov. 1982.

9. Technical Memorandum I.C-United States Coast Guard SARSAT Test Implementation & Logistics Document, C.J. Murphy and Lt. L.R. Skorupa, Report No. DOT/TSC CG-324: TM I.C, Dec. 1982.

10. Technical Memorandum I.D.2-United States Coast Guard SARSAT System Data Reduction and Analysis Plan, J.F. Bellantoni, Report No. DOT/TSC CG-324:TM I.D.2, March 1983.

11. Preliminary Report on SARSAT Workload Assessment, James Leavitt, TSC-5, April 1984.

12. Technical Memorandum III.B.2b U.S. Coast Guard SARSAT Communications Assessment (Interim Report, B.S. Goldstein, Report No. DOT/TSC CG-324: TM III. B.2b, Nov. 1983.

13. Technical Memorandum III.E.1(a), First Quarter Report (Feb.-April 1983); Attachment 1, International SARSAT D&E Quarterly Summary Report (Feb.-April 1983), J. Bellantoni, B. Goldstein and C. Murphy, Report No. DOT/TSC CG-324: TM III.E.1(a), July 1983.

ably directed and assisted by LCDR D. Edwards and LCDR J. Millsaps of the Coast Guard. Their continued suggestions, along with the comments of R. Swanson, CDR A. Arecchi, and LCDR L. Smith, have resulted in important improvements to this report.

The field data upon which this report is based were gathered by U.S. Coast Guard personnel over a period of two years. In particular, the controlled tests were carried out largely through the efforts of the Commanding Officers and crew of the Coast Guard vessels NANTUCKET I and II, the NORTHWIND, the WESTWIND and the FIREBUSH. The exercises were carried out by the First and Eighth Coast Guard District Rescue Coordination Centers, the Air Station at Cape Cod and the POINT MONROE. Credit is due to the operators and maintenance personnel at the Pt. Reyes and Kodiak LUTs, particularly ETCs J. Wells, D. Sweet and R. Bartlett, not only for supplying numerous test runs but also for their valuable recording of maintenance events. The controllers and staff of all the Coast Guard RCCs have faithfully collected and sent to TSC the indispensable SAR case data from which the outstanding SARSAT maritime rescue record has been written. They have also responded to numerous inquiries and visits to provide their insights into the operational aspects of SARSAT, as have the Atlantic and Pacific Commands. Valuable LUT data were contributed for many of the controlled tests by the NASA System Engineering and Development Laboratory, at Goddard Space Flight Center, and for the NORTHWIND tests by the Centre National d'Etudes Spatiales in Toulouse, France. The NASA Location Probability Tests were conducted by F. Kissel under NASA contract to Westinghouse, Inc. The U.S. Mission Control Center and the Coast Guard Operations Computer Center provided records of the thousands of SARSAT alert messages sent to the Coast Guard during the two years covered by this report. The Coast Guard data base on SAR incidents was made available by E. Paulos, of the Coast Guard Information Systems staff, G-OSR-3.

The data reduction and analysis for this report was carried out at the Transportation Systems Center by B. Dodds, D. Bassett, L. Naginsky, and R. DeCoster. The extensive data processing underlying the tables and graphics of this report is due to the skills and energy of L. Karis, K. Zygouras, M. Landino and G. Costigan, all of whose work was of the highest caliber.

Major contributions to the results and preparation of this report were made by over a dozen persons. The controlled tests and exercises were planned, executed and reported by C. Murphy, the TSC/Coast Guard SARSAT Test Director, with assistance from LTs L. Skorupa and R. Malkowski of the Coast Guard. The statistical analyses of the test results

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ACRONYMS AND ABBREVIATIONS

AACRCC	Alaska Air Command Rescue Coordination Center
Ae	Availability (effective)
Ai	Availability (inherent)
AFRCC	Air Force Rescue Coordination Center
AOS	Aquisition of Signal
AUTODIN	Automatic Digital Network
AUTOVON	Automatic Voice Network
CAL	Canadian Astronautics Ltd.
CDA	Command and Data Aquisition (Station)
CGD	Coast Guard District
CMC	COSPAS Mission Control
CMCC	Canadian Mission Control Center
CNES	Centre National D'Etudes Spatiales
CONUS	Continental US (The United States, excluding Hawaii and Alaska)
COSPAS	Kosmicheskaya Sistyema Poiska Avariyny Sudov (Space System for Search of Distressed Vessels)
CSIP	COSPAS/SARSAT Implementation Plan
D&E	Demonstration and Evaluation
DOC	Department of Communications (Canada)
DOD	Department of Defense
DPSS	Data Processing and Service System
DS-1000	Communications Protocol for Hewlett/Packard HP-1000 Computer
ELT	Emergency Locator Transmitter
EPIRB	Emergency Position Indicating Radio Beacon
FAA	Federal Aviation Administration
FMCC	French Mission Control Center
FTS	Federal Telecommunications Systems
GMT	Greenwich Mean Time
ICSAR	Interagency Committee on Search and Rescue
ID	Identification
KM, km	Kilometer
LANTAREA	Atlantic Area Command
LCL	Leased Communication Line
LOS	Loss of Signal
LUT	Local User Terminal
MCC	Mission Contol Center
MHz	Megahertz
MORFLOT	Ministry of Merchant Marine (Soviet Union)
MDT	Mean Down Time
MOT	Mean Outage Time
MTBF	Mean Time Between Failures
MTBM	Mean Time Between Maintenance
MTTR	Mean Time to Repair
MTBO	Mean Time Between Outages
NASA	National Aeronautics and Space Administration
NM	Nautical Mile
NMCC	Norwegian Mission Control Center
NOAA	National Oceanic and Atmospheric Administration
OCC	Operations Computer Center

EXECUTIVE SUMMARY

The COSPAS/SARSAT Satellite Aided Search and Rescue System, a joint venture of the United States, Canada, France, and the Soviet Union, is intended to facilitate world-wide search and rescue by providing satellite derived alert messages that locate downed aircraft and distressed vessels. The system is composed of rescue beacons carried on vessels or aircraft, satellite-borne instruments, ground stations, mission control centers, rescue coordination centers, and the communications lines that link them. This final technical evaluation report, based on data collected during the U.S. Coast Guard's two-year demonstration and evaluation period (D&E), presents a comprehensive evaluation of the COSPAS/SARSAT system, in terms of its technical performance and operational effectiveness. The report

- summarizes the results of the controlled tests and exercises;
- analyzes SARSAT's role in actual distress cases;
- reviews the operations of beacons, satellites, the Coast Guard Rescue Coordination Centers (RCCs), the U.S. Mission Control Center (MCC), Local User Terminals (LUTs), and ground communications during the D&E.
- appraises the economic benefits and costs of the system between 1990 and 2010;
- assesses the extent to which SARSAT has met the objectives of the D&E.

The U.S. Coast Guard tested the COSPAS/SARSAT system in an effort to estimate certain system parameters, including location accuracy, location probability, and message transmission, and to test the entire loop -- beacon, satellite, LUT, MCC, RCC, and rescue unit -- under controlled circumstances (see Section 2). The controlled tests employed both 121.5/243.0-MHz beacons and 406-MHz beacons in at-sea floating and deck-mounted tests, in land-based tests, and in exercises that simulated real search and rescue conditions. The tests showed mean location error magnitudes of about 10 nmi for 121.5/243-MHz and about 4 nmi at 406-MHz (Table 2-6), with location probability of 82% for 121.5-MHz and 76% for 406-MHz.

This report also marshalls the evidence of approximately 660 ELT/EPIRB incidents that occurred within the Coast Guard's search and rescue area during the D&E, in an effort to determine the COSPAS/SARSAT system's effectiveness in detecting and locating distressed vessels and aircraft, as well as its usefulness to the Coast Guard's search and

Among the objectives of the D&E was that of determining the benefits of the COSPAS/SARSAT system to the U.S. maritime community in lives and property saved, and the costs to the Coast Guard of operating and maintaining its segments of the system. The SARSAT cost-benefit analysis assumed an extended planning horizon -- from 1990 to 2010 -- and an assigned economic value of $576,000 (in 1985 dollars) for one human life; the analysis excluded SARSAT related costs incurred by other U.S. government agencies. One scenario for the planning period anticipates gradual, voluntary replacement of current 121.5-MHz beacons with the internationally accepted 406-MHz beacons by the year 2010. A second scenario envisions a regulatory requirement to replace all 121.5-MHz beacons with 406-MHz beacons by 2000. Projected costs for either scenario are nearly the same. Based on the experience of the D&E period, a saving of 37 lives per year with an economic value of $21 million could be annually attributed to SARSAT over the planning period (see Tables 7-2, 7-3, and Section 7.5). Since the estimated value of property saved due to SARSAT approximately equalled the Coast Guard's expenditure of resources on SARSAT related operations, the overall benefits of the system on an annual basis are expected to be about equal to the value of the lives saved. The $21 million figure is substantially higher than previous estimates made by the Interagency Committee on Search and Rescue, which estimated fewer lives saved and more savings in property and resources, but also took into account all U.S. government costs.

The long-term benefits of the COSPAS/SARSAT system, then, are likely to be significant. A review of system parameters, operational parameters, and resource parameters (Sections 8 and 9 and Table 8-3), shows that all D&E objectives were met with decidedly positive results, but with some qualification for planning time, false alarm rate, and 406 location probability. Comparison of the currently used 121.5/243.0-MHz beacon with the 406-MHz beacon, however, shows that while the 121.5-MHz beacon tested better in at-sea location probability, the 406-MHz beacon was significantly better in location accuracy. The 406-MHz beacon also was demonstrated to transmit such information as beacon identification code and country of origin -- information essential to sort false alarms from true distress cases and thus reduce planning times.

Overall, COSPAS/SARSAT has dramatically increased the alerting and locating role of radio beacons in search and rescue cases. Given technical improvements to the 406-MHz beacon, improved discrimination of false alarms and image rejection, and refinements in operational procedures and in the ground-based elements of the system, COSPAS/SARSAT should provide a valuable, cost effective new dimension to the Coast Guard's search and rescue efforts.

1. INTRODUCTION

In order to evaluate the COSPAS/SARSAT Satellite Aided Search and Rescue System, the United States Coast Guard (USCG), with technical assistance from the Transportation Systems Center (TSC), participated in a two year Demonstration and Evaluation (D&E) of the system. The data collected by the Coast Guard during that period (February 1, 1983 through January 31, 1985) are here collected and evaluated in order to determine the extent to which SARSAT can benefit the U.S. Coast Guard Search and Rescue (SAR) operations and whether a fully operational system will be deployed.

This report provides a final technical evaluation of the system, based on two years of tests, exercises, and operational experience.

The U.S. Coast Guard SARSAT Demonstration and Evaluation Plan (Reference 1) outlines the objectives, system performance parameters, data acquisition, tests, and assessments to be performed during the Coast Guard D&E. The D&E plan served as a guide for the Test Implementation and Logistics Document (Reference 2), which describes the test procedures, and for the Data Reduction and Analysis Plan (Reference 3), which describes the data reduction.

1.1 THE COSPAS/SARSAT SYSTEM*

The COSPAS/SARSAT System underwent demonstration and evaluation world-wide from February 1, 1983 to July 31, 1984. Four nations have taken major roles in developing the system: the United States, Canada, France, and the Soviet Union. Several other nations, including Great Britain, Norway, and Sweden, participated in the testing and demonstration phase.

The COSPAS/SARSAT system comprises: the rescue beacons carried on vessels and aircraft; the satellite-borne instruments, which pick up the beacon distress signals; ground stations, which receive the distress signals through the satellites; mission control centers, which receive the distress messages from the ground receiving stations and direct their routing; rescue coordination centers, which receive the messages from the mission control center and direct the actual rescue forces; and the communication lines linking the ground stations, mission control center, and rescue center.

*The COSPAS/SARSAT system is often referred to in this and other reports simply as "SARSAT," or the "SARSAT system." The reader is referred to References 4, 5 and 6 for general descriptions of the COSPAS/SARSAT system.

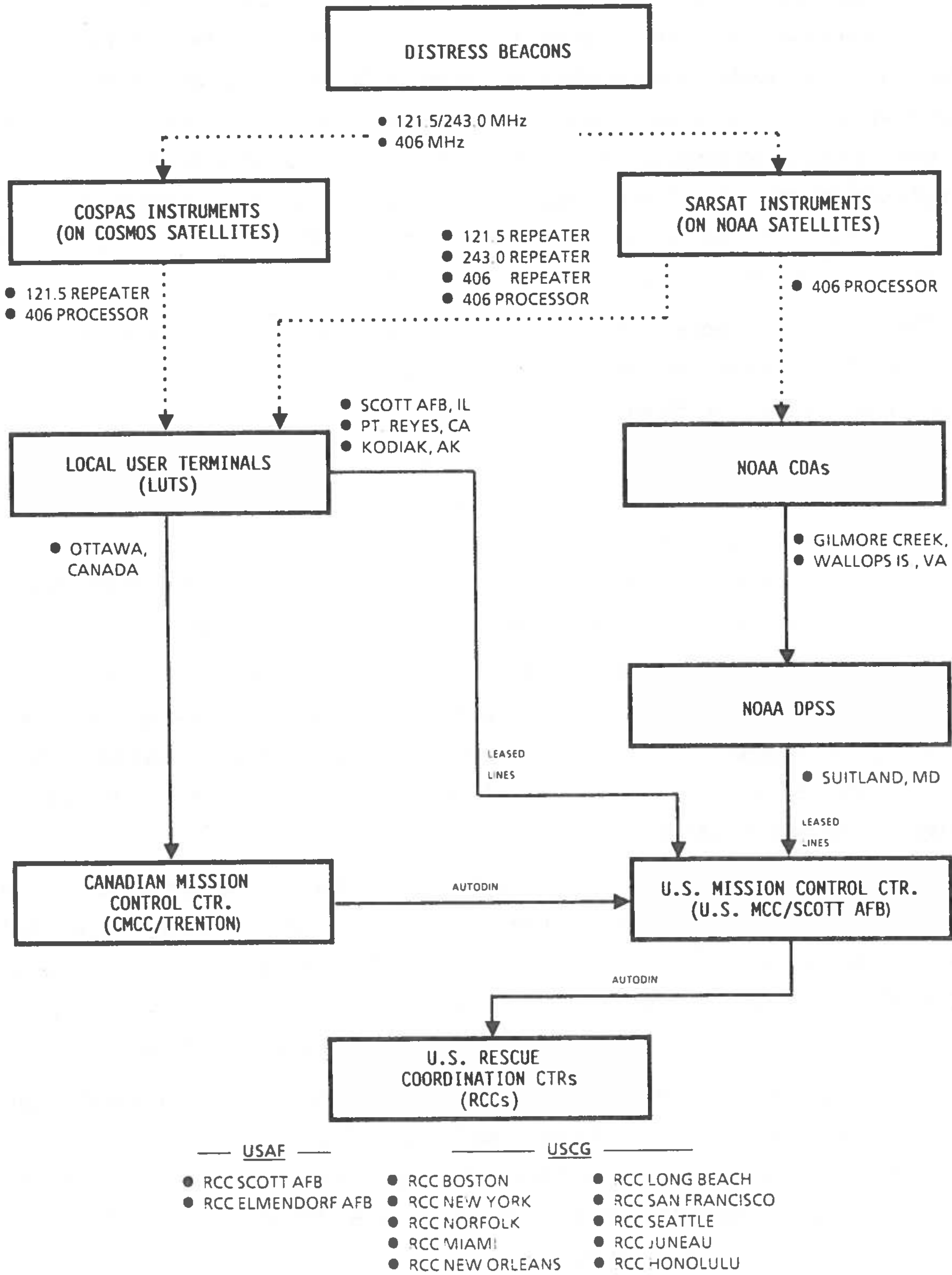

FIGURE 1-1. ELEMENTS OF COSPAS/SARSAT SYSTEM IN NORTH AMERICA

(2) the leased line from NOAA DPSS to USMCC, and (3) AUTODIN from USMCC to the USCG RCCs.

System design goals (Reference 7) include rapid computation of position with good image rejection; accuracy of 3-5 km for 406-MHz beacons and 20 km for 121.5/243.0-MHz beacons; minimum staffing for ground stations; high reliability for satellite instrumentation, LUTS, USMCC and communications; minimum adverse impact on present SAR operations; and low overall cost. The immediate benefits of the system are expected to be reduction in waiting time for distress alerting, more rapid location of the distressed unit, and more effective rescue operations. The ultimate benefits are expected to be an increase in lives and property saved and a reduction in the cost of SAR operations.

1.2 SARSAT D&E CHRONOLOGY

The U.S. and world-wide COSPAS/SARSAT D&E period was February 1, 1983 through July 31, 1984. Results are reported in Reference 8. The Coast Guard D&E period extended through January 31, 1985. Both the space and ground systems were undergoing evolutionary development during 1983 and 1984.

Figure 1-2 shows the launch and operation of the five COSPAS and SARSAT orbiting systems in relation to the world-wide and U.S. Coast Guard D&E periods. Three satellites were in operation for 16 out of the 24 months of U.S. Coast Guard D&E. During this time the USMCC was undergoing completion and improvement. Major revisions in USMCC software were installed in mid 1983. The SARSAT Global Mode was put into operation at the USMCC in January 1984. Further improvements continued through 1984. The Coast Guard and USAF LUTs also underwent software improvements through 1983 and 1984. Spectrum leveling and other changes were added to the LUTs during 1983 and a new software package, Version 2.0, was installed in October 1984.

1.3 USCG OBJECTIVES FOR THE SARSAT D&E

The U.S. Coast Guard objectives for the COSPAS/SARSAT D&E are given in the Coast Guard D&E Plan (Reference 1). They are listed in Table 1-1. The Coast Guard objectives parallel those of the United States, as given in the U.S. D&E Plan (Reference 9), but differ primarily in objectives 9, 10, and 11, which have to do with benefits, workloads, and costs.

TABLE 1-1. OBJECTIVES OF THE U.S. COAST GUARD FOR SARSAT D & E[1]

1. Demonstrate the ability of the SARSAT system to identify, process, and determine the location of single and multiple 121.5/243.0-MHz and 406-MHz EPIRBs in the regional mode of operation.

2. Determine the degree to which the SARSAT system may reduce times between initial incidence occurrence and visual sighting of the distress incident.

3. Evaluate the degree to which 121.5/243.0-MHz EPIRB assisted SAR operations may be improved by SARSAT.

4. Demonstrate the ability of the SARSAT system to identify, process and determine the location of single and multiple 406-MHz EPIRBs in global mode of operation.

5. Compare the demonstrated performance of the 406-MHz EPIRB with that of the 121.5/243.0-MHz EPIRB with respect to both SAR and SARSAT system performance parameters.[2]

6. Evaluate the potential improvements in future SAR operations using 406-MHz EPIRBs.

7. Determine the communications requirements necessary to utilize SARSAT effectively in an operational environment.

8. Characterize SARSAT system performance parameters.[2]

9. Determine cost benefits/disadvantages due to SARSAT.

10. Determine the increase/decrease in Coast Guard workload produced.

11. Evaluate recurring costs of operating SARSAT ground system network and facilities, equipment reliability and maintenance requirements

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1. Reference 1.
2. The performance parameters referred to are those of Reference 1.

TABLE 1-2. USCG/SARSAT PERFORMANCE PARAMETERS AND D&E OBJECTIVES

	D&E OBJECTIVES										
	1	2	3	4	5	6	7	8	9	10	11
SYSTEM PARAMETERS											
1. Coverage	o	o	o	o	●	●		●	o		
2. Accuracy	●	o	o	●	●	●		●	o		
3. Capacity	●			●	●	o		●			
4. Detection	●	o	o	●	●	●		●	●		
5. Reliability											
- Satellite	●			●		o			●		
- LUT	●			●		o			●		o
- Communications	●			●		o	●		●		●
- USMCC	●			●		o			●		
6. 406 MHz Transmission	o			●	o	●	●	●		o	
OPERATIONAL PARAMETERS											
7. Alarm Rates											
- Real	o		●		o		o		●	o	
- Spurious	o		●	o	o	●	o		o	o	
- False	o		●		●		o	●	o	o	
- Redundant	o		●	o	o	●	o		o	o	
8. Image Rejection	o		●		●	●		●	●	o	
9. Waiting Time		●	●		●				o		
10. Process Time											
- LUT	o	●	o	o	o	o		o	o		
- USMCC	o	●	o	o	o	o			o		
11. Communication Time											
- LUT/USMCC		●	o		●		●		o		
- USMCC/RCC		●	o		●		●		o		
- DPSS/USMCC		●		o	●		●		o		
12. Planning Time		●	●		●	●			o	●	
13. Search Time		●	●		●	●			o	●	
RESOURCE PARAMETERS											
14. Workload											
- LUT					o	o			●	●	o
- RCC			●		●	o			●	●	o
15. Comm. Load & Cost			o		o		●		●		o
16. LUT Costs											
- Maintenance					o				●		●
- Operating					o				●		●

Key:

● Performance parameter is considered to be critical to judging achievement of the objective.

o Performance parameter is considered to be contributory but not critical.

Note: This Table incorporates corrections and additions to the one in Reference 17.

1.6 PURPOSE AND STRUCTURE OF THE REPORT

The purpose of this report is to provide an evaluation of the extent to which the COSPAS/SARSAT system meets the USCG/SARSAT D&E objectives.

Section 2 presents the results of field tests and exercises, revelant to the System Parameters 1, 2, 3, 4, and 6.

Sections 3 and 4 present the real SAR incident data and the operational experience with system, as seen at the Coast Guard RCCs. This information is relevant to the Operational Performance Parameters 7, 8, 9, 12, 13, and Resource Parameter 14.

Section 5 presents LUT operational experience, pertinent to parameters 5, 10, 11, 14, and 16.

Section 6 presents the ground system operational experience covering communications and the USMCC, revelant to parameters 5, 10, 11, and 15.

Section 7 presents resource estimates for parameters 14, 15, and 16.

Section 8 evaluates the 16 performance parameters on the basis of the D&E data and experience.

Section 9 reviews the objectives of the D&E and presents the findings for each category of objective.

Section 10 presents observations and conclusions on other aspects of the SARSAT system, such as alerting in remote areas, false alarm causes, fringe area coverage, etc., improved understanding of which was gained in the course of meeting the D&E objectives.

Volume II contains Appendices in which are collected information and test data from the D&E to support the analysis presented in each section of the report.

Volume III consists of programs and data listings.

2. CONTROLLED TESTS AND EXERCISES

The purpose of the U.S. Coast Guard D&E testing was to determine the ability of the COSPAS/SARSAT system to identify and locate EPIRBs in the maritime environment. Several parameters were extracted from the tests: location accuracy, location probability, 406-MHz message transmission, ambiguity resolution and error ellipse accuracy. (See References 2 and 3.)

The purpose of the exercises was to test the entire loop of the COSPAS/SARSAT system -- beacon, satellite, LUT, MCC, RCC, rescue-unit -- in controlled circumstances, using both 406-MHz and 121.5-MHz beacons.

The tests and exercises reported here took place from 1 February 1983 to 31 May 1984.

During the D&E period the COSPAS/SARSAT system underwent (1) continuing ground system development, (2) the addition and removal of satellites to the space segment, and (3) evaluation of new operating procedures. For these reasons, the test results are not entirely consistent or conclusive. Nevertheless, they afford a basis for evaluation of the parameters listed, as well as provide insight into the system operation.

The tests summarized here are described in greater detail in Appendix A, B and C; the exercises are described more fully in Appendix D. Further analysis of the test data is given in Appendix E.

2.1 DESCRIPTION OF TESTS

2.1.1 Beacons Employed

The beacons employed in the tests were of four types: (1) a commercially available EPIRB manufactured by Martech, Inc. with modulated, coherent, 121.5- and 243.0-MHz distress signals emitted at a minimum of 75 milliwatts, (2) an experimental 406-MHz EPIRB with electronics designed by Proteon Associates to meet the international specification for experimental beacons (SARSAT Document No. D-7, Reference 10), (3) a 406-MHz beacon, with the same electronics as the Proteon unit, incorporating a novel floating antenna design by Hazeltine which underwent limited testing, and (4) a production unit of the only commercially available 406-MHz EPIRB, manufactured by A. S. Jotron Elektronikk of Norway. The majority of 406-MHz test results were obtained with the Proteon units.

SARSAT I and COSPAS I and II locations were obtained from printouts of the Scott LUT, the NASA SEDL, and the French LUT at Toulouse, France.

e. The Second Static Tests were conducted from 9 to 25 August 1983. Each test involved the activation of one 121.5-MHz beacon and one Proteon 406-MHz beacon. Fifty-five tests were carried out of which forty were considered valid tests.

   These tests were the first to be conducted by the Coast Guard with the COSPAS II or SARSAT I satellites. The purpose was to establish the static system performance using the two new satellites.

f. FIREBUSH. A third set of at-sea tests was conducted in order to assess the performance of COSPAS II and SARSAT I with floating beacons. These tests were performed between 25 and 31 August 1983, by the USCG cutter FIREBUSH off the southeast coast of Kodiak Island, AK. As with the static tests, only COSPAS II and SARSAT I passes were planned, but a few COSPAS I passes were also detected.

   For each test, one 121.5-MHz and two 406-MHz EPIRBs were activated. In addition to the standard 406-MHz EPIRB built by Proteon (designated "P"), used in all previous tests, which utilizes a dipole whip antenna, an alternative design by Hazeltine (designated "H") was tested simultaneously. The design has a circularly polarized, articulated, floating antenna design to improve reception.

g. Homing Tests were conducted in Massachusetts Bay during November 1983. Using a low power 121.5-MHz beacon and an HH-52 Coast Guard helicopter, the aircraft homing ranges were determined for several EPIRB conditions. The data from this test determine whether the SARSAT 406-MHz beacon accuracy is sufficient to place a Coast Guard aircraft within homing range of the beacon.

h. WESTWIND. A second series of 406-MHz tests was carried out on the USCG icebreaker WESTWIND. The beacon was activated continuously on the voyage from Mobile, AL through the Panama Canal, along the west coast of South America to the Weddell Sea in Antarctica. The WESTWIND returned by the same route and reached Mobile in February. The tests yielded further information on COSPAS 406-MHz Global Mode coverage. The original goal of these tests, to test the SARSAT 406-MHz Global Mode, could not be met due to delayed implementation of that mode.

2.2.2 Gulf Coast Exercise

The objective of the Gulf Coast Exercise was similar to that of the Massachusetts Bay Exercise, i.e., to demonstrate the effectiveness of the 406-MHz system in a realistic SAR situation. A patrol boat out of U.S. Coast Guard Base Galveston carried a 406-MHz EPIRB about 20 nm off shore, where the beacon was activated. The resultant signal was to be picked up by satellite and transmitted through the Scott LUT and the USMCC to the New Orleans OPCEN, where a simulated mission was to be dispatched. Location of the EPIRB by the Coast Guard search vehicle completed the SAR loop.

2.3 DATA GATHERING AND REDUCTION

The overall data gathering and reduction for the controlled tests is shown in Figure 2-1. Greater detail is given in Reference 3 and in Volume III.

The field data sheets (containing the time, location, power readings, and test conditions) were filled out by the field test teams. These teams were composed of TSC personnel for the static tests, Coast Guard crews for the floating and deck tests, and a combined TSC/Coast Guard team for the FIREBUSH Test. The Location Probability tests were performed by NASA. The LUT printouts were forwarded to TSC by the LUT operators; the data entry and reduction were done at the TSC Test Coordination Center. Data from the Toulouse LUT were gathered by CNES and forwarded to TSC for reduction. In addition to the Field Test Data and the LUT printouts, certain data used in planning the tests were also used, such as peak elevation angle, central angle at TCA, and mutual visibility times.

The 406-MHz beacon ID allows positive identification to be made of test activations in the LUT output test data. No such positive identification can be made in the case of the 121.5-MHz beacons. A 121.5-MHz test activation can be identified in the LUT output data only on the basis of location and orbit number. In order to exclude spurious identifications the error analysis program discarded 121.5-MHz solutions that were more than 50 nm from the test site.

Locations of 406-MHz beacons showing greater than 50 nm error were also discarded in the error analysis. The reasons were: (1) the major portion of the 406-MHz error distribution was found to lie within 5 to 10 nm of the mean (errors in excess of 50 nm are more than five standard deviations from the mean and are not typical, but are due to extraordinary circumstances); and (2) positions greater than 50 nm from the distress location would not usually be associated with the distress by the RCC controllers. When the data were reduced, it was found that fewer than one percent of all 406-MHz locations were in error by more than 50 nm.

The data reduction includes calculation of the magnitude and direction of the position error, its components in the east, north, along track and cross track directions, as well as the standard deviation of those errors. It also produces the percent of cases within the normalized error ellipse given on the message, the percent of alerts in which the A-position is the true position, the location probability for the test series, and the fraction of 406-MHz points indicated on the messages relative to the number that were transmitted, assuming a properly operating beacon.

A complete set of listings of the output of the error analysis program is given in Appendix B.

2.4 TEST RESULTS

The results of the U.S. Coast Guard/SARSAT D&E tests are summarized in Tables 2-1 through 2-5. They are given in five groups:

121.5 MHz	Land Tests
121.5 MHz	Floating Beacon Tests
406-MHz	Land Tests
406-MHz	Floating Beacon Tests
406-MHz	Deck Tests

2.4.1 Location Accuracy

The magnitude of the location error is plotted versus the month of the test in Figure 2-2 for 121.5-MHz beacons and in Figure 2-3 for 406-MHz beacons. The land tests are shown as squares, the floating beacon tests are shown as circles.

The mean 121.5-MHz accuracy was about 7 nm (13 km) in the latest tests; the corresponding figure for 406-MHz beacons was about 2.5 nm (4.6 km). Both are within the original accuracy goals for the COSPAS/SARSAT system, which were 10-20 km for 121.5-MHz and 2-5 km for 406-MHz. Although the latest tests are not as statistically reliable as all tests taken together, they are considered more representative of future system accuracy because they are based on a more recent and realistic satellite configurations and LUT software than previous tests

TABLE 2-2. USCG/SARSAT D&E TEST RESULTS -- FLOATING, 121.5/243.0-MHz

Dates	First NANTUCKET 2/1-4/83	Fisheries Patrol 3/7-5/83	FIREBUSH Tests 8/25-31/83	Second NANTUCKET 2/6-24/84
Satellites	C1	C1	C1,C2,S1	C1,C2,S1
LUTs	1,4	1,4	2,3	1,4
Mean Location Error, nm	12.7	12.5	7.1	4.9
Std. Dev. Location Error, nm	11.4	7.3	7.3	6.0
Mean Cross-Track Error, nm	-0.1	5.9	0.4	1.4
Std. Dev. Cross-Track Error, nm	13.7	9.2	7.9	6.7
Mean Along-Track Error, nm	5.6	6.7	-1.6	-1.0
Std. Dev. Along-Track Error, nm	8.5	6.6	6.2	3.4
A-Position Probability, %	70	72	70	83
Number of Beacon Activations	84	41	26	38
Number of Locations Possible	102	47	31	54
Number Located	81	25	30	53
Number Not Located	21	22	1	1
Location Probability, %	79	53	97	98

TABLE 2-4. USCG/SARSAT D&E TEST RESULTS -- FLOATING, 406-MHz

Dates	First NANTUCKET 2/1-4/83	Fisheries Patrol 3/7-5/83	FIREBUSH Tests 8/25-31/83	Second NANTUCKET 2/6-24/84
Satellites	C1	C1	C1,C2,S1	C1,C2,S1
LUTs	1,4	1,4	2,3	1,4
Mean Location Error, nm	6.9	4.5	6.2	2.8
Std. Dev. Location Error, nm	6.4	5.5	7.2	3.6
Mean Cross-Track Error, nm	-5.0	0.1	-0.1	0.3
Std. Dev. Cross-Track Error, nm	7.8	6.2	8.6	4.0
Mean Along-Track Error, nm	1.6	0.3	-1.5	-0.4
Std. Dev. Along-Track Error, nm	4.6	3.3	6.0	2.4
A-Position Probability, %	67	79	72	86
Number of Beacon Activations	95	36	52	118
Number of Locations Possible	103	37	63	185
Number Located	66	24	32	159
Number Not Located	37	13	31	26
Location Probability, %	64	65	51	86

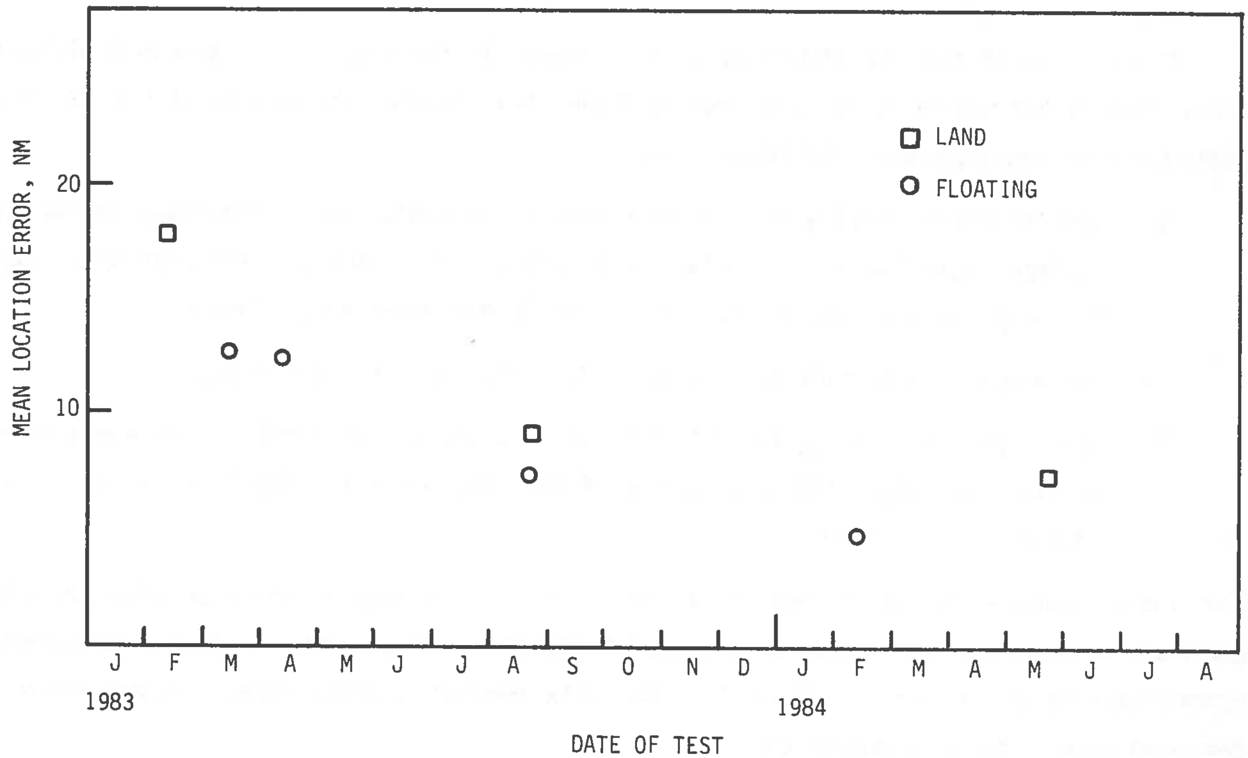

FIGURE 2-2. LOCATION ACCURACY - 121.5-MHz

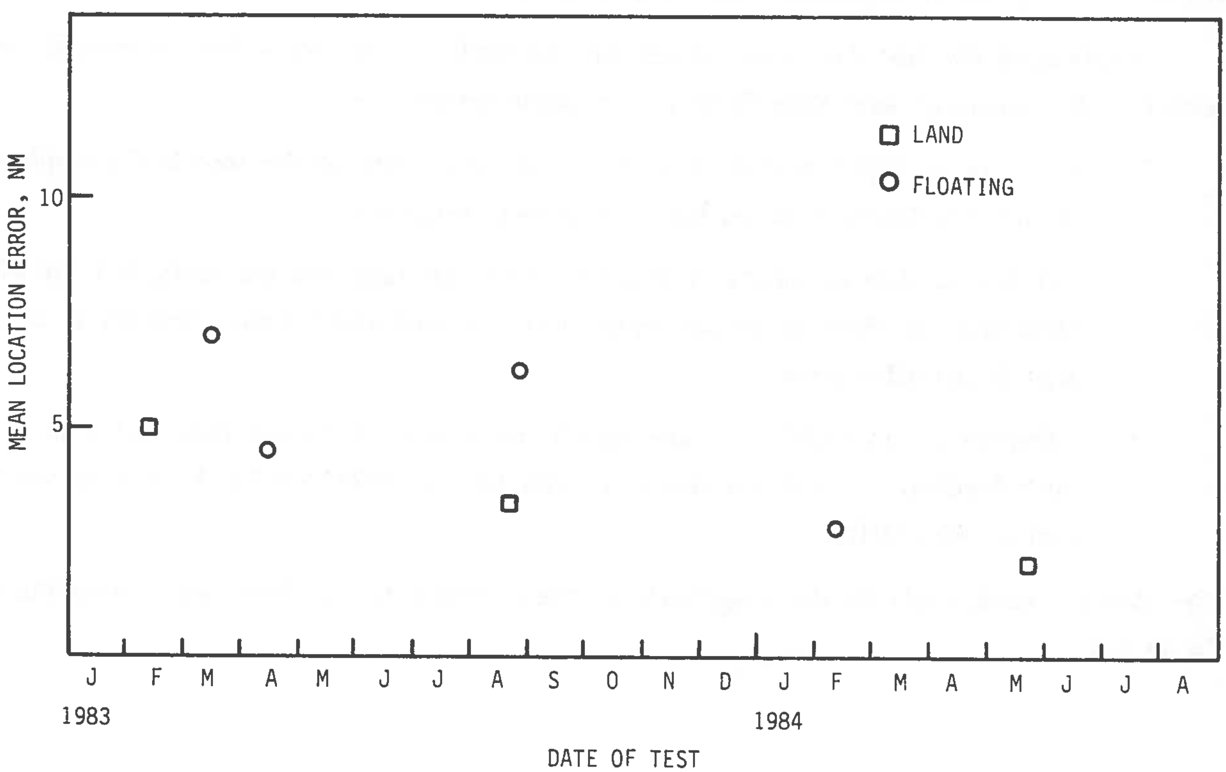

FIGURE 2-3. LOCATION ACCURACY - 406-MHz

TABLE 2-6. MEAN LOCATION ERROR MAGNITUDE, NM
(SAMPLE SIZE/STD DEV, NM)

	121.5/243.-MHz	406-MHz
By Lut		
Scott	10.2 (119/9.5)	3.9 (160/4.5)
Pt. Reyes	10.9 (45/11.7)	5.0 (35/9.2)
Kodiak	12.5 (47/13.6)	5.6 (42/6.3)
Goddard	9.2 (106/9.4)	3.4 (198/5.4)
By Satellite		
COSPAS 1	13.1 (178/11.8)	5.0 (197/6.8)
COSPAS 2	6.7 (70/7.3)	3.0 (114/5.2)
SARSAT 1	6.9 (69/7.2)	3.1 (124/3.0)
By Location		
Land	11.4 (128/11.6)	2.9 (156/4.5)
Floating	9.6 (189/9.7)	4.5 (279/6.1)
All Tests	10.3 (317/10.5)	3.9 (435/5.6)

The analysis of Appendix E shows that all three satellites yield the same 406-MHz location probability (about 87 percent) on land, but that SARSAT 1 had a substantially higher location probability in the at-sea tests (87 percent compared to 69 percent). The analysis suggests that the drop in location probability at sea is due to loss of burst messages which affected the location probability for the COSPAS satellites more than for the SARSAT satellite.

As in the case of location accuracy, many factors such as beacon condition, wave height, peak elevation angle at the beacon, length of mutual visibility period, number of points, etc., influence location probability. A discussion of these effects is given in Appendices A and E.

2.4.3 A-Position Probability (Ambiguity Resolution)

The A-position on the alert message is that one selected by the LUT algorithms as the real ELT/EPRIB location (as opposed to the image location, which is shown on the message as the B-position). The percentage of messages for which the selection was correct is given in Tables 2-1 through 2-5 as "A-Position Probability," and is summarized below as follows:

AMBIGUITY RESOLUTION, PERCENT CORRECTNESS

	121.5-MHz	406-MHz
Land	67.2 (6.2)	91.6 (2.4)
Floating	73.9 (4.3)	79.3 (3.0)
Deck	——	92.2 (1.5)
All	71.2 (3.6)	87.6 (1.3)

Note: The standard deviation of the percentage is given in parentheses.

It can be seen that the 121.5-MHz A-position probability is approximatey 71 percent, and that there is little significant difference between land-based and floating beacons. The 406-MHz data, however, show that floating beacons have a significantly lower A-position probability than those on land, i.e., 79 percent compared to 92 percent. This result coincides with the lower location probabilities observed for floating 406-MHz beacons, as described above.

2.5.1 Massachusetts Bay Exercise

The Massachusetts Bay Exercise was a success in that the search aircraft located the simulated distress vessel within two and one-half hours of the time the beacon was activated (Table 2-7). However, the search craft (a Coast Guard HH-52 helicopter) that located the vessel visually was not able to localize the beacon immediately with its DF equipment even though it was within three miles of the beacon when it arrived at the datum for the search. Before further attempts to localize the beacon could be made, the aircraft was diverted from the exercise to an actual SAR case (see Figure 2-4).

2.5.2 Gulf Coast Exercise

Table 2-8 gives the chronology of the Gulf of Mexico Exercise. Figure 2-5 shows the general Gulf Coast area in which the exercise took place, and Figure 2-6 shows the details of the beacon and SARSAT locations.

The exercise demonstrated the feasibility of SAR using the 406-MHz SARSAT system presently in place. The time from beacon activation to time of distress sighting was just under 3-1/2 hours. Although all participants knew that they were involved in an exercise, they reacted as they would in a real distress situation.

The system component performances are detailed in Appendix D. Some of the segments did not totally meet expectations. It should be noted that the 406-MHz system presently in place may not be the final system. In particular, the present homing equipment will be replaced eventually by the newer ANS-4 on most Coast Guard search vehicles, with a significant increase in homing range.

The Gulf Coast Exercise produced some unexpected and significant results.

The most striking result was that the relatively weak (20 mW) 121.5-MHz beacon component, which was designed only for short range homing, actually performed as well as the main 5-Watt 406-MHz beacon signal with regard to SARSAT position location. This is evident in that six out of eleven SARSAT positions were from the 121.5 signal. Moreover, these positions were, on the average, no less accurate than the 406 positions.

Another result is that the average of all SARSAT positions taken at three times during this exercise reflected both speed and direction of the drifting beacon, as shown in Figure 2-7. A moving average of SARSAT positions can be expected to do so with even more accuracy.

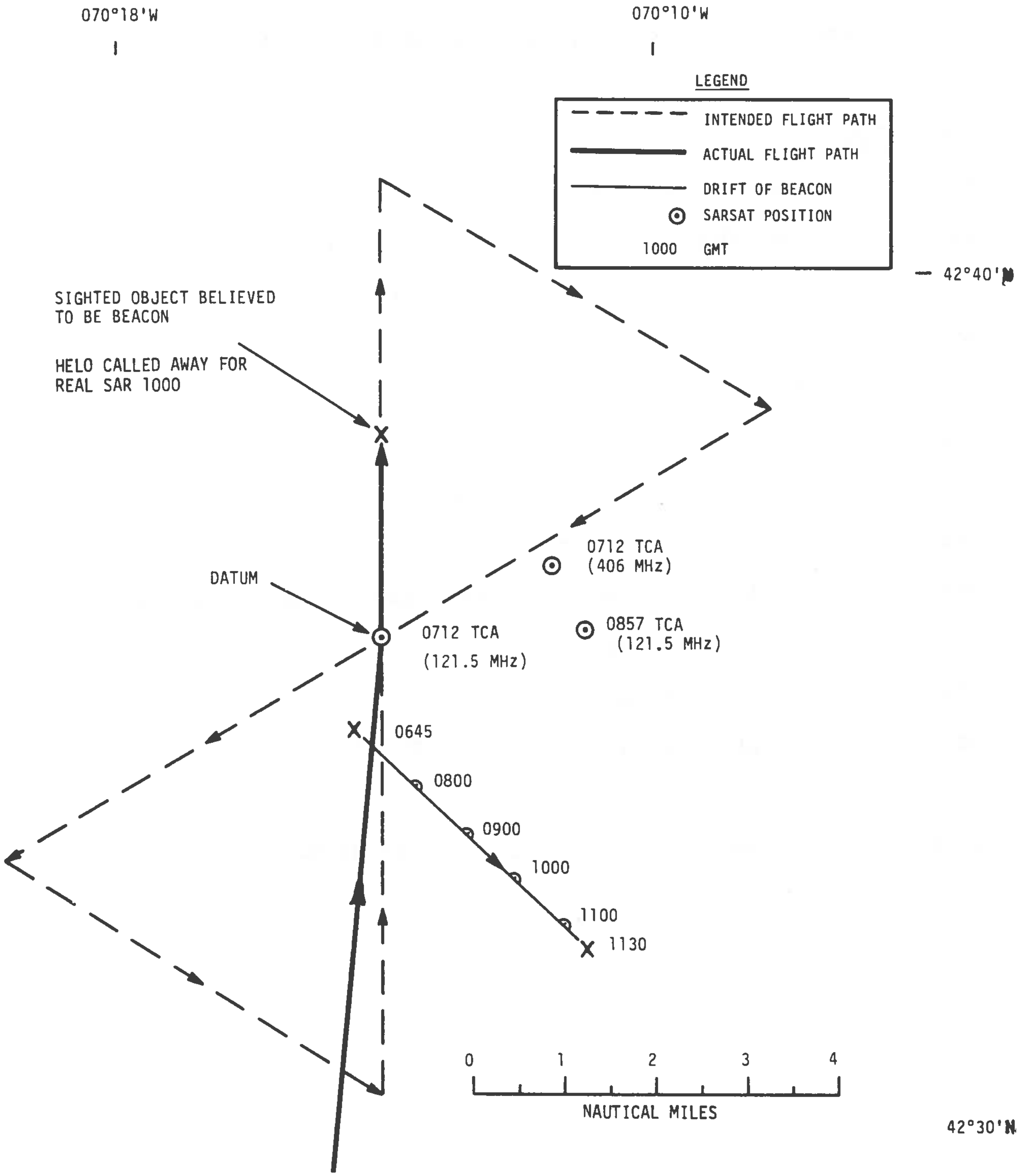

FIGURE 2-4. CHART OF MASSACHUSETTS BAY DEMONSTRATION/EXERCISE

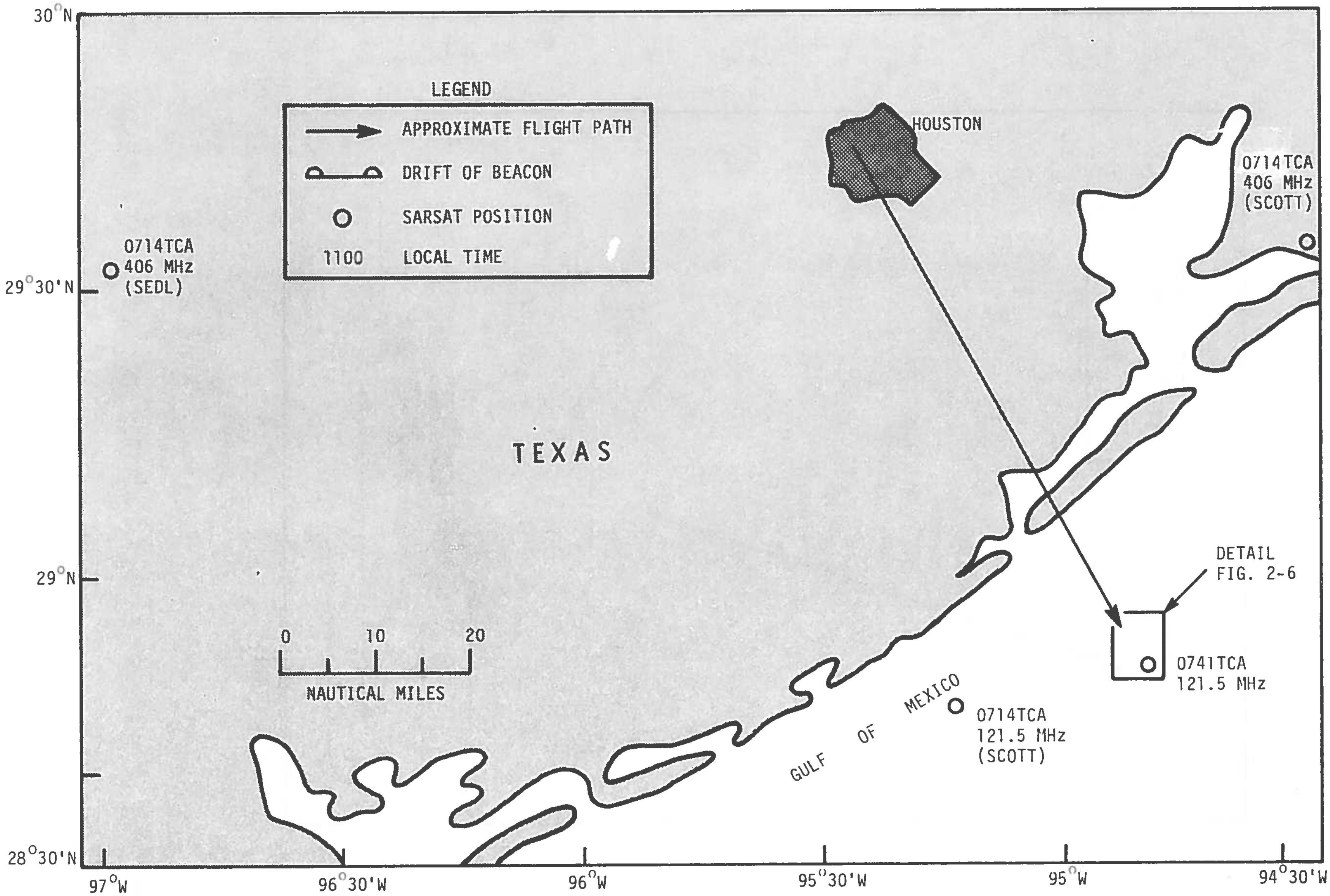

FIGURE 2-5. DISPERSION OF INITIAL SARSAT LOCATIONS IN THE GULF COAST EXERCISE

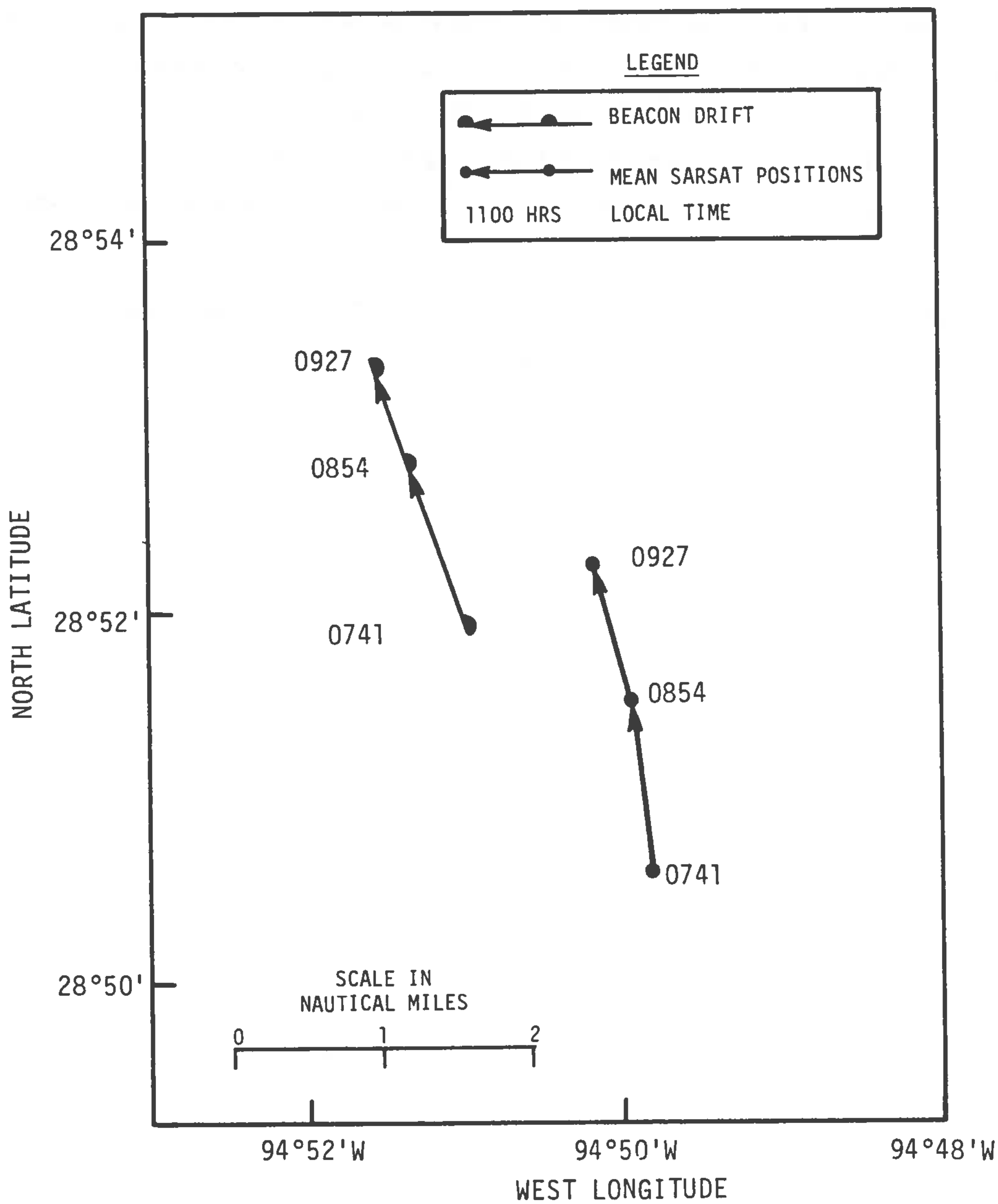

FIGURE 2-7. DRIFTING BEACON AND MEAN SARSAT LOCATIONS DURING GULF COAST EXERCISE

3. ELT/EPIRB CASE ANALYSIS

Over six hundred real ELT/EPIRB incidents occurred in the Coast Guard SAR area during the two-year D&E period. Data from these incidents have been analyzed to answer three questions underlying the D&E objectives listed in Section 1:

- o How effective is the COSPAS/SARSAT system in alerting and locating in real distress cases?
- o What has been the impact on lives and property saved of the COSPAS/SARSAT system?
- o What has been the effect of the COSPAS/SARSAT system on the response times of the Coast Guard SAR system?

This section presents and analyzes the U.S. Coast Guard real incident 121.5/243.0-MHz ELT/EPIRB SAR case data for the period 1 February 1983 to 31 January 1985. The data are based on the information contained in the SAR case folders mailed by the RCCs to the TSC on a weekly basis, where the pertinent information was extracted and analyzed. Comparative data for the preceding three years (with no SARSAT) are also given. These baseline data were obtained from the U.S. Coast Guard SAR data base maintained at Coast Guard Headquarters, G-OSR.

3.1 DEFINITION OF TERMS

All ELT/EPIRB cases received from the Coast Guard were classified by TSC as shown in Figure 3-1.

DISTRESS (D) - A distress is an "incident in which persons or property require immediate assistance to remove them from imminent danger." [1] This assistance was taken to mean the removal of persons from the scene, or provision of food, fuel, parts, medicine, or technical assistance. All distress cases are located.

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[1] SAR Data Systems Manual, COMDTINST M5230.10, Glossary. Official categorization of Actual Severity of the incident occurs at time of filing of the U.S. Coast Guard SAR Assistance Report. These reports were not available for most cases at the time this report was prepared. The categorizations here are based on the best judgement of the authors and may differ from those finally reported in the U.S. Coast Guard SAR Assistance Reports and recorded in the SAR Data Base (SARDAB).

NON-DISTRESS (ND) - Located incidents that were not classified as Distress (D).

TRUE NON-DISTRESS (TND) - A Non-Distress incident other than a False Alarm or False Alert/Unknown.

FALSE ALARM (FA) - An incident based on an ELT or EPIRB activation caused by misinformation (inadvertent activations) or by equipment malfunction or by improper equipment installation.

FALSE ALERT (FU) - An incident for which the source was not verified to be an ELT or EPIRB.

LOCATED (LD) - An incident in which the source of the alarm was found and turned off.

NOT-LOCATED (NL) - An incident that was not Located (not found)

LIVES SAVED (LS) - Persons removed from imminent danger as a result of the SAR operation.

BASELINE PERIOD (BP) - The Baseline Period for any set of months during the USCG/SARSAT D&E is the corresponding set of months in the three years immediately preceding the start of the D&E on 1 February 1983. The baseline period corresponding to this Final Report period covers the months from 1 February 1980 through 31 January 1983, as coded in the Coast Guard SAR Data Base (SARDAB).

3.2 ELT/EPIRB CASE STATISTICS

3.2.1 Analysis by Severity and Notification Class

A total of 659 cases involving ELTs or EPIRBS were received from the Coast Guard Districts in the period 1 February 1983 to 31 January 1985. Table 3-1 shows an analysis of the number of cases and lives saved by Severity (Distress, Non-Distress, etc.) and by means of Notification to the RCC (SARSAT ONLY, SARSAT FIRST, OTHER ONLY, OTHER FIRST). In this context "OTHER" includes radio distress calls, aircraft overflights, over due messages, etc. Complete tables are given in Appendix F.

An analysis of Table 3-1 shows that SARSAT was involved in about 75 percent of the ELT/EPIRB cases that occurred during the Coast Guard D&E. A total of 162 persons were rescued in cases with SARSAT involvement. Moreover, it is seen that SARSAT was the only means of notification in 33 percent of the cases, and for 5.3 percent of the persons rescued.

SARSAT provided notification for more of the Distress than Non-Distress cases (82 percent vs. 73 percent), but SARSAT-only notification was less prominent in the Distress cases than in Non-Distress and Not-Located (9.5 percent vs. 31.5 percent and 43.3 percent). This is because Distress cases more often involve radio communications and aircraft reports than do Non-Distress and Not-Located cases.

3.2.2 Analysis by District

Table 3-2 shows a breakdown of Distress, Non-Distress, and Not-Located cases by Coast Guard District. LANTAREA and PACAREA cases are included under CGD03 and CGD12 respectively. All cases are 121.5/243.0-MHz. A more detailed breakdown of Non-Distress and Not-Located subcategories is given in the Tables of Appendix F.

Table 3-2 also shows a breakdown of lives saved among Coast Guard districts. One would expect that the number of lives saved would be proportional to the number of Distress cases in a district. This is approximately true for all but CGD05, in which the ratio of lives saved to Distress cases is 9.0, compared to 3.0 for all districts. The difference in ratios is probably due to the S/V HARBINGER case in which nine lives were rescued in CGD05.

3.2.3 Comparison with the Baseline

Table 3-3 shows the cases by severity for the two D&E years and for the three year Baseline period. It will be noticed that the total number of D&E cases is less than shown in Tables 3-1 and 3-2. Only those cases are counted in Table 3-3 for which the ELT or EPIRB was the first means of notification, either directly or indirectly, to the RCC. This is done in order to make the D&E data comparable to the Baseline data. The Baseline cases are those for which the data element B03 in the SARDAB indicates that a 121.5/243.0-MHz EPIRB/ELT was the "initial means by which the assisted unit communicated or attempted to communicate its request for assistance to the Coast Guard." Cases in which the ELT or EPIRB was not the initial means of communication to the Coast Guard are essentially unrecoverable from the SARDAB and hence also have been excluded from the SARSAT D&E cases shown in Table 3-3.

Even with the above exclusion, however, the number of SARSAT D&E ELT/EPIRB cases is substantially greater than that for the Baseline in the major categories of severity: Distress, Non-Distress and Not-Located. In the sub-categories, however, one

TABLE 3-3. COMPARISON OF USCG ELT/EPIRB CASES
SARSAT D&E VS 1980-82 BASELINE
(121.5/243.-MHz)[1]

	BASELINE				D&E		
	FEB 80- JAN 81	FEB 81- JAN 82	FEB 82- JAN 83	AVERAGE	FEB 83- JAN 84	FEB 84- JAN 85	AVERAGE
DISTRESS CASES	14	16	13	14.3	23	34	28.5
LIVES SAVED	16	15	6	12.3	56	117	86.5
NON-DISTRESS CASES							
TRUE NON-DISTRESS	21	13	30	21.3	5	7	6.0
FALSE ALARM/UNKNOWN	40	43	81	54.7	177	150	163.5
NOT LOCATED							
FALSE ALARM/UNKNOWN	47	34	80	53.7	122	98	115.0
TOTAL CASES	122	106	204	144.0	326	300	313.0

(1) Only cases in which the ELT or EPIRB was first means of notification to the Coast Guard

TABLE 3-4. SUMMARY OF USCG ELT/EPIRB DISTRESS CASES, FEBRUARY 1983 - JANUARY 1985

DATE MM/DD/YY	CG DIST	CASE #	DISTRESSED UNIT NAME	LIVES SAVED	LIVES LOST	SARSAT PARTICIPATION #MESSG	SARSAT PARTICIPATION ROLE
02/08/83	07	3269	35 FT SCORPION	4	0	1	SARSAT MINOR
02/27/83	07	3716	S/V WANDERING STAR	2	0	0	OTHER ONLY
04/11/83	07	4905	WELLCRAFT	2	0	7	SARSAT KEY
05/01/83	14	409	F/V FORTUNA	4	0	0	OTHER ONLY
05/04/83	07	5645	CESSNA	0	0	0	OTHER ONLY
05/28/83	03	95	S/V WALRUS	1	0	6	SARSAT ASSIST (LOCATE)
05/30/83	12	101	S/V SANDMAN	3	0	4	SARSAT ASSIST (LOCATE)
06/02/83	07	6759	S/V MICLARALUZ	3	0	6	SARSAT ONLY
06/25/83	07	7542	PIONEER II	5	0	3	SARSAT KEY
06/26/83	12	237	S/V TIEN HOU	2	0	0	OTHER ONLY
07/23/83	11	303	F/V RAIDER	3	0	9	SARSAT MINOR
07/24/83	14	607	F/V MAKAI	5	0	0	OTHER ONLY
07/25/83	03	123	S/V GUSTO	9	0	9	SARSAT ASSIST (LOCATE)
08/08/83	17	910	A/C ON DAKAVAK LAKE	1	0	17	SARSAT KEY
09/25/83	12	328	S/V BLONDIE	2	0	2	SARSAT MINOR
10/21/83	03	7011	S/V ELITIJA	1	0	8	SARSAT KEY
10/25/83	08	27	CESSNA 172	3	0	0	SARSAT MINOR
10/27/83	03	11	S/V LOON	2	0	9	SARSAT MINOR
10/27/83	03	9	TRIMARAN BEEFEATER	3	0	5	SARSAT ASSIST (LOCATE)
11/01/83	01	335	CESSNA	0	0	0	OTHER ONLY
11/03/83	07	835	S/V KITSUNE	0	0	2	SARSAT MINOR

TABLE 3-4. SUMMARY OF USCG ELT/EPIRB DISTRESS CASES, FEBRUARY 1983 - JANUARY 1985 (CONTINUED)

DATE MM/DD/YY	CG DIST	CASE #	DISTRESSED UNIT NAME	LIVES SAVED	LIVES LOST	SARSAT PARTICIPATION #MESSG	ROLE
05/04/84	03	35	F/V TABOOMA	5	0	20	SARSAT KEY
05/12/84	07	5242	A/C PIPER AZTEC	1	0	0	OTHER ONLY
05/18/84	07	5481	A/C CESSNA 206	4	0	0	OTHER ONLY
05/19/84	03	68	S/V CHRISTINE MARIE	4	0	10	SARSAT KEY
05/29/84	03	7126	S/V RELAX	5	0	4	SARSAT ASSIST (LOCATE)
05/31/84	03	7131	S/V CARLOTTA	4	0	3	SARSAT KEY
05/31/84	03	7134	S/V RANGER	3	0	9	SARSAT KEY
06/02/84	03	7130	S/V KARI	3	0	2	SARSAT ASSIST (LOCATE)
06/08/84	07	6107	A/C CESSNA (N2493E)	1	0	2	SARSAT MINOR
06/17/84	03	7149	F/V MARGARITA	4	0	7	SARSAT ASSIST (LOCATE)
06/23/84	07	6621	A/C CESSNA (N738VS)	2	0	0	OTHER ONLY
06/22/84	17	643	KAYAKERS AT ADAK IS.	1	0	7	SARSAT KEY
06/23/84	01	2011	F/V CORMORANT	4	0	14	SARSAT KEY
06/25/84	03	90	S/V ROTARCT CHALLENGE	1	0	15	SARSAT KEY
07/01/84	03	55	S/V IBIS	2	0	5	SARSAT KEY
07/03/84	08	129	CESSNA (32538)	0	0	21	SARSAT ONLY
07/06/84	07	7101	M/V IMPOSSIBLE DREAM	34	0	0	OTHER ONLY
07/17/84	13	368	S/V BUTTERFLY	3	0	1	SARSAT ASSIST (LOCATE)
07/26/84	17	132	YES BAY LODGE ACFT	5	2	13	SARSAT KEY
07/27/84	07	7829	P/C FL1276DB	3	0	0	OTHER ONLY
08/11/84	12	267	SINGLE ENGINE ACFT	2	0	5	SARSAT ASSIST (LOCATE)

TABLE 3-4. SUMMARY OF USCG ELT/EPIRB DISTRESS CASES, FEBRUARY 1983 - JANUARY 1985 (CONTINUED)

DEFINITIONS

SARSAT ONLY - SARSAT was the only means of notification; only SARSAT coordinates were used for the search and rescue.

SARSAT KEY - SARSAT was the first or primary means of notification*; the coordinates provided by SARSAT were instrumental in the search and rescue.

SARSAR ASSIST (ALERT) - SARSAT was the primary means of notification*, but not the primary source of location information.

SARSAT ASSIST (LOCATE) - SARSAT was not the first means of notification; but the coordinates it provided were of use in the search and rescue.

SARSAT MINOR - SARSAT was involved but was not the primary alerting or locating method because the SARSAT messages were received after the search area had been determined or after the distress was sighted.

OTHER ONLY - The only means of notification was from a source other than SARSAT; only non-SARSAT coordinates were used for the search and rescue.

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*Note: SARSAT was considered the primary means of notification if it preceded other means by more than two hours or was otherwise essential to establishing the alert.

then that SARSAT is significantly more effective in alerting in Alaska than in the remainder of the U.S. maritime and coastal area. The possible reasons for this are (1) the lower density of overflying aircraft (2) the greater difficulty in radio contact, and (3) a (possibly) higher usage of ELTs and EPIRBs in Alaska.

3.3.3 SARSAT Effectiveness in Locating

SARSAT provided the only or the primary location information in 43 of the 74 Distress cases, which is about 58 percent of the Distress cases. In the remaining 42 percent of the cases, the vehicle location was known soon after the occurence either through aircraft pick-up or through ground station pick-up.

It is not possible to compare the accuracy of SARSAT locations with that of aircraft locations because the accuracy of aircraft locations is not usually known.

3.4 NON-DISTRESS CASES

Non-Distress cases comprise (1) True Non-Distress cases, (2) Located False Alarms, and (3) Located False Alerts or Unknown sources. Table 3-1 shows that only 14 True Non-Distress cases occurred in the D&E period; 322 Located False Alarms, however, did occur. These False Alarms include one case in which it was not possible to determine from the Case Folder whether the activation was a False Alarm or True Non-Distress.

An analysis of Table 3-2 shows that no District has a significantly larger or smaller number of Non-Distress cases than could be expected from the distribution of cases of all types among the Districts. This is not surprising, since Non-Distress cases themselves constitute a majority of all cases.

3.5 TIME LINES

The advantages of satellite detection and location of distressed vehicles should appear in reduced notification time, planning time, and search time, particularly in remote areas. Also, in so far as sortie time includes search time, one would expect SARSAT to contribute to reduced sortie times. The definitions of the times in question are:

Notification Time: Time from incident occurrence to receipt of first notification of the distress at the RCC.

TABLE 3-5. MEAN TIMES FOR USCG ELT/EPIRB CASES, 1 FEBRUARY 1983 - 31 JANUARY 1985

DISTRESS CASES
02/01/83 TO 01/31/85

	SARSAT ONLY	SARSAT FIRST	OTHER ONLY	OTHER FIRST	AVERAGE
	(HOURS PER CASE/NUMBER OF CASES)				
NOTIFICATION TIME	0.0/0	6.2/8	2.3/3	1.6/9	3.5/20
PLANNING TIME	9.9/6	9.4/23	1.5/7	4.2/24	6.4/60
MODIFIED PLAN TIME	0.0/0	2.1/17	1.5/7	4.2/24	3.1/48
	(HOURS PER SEARCH/NUMBER OF SEARCHES)				
SEARCH TIME	0.6/4	3.9/23	0.6/6	11.5/30	7.0/63
HH-52	0.0/0	0.0/0	0.1/1	12.0/3	9.0/4
HH3F	0.0/0	0.4/3	1.1/1	5.1/6	3.3/10
HC-130	0.2/2	1.2/9	1.0/2	4.0/11	2.4/24
HH-25	1.0/2	0.7/8	0.3/2	1.3/6	0.9/18
OTHER	0.0/0	24.2/3	0.0/0	56.4/4	42.6/7
	(HOURS PER SORTIE/NUMBER OF SORTIES)				
SORTIE TIME	4.0/7	4.6/44	3.3/10	8.7/38	6.0/99
HH-52	0.0/0	4.8/2	1.4/1	13.2/5	9.6/8
HH3F	2.5/1	3.4/7	2.5/1	8.8/5	5.2/14
HC-130	7.8/2	4.7/11	9.4/2	8.9/9	6.9/24
HH-25	2.6/2	3.5/9	2.2/3	3.5/6	3.2/20
BOAT	0.0/0	5.5/1	0.0/0	18.0/2	13.8/3
CUTTER	5.1/1	39.5/2	3.9/1	42.1/2	28.7/6
OTHER	1.8/1	29.0/12	11.6/2	23.5/9	24.3/24

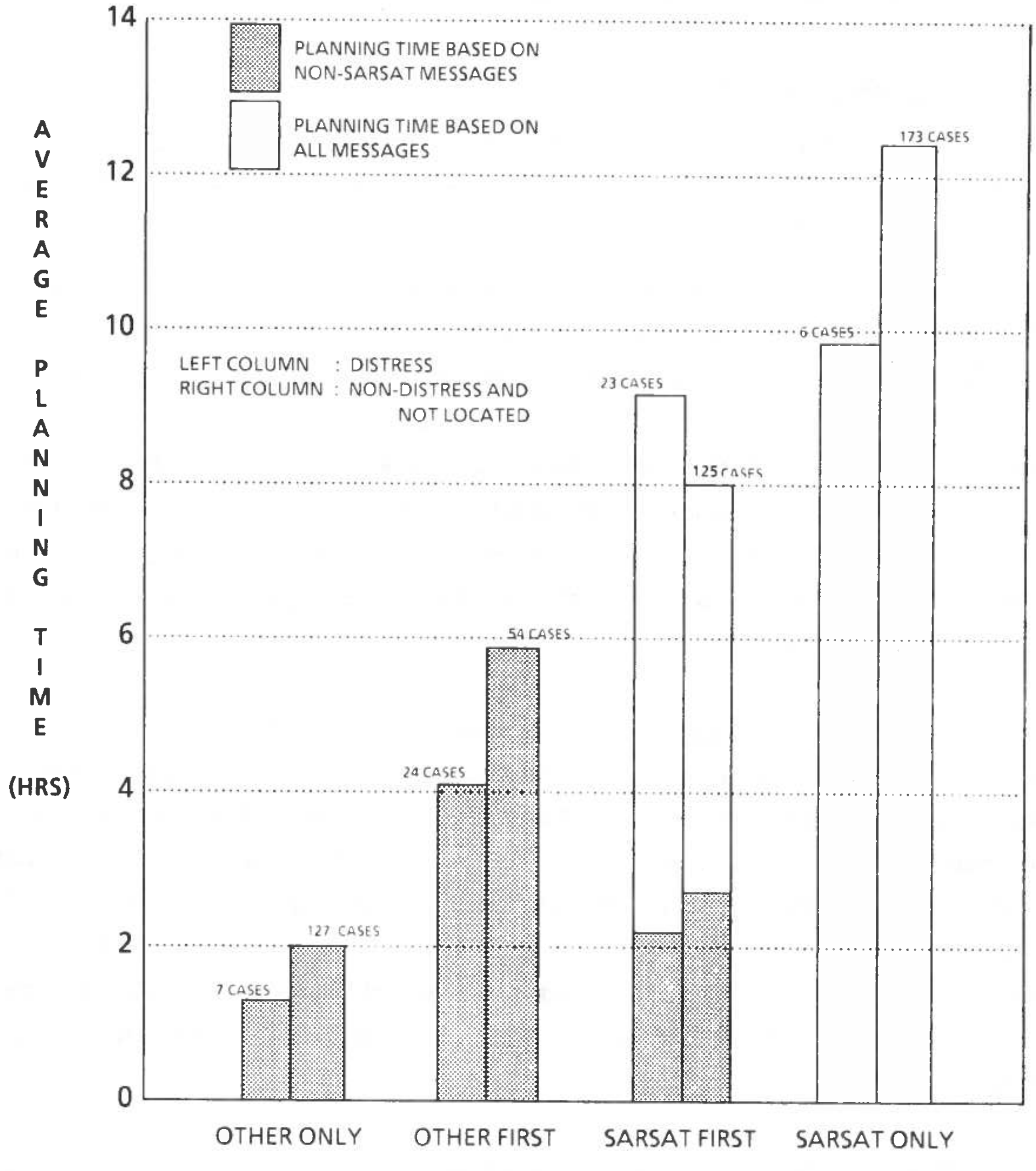

FIGURE 3-2. AVERAGE PLANNING TIME FOR ELT/EPIRB DURING COAST GUARD D&E

TABLE 3-6. MEAN TIMES FOR USCG ELT/EPIRB CASES,(1) SARSAT D&E PERIOD VS. BASELINE-HOURS (CASES/SORTIES)

	DISTRESS		NON-DISTRESS		NOT-LOCATED		TOTAL	
	D&E	BASE LINE	D&E	BASE LINE	D&E	BASE LINE	D&E	BASE LINE
NOTIFICATION TIME(2)	5.8 (11)	2.8 (9)	10.4 (7)	1.1 (39)	- (0)	2.0 (26)	7.6 (18)	1.6 (74)
PLANNING TIME(2)	7.8 (45)	3.1 (30)	8.2 (286)	3.4 (82)	6.9 (181)	3.9 (79)	7.7 (512)	3.5 (191)
MODIFIED PLANNING TIME(2)	3.3 (33)	3.1 (30)	3.0 (180)	3.4 (82)	2.8 (95)	3.9 (79)	3.0 (308)	3.5 (191)
SEARCH TIME(2)	2.7 (42)	2.7 (86)	0.8 (295)	1.1 (257)	0.9 (187)	1.4 (212)	1.0 (524)	1.4 (555)
HH-52	1.6 (1)	0.9 (13)	0.6 (105)	0.5 (91)	0.7 (66)	0.7 (66)	0.6 (172)	0.6 (170)
HH-3F	0.3 (4)	1.7 (14)	0.8 (61)	0.5 (47)	1.0 (30)	1.1 (30)	0.8 (95)	0.9 (91)
HC-130	0.9 (20)	2.2 (40)	1.2 (35)	1.8 (74)	1.3 (27)	1.5 (82)	1.2 (82)	1.8 (196)
HU-25	0.7 (12)	0.0 (0)	0.6 (69)	2.5 (14)	0.8 (54)	1.3 (9)	0.7 (135)	2.0 (23)
BOAT	-	3.9 (3)	-	0.4 (11)	-	1.2 (11)	-	1.2 (25)
CUTTER	-	12.9 (5)	-	4.8 (5)	-	3.0 (1)	-	8.3 (11)
OTHER	16.2 (5)	2.6 (11)	1.3 (25)	0.9 (15)	1.5 (10)	4.2 (13)	3.2 (40)	2.5 (39)

(1) Only cases in which the ELT/EPIRB was the first means of notification to the Coast Guard.

(2) Average of positive times.

This conclusion is verified by the Modified Planning Time values, which are planning times computed without taking account of SARSAT messages. In other words, the Modified Planning Time shows how the time from first non-SARSAT message to launch was affected by the presence of SARSAT alerts. It is seen that SARSAT has produced a reduction in the normal non-SARSAT Planning Time for Non-Distress and Not-Located cases, but actually increased its value slightly for Distress cases. Overall, the Modified Planning Time during the D&E shows a 15 percent reduction relative to the Baseline.

Search Time Comparison. The vehicle-by-vehicle comparison of total search times drawn from the last two columns of Table 3-6 shows that the HH-3F and HH-52A helicopter search times were unchanged during the D&E, but the HC-130 and HU-25 fixed wing search time were reduced by 33 percent and 65 percent respectively. These reductions were accomplished by a shift of total searches from the HC-130 to the HU-25; while the HC-130 carried out 89 percent of the fixed wing searches during the Baseline, and the HU-25 carried out the remaining 11 percent, the division shifted to 38 percent versus 62 percent during the D&E. This shift is seen in all severity types, and is probably due to a change in operating procedures, rather than to SARSAT. Whatever the reason, the reduction in fixed wing search hours resulted in an overall reduction in time per search of 29 percent during the D&E.

Sortie Time Comparison. The vehicle sortie times of Table 3-6 show similar effects as the search times. While average helicopter sortie time showed a slight increase, average fixed wing sortie times showed a reduction in the D&E relative to the Baseline. The shift in sorties from HC-130 to HU-25 is also apparent. The net result is similar to that for search times; average sortie time during the D&E was 41 percent less than during the Baseline.

4. RCC OPERATIONAL EVALUATION

This section gives the statistics of the SARSAT alert messages and SARSAT false alarms and describes their impact on the Coast Guard RCC operations.

4.1 MESSAGE STATISTICS

4.1.1 Message Flow by District, LUT, and Satellite

Table 4-1 shows the average daily SARSAT message receipts at 121.5/243.0-MHz reported by the Coast Guard RCCs in four-week intervals from 1 February 1983 to 31 January 1985. These data were obtained by count of messages mailed weekly to TSC from the Coast Guard Districts during the D&E. (See Appendix J.4). Figure 4-1 shows the mean daily message receipts for all districts at 4-week intervals obtained from the same data.

It is apparent from Figure 4-1 that the message flow to the Coast Guard RCCs rose over the first six months of the D&E to about 90 per day, and then fluctuated about that level for the remainder of the two years. A total of about 59,000 messages were received during the two years, as shown in Table 4-1.

The breakdown of messages received by the RCCs is confirmed by the counts received by the Operations Computer Center (OCC), also shown in Table 4-1. The OCC received duplicates of the SARSAT messages sent to the RCCs. While the OCC data are incomplete, as seen in the Table, they still reflect the same percentage distribution among the RCCs. The Table also shows the breakdown by LUT and by satellite for the two year period.

4.1.2 Flagged Messages

Many of the messages received by the RCCs showed locations within 50 km of the location shown on a previous message. These were indicated by a 'flag' line at the bottom of each message after the first. A 'multiple-hit' location thus consists of an initial unflagged message followed by one or more flagged messages. The flagged messages are tabulated by District in Table 4-2. Detailed listings are given in Appendix J.5. By subtracting the number of flagged messages from the number of unflagged messages, one can obtain a lower limit to the number of messages that did not have flags associated with them in subsequent messages.

TABLE 4-1. ELT/EPRIB MESSAGE TRAFFIC BY COAST GUARD DISTRICT -- ALL MESSAGES RECEIVED AT RCCs DURING THE D&E PERIOD (121.5/243.0-MHz)

DISTRICT	RECEIVED BY RCCs(1) TOTAL MESSAGES	RECEIVED BY RCCs(1) MESSAGES PER DAY	RECEIVED BY RCCs(1) PERCENT OF TOTAL	RECEIVED BY OCC(2) MESSAGES PER DAY	RECEIVED BY OCC(2) PERCENT OF TOTAL
01	1,600	2.19	2.7	1.92	3.2
03	13,351	18.26	22.6	13.62	22.4
05	1,704	2.33	2.9	1,78	2.9
07	11,371	15.56	19.2	10.58	17.4
08	5,397	7.38	9.1	5.48	9.0
11	7,824	10.70	13.2	8.02	13.2
12	6,323	8.65	10.7	5.97	9.8
13	2,491	3.41	4.2	2.80	4.6
14	2,413	3.30	4.1	2.99	4.9
17	6,644	9.09	11.2	7.76	12.6
	59,118	80.87	100.0	60.82	100.0

BY LUT(2)

SCOTT AFB	29.5%
PT. REYES	17.7
KODIAK	14.9
OTTAWA	25.5
	100.0

BY SATELLITE(2)

COSPAS I	43.8%
COSPAS II	32.5
COSPAS III	5.6
SARSAT I	18.1
	100.0

(1) 1 February 1983 - 31 January 1985; Reported by the District

(2) February 1983 - November 1983 plus Feburary 1984 - October 1984; Reported by the OCC.

A 'single-hit' location consists of a single unflagged message not followed by any flagged messages. Table 4-2 shows an estimate of the number of single'hit' messages obtained by removing all case related messages from both the unflagged and flagged messages and by assuming the remaining flagged messages are each attached to a single unflagged message. The remainder is an estimated 41,626 single hits in the two years. This estimate is a lower limit.

The vast majority of 'single hit' messages are outside of case folders because the Coast Guard RCCs do not normally prosecute a case on the basis of a single SARSAT alert. The usual RCC procedure in the case of a single hit is to plot and/or file the location. Upon receipt of a second SARSAT hit in the same vicinity, as indicated by the wall plot, the RCC usually initiates inquiries to the FAA, airports, and other sources. If no second hit occurs within a specified period (usually 18 to 24 hours) the unconfirmed first hits are removed from the plot.

4.1.3 Analysis by Severity, Source and Notification

Table 4-3 shows the number of ELT/EPIRB case messages received in the reporting period by the Coast Guard RCCs, analyzed by severity. The number of SARSAT messages per case shown in the fourth column includes cases in which no SARSAT messages were received; the fifth column includes cases in which no OTHER messages were received. The bottom line shows that, on the average, SARSAT provided four times as many messages per case as did all other sources combined.

The source of the messages are shown in more detail in Table 4-4, which breaks down the messages by source and first notification. The vast majority of non-SARSAT messages (580 out of 724) originated from overflying aircraft. Other ELT/EPIRB sources, such as airports and FAA messages, played a minor role in terms of number of messages received.

A simple count of messages received does not indicate directly the amount of information provided by the various sources. The information value of the SARSAT alerts is reduced by the large number of single hits and false alarms that they include. The data on false alarms are discussed in the next section of this report.

In summary, it can be seen from Tables 4-1 through 4-4 that, for U.S. Coast Guard ELT/EPIRB incidents in the reporting period:

1) The great majority of SARSAT messages were 'single hits' unaccompanied by confirming messages. These were not developed into SAR cases.

TABLE 4-4. MESSAGES RECEIVED BY COAST GUARD RCCs IN ELT/EPIRB CASES, ANALYZED BY SOURCE AND NOTIFICATION MEANS, 1 FEBRUARY 1983 - 31 JANUARY 1985

	NOTIFICATION MEANS				
	SARSAT ONLY	SARSAT FIRST	OTHER ONLY	OTHER FIRST	TOTAL
ALL CASES					
NUMBER OF MESSAGES	1276	1107	273	576	3232
SARSAT ALERTS	1276	845	0	387	2508
AIRCRAFT ELT/EPIRB	0	238	193	149	580
RADIO DISTRESS	0	2	5	16	23
OTHER ELT/EPIRB	0	13	70	19	102
OTHER	0	9	5	5	19
DISTRESS CASES					
NUMBER OF MESSAGES	68	278	22	175	543
SARSAT ALERTS	68	235	0	123	426
AIRCRAFT ELT/EPIRB	0	38	15	34	87
RADIO DISTRESS	0	0	3	12	15
OTHER ELT/EPIRB	0	1	2	4	7
OTHER	0	4	2	2	8
NON-DISTRESS CASES					
NUMBER OF MESSAGES	803	567	154	339	1863
SARSAT ALERTS	803	435	0	232	1470
AIRCRAFT ELT/EPIRB	0	120	101	87	308
RADIO DISTRESS	0	2	0	3	5
OTHER ELT/EPIRB	0	8	50	14	72
OTHER	0	2	3	3	8
NOT-LOCATED CASES					
NUMBER OF MESSAGES	405	262	97	62	826
SARSAT ALERTS	405	175	0	32	612
AIRCRAFT ELT/EPIRB	0	80	77	28	185
RADIO DISTRESS	0	0	2	1	3
OTHER ELT/EPIRB	0	4	18	1	23
OTHER	0	3	0	0	3

TABLE 4-5. ELT/EPIRB FALSE ALARM/ALERT CASES, BY COAST GUARD DISTRICT
1 FEBRUARY 1983 - 31 JANUARY 1985

CG	LOCATED					NOT-LOCATED					TOTAL				
DIST	SO	SF	OO	OF	TOT	SO	SF	OO	OF	TOT	SO	SF	OO	OF	TOT
01	11	8	8	8	35	9	11	3	2	25	20	19	11	10	60
03	8	15	10	7	40	6	9	11	1	27	14	24	21	8	67
05	7	8	1	3	19	6	5	3	1	15	13	13	4	4	34
07	11	12	28	11	62	34	11	21	6	72	45	23	49	17	134
08	37	14	26	10	87	20	11	7	3	41	57	25	33	13	128
09	3	5	1	0	9	6	4	0	0	10	9	9	1	0	19
11	7	3	0	0	10	6	2	0	0	8	13	5	0	0	18
12	3	7	2	2	14	4	1	3	1	9	7	8	5	3	23
13	3	5	1	2	11	0	0	0	1	1	3	5	1	3	12
14	2	1	19	4	26	5	1	8	1	15	7	2	27	5	41
17	13	9	0	3	25	5	3	0	2	10	18	12	0	5	35
TOT	105	87	96	50	338	101	58	56	18	233	206	145	152	68	571

(1) LANTAREA and PACAREA included in District 03 and 12 respectively.

CG DIST	FALSE ALARMS/ALERTS AS PERCENT OF ALL CASES: IN DISTRICT	IN ALL DISTRICTS
01	93.6	9.4
03	76.4	10.3
05	97.1	5.4
07	88.2	19.0
08	93.4	20.3
09	95.0	3.0
11	90.0	2.9
12	75.9	3.5
13	86.7	2.1
14	92.5	5.9
17	58.0	4.6
	86.4	86.4

	FALSE ALARMS/ALERTS AS PERCENT OF: ALL FALSE ALARMS	ALL USCG CASES
SO: SARSAT ONLY	36.2	31.3
SF: SARSAT FIRST	25.9	22.4
OO: OTHER ONLY	26.1	22.5
OF: OTHER FIRST	11.7	10.2
	100.0	86.4

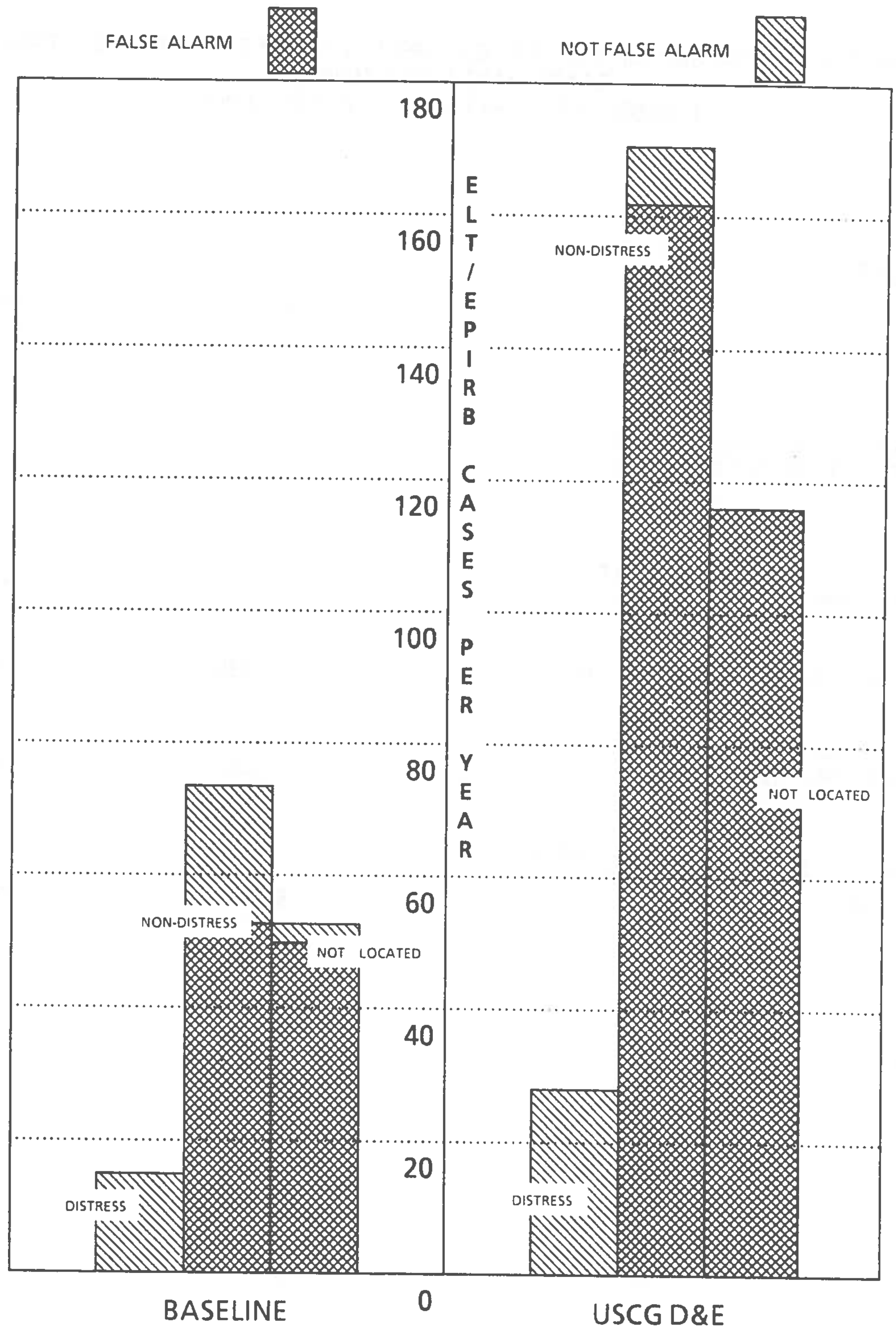

FIGURE 4-2. DISTRIBUTION OF FALSE ALARMS BY SEVERITY OF CASE-- USCG D&E VS. BASELINE

the Baseline. The multiple and single hit locations are not necessarily false alarms in the sense defined above (Section 3.1), since it is not verifed that the activations were caused by human or equipment error, or, indeed, that a real ELT or EPIRB activation was involved.

4.2.3 Analysis of Sources, Causes, and Resources

Table 4-8 shows the sources of ELT/EPIRB False Alarms and False Alerts during the reporting period. Appendix F shows the corresponding sources for False Alarms only. It is seen in Table 4-8 that about 18 percent of False Alarms and Alerts originated from ELTs, about 30 percent from EPIRBs, and the remainder, about 52 percent, from either. It was not possible to determine the sources of this 52 percent from information available in the case folders, except that the source was transmitting on 121.5/243.0-MHz and in most cases had the characteristic audio modulation of an ELT or EPIRB. The 276 uncategorized cases lend an uncertainty to the estimated proportion of ELTs and EPIRBs among the false alarms received.

Table 4-8 also shows that the cause of the False Alarms and Alerts was determined to be human error in about 12 percent of the cases, equipment malfunction or misinstallation in 8 percent of the cases, and could not be determined in the remaining 80 percent of the cases. Again, the undetermined cases lend an uncertainty to the other estimates.

Table 4-8 also shows that 59 percent of false alarms/alerts were found and secured (turned off) by the SAR forces or as a result of the search; 41 percent ceased transmitting before they could be found. Relatively fewer of the SARSAT ONLY beacons (52 percent) were found and secured than were OTHER ONLY beacons (63 percent).

Finally, Table 4-8 shows the origin of the false alarms/false alerts during the D&E period. About 19 percent of the Coast Guard false alarms/alerts originated "INLAND", i.e., from ELTs or land-based transmitters, 31 percent from MARITIME sources, i.e., EPIRBs or other maritime based sources, and the remaining 50 percent could not be traced to their source. If this remaining 50 percent is divided in proportion to those that were traced, then it appears that 40 percent of the ELT/EPIRB false alarms to which the Coast Guard responded during the D&E period originated INLAND.

A more detailed breakdown of the locations of False Alarms (excluding False Alerts) is given in Appendix F. Of the INLAND False Alarms, 57% occured at or near airports and 4% in the air; of the MARITIME False Alarms, 31% occurred in or near harbours, and

45 percent offshore. Therefore, the chance of locating an Inland false alarm by a phone call to an airport is about twice that of locating a Maritime false alarm by a call to a port or marina. Again, this conclusion must be qualified by the large number of false alarms that could not be located.

Table 4-9 gives an analysis of the D&E False Alarms and False Alerts by number of messages and search resources expended. A total of 1787 messages were received at Coast Guard RCCs in connection with the 571 ELT/EPIRB False Alarm/Alert cases. The majority of these (1404) were SARSAT alerts. As seen from Table 4-3, the RCCs received about 3.5 SARSAT alerts per false alarm, compared to about 1.0 other messages per false alarm.

Table 4-9 also shows that SARSAT ONLY false alarms involved more search hours and sortie hours than did OTHER ONLY false alarms but that the difference was not significant on a per-case basis. A total of about $2.0 million was expended in the two year D&E period to locate ELT/EPIRB false alarms and false alerts. Of this sum about $775,000 was expended on SARSAT-ONLY incidents. Further data are given in Appendix F.

4.2.4 Analysis of Time Lines

The time-lines for False Alarms and False Alerts are shown in Table 4-10. These times are not substantially different from those for non-false alarm cases. In particular, the Planning Time for SARSAT FIRST cases is about 2 to 3 times the Modified Planning Time, similar to the ratio for Distress cases. This is not surprising since the RCC response to false alarms is similar to that for Distress cases up to search time. Both involve one or more SARSAT alerts, and/or one or more aircraft reports. Searches for distress cases, however, are generally more prolonged than for false alarms, as seen by comparison of Table 4-10 with Table 3-5. A more detailed breakdown is given in Appendix F.

4.3 RCC OPERATING PROCEDURES

At the present time there is no formal Coast Guard Standard Operating Procedure for the handling and use of SARSAT messages in the SAR process. The RCC controllers in each Coast Guard District have adapted their procedures to make use of the SARSAT alert messages in their normal operations. Generally no controller will respond to a single SARSAT alert which is not confirmed by a non-SARSAT notification of distress or by

TABLE 4-10. MEAN TIMES FOR COAST GUARD ELT/EPIRB FALSE ALARMS/ALERTS
1 FEBRUARY 1983 - 31 JANUARY 1985

	SARSAT ONLY	SARSAT FIRST	OTHER ONLY	OTHER FIRST	AVERAGE
	(HOURS PER CASE/NUMBER OF CASES)				
NOTIFICATION TIME	8.5/ 5	14.6/ 1	0.0/ 0	15.7/ 1	10.4/ 7
PLANNING TIME	12.3/172	8.1/124	2.0/127	5.8/ 54	7.7/477
MODIFIED PLAN TIME	0.0/ 0	2.6/104	2.0/127	5.8/ 54	3.0/285
	(HOURS PER SEARCH/NUMBER OF SEARCHES)				
SEARCH TIME	0.7/173	1.0/127	0.7/133	1.1/ 61	0.8/494
HH-52	0.6/ 61	0.6/ 47	0.5/ 52	1.0/ 15	0.6/175
HH-3F	0.7/ 34	1.1/ 21	1.0/ 26	0.7/ 14	0.9/ 95
HC-130	1.0/ 26	1.9/ 14	0.6/ 14	1.8/ 10	1.2/ 64
HH-25	0.7/ 46	0.7/ 35	0.6/ 31	1.0/ 14	0.7/126
OTHER	0.8/ 6	2.1/ 10	0.8/ 10	1.6/ 8	1.4/ 34
	(HOURS PER SORTIE/NUMBER OF SORTIES)				
SORTIE TIME	1.8/176	1.7/125	1.3/129	1.4/ 61	1.6/491
HH-52	1.5/ 56	1.6/ 36	1.0/ 52	1.1/ 14	1.4/158
HH-3F	2.1/ 28	2.0/ 19	1.7/ 25	1.1/ 14	1.8/ 86
HC-130	2.8/ 26	2.7/ 15	1.4/ 11	3.3/ 5	2.6/ 57
HH-25	2.1/ 46	1.8/ 35	1.7/ 31	1.9/ 16	1.9/128
BOAT	1.6/ 1	2.6/ 3	1.4/ 1	2.0/ 2	2.1/ 7
CUTTER	0.0/ 0	4.6/ 1	0.0/ 0	0.0/ 0	4.6/ 1
OTHER	1.4/ 19	2.0/ 16	1.1/ 9	2.3/ 10	1.7/ 54

order to authorize a search. The appropriateness of the search craft is determined by such factors as transit distance to distress site, weather conditions, and type of distress expected. In the SARSAT indicated case the alert originates from an ELT or EPIRB and the equipment should have a homing capability.

4.3.1.3 Weather and Time of Day enter into SARSAT-aided launch decisions in the same way as in other launch decisions. For a given situation, controllers are less likely to launch in adverse weather, poor visibility, or darkness. However, in so far as SARSAT provides additional confirmation of the existence of a distress beacon, and coordinates at which to initiate a search, the launch decision is expedited by the alert messages. In one actual case (PIONEER II) the SARSAT coordinates were a key factor in the decision to launch at night rather than to wait until first light.

4.3.2 Search Justification - Summary

The reasons behind the decision to launch a search are not always well defined. The decision is based on the integrated consideration of a particular District's situation, the search factors previously described and SARSAT and/or verifying information. However, generalized, specific criteria can be developed for SARSAT and correlating information. The following launch criteria are derived either directly from controller interviews at the districts visited or inferred from the data gathered. A full description of the practices in the districts visited is given in Appendix H, "Response Scenarios."

CGD01:

- o In an air traffic zone - two SARSAT hits and one aircraft verficiation; or
- o Out of air traffic zone - two SARSAT hits.

CGD03

- o In air traffic zone - three SARSAT hits and one aircraft verification; or
- o Out of air traffic zone - three or four SARSAT hits.

CGD07:

- o In air traffic zone - three or four SARSAT hits and aircraft verification; or
- o Out of air traffic zone - four or five SARSAT hits; or
- o Two or three SARSAT hits and an Overdue Aircraft report.

4.4.1.1 Operations Center Workload - The Operations Centers visited did not report significant workload problems as a result of the SARSAT system. Each district has adopted procedures and priorities for handling SARSAT messages that are strongly influenced by non-SARSAT workload, the volume of SARSAT message traffic, and the number of actual SAR cases at an Operations Center. These influences appear to be determining factors in how the messages are handled and what procedures have evolved to process them. Operational evidence of this is in (a) geographical responsibility, (b) orbit predictor use, and (c) plotting of hits:

a. CGD07 has made a significant commitment to Law Enforcement, receives a high volume of SARSAT messages, and prosecutes the greatest number of SAR cases. All of these factors contribute to its placing unequal handling and processing weight on SARSAT hits in different locations.

b. CGD07 and CGD03, which each received more SARSAT messages than any of the other eight Coast Guard Districts (see Table 4-2), do not use the satellite orbit predictor at all. CGD01, which receives the least amount of messages, and CGD12 often use the predictor to determine a satellite's next pass and the potential visibility of the location to that satellite. The VISTRAK program is used in most districts, primarily CGD01, CGD03, CGD11, CGD12, CGD13, CGD14 and CGD17.

c. CGD03 controllers plot only SARSAT messages that represent at least a second hit. All other districts also plot single hits.

Since there are no official, binding procedures for handling SARSAT messages, handling and priority given to handling have evolved in their own way for each district and even for each controller. Partly because of this flexibility, handling SARSAT messages has not created a significant workload problem.

4.4.1.2 Communications Room Workload - In contrast to the Operations Center, the Communications Room is restricted in how it handles a SARSAT message. Since SARSAT messages are for "Immediate" handling, they should be processed within 0.5 hour. In addition, each SARSAT message must be processed and prioritized equally.

There does seem to be a workload problem in the Communications Rooms. In present operations, Communications Room staffs are heavily burdened by all message traffic. Future increases in SARSAT messages as a result of increased ELT/EPRIB use

5. LUT OPERATIONAL EVALUATION

The U.S. Coast Guard operated two Local User Terminals (LUTs) during the COSPAS/SARSAT D&E period, one at Pt. Reyes, CA and one at Kodiak, AK. Both were installed in January-May 1982 and have undergone several software and hardware revisions in the three years since installation. Data were gathered at both LUTs during the D&E in order to assess:

(1) The additional workload imposed on the COMMSTAs to operate and maintain the LUT equipment.

(2) The reliability, maintainability, and availability (RMA) of the equipment.

This section summarizes the results of the data gathering and analysis.

5.1 LUT WORKLOAD ASSESSMENT

The impact of the COSPAS/SARSAT system on the COMMSTA workload was assessed by several field trips to the two LUT sites, by discussion with COMMSTA and contractor personnel, and by a review of training, operating, and maintenance manuals. The results of the LUT Workload Assessment are given in Appendix I, which is summarized here:

5.1.1 Type and Frequency of SARSAT LUT Work Efforts

5.1.1.1. Work Sampling - The technique of work sampling was chosen for studying the SARSAT workload activity at the U.S. Coast Guard LUTs.

Work sampling is an industrial engineering technique for studying an activity by making randomly spaced observations of the activity. The observations are used to estimate the percentage of time devoted to given tasks. Work sampling does not apply to infrequently occurring tasks, which were analyzed separately, as seen in Section 5.1.1.2 below. From an industrial engineering perspective, there are three basic types of frequently occurring work efforts performed for SARSAT operations at the LUTs. They are:

1. Operator functions - Inputting or requesting information from the computer system through the terminal keyboard(s); mounting and demounting tapes;

the following section. The percent occurrences observed at COMMSTA San Francisco are considered to be representative of actual "busiest SARSAT workload conditions" at both U.S. Coast Guard LUT locations.

5.1.1.2. Infrequently Occurring Tasks - Four types of infrequently occurring tasks at the Coast Guard LUTs were analyzed. Estimates of the workload associated with these tasks were made by consultation with the COMMSTA supervisory personnel and from trip reports.

1. Formal Training. It is estimated that at least 80 hours of instruction is required to bring an Electronics Technician (ET) up to standard capability on SARSAT. In addition about 80 hours practical experience is required. If the training is conducted by a contractor (recommended), then the required manpower is 80 hours per attendee. A minimum of two attendees per site is recommended and four is common.

   If formal on-site training is conducted by Coast Guard personnel then allowance must be made for the instructor's time, both in class and in preparation. It is assumed in what follows that all formal on-site training is conducted by contractors.

   In addition to the 80-hours classroom instruction and 80 hours practical experience, it is necessary to invest about four hours per month per trainee in refresher training. This is necessitated not only by the infrequent nature of many operations and maintenance duties on the equipment, but also by the inevitable updates and improvements added to the equipment and software.

2. Informal On-site Training. This type of training differs from Formal Training in that there are no pre-set class hours and in that it is usually conducted with only one or, at most, two trainees. It was observed during the Work Sampling at Kodiak, that ET1 spent much time in training ET3 to perform the SARSAT workload in preparation for an upcoming absence of ET1 for training in July. Thus the training itself creates the need for training of replacements. The level of on-site informal training required can be estimated from Table 5-1. The operator and administrative tasks for Kodiak include informal training, while those at San Francisco do not. Thus about 10 to 15 percent of the Kodiak workload is attributed to informal on-site training.

3. Tasks Due to System Outages. These occurrences were considered very infrequent at the time of the Work Sampling study, but a broader view may be obtained from USMCC availability data (Reference 18). These show the USMCC effective availability, i.e., the percent of time the USMCC is operational, to be 87.8 percent as of October 1983. (This figure is typical of that for the first year D&E.) Therefore, the fraction of passes at any one LUT that occur during USMCC outages is less than 12.2 percent. Many MCC outages are scheduled maintenance events occurring outside of satellite visibility periods at any LUT. Is is assumed that 3 percent of the passes at any one LUT occur during system outages. This would result in about 164 passes per year occurring under failure conditions at Pt. Reyes, and 274 per year at Kodiak. The estimates are based on 15 passes tracked per day at Pt. Reyes and 25 at Kodiak in an operational four satellite system. (See Reference 11).

   The operator workload due to system outages is approximately proportional to the number of passes, since the LUT operator must activate the backup message generation software, oversee message transmission, and return the LUT to normal operation for each pass. Allowing 15 minutes of operator or ET time per pass gives about 40 hours per year at Pt. Reyes and 70 hours per year at Kodiak for failure mode operation.

4. Travel Connected with SARSAT. SARSAT-related travel covers (1) travel time and expense for training off-site, over and above the training time itself, and (2) travel for attendance at annual SARSAT User Conferences. If each ET to be trained attends one off-site training session upon assignment to the COMMSTA, and one per year thereafter, the travel load will be approximately two days per year per ET over and above training time itself. Similarly about twelve days per year per LUT is estimated for conference attendance, based on two attendees per LUT.

5.1.2 Net Workload Increment Due to SARSAT

Estimates were made of the total additional manpower required to operate the LUT. The estimates are in annual labor years for an operational system. They are based on the following assumptions:

Finally, the major workload of the substitute ETs must be estimated. It is assumed that because of leave the SARSAT ET1 produces 1750 hours per year out of the maximum 2080 hours per year, or 0.159 labor years of leave per year, a typical production level. Further, he is assumed to be on travel approximately 0.030 labor years per year, which time must be made up by the other COMMSTA ETs. The total is 0.189 labor years per year at each LUT for the non-SARSAT ETs.

5.1.2.3 RM Workload - The Radio Man (RM) workload imposed by SARSAT was found to be minimal during the work sampling study. He attends the LUT operator console during performance of his other duties and alerts the ET1 to unusual conditions. The RM will also change the analog tape if the ET1 is unavailable, or if he (the RM) finds he has both time and interest in doing so. A nominal value of 5 percent of the RM's time was allowed for SARSAT-related tasks. This is considered an upper limit.

5.1.2.4 Total SARSAT Workload - The total SARSAT Workload at each LUT is shown in Table 5-2. It is seen from this table that although the SARSAT ET1 workload is close to 1.0 labor year per year the workload for the non-SARSAT ETs and RM at the COMMSTA totals to about 0.50 labor year per year. These estimates are conservative, i.e., they represent an upper limit of what can be expected. Nevertheless the non-SARSAT ET and RM workload is a substantial load that was not foreseen at the beginning of the program.

The estimates of Table 5-2 are expected to prove greater than what actually will occur for several reasons. First, they apply to the fully operational four-satellite system. If the programming and computational efficiencies envisioned for the operational system are not realized the number of tracked passes at the LUTs will be less than that projected, and the workload will be somewhat less than shown in the table. Secondly, operator workload is less than linearly related to number of tracked passes, as was assumed in Appendix I. Moreover, the estimates assume no improvement in reliability and maintainability of the system compared to the experience of June - July 1983 (the time of the Work Sampling Study). Improved hardware and maintainance methods will probably increase the LUT reliability and maintainability, but these advances may be offset by aging of the equipment. One improvement to maintainance procedures was made in late 1984 when use of the analog tape recorder was suspended at both Coast Guard LUTs. Finally, the table's estimates allow for more adequate formal training of all ETs involved than is presently being realized.

5.1.3 Conclusions on LUT Workload

In summary, it is concluded that one ET1 permanent billet at each LUT will be adequate to accommodate the SARSAT workload so long as the existing contractor support relationships are maintained. The presently assigned ET personnel performing SARSAT duties are doing an excellent job with a minimum of external guidance. They have established and are maintaining excellent working relationships with the other government agencies (NASA, NOAA, USAF) and contractor organizations involved in the current Demonstration and Evaluation phase. The U.S. Coast Guard LUTs are considered ready for transition to an operational phase.

It is also concluded that one ET SARSAT billet will be adequate for an operational four-satellite system, but that up to one-half labor years/year will be required from non-SARSAT ETs at each COMMSTA, particularly if adequate training levels are to be maintained.

The importance of training was recognized at the outset of the program, but both COMMSTA personnel, as well as those at Coast Guard Headquarters and TSC were disappointed in the initial installation training. The OJT has required the use of non-SARSAT resources not planned upon because it is essential that 24 hours on-site support be provided. Although a single ET1 can provide the major support it is essential to provide continued training to the other ETs for his relief.

5.2 LUT RELIABILITY, MAINTAINABILITY, AND AVAILABILITY

The Reliability, Maintainability, and Availability (RMA) of the Coast Guard-operated LUTs at Pt. Reyes, CA and Kodiak, AK was assessed in accordance with Annex C of the U.S. SARSAT Demonstration and Evaluation Plan. This Annex was intended to provide guidance for assessing both system, subsystems and component reliability, maintainability, and availability. The list of LUT subsystems and components and the parameters to be evaluated are given in Table 5-3. The parameters to be calculated for the LUT system, subsystems and components are:

RELIABILITY, given by

MTBF = Mean Time Between Failures, Hrs

MTBM = Mean Time Between Maintenance Events, Hrs

MAINTAINABILITY, given by

MTTR = Mean Time to Repair, Hrs

TABLE 5-3. LIST OF SUBSYSTEMS AND COMPONENTS FOR LUTs

1.* RADIO FREQUENCY SUBSYSTEM

   1.* Antenna Assembly
   2.* Antenna Control Unit
   3.* Servo Amplifier Assembly
   4.* Microdyne Telemetry Receiver

2.* CARRIER TRACKING SUBSYSTEM

3. ANALOG TAPE RECORDER SUBSYSTEM(1)

   1. Analog Tape Recorder Switching Unit
   2. Analog Tape Recorder

4. SPECTRUM ANALYZER SUBSYSTEM

   1. Spectrum Analyzer
   2. Spectrum Analyzer Interface Panel

5.* PROCESSOR INPUT SUBSYSTEM

6. STATUS AND ALARM SUBSYSTEM

7. SYSTEM TEST SOURCE SUBSYSTEM

8.* COMPUTER SUBSYSTEM

   1.* HP 1000
   2. Disc Drive
   3. Printer
   4. Terminal
   5.* Array Processor
   6. Digital Tape Recorder(2)

9.** TIME REFERENCE SUBSYSTEM

   1. Satellite Synchronized Clock
   2. Time Coder Reader

10.** SOFTWARE SUBSYSTEM

11.** OPERATOR SUBSYSTEM

12. 406-MHz CALIBRATION BEACON

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* Critical.
** Critical under certain conditions.
(1) This subsystem was removed from the LUT in the second year D&E.
(2) This component was added to the LUTs after the first year of D&E.

TABLE 5-4. FORMULAS FOR RMA CALCULATIONS

The formulas employed in the calculations of LUT Reliability, Maintainability, and Availability (RMA) from the USCG LUT R&M Logs are as follows:

N_F	=	Number of Failures
	=	Number of Corrective Maintenance events recorded on LUT Logs.
T_D	=	Total Down Time (= Total Failure Time)
	=	Total Time Back in Operation minus Time Out of Operation, for corrective maintenance events, from LUT Logs.
T_R	=	Total Repair Time
	=	Total Time of Eng of Servicing minus Time of Start of Servicing for corrective maintenance events, from LUT Logs.
N_S	=	Number of scheduled maintenance events, recorded on LUT Logs.
T_S	=	Total Time from start of Servicing to Time of end of Servicing, for scheduled maintenance events, from LUT Logs.
H_M	=	Total man hours of servicing for both corrective and scheduled maintenance events, from LUT Logs.
T_T	=	Total time covered by LUT data, adjusted
	=	6499 hours in First Year, 8784 hours in Second Year.
T_O	=	Total operating time covered by LUT data
	=	T_T, T_D, T_S.
MTBF	=	T_O/N_F
MTBM	=	$T_O/(N_F + N_S)$
MTTR	=	T_R/N_F
MDT	=	T_D/N_F
MMH/OH	=	H_M/T_O
A_i	=	T_O/T_T
A_e	=	T_{CO}/T_T

TABLE 5-5. SUMMARY OF RMA DATA

	Point Reyes	Kodiak
Time Period Covered	1 May 83 - 31 Jan 84	March 83 - June 83
Data sheets Employed	62	9
Number of Entries Used	67	0
Total Hours Covered	6624	2928
Net Hours Covered	6499	-
Time Period Covered	1 Feb 84 - 31 Jan 85	1 Feb 84 - 31 Jan 85
Data Sheets Received	144	40
Data Sheets Employed	113	29
Number of Entries Used	119	0
Total Hours Covered	8784	7544
Net Hours Covered	8784	-

TABLE 5-6. PT. REYES LUT RELIABILITY ANALYSIS RESULTS FOR FIRST YEAR AND SECOND YEAR D&E (TIME IN HOURS)

SYSTEM/SUBSYSTEM	FIRST YEAR D&E NUMBER OF FAILURES	DOWNTIME	MTBF	MTBM	SECOND YEAR D&E NUMBER OF FAILURES	DOWNTIME	MTBF	MTBM
LUT SYSTEM	42	1080.7	129.0	80.5	76	69.3	114.8	72.8
1.0 RF SUBSYSTEM	6	22.5	1079.4	925.1	10	3.8	878.0	878.0
2.0 CARRIER TRACKING SUBS.	-	-	-	-	2	4.0	-	2194.0
3.0 ANALOG TAPE RECORDER SUBS	3	509.5	-	1497.3	1	7.0	-	8784.0
6.0 STATUS AND ALARM SUBS	1	260.0	-	6239.0	1	0.5	-	8783.5
8.0 COMPUTER SUBSYSTEM	14	64.2	459.6	357.2	13	32.7	673.2	415.7
9.0 TIME REFERENCE SUBS	-	-	-	-	-	-	-	8783.5
10.0 SOFTWARE SUBSYSTEM	13	100.8	492.2	199.3	42	20.3	208.7	118.1
11.0 OPERATOR SUBSYSTEM	5	123.8	1275.0	1275.0	3	0.5	-	2927.8
12.0 406 CALIB. BEACON	N/A	N/A	N/A	N/A	4	0.5	2195.9	2195.9

reduction of 97 percent. Whereas one failure resulted in an MDT of 7 hours for the analog Tape Recorder Subsystem, all of the major LUT Subsystems exhibited a drastic reduction in MDT.

5.2.4 Availability - Pt. Reyes LUT

The availability was calculated only for the overall LUT system. In the calculation of Effective Availability (Ae) the downtime of only critical components was used to reduce the operating time. Time was removed from the Software Subsystem (2.25 hours) and the Operator Subsystem (0.5 hours) after determining that the reported downtime in certain instances did not affect the essential functions of the LUT. In the calculation of Inherent Availability (Ai), the downtime of all components was used. In both cases corrective maintenance and scheduled maintenance downtime was used to determine operating time. An Ai of 98.7 percent resulted from 117.42 hours of downtime due to corrective and preventative maintenance. An Ae of 99.2 percent resulted from 67.12 hours downtime of critical components and subsystems with the adjustments discussed above.

The availability data for the First Year and Second Year D&E are contained in Table 5-8. A dramatic improvement in inherent availability (Ai) (15.7 percent) resulted from the decrease in overall downtime from 1106.5 hours in the first year D&E to 117.42 hours in the second year D&E. This represents an effective reduction of 89 percent when the data are normalized by the number of available hours in each year. This was due to the reduction in corrective maintenance time despite the fact that scheduled maintenance was nearly doubled from the First Year D&E (48.08 hours versis 25.85 hours).

A significant improvement from year to year in effective availability (Ae) was also noted (2.36 percent) due to the reduction in overall maintenance time of critical components and subsystems from 205.35 hours to 67.12 hours. This represents a reduction in downtime of 76 percent when the data is normalized by the number of available hours for each period (The First Year D&E available hours were only 74 percent of the available hours for the Second Year D&E).

5.2.5 Availability - Kodiak LUT

After review of the 40 log sheets received from Kodiak in the second year the total available time for the period 1 February 1984 to 31 January 1985 was 7544.46 hours and the down time for inherent availability was determined to be 322.75 hours, for an inherent availability (Ai) of 95.6 percent. For calculating effective availability the downtime was based on the assumptions and decisions given in Appendix J for a total downtime of 123.75 hours and an effective availability (Ae) of 98.4 percent. These data are summarized in Table 5-9.

TABLE 5-9. KODIAK LUT SYSTEM AVAILABILITY FOR SECOND YEAR D&E (EXCLUDING ANTENNA)

	TOTAL HOURS AVAILABLE	TOTAL DOWNTIME (HRS)	TOTAL OPERATING HOURS	AVAILABILITY
Ai	7544.46	332.75	7211.71	95.6 percent
Ae	7544.46	123.75	7420.71	98.4 percent

The above Availability Table excludes the Antenna. The Kodiak antenna experienced a catastrophic failure on 9 May 1984 and was returned to full service on 21 June 1984. This outage must be consided in any over-all assessment of LUT reliability. Antenna failures are relatively rare: the four U.S. LUTs have logged about 3.5 years each, thus yielding one major failure per 14 years of operation. The antenna, however, is a critical component, not readily replaced or repaired, out of the operator's view, and subject to the extreme environmental conditions of its site. Moreover, at the latitude of Kodiak it can receive about 25 passes per day as opposed to about 15 per day at Pt. Reyes (four satellite system).

When the 1984 antenna failure is allowed for, the availabilities of the Kodiak LUT drop to the 70-75 percent range. This is due more to the extended time of the outage, rather than to the frequency of occurrence. Providing for rapid repair or replacement of the antenna, therefore, can be a major step toward increasing overall LUT availability.

5.2.6 Conclusions on RMA - Pt. Reyes

Based upon the number of log sheets, the scattering of the data, and the log sheet entries made by the on-site ETs, the Pt. Reyes RMA results appear to be valid and can be used as a basis for corrective action and operational system planning. The extent to which they apply to other LUTs (in particular to the Kodiak LUT) is discussed in the next section.

- o The highest Mean Down Time (MDT) was exhibited by the Computer Subsystem (2.51 hours) followed by the Carrier Tracking Subsystem (2 hours). All other subsystems exhibited an MDT of 0.5 hours or less.

5.2.7 Conclusions on RMA - Kodiak

The availability of complete data from only one site calls for some caution in the application of the study results to the LUT system as a whole.

Extensive discussions were held with on-site personnel at Kodiak to ascertain differences that could be expected with the Kodiak LUT which were located unique and to determine if the Pt. Reyes RMA analysis could be applied at other LUTs. It was concluded that the Pt. Reyes RMA analysis was representative of both LUTs with the exception of remoteness from mainland based contractor repair personnel. Because of weather conditions there can be several days delay in getting on or off Kodiak Island, as the only practical means of transportation is by air. There are frequent occasions when the airport is closed down for days at a time. In at least one occassion noted on a maintenance report on the HP-1000 computer, there was a "long time delay due to no air transport to Kodiak" for the Hewlett Packard service technician to respond to the maintenance call. From the log entry this delay resulted in an additional downtime of 45.5 hours.

The extended outage due to the Kodiak antenna failure is another case in point. Rapid repair or replacement of the antenna is made difficult by the remoteness of the site. A straightforward solution to this problem would be the provisioning of a spare antenna at Kodiak, either on-line or in storage. Consideration may also be given to dual LUT installations at Kodiak; not only would this guard against protracted outages, but it would also increase the number of passes that can be tracked.

A second installation would increase Kodiak's output by 63 to 80 percent (based on planned algorithm speed-up (b) and present algorithm (a) of Reference 11). The second installation could also serve as part-time training site.

5.2.8 Comparison with Contractor Data

The MTTR and MTBF data developed above are substantially different from those developed by Canadian Astronautics Limited (CAL), the LUT contractor. The CAL data of May 1984 are: MTTR = 121.1 hours, MTBF = 1647. hours, based on eight failures in the

6. COMMUNICATIONS AND GROUND SYSTEM EVALUATION

The purposes of the Communications and Ground System Assessment are (1) to estimate the impact of COSPAS/SARSAT messages on the existing Coast Guard communications network, as well as (2) to evaluate the overall SARSAT ground system as it affects the Coast Guard SAR operations. Figure 6-1 shows the flow of SARSAT messages through the SARSAT ground system.

Two assumptions are made at the start:

1. The impact of SARSAT messages on Coast Guard communication lines is concentrated in the AUTODIN lines from the USMCC to the RCCs. The Coast Guard shares these lines with DOD. They carry a large volume of non-SARSAT message traffic to the Coast Guard RCCs. The leased communication lines (LCL) from the LUTs to the USMCC are high speed (9600 bit/sec) data lines that transfer the SARSAT alerts computer-to-computer. These lines carry only SARSAT alerts and are not part of the existing Coast Guard communication network. Therefore, in assessing the impact of the SARSAT message traffic on USCG communications, only the AUTODIN lines were considered.

2. In evaluating the overall SARSAT ground system, the main considerations are the volume and delays of SARSAT alert messages distributed to the Coast Guard SAR Coordinating Centers. The overall system, in this context, includes the LUTs, the U.S. Mission Control Center itself, the communiction lines from LUTs to USMCC, and the AUTODIN lines from the USMCC to the Coast Guard RCCs (see Figure 6-1).

6.1 COMMUNICATIONS ASSESSMENT

The impact on Coast Guard communications is restricted to the AUTODIN circuits going from the USMCC to the Coast Guard RCCs. The impact is measured by the following parameters:

a) Volume of message traffic
b) Line utilization

The time period for the impact assessment is taken as the high-volume months of August, September and October, 1983. (Reference 13.)

6.1.1 AUTODIN Message Volume

Table 6-1 compares the SARSAT message traffic with the total number of messages received in August, September and October, 1983 via AUTODIN by each COMMCEN in the listed districts. The table gives the percent increase due to SARSAT alerts. In a four satellite system the projected number of SARSAT messages routed to each district would be higher. The large volumes shown for CGD03 and CGD12 are due to the fact that they include message traffic to the LANTAREA and PACAREA. Each of the two Area Commands receives duplicates of messages sent to the districts within its jurisdiction. Thus, the 80.0 messages per day shown for CGD03 in August consists of 53.6 messages per day addressed to LANTAREA Command and 26.4 messages per day directed to CGD03 itself. The CGD03 and CGD12 message traffic presents an occasionally heavy workload to the COMMCENs in those districts, as described in Section 4.4. Reducing the SARSAT message priority from "Immediate" to INFO for LANTAREA and PACAREA would not reduce the communication lines load but would allow other "Immediate" messages to move more rapidly and would also provide some alleviation of the peak COMMCEN workload. (See Section 4.)

6.1.2 AUTODIN Line Utilization

The AUTODIN line utilization was computed for the non-SARSAT and SARSAT message traffic for the months of August, September and October, 1983. The results are given in Table 6-2. The three columns show the computed percentage of line utilization for the non-SARSAT and SARSAT messages. In the computation each SARSAT message was assumed to consist of 7.45 block lines.

From the table it is seen that SARSAT messages utilize a small percentage of the line capacity. For example, even for CGD03 (LANTAREA), the line utilization due to SARSAT was only 1.55 percent, 1.3 percent and 1.2 percent in August, September and October, respectively. For a four satellite system this would increase by no more than 25 percent. It should be noted that CGD17 has a

TABLE 6-2. SARSAT AND NON-SARSAT UTILIZATION OF USCG COMMCEN AUTODIN LINES (PERCENT OF CAPACITY)

	AUGUST			SEPTEMBER			OCTOBER		
CGD	NON-SARSAT AVERAGE	PEAK*	SARSAT AVERAGE	NON-SARSAT AVERAGE	NON-SARSAT PEAK*	SARSAT AVERAGE	NON-SARSAT AVERAGE	PEAK*	SARSAT AVERAGE
01	10.7	17.1	0.06	11.4	17.5	0.05	14.1	21.2	0.04
03	28.1	35.4	1.55	23.4	37.5	1.30	28.3	42.2	1.20
05	9.9	16.2	0.05	12.1	38.5	0.05	11.4	18.6	0.05
07	25.1	31.2	0.27	25.5	35.4	0.31	24.5	33.6	0.24
08	11	15.5	0.14	10.7	16.0	0.13	12.2	17.8	0.13
11	12.1	16.0	0.20	11.7	23.7	0.23	12.3	18.1	0.21
12	17.8	25.3	0.96	20.0	25.2	1.14	20.9	29.1	0.62
13	NA	NA	0.02	NA	NA	0.02	NA	NA	0.02
14	7.0	10.3	0.02	7.1	10.3	0.02	7.2	11.2	0.02
17	41.9	54.6	0.95	45.4	61.2	1.40	41.8	59.5	0.68
OCC	9.5	13.2	1.80	8.6	11.2	1.79	8.2	10.0	1.50

*Daily high

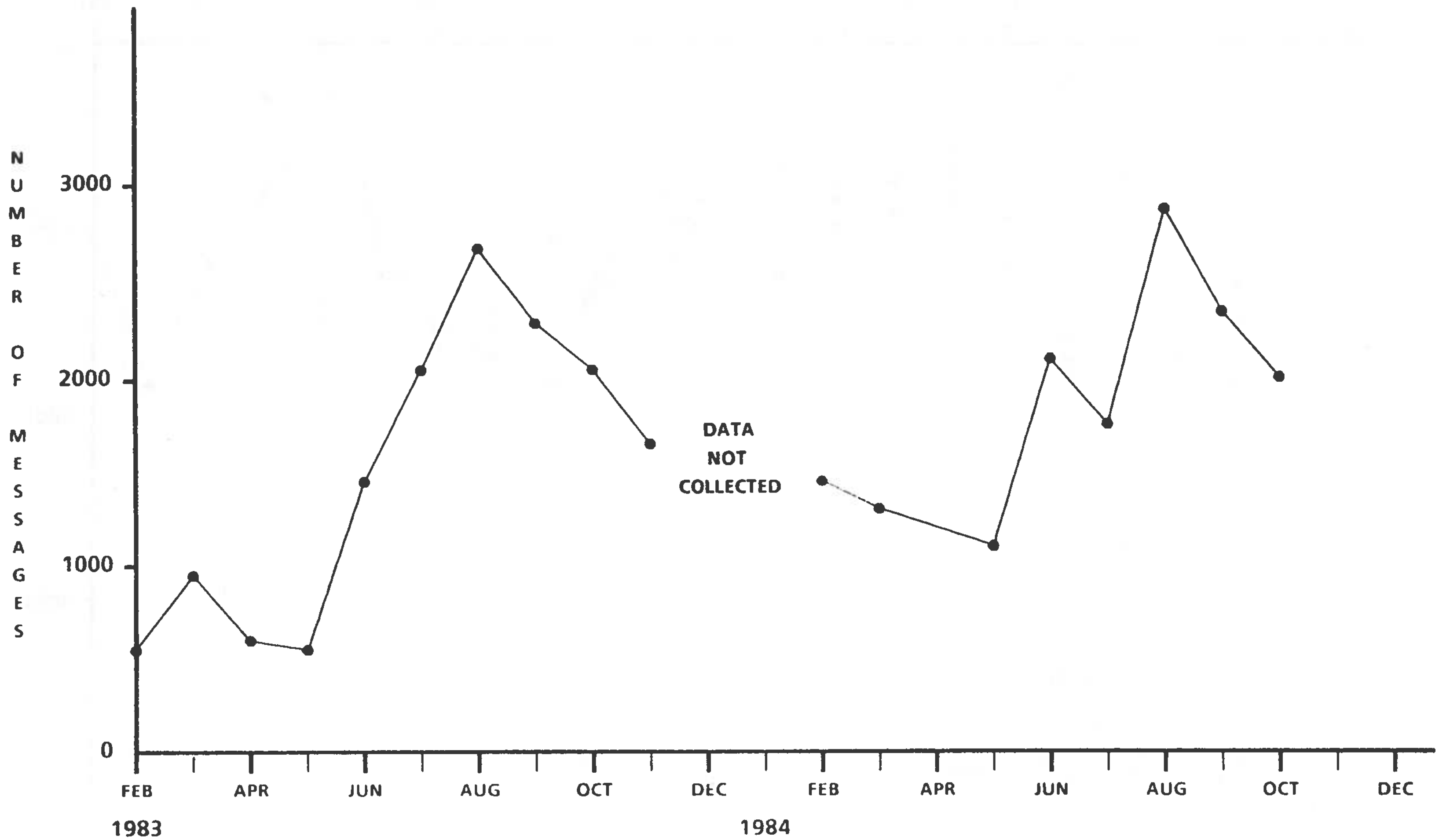

FIGURE 6-2. TOTAL MESSAGES RECEIVED BY USCG, FEBRUARY 1983- OCTOBER 1984

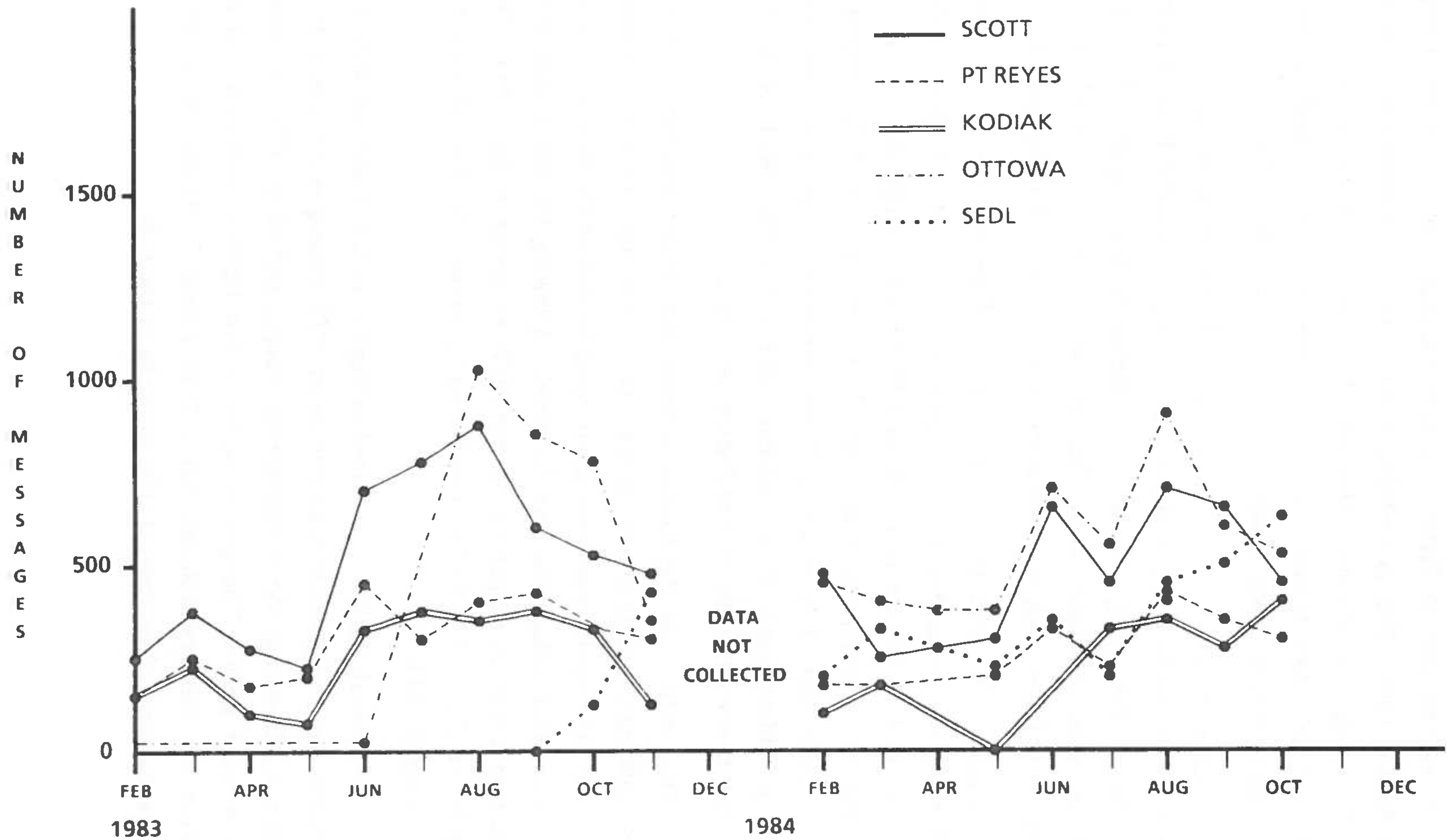

FIGURE 6-4. MESSAGES RECEIVED BY USCG, BY LUT -- FEBRUARY 1983-OCTOBER 1984

6.2.2 SAR Case Message Volume

The alert messages received by the Coast Guard RCCs in connection with real SAR incidents during the D&E were extracted from their case folders and analyzed by TSC for volume and delays. The results are given in Appendix J2 and J3, and shown in Table 6-3 and Figure 6-5 .

The overall volume of case messages shows a general upward trend, seen in Figure 6-5. This is similar to the upward trend of total message volume seen in Figure 6-2. The case message volume, however, is more erratic than the total message volume because of occasional cases that involve a flood of alerts generated by an unsecured ELT or EPIRB.

Table 6-3 shows how the SARSAT case messages were distributed among satellites, LUTs, SRRs, and Inland/Maritime areas. There were 2098 SARSAT messages sent to Coast Guard RCCs during the D&E. Since each message has two locations, each with a SAR region of responsibility, many of the messages were also sent to the Inland or Other SAR regions.

6.2.3 Ground System Delays-Distributions

The time for an alert message to pass through the ground system was measured in three parts, which are illustrated in Figure 6-6. The distributions of the three time intervals are given in Figures 6-7, 6-8 and 6-9. The distribution of the total time from TCA to RCC is shown in Figure 6-10. These distributions are for 1652 case messages from the U.S. LUTs and the SEDL to the Coast Guard RCCs during the D&E. They do not include messages originating from the Ottawa LUT.

In general, the time from TCA (Time of Closest Approach) to TPC (Time LUT Processing Complete) was under 30 minutes, showing an average of 13.7 minutes, and a median of 12.0 minutes. The time TPC to TMC (Time MCC Processing Complete) averaged 20 minutes with a median of 5 minutes, but had a standard deviation of 41 minutes, indicative of occasional large delays. The time from MCC to RCC showed similar characteristics: the median delay was 5.5 minutes, but the mean of 27.0 and standard deviation of 60.3 minutes indicated a few large delays were present.

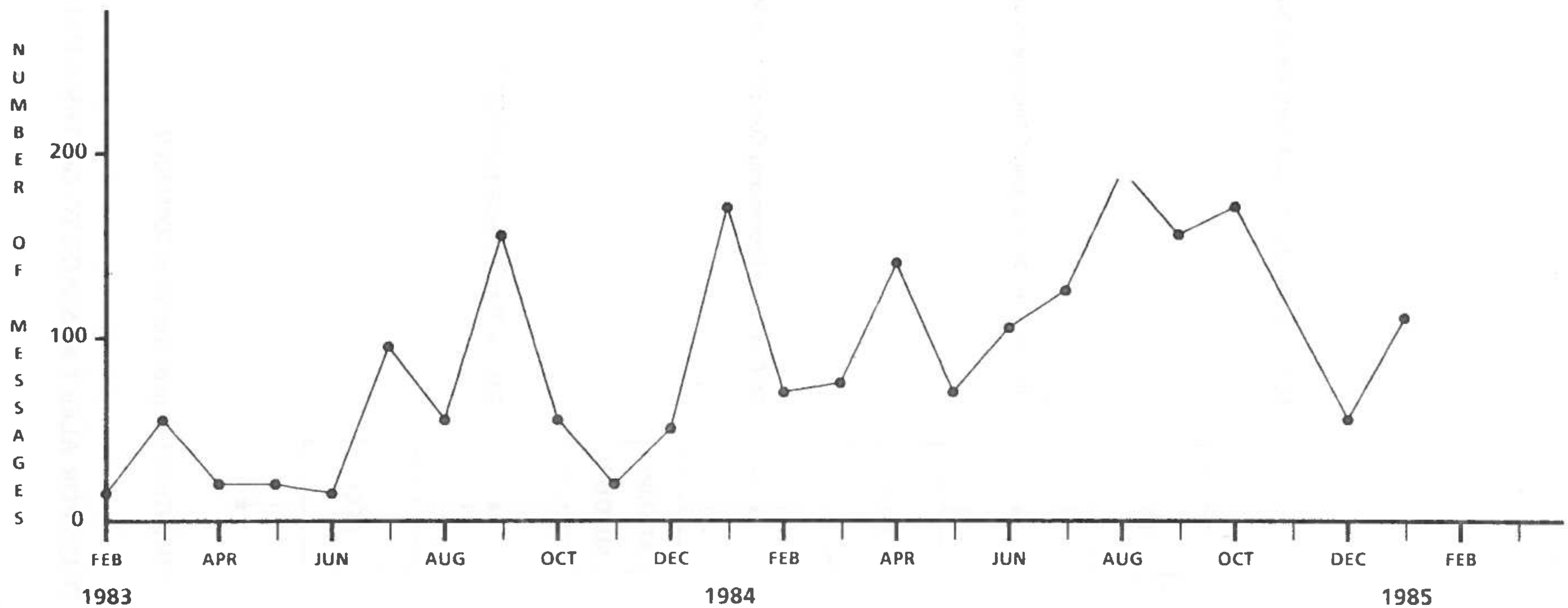

FIGURE 6-5. CASE MESSAGES RECEIVED BY USCG -- FEBRUARY 1983-JANUARY 1985

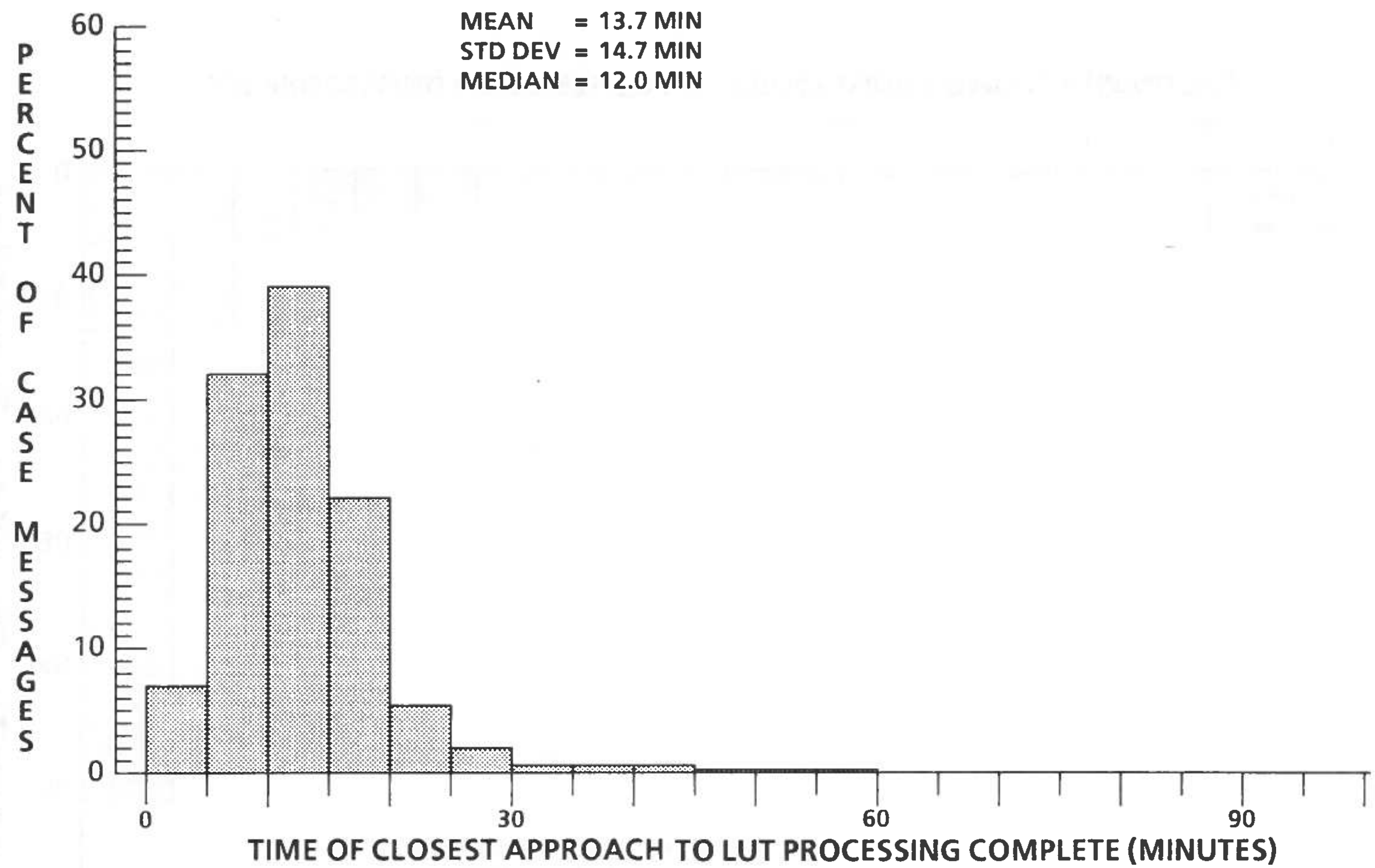

FIGURE 6-7. DISTRIBUTION OF TIME FROM TCA TO TPC -- 1652 USCG CASE MESSAGES -- 1 FEBRUARY 1983-31 JANUARY 1985

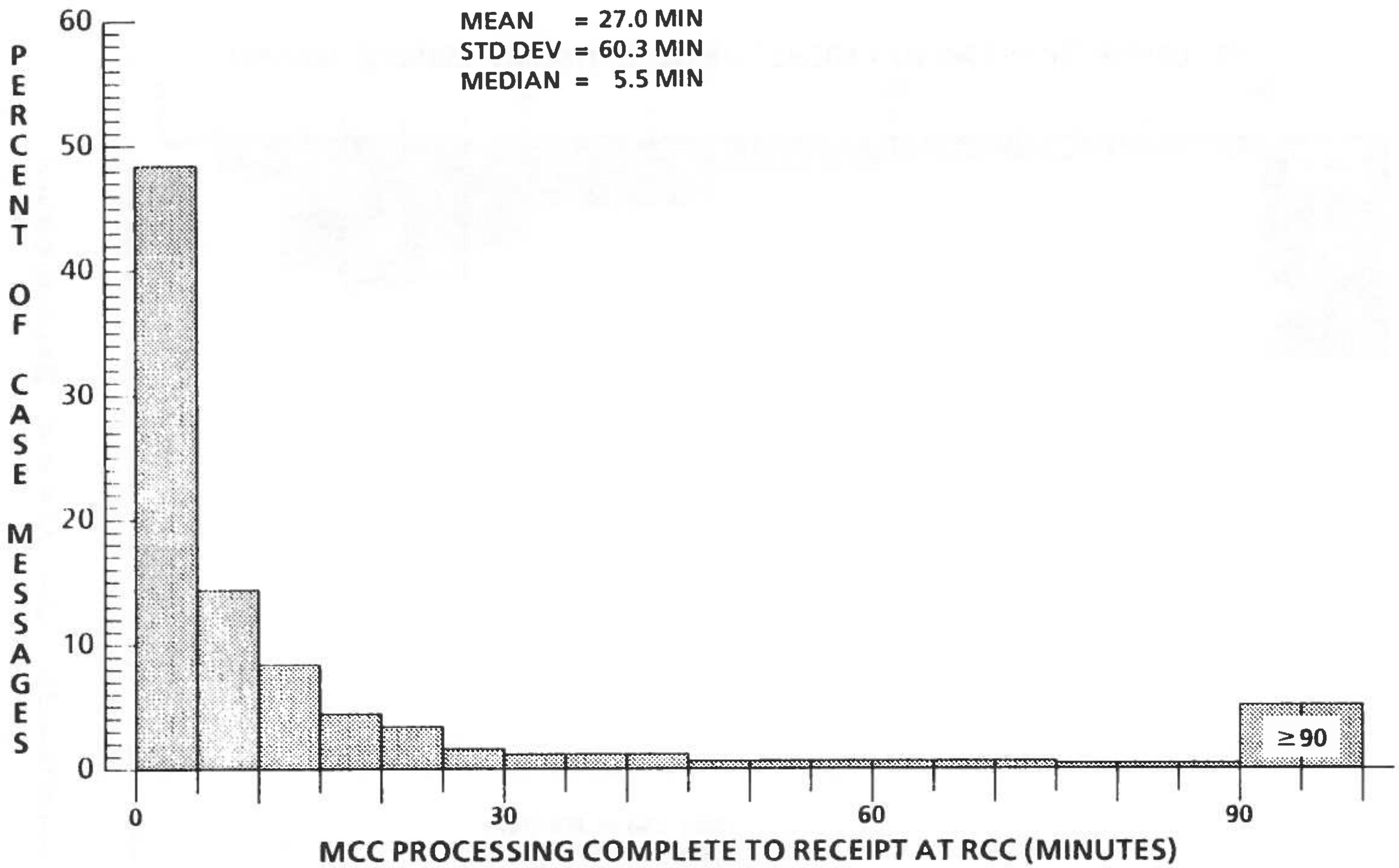

FIGURE 6-9. DISTRIBUTION OF TIME FROM TMC TO TRC -- 1652 USCG CASE MESSAGES -- 1 FEBRUARY 1983-31 JANUARY 1985

The overall distribution of times from TCA to RCC is shown in Figure 6-10. The average time is 60.4 minutes, with a median of 35 minutes and standard deviation of 74.8 minutes. Almost 18 percent of the case messages had a total TCA to RCC time greater than 90 minutes. This is a combination of the compact distribution of Figure 6-7 and the more extended distributions of Figure 6-8 and 6-9. The occasional large delays from LUT processing complete to MCC processing complete, as well as from MCC processing complete to RCC receipt, shown in the later two figures, have the following results (Table 6-4):

TABLE 6-4. TIMES FROM TCA TO RCC RECEIPT

72.2 percent less than	1 hour
27.8 percent greater than	1 hour
13.5 percent greater than	2 hours
6.8 percent greater than	3 hours
3.8 percent greater than	4 hours
2.5 percent greater than	5 hours
1.4 percent greater than	6 hours

6.2.4 Ground System Delays - Variation Over D&E Period and by District

The average values of the three time intervals of Figure 6-6,

- o TCA to TPC
- o TPC to TMC
- o TMC to TRC

as measured from 1652 U.S. Coast Guard case alert messages, varied over the D&E period as shown in Figure 6-11. As seen in that Figure, the LUT processing time (TCA to TPC) averaged consistently between 10 and 20 minutes for the entire two-year D&E period. The MCC processing time (TPC to TMC) peaked in August-September 1983 and then remained in the 6-32 minute range for the rest of the D&E. The time from MCC to RCC receipt, however, fluctuated extensively from 1 to 74 minutes during the two years. One reason for the fluctuations in time from MCC to RCC is the fact that 20 or fewer case messages were involved in some months, (i.e., February, April, May, June and November 1983). The small sample sizes in those months are more susceptible to fluctuations than are the larger sample sizes of the other months.

Another explanation for the extensive variation in the MCC-to-RCC time of Figure 6-11 is apparent from Table 6-5. This table shows the mean, median, and standard deviation of the three time intervals in question for each of the ten Coast Guard RCCs receiving SARSAT messages during the D&E. Certain districts, in particular CGDs 08, 12, 13, 14 and 17, show large values for the time from MCC Processing Complete to RCC receipt. The largest over-all ground system delays occur for the RCCs of CGDs 08, 14 and 17. Although there is no ready explanation for the delays to CGD08, the latter two districts are far separated from the mainland; communication to Hawaii (CGD14) is via a 300 baud line to a switching center, the Remote Terminal Interchange (RIXT) system. The data of Table 6-5, then, indicate that ground system delays are strongly influenced by communications. The data of Table 6-5 are given in more detail in Section J.3 of Appendix J. In order to avoid skewing the statistics by non-representative points, delays calculated to be less than 0 hours, or more than 10 hours, were excluded. Such values are caused by data errors, or by extraordinary malfunctions of ground system components, including communications lines. Therefore, the delays shown in Table 6-5 and Section J.3 of Appendix J are representative of delays during normal day-to-day operation of the ground system.

The highly variable MCC to RCC delays of Figure 6-11 may be contrasted with the more stable MCC-OCC delays of Figure 6-12, based on messages received at the Operations Computer Center. Transmissions from MCC to OCC are more typical of the delays from MCC to CGD01, CGD03, and CGD05, as shown in Table 6-5. These delays typically averaged under 10 minutes in the latter half of the D&E period. The larger fluctuations seen in the case message delays, then, are due primarily to transmission delays to the West Coast, Alaska, and Hawaii. The overall picture that emerges from Figure 6-11, 6-12, Table 6-5, and Section J.1 and J.2 of Appendix J, is that

(1) LUT Processing Times are very stable, and average between 12 and 18 minutes.

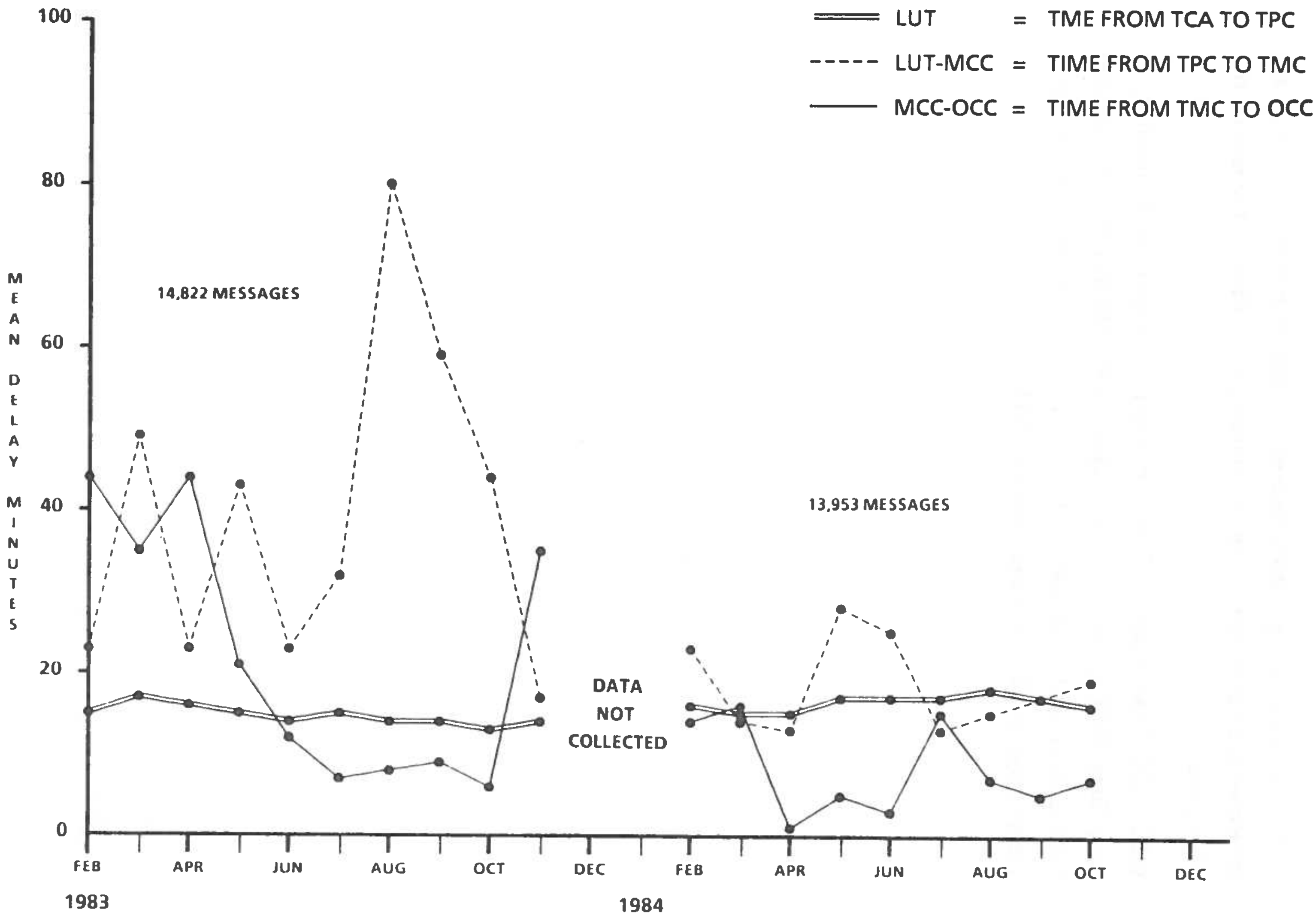

FIGURE 6-12. MEAN DELAYS IN SARSAT GROUND SYSTEM FEBRUARY 1983-JANUARY 1985, BASED ON MESSAGES RECEIVED AT OCC

7. ECONOMIC EVALUATION

The Interagency Committee on Search and Rescue's (ICSAR) ad hoc working group on satellites for distress alerting and locating estimated in 1976 that a maximum quantifiable savings of $10.7 million per year could be realized by a satellite-based system. (Reference 14.). This estimate of benefits was based on reduction of search time, savings in property, and savings in lives.

After two years of data gathering and operational experience it is possible to make a more accurate estimate of the benefits and costs of the COSPAS/SARSAT system to the U.S. maritime community. The benefits and costs are estimated in this section in order to address the D&E objectives 9 and 11, to determine cost benefits/disadvantages due to SARSAT, and to evaluate recurring costs of operating the SARSAT ground system network and facilities, equipment reliability, and maintenance requirements.

The economic evaluation presented here is based on the real SAR case data presented in Section 3, the RCC and LUT operational experience of Sections 4 and 5, and on a contractual study of SARSAT operational costs by ORI, Inc. The ORI cost models, as modified by TSC, are given in Appendix N.

7.1 APPROACH AND ASSUMPTIONS

The outcome of any economic evaluation depends on the approach and assumptions taken.

The approach taken is that of cost-benefit analysis, as opposed to cost/effectiveness or cost/benefit analyses. Although the calculation of cost/effectiveness and cost/benefit ratios is certainly possible, the straightforward addition of costs and benefits was chosen for two reasons:

1. The cost-benefit analysis is directly comparable to the ICSAR projections and is easily understood.
2. The cost-benefit approach does not require dichotomization of benefits and costs, but allows negative benefits (e.g., increased property loss) and negative costs (e.g., reduced search time). The benefit/cost criteria can vary depending on categorization of benefits and costs, as will be shown in Section 7.5.1.

The major economic assumptions made for the study are:

4. Increased utilization of Coast Guard and other U.S. government facilities and personnel are considered cost only insofar as they result in Coast Guard budget increases.

7.2 SCENARIOS

The specific assumptions for the two scenarios are given in what follows.

7.2.1 Baseline 121.5-MHz Scenario (Scenario 1)

This scenario represents a likely course of events if the present technical and regulatory environment is extrapolated to 2010 with no major initiations or changes. Under this scenario, the current 121.5-MHz ELT/EPIRB will continue under present regulation through 2010, but users will be allowed after 1990 to satisfy the regulatory requirements by means of the 406-MHz unit as internationally specified. It is assumed that, under these conditions, the 121.5/243.0-MHz EPIRB population will be 10,000* in 1990 and the 406-MHz population will still be at experimental levels in 1990. The assumed growth of the two populations after 1990 is shown in Figure 7-1. Because of an assumed price differential in favor of the 121.5/243.0-MHz unit ($250 versus $500) they will only gradually be equalled by the 406-MHz beacons. There will be a total of 20,000 EPIRBS of both types in 2010.

The additional assumptions in Scenario 1, having to do with the SARSAT ground system, are:

1. Two additional Coast Guard LUTs have been added before 1990.
2. The USMCC is operated by NOAA in Suitland MD, with alert messages distributed to the Coast Guard RCCs via Telenet and via a dedicated line to the OCC in New York.

*The conventional assumption regarding the number of EPIRBs in U.S. waters today is that there are about 6000. No substantiation could be found by TSC for that assumption during the SARSAT evaluation program. Rather, the D&E data themselves suggest there are many more than 6000. There were about 27 maritime distress cases involving an EPIRB (but not an ELT) per year during the D&E. This is about .23 percent of the 12,000 distress cases prosecuted by the Coast Guard each year. If the Coast Guard distress cases are randomly distributed among the estimated 14 million boats in the U.S., then there are about $.0023 \times 14 \times 10^6$, or 32,000 EPIRBs in U.S. waters. If the distress cases are concentrated in, say, 1/2 of the boats that frequent the coastal waters (in which EPIRBs are required for certain classes of vessels), then there are about 16,000 EPIRBs in the U.S. at present. A more accurate estimate is difficult to arrive at; 10,000 is a conservative guess.

7.2.2 406-MHz Implementation Scenario (Scenario 2)

In this scenario the 406-MHz beacon is required by regulation on new vessels and as replacement for existing 121.5/243.0-MHz units commencing 1990, with all 121.5/243.0-MHz units out of service by 2000. In parallel with this, the space segment will transition to a Low-Earth Orbiter/Geostationary relay (LEO/GEO) system with parallel phase-out of all four U.S. Coast Guard LUTs by the year 2000.

The assumed population of EPIRBs is shown in Figure 7-2. The 406-MHz EPIRBs replace the 121.5/243.0-MHz units one-for-one, plus an added growth of 500 units per year through the 1990-2010 period. At any time the total number of units in the field is the same as in Scenario 1.

Scenario 2 requires the definition of two operational ground system configurations. During the period 1990 to 2000 the ground system is essentially the same as in Scenario 1, except for the addition of a geosynchronous satellite relay of 406-MHz EPIRB data directly to the USMCC. In the 2000 to 2010 period, the ground system changes dramatically. The LUTs are removed in 2000, and all SAR/EPIRB data go directly to the USMCC via the geosynchronous satellite from the Low Earth Orbiters.

7.3 COSTS

A set of cost models was developed by ORI and revised by TSC to delineate the costs for each of the two scenarios. The costs considered are listed in Table 7-1. The resulting costs by year from 1990-2010 are shown in Tables 7-2 and 7-3 (only non-zero cost elements are given.) The basis of the cost model for each scenario is given in Appendix N.

The net cost per year of beacon purchase and replacement is developed in Appendix N, with the results entered into Tables 7-2 and 7-3, Item 10.3, EPIRB COST TO USERS. The cost to the user in these tables is the cost over and above the normal non-SARSAT costs of beacon purchase and replacement.

7.4 BENEFITS

The benefits evaluated are changes in search cost, and sortie time, and increases in property and lives saved. The economic value of lives saved is probably the greatest dollar benefit to be realized. The humanitarian, social, and personal benefits of the lives saved, while providing the major incentive for the satellite-aided search and rescue development, must be assessed outside of, and in addition to, the present purely economic evaluation.

TABLE 7-2. SCENARIO 1 -- MARITIME COSTS FOR SARSAT SYSTEM, 1990-2010

ITEM NO.	DESCRIPTION/YEAR	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
1.0	MANAGEMENT	88	88	88	88	88	88	88	88	88	88	88	88	88	88	88	88	88	88	88	88
1.3	REGULATORY SUPPORT		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.0	SPACE SEGMENT	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3.1	LUT REFURBISHMENT	-	-	250	-	250	-	-	250	-	250	-	-	-	-	-	-	-	-	-	-
3.2	LUT REPLACEMENT	-	-	-	-	-	-	-	-	-	-	-	-	2.3M	2.2M	-	-	-	-	-	-
3.3	LUT PERSONNEL	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86
3.4	LUT MAINTENANCE SUPPORT	440	440	440	440	440	440	440	440	440	440	440	440	440	440	440	440	440	440	440	440
3.5	LUT TRAINING	67	67	67	67	67	67	67	67	67	67	67	67	67	67	67	67	67	67	67	67
4.	USCG MCC REQUIREMENTS	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
5.4	OCC-SARSAT SOFTWARE MODS	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
6.2	LUT COMMO. LINES TO MCC	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120
6.3	MCC-OCC COMMO. LINES	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
7.4	406 BEACON REGISTRATION	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44
8.0	USCG OPCENS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9.1	406 HOMING DEVELOPMENT	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9.2	406 HOMING EQUIPMENT	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10.3	EPRIB COST TO USERS	250	250	250	250	250	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500
TOTAL COST 1985 DOLLARS		1175	1175	1425	1175	1425	1425	1425	1675	1425	1675	1425	1425	3725	3625	1425	1425	1425	1425	1425	1425
TOTAL COST DISCOUNTED TO 1990 $s DOLLARS		1175	1068	1178	883	973	885	804	860	665	710	549	499	1187	1050	375	341	310	282	256	233

GRAND TOTAL DISCOUNTED TO 1990 DOLLARS 14,283

As in the case of system costs, benefits are evaluated for the US maritime community, as described above, and for the 1990-2010 time period. The net benefit to be evaluated is the difference between benefits with SARSAT and without SARSAT.

7.4.1 Lives Saved

Table 3-4 is a tabulation of persons rescued in US Coast Guard ELT/EPIRB cases during the D&E. Not all of these rescued are attributable to SARSAT, since many rescues were made primarily, or exclusively, through aircraft or other means of notification. The rescues were attributed entirely to SARSAT if SARSAT was the only means of notification (SARSAT ONLY in Table 3-4), or if SARSAT was the primary means of both alerting and locating the distress (SARSAT KEY in Table 3-4). Lives saved in cases in which SARSAT was either primary only in alerting (SARSAT ASSIST-ALERT) or primary only in locating the distress (SARSAT ASSIST-LOCATE), are not easily attributable to SARSAT or to OTHER. These rescues were attributed to OTHER. This results in a low, or conservative estimate of the benefits of SARSAT. On the other hand the assumption has been made that SARSAT is entirely responsible for results in the SARSAT KEY category, which is not completely accurate either. The two approximations tend to cancel out. In addition, the SARSAT contribution to lives saved in the SARSAT MINOR category is also ignored.

The result of the above reasoning is about 73 lives rescued attributable to SARSAT in the two year D&E, or 37 lives per year. When the 1976 ICSAR economic value of a life $300,000 (Reference 14), is adjusted for inflation to 1985 (Reference 15), the result is about $576,000 per person or a total saving of $21,300,000 per year attributed to SARSAT (1985 dollars).

7.4.2 Property Saved

It was not possible to extract from the SAR case folders sent to TSC an estimate of property loss prevented. An estimate, however, may be made in one of at least three ways.

1. The 1982* SAR statistics show $7,640 of property saved per SAR case. There were 393 cases during the D&E in which SARSAT was the first or only means of notification as shown in Table 3-1. This yields about $1,500,000 property loss prevented per year due to SARSAT.

*See Reference 16. The 1983 statistics were not used because they may have been affected by COSPAS/SARSAT cases.

7.4.4 Projection of Benefits

It is reasonable to assume that after 1990, the number of Coast Guard distress cases involving ELTs and EPIRBs will be proportional to the number of such beacons in US waters. The fraction of these cases involving SARSAT will probably be greater than during the D&E, when fewer than four satellites were operating, on the average. As a conservative estimate, the expansion in future years of SARSAT's proportion of ELT/EPIRB cases will be ignored, and the fraction of ELT/EPIRB cases involving SARSAT will be assumed to remain constant, and hence proportional, to the beacon deployments assumed in Figures 7-1 and 7-2 for the two scenarios. It should be noted that at present less than 0.5 percent of U.S. vessels and boats carry EPIRBs, and that the D&E ELT/EPIRB cases represent less than 1 percent of all Coast Guard cases in the same period. Lives saved, property saved, and resources expended, then, are assumed to be proportional to the beacon populations shown in Figures 7-1 and 7-2. This is a conservative assumption also in that it ignores any reduction in false alarms or improvement in effectiveness achieved through deployment of the 406-MHz beacon in either scenario.

Since the total beacon population is the same for both scenarios in each year from 1990-2010, the stream of benefits is the same for both scenarios, and is shown in Table 7-4. The resources spent are approximately balanced by the property saved, so that the total benefit in each year is approximately equal to the economic value of lives saved.

7.5 NET ECONOMIC EVALUATION

When the stream of benefits, given in Table 7-4 is reduced by the streams of costs, presented in Tables 7-2 and 7-3 for the two scenarios, the result is the stream of net benefits shown in Table 7-5, and in Figures 7-3 and 7-4. The net 1990 value for the two scenarios is about the same:

	Net 1990 Value (in 1985 dollars)
Scenario 1, 121.5-MHz Baseline	$253.8M
Scenario 2, 406-MHz Implementation	255.6M

The annual net benefits are also similar, as Figures 7-3 and 7-4 show. The major difference is a slight drop in the annual net benefit of Scenario 1 in the years 2002-2003, when the LUTs are replaced. Both scenarios show annual benefits rising from about $20 million in 1990 to about $40 million in 2010. This behavior is traceable to the D&E data

TABLE 7-5. SCENARIOS 1 & 2 -- NET MARITIME BENEFITS FOR SARSAT SYSTEM 1990-2010 (AMOUNTS IN MILLIONS OF DOLLARS)

	SCENARIO 1 121.5-MHz BASELINE		SCENARIO 2 406-MHz IMPLEMENTATION	
	1985 DOLLARS	DISCOUNTED TO 1990	1985 DOLLARS	DISCOUNTED TO 1990
1990	20.2	20.2	19.7	19.7
91	21.3	19.3	20.8	18.9
92	22.1	18.3	21.8	18.0
93	23.5	17.7	23.2	17.5
94	24.4	16.6	24.1	16.4
95	25.5	15.8	25.2	15.6
96	26.7	15.1	26.4	14.9
97	27.5	14.1	27.6	14.2
98	28.9	13.5	28.7	13.4
99	29.7	12.6	31.0	13.1
2000	31.2	12.0	31.8	12.3
01	32.3	11.3	33.0	11.6
02	31.1	9.9	34.1	10.9
03	32.3	9.3	35.2	10.2
04	35.6	9.4	36.3	9.6
05	36.8	8.8	37.4	9.0
06	37.9	8.2	38.5	8.4
07	40.0	7.7	39.6	7.8
08	40.1	7.2	40.7	7.3
09	41.2	6.7	41.8	6.8
		253.8		255.6

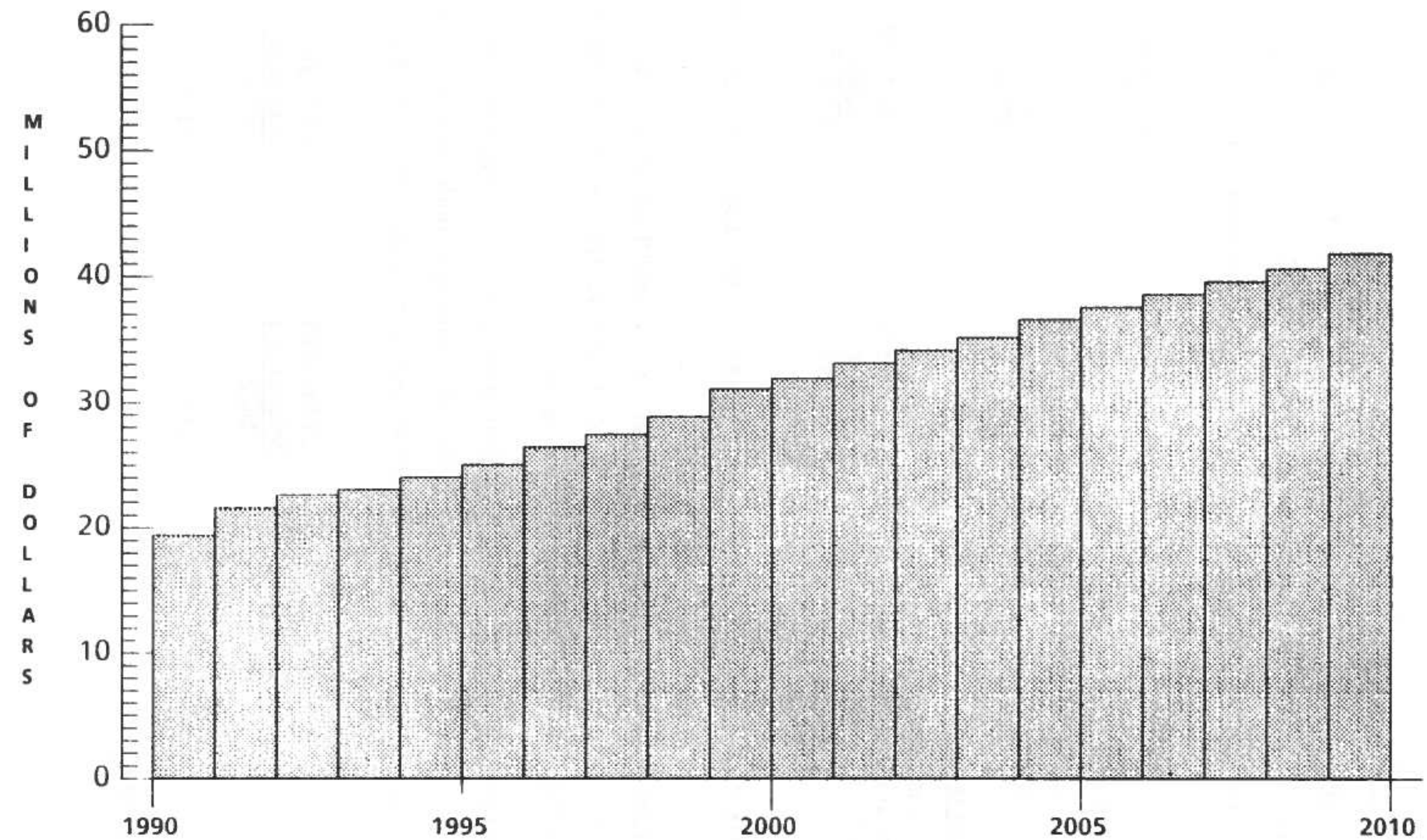

FIGURE 7-4. ANNUAL NET BENEFITS FOR SARSAT SYSTEM, 1990-2010--
SCENARIO 2

The SARSAT cost per life saved shown here is a marginal ratio, while the 1982 SAR cost per life saved is an average. The meaning of the comparison, then, is that additional dollars invested in SARSAT will return lives saved at a cost of about $42,000 to $51,000 per life, compared to an average cost of $70,000 per life for the total SAR operation in 1982 without SARSAT. Both of these figures are substantially less than the assumed 1985 economic value of $576,000 for a life (Section 7.4.1).

7.5.2 Comparison with ICSAR Estimates

The 1976 ICSAR ad hoc working group estimated lives saved, property saved, and resources saved on an entirely different basis than that outlined above. Nevertheless, the following comparisons of results may be made:

	1976 ICSAR Report	This Report
Lives Saved in 1990		
Lives	16.3	37
$M, 1985	9.388	21.30
Property Saved in 1990		
$M, 1985	9.715	0.81
Resources Saved in 1990		
$M, 1985	1.459	-0.78

Thus the ICSAR group estimated substantially fewer lives saved, but much greater amounts in property and resources saved, than is estimated in this report. Comparison of costs with those estimated by the ICSAR group is not possible, since ICSAR estimated all U.S. government costs, while this report is restricted to Coast Guard and maritime user costs. Thus, the economic evaluation presented here cannot be interpreted as a total U.S. maritime SARSAT evaluation, as was the ICSAR report.

7.5.3 Summary

1. The economic evaluation shows a benefit-cost of about $250M over the twenty years 1990-2010. The evaluation was conservative in estimating lives saved, property saved, EPIRB deployment and search time savings. It does not consider non-Coast Guard costs, however.

8. PERFORMANCE PARAMETERS

The performance parameters given in Table 1-2. form the basis for evaluation of the U.S. Coast Guard/SARSAT D&E Objectives. Evaluation of these sixteen performance parameters is made here on the basis of the D&E data and experience. In general the data are adequate to make a final evaluation of most of the parameters.

8.1 COVERAGE

8.1.1 Factors in Coverage

As discussed in Appendix H of Reference 17, the most useful method of describing coverage in the Regional Mode is by means of contours of equal mean waiting time, or of equal maximum waiting time. Coverage area, then is (1) the area within which the mean waiting time is x hours or less, or (2) the area within which the maximum waiting time is x hours or less. Complete coverage charts are beyond the scope of the present evaluation; nevertheless, the D&E data have clarified some of the major factors in determining coverage. These factors are, for the Regional Mode,

(1) Satellite availability

(2) LUT location relative to satellite orbit

(3) Minimum elevation angle at the beacon at which the satellite can detect and relay its signal.

Data taken on the floating beacon during the two Nantucket tests, the Firebush test and the Fisheries test show how elevation angle and wave height affect location probability (see Appendix E). It was found that the 121.5/243.0-MHz location probability reaches 80 percent of its maximum value at about 15 degrees peak elevation angle. For 406-MHz beacons the corresponding number is about 10 degrees, but SARSAT 1 has a decidedly lower minimum visibility angle at 406-MHz than have COSPAS 1 or 2. It was also found that wave heights above 3-5 feet have a perceptible effect on location probability, but data for wave heights above 20 feet are scarce.

Another factor became apparent during the data reduction: location error and location probability for 406-MHz beacons diminish with the number of points relayed by the satellite. (See Appendix E.) Beacons located further from the LUT have smaller overlapping areas of their visibility circles, and hence the number of points that may be

8.2 ACCURACY

The overall accuracy for 121.5/243.0-MHz tests was 11.4 nm (21.1 km) on land and 9.6 nm (17.8 km) floating. The overall accuracy for the 406-MHz tests was 2.9 nm (5.6 km) on land and 4.5 nm (8.3 km) floating, which difference is significant at the 95% level. The 406-MHz accuracy was found to be strongly influenced by the number of points relayed by the satellite and used in the solution (see Appendix E). It was found that COSPAS 2 and SARSAT 1 were significantly more accurate (about 2:1) than COSPAS 1 at both frequencies. No significant difference could be found among LUTs.

In the latest test, which is considered to be more representative of the future system, the mean 121.5-MHz accuracy was about 7 nm (13 km); the corresponding figure for the 406-MHz beacons was found to be 2.5 nm (4.6 km). Both are within the system design goals of 10-20 km for 121.5-MHz and 2-5 km for 406-MHz.

The factors influencing accuracy, such as beacon type, wave height, pass geometry, LUT, and satellite are discussed in Appendix E.

8.3 CAPACITY

The COSPAS/SARSAT System Summary (Reference 4) calls for a capacity of at least 10 simultaneous 121.5-MHz beacons and 20, 406-MHz beacons (COSPAS) or 90, 406-MHz beacons (SARSAT). No direct tests of capacity were performed by TSC, but results from other participants have verified that at least 10 beacons of either type can be simultaneously relayed by the satellite and computed by a LUT. Recent French tests (Reference 18) has verified SARSAT capacity at 90 simulated beacons with a slightly reduced detection probability.

8.4 DETECTION (LOCATION PROBABILITY)

Location probability is the probability that a properly functioning beacon, activated so that mutual visibility conditions are satisfied with a given LUT and satellite pass, will be detected by the satellite <u>and</u> located by the LUT, assuming the LUT tracks the satellite. (The term 'detection' alone refers to satellite detection of single 406-MHz burst messages.) Location probability was determined from controlled tests only.

8.4.1 121.5-MHz Location Probability

The overall location probability for both land and sea tests over the D&E was 82 percent. There was little difference between the location probability on land (83 percent) and at sea (81 percent).

	Initial Operating Date in D&E	Days Out of Service	Days In Service	Percent Availability in D&E
COSPAS I	1 Feb 83	6	725	99
COSPAS II	25 May 83	0	646	100
COSPAS III	15 Aug 84	0	170	100
SARSAT I	5 July 83	213	363	63
SARSAT II	7 Jan 85	0	25	100

These data are upper limits to availability; additional short outages may have occurred that are not included here.

8.5.2 LUT Reliability

Data taken at the Pt. Reyes LUT, as reported in Section 6 for the second year D&E shows

	Pt. Reyes	Kodiak
Effective Availability %	99.2	98.4
Inherent Availability %	98.7	95.6

These are exclusive of the antenna system, the failure of which at Kodiak reduced the Kodiak Ae to 70-75 percent.

8.5.3 Communications Reliability

The LUT to USMCC communication line effective availability, extracted from USMCC data, was calculated as

Pt. Reyes to USMCC	99.99%
Kodiak to USMCC	99.22%

The line from the USMCC to the RCCs is AUTODIN, for which effective availability data are not available.

8.7 ALARM RATES

8.7.1 Real Alarm Rate

The two years of D&E saw a sharp increase in the number of real Distress ELT/EPIRB cases compared to the Baseline, as shown in Table 8-1. The table below shows an average of 28.5 Distress cases per year during the D&E period, in which the ELT or EPRIB was the first means of notification. This is to be compared with 14.3 cases per year during the Baseline, a 99 percent increase. About 3.5 cases per year of the D&E were SARSAT ONLY and 13 per year were SARSAT FIRST. All of the SARSAT ONLY and at least some of the SARSAT FIRST cases would not have been opened without SARSAT alerts. Thus, of the 99 percent increase in comparable cases (28.5 vs. 14.3) at least 25 percent and possibly as much as the entire 99 percent would not have been recorded without SARSAT.

Another explanation for the increase in ELT/EPRIB Distress cases during the D&E may be an increase in the number of EPIRBs in operation in US waters during 1982-1984. This explanation is supported by the increase in such cases in 1982, the year before SARSAT data were taken.

TABLE 8-1. ELT/EPIRB DISTRESS CASES PER YEAR, BASELINE VS. COAST GUARD D&E PERIOD

	SARSAT ONLY	SARSAT FIRST	OTHER ONLY	OTHER FIRST	TOTAL
BASELINE* FEB 80-JAN 83	-	-	14.3	-	14.3
D&E* FEB 83-JAN 85	3.5	13.0	5.0	7.0	28.5
D&E** FEB 83-JAN 85	3.5	13.0	6.5	14.0	37.0

*Only cases in which the ELT or EPRIB was the first means of notification.
**Including cases in which the ELT or EPIRB was not the first means of notification.

preliminary analysis shows that about 86 percent of the ELT/EPIRB cases in the D&E are classifiable as False Alarms or False Alerts (see Table 4-7). Another unknown, and potentially large, number of false alarms is contained in the estimated 9600 SARSAT messages involved in multiple 'hits,' and in the 40,100 or more single 'hits,' that were received but not prosecuted as cases during the D&E (see Table 8-2).

TABLE 8-2. DISTRIBUTION OF COAST GUARD SARSAT MESSAGES AMONG CASES AND LOCATIONS

	Number of Cases or Locations	Number of SARSAT Messages	Number of Other Messages	Total Number of Messages
DISTRESS CASES	74	426	117	543
NON-DISTRESS CASES				
TRUE NON-DISTRESS	14	63	9	72
FALSE ALARMS & FALSE ALERTS	338	1407	384	1791
NOT LOCATED				
FALSE ALARMS & FALSE ALERTS	233	612	214	826
TOTAL PROSECUTED	659	2508	724	3232
NOT PROSECUTED				
MULTIPLE HITS*	7,492 or fewer	14,984 or fewer	0	14,984 or fewer
SINGLE HITS*	41,626 or more	41,626 or more	0	41,626 or more

*Based on an estimated 59,118 messages received during the D&E of which about 9,341 had flags (Table 4-2.); and 2508 case messages of which 1849 had flags (Table 4-3.).

If all single and unprosecuted multiple hits are false alarms, originating from ELTs or EPIRBs, there would be a total of about from 24,000 false alarms per year detected by SARSAT. The US Air Force prosecutes about 24 ELT/EPIRB false alarms per day, or about 9000 per year.

121.5/243.0.0-MHz and 88 percent for 406 MHz. No pronounced difference was noted between land, deck, and floating beacon tests for 121.5/243.0-MHz. The 406-MHz beacons, however, showed a lower A-position correctness (79 percent) when floating than when on land (92 percent) or on deck (92 percent).

8.9 WAITING TIME

Waiting time is the interval from beacon activation to TCA. The real cases do not afford an adequate basis on which to evaluate waiting time accurately, because the time of beacon activation is not usually known accurately or recorded, and because the number of satellites was not constant throughout the D&E.

A broader estimate of waiting time can be obtained from simulation, as described in Section 8.1, Coverage. Although such a simulation has not been constructed, a crude estimate of waiting time can be obtained without it by making certain simplifying assumptions. It is assumed that:

a. Satellite visibility occurs at 15 degrees or more elevation angle at the beacon

b. The beacon visibility circle is entirely within some LUT visibility circle

c. The beacon latitude is between -40 degrees and +40 degrees

d. The satellites' orbital planes are equally spaced

e. The satellites all have the same period, p

f. The location probability is 1.0 per LUT per pass.

With these assumptions the beacon will be detected four times per day per satellite and the mean inter-pass time $\bar{y}$ will be 1440/4n minutes, where n is the number of satellites. Moreover, the mean square inter-pass time will be

$$\overline{y^2} = (\bar{y} - p)^2 + (\bar{y})^2,$$

and the mean waiting time $\bar{x}$ (see Appendix L) will be

$$\bar{x} = \tfrac{1}{2}\, \overline{y^2}/\bar{y}.$$

1 February - 30 November, 1983	42 minutes
1 August - 31 October, 1983	59 minutes
1 February - 31 October, 1984	17 minutes

The second year data may be taken as more typical of what could be expected in the next five years. The standard deviation of MCC processing time in the second year of the D&E was about 30 minutes. Over the two years the LUT-MCC delay had an average value of 20 minutes, a median of 5 minutes, and a standard deviation of 41 minutes.

8.11 COMMUNICATION TIME

8.11.1 LUT/USMCC

This time was not directly measurable. It may be assumed that, because its capacity of 9600 baud is far above the loads imposed, the delays were not excessive (see Section 6). Nevertheless the temporary loss of communications would result in delays added to the MCC processing time numbers alone.

8.11.2 USMCC/RCC

Average delays from USMCC transmission to RCC receipt were measured for the two year D&E period. The results, given in Section 6, are:

Average Delay	27.0 minutes
Median Delay	5.5 minutes
Range of Delays	0-364 minutes
Standard Dev	60.3 minutes

These delays include all districts, and include the AFAMPE delays. It is noted that delays for CGDs 13, 14 and 17 were affected by the lower speed lines available to them, averaging 12.1, 23.2 and 13.5 minutes, respectively.

8.12 PLANNING TIME

Planning time is the time from first notification of the RCC to time of tasking the first resource. The average planning time for distress cases during the D&E was 6.4 hours, as shown in Table 3-5. The 29 cases in which SARSAT provided the only or the first means of notification show larger planning times, 9.9 and 9.4 hours, respectively than the Other Only or Other First cases, which are 1.5 and 4.2 hours. This is probably due to the

(1) The additional workload imposed by SARSAT is being absorbed by the RCC controllers by adaptation of procedures.

(2) The additional workload imposed by SARSAT messages is causing occasional overloads at peak times at CGD03 and CGD12, primarily due to the SARSAT messages addressed to the Area Commands. This loading is expected to be alleviated by changes presently being implemented in USMCC software.

8.15. COMMUNICATION LOAD AND COST

The load on U.S. Coast Guard communications induced by SARSAT occurs in two areas, the LUT/USMCC leased lines and the USMCC/RCC AUTODIN lines.

> LUT/USMCC The load on these lines was not directly measured but it is well within the capacity.
>
> USMCC/RCC The average SARSAT message load was measured to be about 1.5 percent of capacity in the most heavily loaded district (CGD03) in the peak month of the first year D&E (August 1983). The loading level is considered to present no problem to the AUTODIN lines to the RCCs.

The cost of the LUT/USMCC communications during the D&E was about $120,000 per year, of which the Coast Guard paid one-third. THe USMCc/RCC communications cost (AUTODIN) is not billed to the Coast Guard under SARSAT.

8.16 LUT COSTS

The cost of LUT maintenance and operation are covered in Section 7. If the present 121.5/243.0-MHz beacon regulations are retained with gradual phase-in of 406.-MHz beacons by 2010, they will average $593,000 per year for four LUTs plus $1.0 million for refurbishment, plus $5.5 million for replacement in the 1990-2010 period (see Table 7-2). If the 406-MHz beacon is phased in by regulation by 2000, the LUT costs will be $593,000 per year for four LUTs from 1990 to the year 2000, plus $0.5 million refurbishment, with no replacement costs. (See Table 7-3.)

8.17 SUMMARY OF PARAMETERS

The sixteen United States Coast Guard/SARSAT performance parameters, as observed during the D&E, are summarized in Table 8-3.

TABLE 8-3. USCG/SARSAT PERFORMANCE PARAMETERS (CONTINUED)

SUMMARY OF TWO YEAR D&E

Parameter	Value	Comments
6. 406 Message Transmission		
Short	---	o Operative during D&E
Long	---	o Operative at end of D&E
OPERATIONAL PARAMETERS		
7. Alarm Rates		
Real	28.5 distress cases per year	o Compared to 14.3/per Baseline
	81% prob of pickup	o Compared to 88% by other than SARSAT
Image	56%	o Of CG messages are images from Inland and Other areas
False	86%	o CG ELT/EPIRB cases are 86% False Alarms
		o About 28,300 false alarm messages/year
Spurious	---	o Extent unknown
Redundant	5.8	o SARSAT messages per distress case
8. Image Rejection		
121.5-MHz	71%	
406-MHz	79% floating 92% land	
9. Waiting Time	46 min	o Very simplified estimate for 4 satellites, Regional coverage, within $\pm 40^{\circ}$, latitude
10. Processing Time		
LUT	12-18 min	o Constant over the year.
USMCC	17 min	o Average over the second year; median 5 min.
		o monthly average peaked in August 1983 at 59 min.
11. Communication Time		
LUT/USMCC	---	o Not measured
USMCC/RCC	27.0 min	o Average; peaks to 6 hours in 1983; median 5.5 min.
DPSS/USMCC	---	o Not measured

9. USCG/SARSAT D&E OBJECTIVES

Accomplishment of the USCG/SARSAT D&E objectives was judged on the basis of the critical performance parameters presented in the preceding section, acccording to Table 1-2. In interpreting the objectives, 'identify' was taken to include detection as well as identification; 'SARSAT' was taken to include COSPAS as well as SARSAT.

Objective 1

Demonstrate the ability of the SARSAT system to identify, process and determine the location of single and multiple 121.5/243.0-MHz and 406-MHz EPIRBs in the Regional mode of operation.

121.5/243.0-MHz

The D&E data show that this objective has been met with regard to the 121.5/243.0-MHz system, and with unexpected success in the area of detection and location. The conclusion is based on:

a. Average location accuracy within the 6 nm to 12 nm (10-20 km) goal;

b. Capacity better than the 121.5/243.-MHz goal of 10 simultaneous beacons;

c. Detection (Location Probability) of 82 percent; and

d. Reliability (as measured by effective availability) of 98.8 for the LUTs, over 99 percent for the LUT/MCC communication lines, and 87.8 percent for the USMCC.

Within days of the first launch on 30 June 1982, the COSPAS/SARSAT system demonstrated its unexpectedly high sensitivity to the 121.5-MHz ELT/EPIRB signal, even though the output power is less than 100 mw for the ELT/EPIRB common in the U.S. During the D&E period over 650 beacon activations were detected by the system, reported to the Coast Guard, and recorded as SAR cases. The system has provided a location for all detections, and tests have shown the location accuracy to be within the system design goal of 10-20 km. System capacity has on numerous passes been observed at 18-24 beacons simultaneously, compared to a design requirement of 10 beacons.

and French -- 76 percent -- (Reference 8). It is likely that improved mechanical and electrical design can increase this probability to the range of the 121.5-MHz beacon, and above.

In addition to the excellent accuracy and ambiguity resolution, the 406-MHz system identification and short message transmission were successfully demonstrated in the D&E tests.

Objective 2

Determine the degree to which the SARSAT system may reduce times between initial incident occurence and visual sighting of the distress incident.

The D&E data show no reduction in time from incident occurrence to visual sighting due to SARSAT. In fact, in cases in which SARSAT was the only or the first means of notification, the time from occurrence to sighting was substantially longer than in cases in which SARSAT was not present or not first in the notification (see Table 9-1).

The time from incident occurrence to visual sighting of the distress unit consists of notification time, planning time and search time. These are estimated in Table 9-1 for SARSAT ONLY and FIRST cases, OTHER ONLY and FIRST cases, and for the Baseline cases. The D&E Notification Times in Table 9-1 are estimated on a four-satellite system; the actual times recorded in the D&E are much longer (see Appendix F), because there were fewer than four satellites during the D&E. Even with these relatively low 1.48 hour Notification Time estimates, the Total Times for SARSAT ONLY and SARSAT FIRST cases are about twice those for the Baseline cases, primarily because of the long Planning Times connected with the SARSAT ONLY and FIRST cases. It appears that a lack of credibility in the SARSAT alerts has contributed to an extended Planning Time when other information sources are not present. (See Section 4.) Development of the 406-MHz beacon with ID should help reduce the SARSAT planning time by allowing the controller to check more rapidly whether the beacon owner is aware of the transmission.

Objective 3

Evaluate the degree to which 121.5/243.0-MHz assisted SAR operations may be improved by SARSAT.

The relevant performance parameters that have been estimated in the D&E are:

a. Real alarm rate of 28.5 cases per year (effective increase of 99 percent over Baseline) for distress cases;

b. False alarm rate in excess of 86 percent;

c. Redundant alarm rate of 5.8 messages per distress case;

d. Image alarm rate of 56 percent;

e. Image rejection of 70 percent for 121.5 MHz;

f. RCC workload within capacity of controllers;

g. Mean waiting time of 46 minutes (estimated);

h. Planning time of 6.4 hours for distress cases;

j. Search time of 1.0 hours for all cases; overall 40% below Baseline.

Overall, SARSAT seems to have dramatically increased the ELT/EPIRB involvement in SAR cases. The number of ELT/EPIRB distress cases has gone up by 99 percent during the D&E. Many of these cases would probably have been prosecuted, but without ELT/EPIRB information, in the absence of SARSAT. SARSAT can only have expedited their prosecution. At least 7 of these cases during the D&E had no means of notification other than SARSAT. Moreover, SARSAT provided key alerting or locating information in another 37 cases, in which 107 people were rescued during the D&E. In addition, the RCC controllers have assimilated the alert messages into their operations without disruption or excess workload.

SARSAT may have resulted in a reduced search time. As seen in Table 9-1, the hours per search when SARSAT was the only, or first, means of notification were about 27 percent less than those for the Baseline cases, although the reduction may not be due to SARSAT.

On the other side of the picture, the high false and image alarm rates in the present SARSAT system have hindered the effectiveness of the RCC operations. The planning time for SARSAT based SAR operations is twice that of non-SARSAT operations. (Table 3-5.) Over 86 percent of SARSAT cases are false alarms, compared to 63 percent in Baseline ELT/EPIRB cases. The 121.5/243.0-MHz image rejection probability of 71 percent is inadequate for practical use. Over 56 percent of the alerts received at Coast Guard RCCs are images, primarily of real inland locations.

No comparison can be made with regard to the remaining critical parameters (planning time, search time, RCC workload).

<u>Objective 6</u>

Evaluate the potential improvements in future SAR operations using 406-MHz EPIRBs.

The potential improvements in SAR operations using the 406-MHz EPIRB are in the following areas:

a. Accuracy: The 406-MHz position error magnitude averages about 40% of that for the 121.5/243.0-MHz system. This reduces the area of uncertainty by 84 percent, which should greatly facilitate the identification of the source by the RCC controller. It will tend to reduce launches for false alarms and reduce search times. It will also improve the merge process at the USMCC by reducing erroneous groupings of locations. In addition it will provide much better information for drifting EPIRBs, since the controller will be able to observe the motion of the EPIRB with fewer alert locations on hand.

b. Location Probability: The 406-MHz location probability was estimated to be less than that of the 121.-MHz system for floating beacons. Investigations underway should clarify the causes and lead to remedies. Moreover, the digital reception of 406-MHz signals makes it economic to install 406-only LUTs, thus reducing costs and improving the probability of locating a beacon. Finally the 406-MHz Global Mode removes the requirement for LUT visibility, thus increasing the visibility time. Therefore, Global Mode location probability, which is accessible only to 406-MHz beacons, although not tested during the D&E, should be greater than the Regional Mode location probabilities to which the 121.5-MHz system is restricted.

c. Image Rejection: The 406-MHz image rejection (79 percent floating, 92 percent land) may not be high enough to allow the RCC controller to ignore a 'B' solution, and hence would result in only slight improvement in operation.

d. False Alarm Identification: The beacon identification code contained in the 406-MHz message has been demonstrated successfully. It should aid in more rapid identification of false alarms. In addition, the improved accuracy will allow the controller to isolate more rapidly the particular airport or marina

Objective 8

Characterize SARSAT system performance parameters.

The system performance parameters referred to in this objective are those of Reference 1. They are discussed individually in Section 8, Table 8-3.

Objective 9

Determine cost benefits/disadvantages due to SARSAT.

The economic analysis of Section 7 shows that SARSAT benefits far exceed its costs when considered over the 1990-2010 time period. There is relatively little difference economically between the 121.5-MHz baseline (no change) scenario and the 406-MHz (full implementation) scenario, until the year 2000, when the 406-mHz scenario begins to show a slight advantage.

Objective 10

Determine the increase/decrease in US Coast Guard workload produced.

This objective has been largely achieved (Sections 4.4 and 5.1). Both LUT and RCC workloads have been studied and evaluations made of loading. In the case of the RCC, however, these estimates are qualitative. Some further adjustments are expected at the RCC due to additional satellites and evolution of the ground system techniques in message merging and processing.

Objective 11

Evaluate recurring costs of operating the SARSAT ground system network and facilities, equipment reliability and maintenance requirements.

As the results given in Section 7.0 indicate, this objective has been achieved.

10. OBSERVATIONS AND CONCLUSIONS

The main conclusions of this report are contained in the preceding section on D&E objectives. Other less obvious but important results have emerged from the D&E effort and are collected here (relevant sections are indicated in parentheses).

SARSAT Alerting In Remote Areas (3.3.2)

The COSPAS/SARSAT system has been extraordinarily effective in alerting in remote areas such as Alaska. SARSAT was the primary means of alerting in 75 percent of the Alaskan ELT/EPIRB cases reported by the Coast Guard, but in only 32 percent of ELT/EPIRB cases outside of Alaska. Eighty percent of the lives saved in Alaska via ELT/EPIRB were done so in SARSAT FIRST or SARSAT ONLY notification cases, compared to 31 percent outside of Alaska.

False Alarm Causes (4.2.3)

ELT/EPIRB false alarms with known causes during the D&E were attributable 53 percent to human error, 35 percent to equipment or installation faults, and 22 percent to other causes. But in the vast majority (over 78 percent) of false alarms the cause was not ascertained.

Similarly, 61 percent of false alarms during the D&E in which source was identified originated from EPIRBs, and 39 percent from ELTs. But in about half of all maritime false alarms, the case was not prosecuted far enough to determine whether the source was an EPIRB or an ELT.

Fringe Area Coverage (8.1.2)

Hawaii is on the fringe of LUT coverage. As a result, SARSAT was involved in only 21 percent of ELT/EPIRB cases in CGD 14, compared to 59 percent for all districts. In

Kodiak Remoteness (5.2.7)

The remote location of the Kodiak LUT has contributed to delays in maintenance. This situation, plus the larger number of missed passes due to pass conflicts, make a second LUT at Kodiak an attractive option for improving performance of the system as a whole.

Accuracy vs. LUT (2.4.1, Appendix E)

The LUTs showed, overall, no significant difference in accuracy of their position solutions.

Accuracy vs. Frequency Stability

The 121.5/243.0-MHz beacons had a mean location error of 10. nm with an intermediate (15 min) frequency stability of about one part in 10^7 per minute; the 406-MHz beacon had a mean location error of about 4 nm with a frequency stability of about 1 part in 10^9 per minute. This suggests that location error is not proportional to frequency stability, and that good location accuracy can be achieved with less than 1 part in 10^9 per minute frequency stability.

LUT Performance (5.2.4, 5.2.5)

The Pt. Reyes LUT effective availability increased from 98.6 percent in the first year of the D&E and 99.2 percent in the second, due to improved maintainance procedures. Software failures and maintainance, although improved, continued to be the major source of LUT non-availability at Pt. Reyes.

A single antenna failure at the Kodiak LUT resulted in over 30 days outage. The effect on availability was due more to the extended time to repair rather than to frequency of occurrence.

Drifting Beacons (2.5.2)

The Gulf of Mexico Exercise showed that a running average of SARSAT positions can be expected to follow a drifting beacon. The requirements for drifting beacon alerts need to be documented for incorporation into the USMCC. The exercise also demonstrated the accuracy of the 121.5/243.0-MHz system in real SAR situations.

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