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FINAL REPORT

CONTROL OF ELT FALSE ALARMS

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October 1979

NASA Headquarters
Communications Division
Code EC-4
under Contract NASW-3229

ARINC RESEARCH CORPORATION

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CONTROL OF ELT FALSE ALARMS

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by

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ABSTRACT

This report presents the results of a study of the statistics of Emergency Locator Transmitter (ELT) alarms for NASA's Communications Division (Code EC-4). The primary sources of data include ELT Incident Logs, Service Difficulty Reports, and Frequency Interference Reports. The number of reported and unreported alarms is discussed, as are seasonal variations, duration of ELT transmissions, and cost of silencing. Origin, causes, and possible strategies for reducing the impact of alarms on the aviation community are considered.

SUMMARY

Emergency Locator Transmitters (ELTs) are acceleration-triggered emergency radio beacons intended to assist in locating aircraft crashes. However, ELTs have demonstrated an excessive false alarm rate. On the basis of incident records examined, at least 95 percent of all ELT alarms represent nondistress situations.

This report examines ELT false alarms based on records collected since the inception of the ELT program. The primary sources of information were ELT Incident Logs collected at the Air Force Rescue and Coordination Center (AFRCC), Service Difficulty Reports (SDRs) collected by the FAA at Oklahoma City, and Frequency Interference Reports (FIRs) submitted by Air Traffic Control Towers (ATCTs) and Flight Service Stations (FSSs) to FAA Headquarters.

The number of reports of ELT alarms has decreased significantly since 1975; however, indications are that this reduction may be attributable more to factors related to reporting efficiency than to an actual decrease in the number of alarms. It is estimated that approximately 19,300 total ELT false alarms occurred during 1978, of which only 22 percent, or 4,250, were reported. The other 15,000 were terminated without any centralized records being maintained of the incidents. The expected average of 6.5 simultaneous alarms is well under the expected capacity of the proposed search and rescue satellite (SARSAT).

ELT false alarms exhibit seasonal variation of approximately ±20 percent about the annual mean, occurring most frequently during spring and early summer and decreasing significantly during fall and winter.

Most ELT false alarms occur at airports and transmit, on the average, about three hours. Alarms at towered airports, which account for nearly 45 percent of all false alarms, are silenced noticeably more rapidly than those occurring at nontowered airports and off-airport environments. Silencing is typically accomplished by local search and rescue crews, who will either disarm the unit themselves or request the owner to do so.

The cost of resources applied to silencing ELT false alarms is estimated at more than $2 million annually. Most of these resources are expended by local governments and volunteers; however, the Federal Government provides significant support in coordinating interstate search and rescue

(SAR) operations. The most expensive alarms to locate and silence originate at nontowered airports.

The primary causes of false alarms are related to technical difficulties with the units' internal batteries and trigger mechanisms. Short of replacing all units in the field, there appears to be no universally effective solution to the present situation, although significant improvements can be achieved within several years through a combination of educational and administrative actions.

The recent Airworthiness Directive issued by the FAA concerning lithium sulfur dioxide ($Li-SO_2$) batteries is expected to reduce the number of corrosion-induced false alarms by 37 percent. In addition, the most promising strategy to alleviate the remaining problems experienced with ELTs consists of the specific activities listed in Table S-1.

Table S-1. RECOMMENDED SOLUTIONS FOR REDUCING ELT FALSE ALARMS

Activity	Benefit*
Review records for defective trigger mechanisms; Survey ELT alarm reports to manufacturers	Prepare detailed plan for implementing corrective actions
Distribute ELT alarm reports to manufacturers	Encourage redesign of faulty units
Develop ticketing procedure for offenders	Reduce false alarms by 10 percent; Reduce cost of SAR operations by 10 percent
Provide daily reminders to pilots	Reduce cost of SAR operations by 5 percent
Encourage pilots to monitor emergency bands	Reduce cost of SAR operations by 6 percent
Distribute direction-finding equipment to SAR organizations	Reduce cost of SAR operations by 5 percent
Develop alternative triggering mechanisms	Reduce false alarms by 25 percent
Establish automatic ELT signal detector and notification capability at airports	Reduce cost of SAR operations by 3 percent
Develop and encourage use of standard ELT localizing procedure	Reduce cost of SAR operations by 3 percent

*Benefits calculated on the basis of sources and causes of ELT transmissions and estimated costs of locating and silencing.

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CHAPTER ONE

INTRODUCTION

Emergency Locator Transmitters (ELTs) are self-contained radio beacons that are installed in most general aviation and military aircraft and are designed to broadcast an emergency radio signal in the event of an aircraft crash. The effectiveness of search and rescue (SAR) operations for downed aircraft depends in part on the ability of SAR units to detect and locate the crash site rapidly by homing in on transmissions from the ELT installed in the downed aircraft.

Although ELTs theoretically are a very valuable safety device, they have exhibited an excessive false alarm rate. In fact, it has been estimated that more than 95 percent of all ELT signals detected represent false alarms. Each of these false alarms places unnecessary burdens on SAR operations by triggering unproductive search flights and diverting resources away from true emergencies. In addition, the entire SAR community has been demoralized by the psychological impact of these false alarms to the point where ELT signals frequently are not taken seriously.

Therefore, to take full advantage of the possible benefits of ELTs, the number and duration of false transmissions must be minimized -- either by developing a new generation of more effective ELTs or by improving the efficiency of current SAR operating procedures. This report, prepared for NASA's Communications Division (Code EC-4) under Contract NASW-3229, describes the nature and extent of the false alarm problem. The report also addresses the costs and benefits of changes to current operating procedures, with the goal of reducing false alarms and better identifying both distress and nondistress ELT transmissions.

1.1 BACKGROUND

The ELT is an inexpensive device designed to broadcast an emergency 121.5 or 243.0 MHz radio signal automatically when triggered by a large deceleration characteristic of an aircraft crash. ELTs have been used on military aircraft since the mid-1950s; however, they have been required on civil aircraft only since 1974.

Major problems with the ELT concept implementation began to surface at the outset of the program. In 1970 Congress mandated the installation of ELTs in most general aviation aircraft by 1 January 1974. Later, Congress extended that deadline by six months to allow more time for retrofitting existing aircraft. An estimated 140,000 ELTs were installed in this initial period; since then, the market has been limited to 20,000 annual original equipment (OEM) installations in new aircraft and 5,000 annual replacement units.

Many manufacturers, some with little avionics design experience responded to accommodate the mandated demand. The rush to fill the nonrecurring demand, coupled with the inexperience of many suppliers, resulted in significant technical and operational problems. Many of these problems still remain. For example, the present ELT program suffers from inadequate receiver coverage, ELT malfunctions, and ELT misuse as follows:

- Ground coverage is limited by line-of-sight transmission constraints.
- Airborne coverage is accomplished voluntarily by general aviation pilots.
- Accurate localization of signals is frequently limited to a large area.
- Broadcasting may cease before the source is located.
- ELTs frequently fail to activate when crashes do occur.
- Only about three percent of all reported ELT broadcasts represent legitimate emergencies.

In the long term, the installation of a new generation of ELTs could solve many of these problems, but retrofitting the aviation fleet with new equipment would be expensive and time-consuming. The Radio Technical Commission for Aeronautics (RTCA) is currently developing a specification for a second-generation unit. The specification is expected to result in a new FAA Technical Standard Order (TSO) some time in 1983. Even then, retrofitting of all existing aircraft probably will not be required. Therefore, alternative short-term solutions must be developed to improve the effectiveness of existing ELTs. Even without the benefit of a new generation of improved ELTs, more acceptable monitoring of emergency frequencies and more rapid identification and silencing of ELT transmissions could improve the effectiveness of the current system.

NASA is supporting the application of search and rescue satellites to enhance significantly the monitoring of emergency signals and to assist in the location and silencing of ELT transmissions. The first of these satellites, SARSAT, will provide national coverage at least twice daily, beginning in 1982. SARSAT will be capable of receiving and sorting up to about 10 ELT signals simultaneously while locating each signal source to within an average radius of 10 kilometers. The instantaneous capacity and accuracy of the satellite will depend on the geographic, spectral, and temporal distribution of ELT signals. Thus it is desirable to reduce the instantaneous number of ELT false transmissions in order to minimize the possibility of overloading the satellite. Alternatively, the same effect could be achieved through more rapid silencing of detected false alarms.

1.2 PURPOSE

The purpose of this study is to evaluate the causes and characteristics of nondistress ELT transmissions and to develop a short-term strategy for minimizing their impact on search and rescue (SAR) operations. Specifically, the objectives and effectiveness of this strategy may be defined in terms such as reductions of instantaneous multiple alarm rates, higher ratio of true distress calls to false alarms, shorter SAR missions, and lower costs of missions.

An ideal strategy is one that could be fully effective within three years and yet involve only a minimal number of personnel. It would be desirable not to burden aircraft owners with any additional "up front" expenses.

1.3 SCOPE

The short-term perspective of this study limits the set of possible alternative strategies. For example, major technical perturbations to either ELT or satellite design cannot be completed in less than five years and therefore do not fall within the scope of this effort. Efforts must be focused on developing administrative approaches that can be implemented easily, effectively, and quickly so as to be fully operational and effective within three years of adoption.

The statistics of the ELT population have changed markedly since 1974 and continue to change daily. Manufacturers' experience has resulted in product modifications, customer preferences have altered the mixture of available models, and user perceptions of ELT effectiveness have been tempered by personal experiences. Although the existence of such trends in the aviation community cannot be ignored, this report makes no attempt to extrapolate these trends into the future. This study uses 1978 "snapshot" data from a dynamically changing ELT environment and implicitly assumes that the characteristics of this "snapshot" will hold over a 5- to 10-year period. However, for the purpose of evaluating the effectiveness of various alternative strategies, careful consideration has been given to recent developments within the industry.

There is an important distinction between a false alarm (nondistress transmission) and a missed alarm (failure to transmit after a crash). The latter problem is not a major focus of effort in this study.

ELTs were assumed to be black boxes that exhibit specific definable statistical characteristics. Proposed solutions are directed toward changing those statistics through administrative procedures rather than changing the black boxes themselves. Hardware solutions involving internal changes to ELT designs are, for the most part, beyond the scope of this study.

Most ELT false alarms occur within the boundaries of the contiguous 48 states in the continental United States. The aviation community and search and rescue operations in Alaska and Hawaii are sufficiently different to require special consideration. For this reason, and because the data sources for Alaska and Hawaii are not collocated with the data sources for the rest of the country, Alaska and Hawaii were not examined.

1.4 ORGANIZATION OF REPORT

This report is divided into seven chapters covering four broad topics. Chapter One presented the background, purpose, and scope of the study, and addressed some of the initial constraints imposed on the effort. Chapter Two addresses the mechanics of search and rescue operations and how they affect the search for ELTs. Chapter Three describes the available sources of data and summarizes the procedures used to collect these data.

Chapter Four presents the statistics of the false alarm reports compiled in the data sources described earlier. However, many ELT alarms are not reported; therefore, the statistics presented in Chapter Four represent only a sample of the total number of ELT false alarms. Chapter Five, therefore, develops estimated statistics for the total population of ELT false alarms, reported and unreported. It is important to note that the same parameters are discussed in Chapters Four and Five, but their values are different because Chapter Four describes only a sample of the total universe of ELT alarms addressed in Chapter Five. Chapters Six and Seven are discussions of corrective action strategies that might be used to solve the ELT false alarm problem. The effectiveness of these strategies is evaluated on the basis of total ELT alarm estimates developed in Chapter Five. Chapter Six evaluates the relative priorities, goals, and approaches for corrective action relative to the false alarm problem. Chapter Seven provides conclusions and recommendations for specific implementation plans that would alleviate the false alarm problem.

A bibliography is presented in the appendix.

CHAPTER TWO

SEARCH AND RESCUE OPERATIONS

This chapter addresses the mechanics of search and rescue operations and the technical performance characteristics of ELTs. The division of search and rescue responsibilities is discussed first. Search and rescue operations with respect to ELTs are described and a standard scenario is developed. This chapter also examines the historical performance of ELTs and the problems that have emerged relative to the original objectives of the program.

2.1 OVERVIEW

The current National Search and Rescue Plan has divided federal emergency assistance responsibilities into three Search and Rescue (SAR) jurisdictions -- the Inland, Maritime, and Overseas Regions, shown in Figure 2-1. The U.S. Air Force Rescue Coordination Center (AFRCC) (located at Scott Air Force Base, Illinois) is responsible for coordinating federal SAR efforts in the Inland Region. This same function is performed by the U.S. Coast Guard in the Maritime Region and by the appropriate military overseas unified command in the Overseas Region. The Inland Region is of particular interest to this study because it encompasses the continental United States, from which the vast majority of ELT alarms originate.

2.1.1 Search and Rescue Responsibilities in the Inland Region

State and local authorities are primarily responsible for the successful accomplishment of SAR operations. However, there are substantial variations in the attitudes, structures, capabilities, and facilities of state and local SAR programs. Generally, most search and rescue efforts are manned and organized through the local sheriff, fire, and police departments, and volunteer organizations such as the Civil Air Patrol. State officials are responsible for coordinating intrastate efforts that involve these different organizations and for requesting federal SAR assistance through the AFRCC if needed.

The relationships between these state and local jurisdictions and the Federal Government are based on legal agreements between the respective states and the AFRCC. Some states, particularly in the west, take

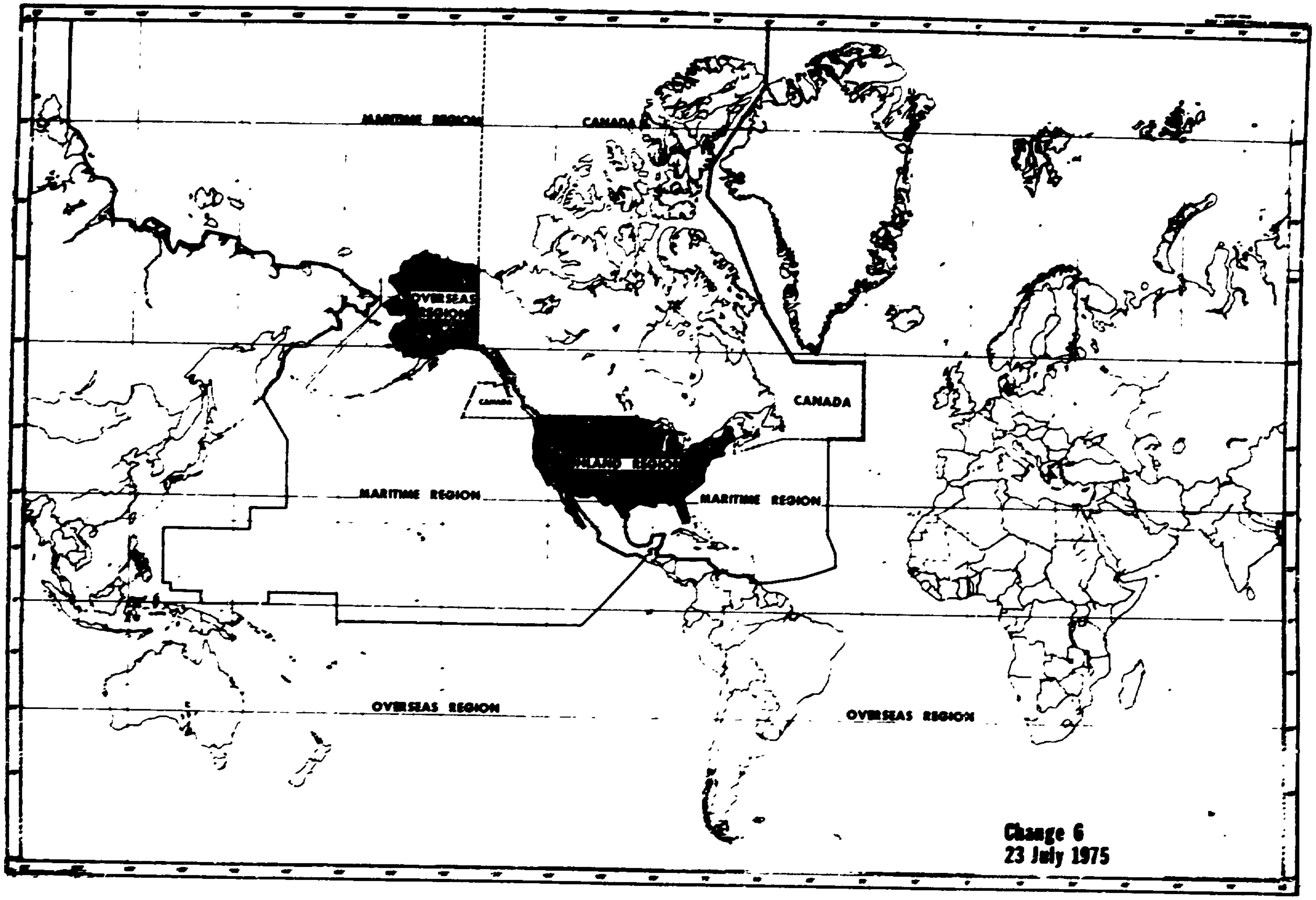

Figure 2-1. NATIONAL SEARCH AND RESCUE PLAN (SOURCE: INTERAGENCY COMMITTEE FOR SEARCH AND PESCUE)

full responsibility for their SAR efforts, while others prefer to let the AFRCC assume control.

The success of SAR operations, especially with respect to distressed aircraft, depends on assistance received from the entire aviation community. Private pilots, although not required to listen for ELT signals, frequently report or assist in their searches. In fact, more than 90 percent of the distress signals detected are first reported by private pilots on personal or pleasure flights.

2.1.2 Emergency Rescue Operations

Most fixed-wing aircraft in the United States are required to carry an Emergency Locator Transmitter (ELT) that will transmit a radio distress signal in the event of a crash. (Exceptions are listed in Section 2.2.) These signals are transmitted simultaneously on 121.5 and 243.0 MHz, two frequencies specifically allocated for emergency use. These bands are monitored continuously by most air traffic control towers (ATCTs) and flight service stations (FSSs). Because of line-of-sight transmission limitations of these signals, a true distress signal from a downed aircraft will probably not be detected by a ground receiver at ATCTs or FSSs. Those signals which are detected from the ground are usually either airborne or located in the immediate vicinity of the receiver.

Airborne signal sources are easily distinguished since the signal strength will fade in a few minutes and many ground stations scattered over a large area will detect the signal. Ground-based signal sources that are detected by a ground receiver must be in the immediate vicinity of the receiver and are therefore handled locally if at all. Typically, airport personnel will search the local area for the ELT, using direction-finding (DF) equipment if available. This procedure, in almost all cases, locates the ELT. If it does not, appropriate SAR resources are marshaled. Figure 2-2 illustrates a typical rescue mission procedure.

In addition to the ground stations, military flight crews routinely monitor 243.0 MHz and many civilian pilots monitor 121.5 MHz voluntarily. As a result, ELT signals are typically detected first by a pilot. When a pilot hears an ELT transmission, he normally radios the nearest FAA facility although he is not required to do so. The Air Traffic Control staff asks the pilot's position, where the ELT was first and last heard, and where the signal was the strongest. This information is then forwarded to the nearest Air Route Traffic Control Center (ARTCC), which serves as the focal point for FAA assistance to the SAR operation. ARTCC staff are required to notify the AFRCC immediately.

Once notified, the AFRCC assumes a management role in locating the signal source. The first report may have been received from high-altitude (30,000 feet or higher) aircraft. Under these circumstances the ELT could be anywhere in an area as large as 300,000 square miles. Therefore, the first step in the investigation is to localize the ELT to

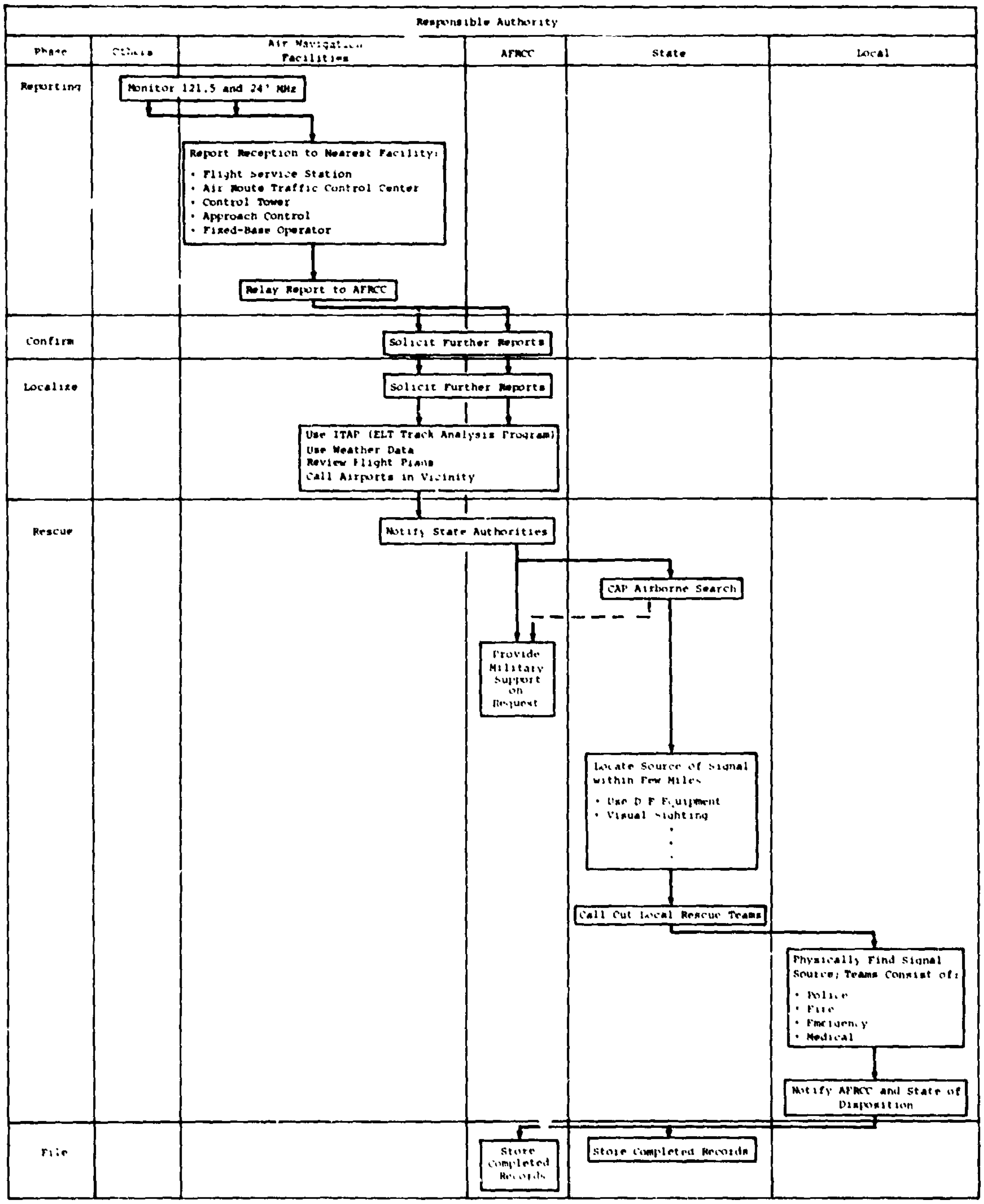

Figure 2-2. FLOW DIAGRAM OF TYPICAL RESCUE MISSION

a smaller area. Typically, the AFRCC asks the reporting ARTCC to solicit additional pilot reports, particularly low-altitude reports, that can narrow the search area. This process usually takes one to two hours.

When the ELT has been localized to an area perhaps 60 miles in diameter, the AFRCC will solicit reports from ground stations in the region. The stations may be unattended, particularly late at night; thus no reports may be obtained or the reports may be negative. In this situation, the AFRCC will open a mission, which denotes the marshaling of SAR resources to locate and silence the ELT. No firm criteria exist for opening a mission; each situation is handled on a case-by-case basis. AFRCC next notifies the responsible state official that a mission has been opened. The official, in turn, authorizes an air or ground search, or both, using either state resources or those of the Civil Air Patrol (CAP).

The CAP is an official auxiliary of the Air Force, although all CAP members are strictly unpaid volunteers primarily flying private aircraft. High-wing aircraft, such as the Cessna 172, are particularly popular because they provide better ground visibility. Aircraft owners are reimbursed by the Air Force only for the fuel they use; owners must bear all other operating costs associated with the mission. Direction-finding (DF) equipment is used to locate the source of the ELT signal from the air. Once it is located, further action depends on the circumstances of the case. If the ELT is localized to an airport, ground personnel can take over. If the airport is unattended, as might be the case after midnight, the CAP aircraft can land and search the airport on foot. If the signal is traced to a populated area, local law enforcement officials may be called upon to track down the ELT. Finally, if the signal is traced to a remote area, there is a strong possibility of an actual crash and local SAR teams are dispatched as appropriate.

Once the ELT signal has been traced to a specific nondistress aircraft, attempts are made to silence the signal, which could be difficult to do. Typically, officials try to summon the owner to disarm the ELT; this approach minimizes potential liability problems. Alternatively, the SAR crew will attempt to shut the ELT off, but they may be unsuccessful because the switch may not be accessible or the unit may be stuck "on". In such cases the device can sometimes be neutralized by wrapping the antenna with foil. If all attempts fail, FCC assistance may be requested to obtain legal authorization to break into the airplane and disarm the ELT. Although a false alarm is a violation of FCC regulations, the FCC is seldom called into a case, and citations for an ELT false alarm are rarely issued.

AFRCC scrutiny of the ELT incident continues until notification is received that the ELT has been located or silenced and that necessary rescue operations have been accomplished. If at any time during the investigation the AFRCC receives several consecutive negative reports from the same vicinity in which the reports were originally heard, the ELT is assumed to have ceased and the investigation is closed.

2.2 DISCUSSION OF EMERGENCY LOCATOR TRANSMITTERS

2.2.1 Legal Requirement

The Occupational Health and Safety Act of 1970, Section 31, amended the Federal Aviation Act of 1958 to require that Emergency Locator Transmitters (ELTs) be installed in all fixed-wing aircraft manufactured in the United States or imported after 31 December 1971. The following aircraft were exempted:

- Jet-powered aircraft
- Aircraft used in air transportation, other than air taxi and charter service
- Military aircraft
- Aircraft used solely for training in flights of not more than 20 miles
- Aircraft used for the aerial application of chemicals

This law ultimately became effective 30 June 1974 and was implemented by the FAA in an amendment to the Federal Aviation Regulations. Technical Standard Order (TSO) C91 specified minimum performance standards for Emergency Locator Transmitters and referenced design standards and parameters described by the Radio Technical Committee for Aeronautics (RTCA) as follows:

- RTCA DO-145, "Minimum Performance Standards - Emergency Locator Transmitters, Survival Type - ELT(s)", for use of portable Emergency Position Indicator Radio Beacons (EPIRBs) for marine applications
- RTCA DO-147, "Minimum Performance Standards - Emergency Locator Transmitters, Automatic Fixed - ELT(AF)*, Automatic Portable - ELT(AP)*, Automatic Deployable ELT(AD)*, for crash-activated emergency radio beacons to be used in aircraft

2.2.2 ELT Specifications

ELTs of primary concern in this study are of the "AF" or "AP" type. Typically, they are self-contained, are less than 12 inches long on any one side, and weigh only a few pounds. They are triggered by a crash sensor, which is usually an acceleration-sensing switch activated by a force along one or more axes.

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*"AF" equipment is intended for permanent installation on the airframe; "AP" equipment may be attached or portable; and "AD" equipment is a bouyant ELT that is automatically ejected from the aircraft and activated when subjected to crash forces.

Mounting of ELTs varies significantly by type, aircraft, and manufacturer's make and model. It is most desirable to install an ELT by fastening it to a structural member of the airframe slightly aft of the midsection of the fuselage. If it is mounted too far forward, there is a significant risk of destruction; if it is mounted too far aft, the unit may experience insufficient crash forces to trigger. The most common practice in general aviation is to mount the ELT in or aft of the baggage compartment.

On the basis of the experience gained by the aviation community since 1974, the original specifications are being reevaluated. The Radio Technical Commission for Aeronautics, Special Committee 127, has issued a preliminary specification for a second-generation unit. Special Committee 136 is considering the applicability of these specifications with respect to other components of the ELT program. Table 2-1 is a comparison of key ELT requirements as they were originally released through DO-147 and the most recently proposed specifications for the second generation of ELTs.

Table 2-1. KEY ELT PARAMETERS		
Function	Per RTCA DO-147	Proposed Revision*
Local Controls	On-off switch	On-off arm switch
Remote (Cockpit) Controls and Indicators	None	On-off arm switch transmitter "on" indicator, false alarm reset
Power Source	Independent of aircraft supply	Independent of aircraft supply; battery gas or leak will not degrade performance
Antenna Mounting	Omnidirectional aircraft external mounting	Vertically polarized omnidirectional, aircraft external mounting, locking, noncorrosive rf cable connectors
Operating Frequencies	121.5 MHz, 243.0 MHz, ±0.005 percent	121.5 MHz, 243.0 MHz, ±0.005 percent; carrier stability over audio sweep cycle ±150 Hz
Modulation	Amplitude modulation; modulation factor, 0.85; $\geq$700 Hz down sweep between 1,600 and 300 Hz at 2 to 4 Hz repetition rate	Amplitude modulation factor, 0.85; $\geq$700 Hz down sweep between 1,600 and 300 Hz at 2 to 4 Hz repetition rate
Modulation Duty Cycle	33 to 55 percent	33 to 55 percent
Peak Effective Ratio Radiated Power	$\geq$75 mW on each frequency	≥75 mW per frequency average during 50 hours of transmission**
Operating Life	48 hours	50 hours
Automatic Activation	5 +2,-0 g longitudinal for 11 ms; stay latched during 50 g for 11 ms; alternate sensor acceptable	Inhibit below 2 ±0.3 g; activate if ∇V ($\overline{G} \times T$) exceeds 3.5 ±0.5 ft/sec (e.g., at 5 g per 21.7 ms or 20 g per 5.4 ms, etc.); alternate sensor acceptable
Crashworthiness	--	Mounting to withstand 100 g
RFI	--	Unaffected by 103 to 136 MHz (no activation, no reradiation)
Temperature Low Storage Low Operating High Storage High Operating	 -65°C -20°C +71°C +55°C	 -55°C† -20°C† +85°C† +55°C†
Shock	50 g for 11 ms	100 g for 23 ms
Vibration	10 g maximum nonoperating, 5 Hz to 2000 Hz	7 g maximum (operating, no activation permitted), 5 to 2000 Hz

*Source: RTCA Paper No. 107-78/SC127-52, dated 24 May 1978.
**Note that calculation of "average" power has been changed.
†Test method modified.

CHAPTER THREE

DESCRIPTION OF INVESTIGATION

This chapter is a discussion of the general analysis procedures applied to this study. A work plan for the study is described, and a more detailed description of the methodology and a list of the data sources considered are provided. A detailed description of the three major data sources used in the study is presented, with each source characterized in terms of the quantity and quality of data collected, coverage of incidents, and expected data accuracy.

3.1 PLAN OF INVESTIGATION

This investigation consisted of eight tasks arranged into three major multi-task phases. In the first phase available statistical data on ELT incidents were compiled and analyzed. In the second phase specific goals and measures of performance were established for use in evaluating plans proposed to reduce the false alarm problem. In the third phase proposed programs were developed and analyzed against the criteria developed during the second phase.

3.1.1 Phase I: Collect Data

The data used for the analyses in this study consisted of statistical information concerning the nature of ELT incidents; qualitative background material on the false alarm problem; and supporting information concerning government, industry, and user community plans and desires. Supplementary information was obtained through literature review and interviews with knowledgeable officials of the FAA, FCC, NASA, and various state and local SAR organizations. The nonstatistical information sources were used mainly to provide an understanding of the problem and to direct the scope of the quantitative analysis.

The statistical data were derived by using a computerized data base acquired from existing records of ELT incidents. Prime sources of information for statistical analyses were three independent record sets: the ELT Incident Log maintained by the Air Force Rescue Coordination Center (AFRCC), the Frequency Interference Reports (FIRs) collected by the Airways Facilities Division of the Federal Aviation Administration, and the Service Difficulty Reports compiled by the FAA Flight Standards National Field Office in Oklahoma City.

The following additional data sources were considered but were found to be of peripheral interest to this study:

- The National Transportation Safety Board (NTSB) maintains records on the causes of aircraft accidents and ELT performance in crashes; NTSB does not, however, maintain any files on ELT false alarms since no accident was involved.
- The National Civil Air Patrol (CAP) headquarters maintains some records on ELT incidents, primarily when a CAP aircraft search is launched. The CAP is not as interested when a nondistress ELT is located and silenced without its assistance.
- State aviation agencies maintain records of ELT incidents in their states. The level of detail varies from state to state.
- The Federal Communications Commission maintains records of unusual situations involving a violation of FCC regulations, such as nonemergency use of 121.5 MHz. The FCC is called in on an ELT incident only as a last resort. The FCC was involved in fewer than 70 ELT cases in 1978. Fines for unauthorized use of the emergency frequency (i.e., an ELT false alarm) are extremely rare.

3.1.2 Phase II: Establish Goals and Performance Measures

Data collected in Phase I made it possible to identify useful measures of performance and the maximum savings possible from improvements in false alarm performance. These measures and savings were estimated by calculating the percentage of total ELT transmissions by source and cause and estimating the cost of SAR operations for each category of alarm. The analyses indicated that the efficiency of SAR operations depended not only on the absolute number of ELT alarms detected but also on the procedure used to locate and silence these alarms. A goals structure was developed to define quantitatively the results of changes to the status quo. This goals structure is addressed in detail in Chapter Six.

The estimated cost of SAR operations per alarm was the key to performing cost-benefit analyses required to compare the utility of various alternative strategies. The development of this measure of performance required the application of standard scenarios and representative SAR procedures to estimate the costs involved in silencing ELT alarms. The benefits of each approach were evaluated on the basis of reduction in costs achieved.

3.1.3 Phase III: Identify and Evaluate Possible Solutions

The objectives established in Phase II describe the impact of an improvement in the false alarm problem, but they do not describe how to achieve that improvement, how much it will cost, and whether it will be cost-effective. This last phase of the study evaluated several proposed implementation plans for cost and technical effectiveness with respect to the different goals established in Phase II. Considerations in developing plans included:

- New hardware requirements or modifications to existing hardware
- Changes in regulations or required regulatory actions
- Further demand for government services
- Impact on pilots, FAA personnel, airport personnel, and SAR crews

Each plan was evaluated on the basis of its cost to the parties involved and its effectiveness, political acceptability, and lead time to implementation. The plans with the highest ratings were given more careful consideration to assure the accurate assessment of the possibilities of technical or regulatory delays, legal complications, and noncompliance by the user communities.

3.2 SOURCES OF DATA

The three record sets that form the basis of the statistical analyses presented in this report are discussed in the following subsections.

3.2.1 ELT Incident Log

The U.S. Air Force Rescue Coordination Center (AFRCC), headquartered at Scott Air Force Base, Illinois, has been designated the responsible Federal organization for coordinating SAR activities in the continental United States. As part of its charter, the center maintains a complete record of all ELT incident histories in the form of ELT Incident Logs reported from anywhere in the entire continental United States. Typically, the ELT Incident Log includes the date of the incident, time detected, time of ELT shutoff, location, disposition, and, possibly, cause of the ELT incident. Figure 3-1 presents a sample ELT Incident Log.

Most of the reports of ELT incidents originate from general aviation pilots who monitor 121.5 MHz. The pilots typically report any ELT signals they hear on the emergency frequencies to the nearest FAA Flight Service Station or Air Route Traffic Control Center (ARTCC), which in turn notifies the AFRCC of the incident.

Although all incidents are required by law to be reported, many are not reported. If an ELT alarm is resolved locally, in many cases no FAA (and consequently no ARTCC) facility will hear of the incident;

AFRCC ELT INCIDENT LOG

REPORTING AGENCY TEL NO	DATE TIME	FREQUENCY 121.5 243.0	INITIALS FAA	INITIALS RCC

CENTERS FSS AIRPORTS CONTACTED

1	6
2	7
3	8
4	9
5	10

INITIAL REPORT

MONITORED BY	ALT	HEADING BEARING	OVERDUE ACFT YES NO

	TIME	POSITION
FIRST HEARD		
STRONGEST		
LAST HEARD		

TIME	INIT	ADDITIONAL REPORTS

ELT INFORMATION

Figure 3-1. EXAMPLE OF AFRCC INCIDENT LOG therefore, the incident will probably not appear in the AFRCC records. Thus the reporting rates vary dramatically from one ARTCC to another, depending on the local procedures used to silence the alarm. The existing records themselves are incomplete with respect to identification of location and cause since only about 40 percent of reported incidents are recorded as being located and silenced. In the remaining reports, the ELT transmissions cease before being located by the AFRCC-managed SAR team, or the unit is shut off by someone not in communication with the AFRCC. AFRCC received approximately 13 reports of ELT incidents daily in 1978, for an annual total of approximately 4,700 reports.

This situation underscores the major problem with the AFRCC records. While the Air Force personnel are dedicated and efficient, they receive no first-hand information; i.e., all their data are transmitted second- or third-hand over the telephone. SAR officials at the scene may fail to inform the AFRCC of important developments in the case; at best, their reports are delayed. (In Chapter Four, this delay is quantitatively measured.) Nevertheless, the AFRCC is the best source of nationwide statistics on ELT incidents.

To limit data-collection efforts, a random sampling of 17 weeks' records from 1978 was used to develop the annual statistical measures presented in this report. The weeks ran from Thursday to Wednesday to assure capturing whatever weekday-weekend variance existed. Every fourth week was chosen as part of the sample, beginning with 12-18 January 1978. One additional week each in March, June, September, and December was randomly added to complete the sample. Some minor errors in transcription were corrected. In particular, it was apparent that the change of the Zulu day (6 p.m. Central Standard Time) versus the change of the calendar day (at midnight) was a source of confusion.

Much of the information in the log was a record of activities associated with localizing the signal and coordinating with local SAR resources; neither of these was of direct interest. The following data were extracted for each incident:

- AFRCC incident number. Could be used later to refer to a specific incident.
- Date of incident (month and day). All incidents occurred in 1978.
- Reporting ARTCC. Most incidents are reported by an FAA Air Route Traffic Control Center (ARTCC).
- City and state where ELT was found. Filled in only for those incidents in which an ELT was recorded as being located and silenced.
- Time of initial report.
- Time ELT was located. Filled in only if there was substantial difficulty in silencing the ELT once it was located. This could occur, for example, if the aircraft was locked in a hangar.

- Time ELT was silenced. For those incidents in which ELT was recorded as not found, the time of the closing of the incident would be used.
- Confirmed indicator. If the incident was detected independently by at least two receivers, this box would be checked.
- Found indicator. If the incident was recorded as located and silenced, this box would be checked.
- Mission indicator. If the incident resulted in an AFRCC mission, this box would be checked.
- Environment. If the ELT incident was recorded as located and silenced, the environment where the unit was found would be recorded. The possible environment codes correspond to towered airports, nontowered airports, boats, nonaircraft, airborne vehicles, fields, and legitimate crash sites.

Information concerning incidents that resulted in SAR missions was taken from a separate missions data base, also obtained from AFRCC.

3.2.2 Frequency Interference Reports

The FAA Airways Facilities Service maintains a log of Frequency Interference Reports (FIRs). A report is filed by a control tower (ATCT) or a Flight Service Station (FSS) whenever one of the aviation frequencies is jammed. An ELT signal is considered to be such an occurrence. Each reporting tower or FSS submits completed FIRs to the regional FAA headquarters, which forwards the FIRs to national FAA headquarters.

FIRs usually contain details on the date, time on, time off, location, and sometimes cause of interference, as well as the responsible equipment make and model. These forms are maintained at the national FAA headquarters by the Airways Facilities Division. Figure 3-2 shows a sample FIR form.

Although FIRs must be filed upon detection of frequency jamming, only the FAA Western Region fulfills this requirement conscientiously. For example, of a total of 284 FIRs reviewed, only 9 were not from the Western Region. The statistical validity of FIRs tends to be compromised by several other factors:

- Only about 50 percent (151) of the reports contain adequate cause and manufacturer's make and model information.
- FIRs tend to report only incidents that occur at or near airports, particularly towered airports and flight service stations. This situation is a consequence of the fact that towered airports and FSSs are required to monitor 121.5 MHz.
- FIR files are maintained for only about two years and cannot provide insight into long-term trends.

THRU [Ref. Local AF Office] [illegible]

TO [illegible] FMO [illegible]

FROM [illegible]

SIGNATURE OF ORIGINATOR

DATE 7-1-74

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
FREQUENCY INTERFERENCE REPORT

1. GENERAL

THIS BLOCK TO BE COMPLETED WHEN REPORTING ANY TYPE RADIO FREQUENCY INTERFERENCE

a NAME OF AFFECTED FACILITY: CG/ATCT

b DURATION (Date Time) STARTED 7-1-74 /0458 CLEARED 7-1-74 /0603

c NOTAM ISSUED [ ] YES [X] NO

d FACILITY OPERATION [X] USABLE [ ] USABLE WITH DIFFICULTY [ ] UNUSABLE

e INTERFERENCE DESCRIPTION

(1) SOURCE: ELT (Lee Systems, Share 7 Model # 7J154) C182 73521

(2) TYPE: Warbling Tone

(3) INTENSITY: Loud

2. RADAR

THIS BLOCK TO BE COMPLETED WHEN REPORTING INTERFERENCE TO RADAR

a INTERFERENCE AZIMUTH °

b RADAR CHANNEL IN USE WHEN INTERFERENCE STARTED — CHANNEL — CHANNEL CHANGE MADE [ ] NO [ ] YES — ANY IMPROVEMENT [ ] YES [ ] NO

c OPERATING FREQUENCY — CHANNEL A MHz — CHANNEL B MHz

3. OTHER

THIS BLOCK TO BE COMPLETED WHEN REPORTING INTERFERENCE TO COMMUNICATION OR NAVIGATION AIDS

a AFFECTED FREQUENCY: 121.5 mhz

b TYPE STATION (If airborne, show identification, location, and altitude of aircraft) [X] GROUND [ ] AIRBORNE →

c TYPE EQUIPMENT INVOLVED (See Instructions)

4. CORRECTIVE ACTION

[X] TAKEN [ ] PLANNED [ ] SUGGESTED BY LOCAL AIRWAY FACILITIES OFFICE

Located on airport (FSA) by airport Personel. Turned off by FSA personel.

This same ELT in same aircraft Reactivated this same day from 1947 until 2002.

Signature of Responsible Local AF Official

Prepare attachment if additional space is required

FAA Form 6050-3 (7-73) Supersedes all local forms

AAF 30 - 4

Figure 3-2. SAMPLE OF FREQUENCY INTERFERENCE REPORT

On the other hand, FIRs tend to provide much more accurate information on transmission durations than the AFRCC data because the time-on/time-off data are recorded by field personnel actually listening to the emergency frequency, rather than by someone who must rely on second- or third-hand information. No sampling was used in the statistical analysis of FIRs because of the small number of records involved (251 in 1978).

As in the AFRCC records, not all data contained in the FIRs were extracted for analysis. The fields recorded were as follows:

- FAA region
- City and state
- Reporting organization code (here it was only necessary to record whether it was a tower, FSS, or ARTCC)
- Date
- Time ELT detected
- Time ELT silenced
- Manufacturer, if known
- Reason for the incident, if known

3.2.3 Service Difficulty Reports

Service Difficulty Reports (SDRs) are submitted directly to the FAA Flight Standards National Field Office in Oklahoma City whenever a malfunction or an unexpected or unusual condition is noted in an aircraft or aircraft subsystem during ground inspection, pre-flight preparation, or maintenance. These reports are filed primarily by FAA inspectors, airport personnel, and maintenance personnel. The filing of Service Difficulty Reports is totally voluntary. The purpose of the program is to detect design defects, maintenance-procedure flaws, and other undesirable trends, and to provide a statistical body of information on which to base engineering evaluations of potential safety hazards.

SDRs usually provide an accurate technical summary of the unexpected condition. Typical data on the form include manufacturer make, model, and serial number; problem condition; and geographic origin of report. Each report contains a summary of the problem encountered and its probable cause.

Many tens of thousands of SDRs have been submitted to the Flight Standards National Field Office since 1974. Summaries of these reports have been integrated into a large computerized data base that is accessible for sorting and readout according to many different parameters. Of this total data base, approximately 6,000 report summaries concern ELTs; 75 percent of the report summaries address the failure of equipment to operate properly, either in an inspection or in a crash. The remaining 1,500 reports concern false alarms. Figure 3-3 is an example of the

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CHOK2L
ELT REPORTS FOR 1976 ARINC RESEARCH                RIS FS-8330-15  DATE OF PRINT 03/20/79 FAA SERVICE DIFFICULTY PROGRAM PAGE    67

ATA      COMP MAKE       COMP MODEL   PART NAME      CONDITION         ACFT MODEL   ENG MODEL    PROP MODEL    T CRGN  PP  NAT SGU FILM
 INDEX TERM              COMP SERIAL  PART NUMBER    LOCATION          ACFT SERIAL  ENG SERIAL   PROP SERIAL   SP TT       TSO  CONTROL NO

2562     GARRETTINT     RESCU88                      ACTIVATED         PA28181      UNDET        UNDET          WF03 K     JO  UKCES0933
 EMER LOCATOR BEACON    105C780                                                                               C  C0550 00550 0209B1JAEA
AF SY      TEXT  BATT LEAKAGE CAUSED CORROSION OF FUNCTION SW RESULTING IN INADVERTENT ACTIVATION .BATT EXP DATE 10-80.

2562     GARRETTINT     RESCU88                      ACTIVATED         PA32R300     UNDET        UNDET          WE03 K      J  INCEWC105
 EMER LOCATOR BEACON    85C451                                                                                C  00543 00543 0404B034EA
AF SY      TEXT  ELT ACTIVATED WHILE AC WAS TIED DOWN DURING HEAVY WIND AND RAIN

2562     GARRETTINT     RESCU88                      CORRODED*INOP     PA31350      UNDET        UNDET          SCUE K     LC  INCEZ0855
 EMER LOCATOR BEACON    76C2376                                        317752005                              C  00593 00593 05260C57EA
AF SY      TEXT  CORROSION FND ON ALL EXT CNCTNS.BATTS WERE CLEAN BUT UNIT DID NOT FUNCTION.

2562     GARRETTINT     RESCU88                      ACTIVATED         PA31         UNDET        UNDET          S007 K      N  UKCFC0381
 EMER LOCATOR BEACON    105C6328                                       7612036                                J              0710B051EA
AF SY      TEXT  UNIT ACTIVATED & DEACTIVATED AT COCKPIT REMOTE SWITCH.UNABLE TO GET INFO FRM PIP ER CORP.

2562     GARRETTINT     RESCU88                      CORRODED*GASSING  PA28181      UNDET        UNDET          CE04 K      C  INCFE0763
 EMER LOCATOR BEACON    11501313                                       287690227                              G  C1500 01500 080E80E6EA
AF SY      TEXT  UNIT GASSING & ON-OFF-ARM SW CORRODED.OPERATIONAL CK NORMAL.LITHIUM BATTS INSTLD

2562     GARRETTINT     RESCU88                      ACTIVATED         PA28140      UNDET        UNDET          SC08 K      N  UKCFE1126
 EMER LOCATOR BEACON    112C282                                        287325142                              G              0E1180-5EA
AF SY      TEXT  ELT ACTIVATED.PILOT RPRTD PLANE WAS MAKING TOUCH & GO LNDNGS.

2562     GARRETTINT     RESCU88                      CORRODED          PA31         UNDET        UNDET          WE65 K      G  UKCEV0209
 EMER LOCATOR BEACON    2303514                      CIRCUIT BOARD     31P7300119                             G  01100 01100 0320803JEA
AF SY      TEXT  ELT ACTIVATED INADVERTENTLY ON SEVERAL OCCASSIONS EXCESSIVE CORROSION ON PC BOAR D

2562     GARRETTINT     RESCU88                      SET OFF BY WATER  PA23250      UNDET        UNDET          EA14 K      C  INCEG07C0
 EMER LOCATOR BEACON    95C831                       DORSAL FIN        27754171                               F              0312E036EA
AF SY      TEXT  FACTORY INSTALLED ELT SET OFF BY WATER SEEPING INTO CASE. MOUNTED IN DORSAL FIN  WHICH IS NOT SEALED.

2562     GARRETTINT     RESCU88                      GAS-CORRODED      PA28181      UNDET        UNDET          FA16 K      O  INCER06E2
 EMER LOCATOR BEACON    36C1935                      ELT UNIT          287690373                              F  00598 00598 01238137EA
AF SY      TEXT  GAS AND CORROSION FOUND DURING INSPECTION IN THE ELT HOUSING.

2562     GARRETTINT     RESCU88                      ACITVATED         PA31         UNDET        UNDET          SC0H K     NO  UKCFF0942
 EMER LOCATOR BEACON    75C6266      6276741                           317612013                              G              06258051EA
AF SY      TEXT  CORROSION AT FUNCTION SWITCH PROVIDED CONTINUITY TO ACTIVATE ELT.

2562     GARRETTINT     RESCU88      BATTERIES       CORRODED          PA28R200     UNDET        UNDET          GLC3 K      C  UKCES1109
 EMER LOCATOR BEACON    36C1920      6162461         ELT               28R7635320                             G              0210EC41EA
AF SY      TEXT  ELT BATTERY OVER VOLTAGE,CAUSED ARM SW TO CORRODE,CAUSING BATTERY,TO LOSE ITS VO LTAGE.

2562     GARRETTINT     RESCU88      BATTERY         LEAKING           PA31T        UNDET        UNDET          S013 K      C  INCFA0599
 EMER LOCATOR BEACON    83C1790                                                                               C              06098060EA
AF SY      TEXT  ELT ACTIVATED TWICE IN ARM POSITION DUE TO BATTERY LEAK AND CORR
```

*Since the reports are stored alphabetically by manufacturer, the sample data shown here are from one of several manufacturers.

Figure 3-3. EXAMPLE OF SERVICE DIFFICULTY REPORT TABULATION FROM FAA FLIGHT STANDARDS NATIONAL FIELD OFFICE* summary Service Difficulty Report tabulation available from the FAA Flight Standards National Field Office. Note the detailed information available on make, model, condition, and location.

For purposes of this study, only individual record summaries related to ELT false alarms were extracted for analysis. (Undoubtedly much useful information can be gained from the remaining records on ELT reliability, but that is not a primary concern of this study.) Data from the selected records on make and model and probable cause were extracted, tabulated, and statistically analyzed. The results of these analyses are presented in Chapter Four of this report.

The statistics of Service Difficulty Reports tend to be biased by the original data base. Although such bias is not significant enough to invalidate the statistics, some of the following effects should be considered in drawing conclusions from Service Difficulty Report statistics:

- Because the form's use is strictly voluntary, there seems to have been a significant loss of interest over the years in reporting ELT false alarms. This appears to be confirmed if one compares the decrease in ELT Incident Log Reports at AFRCC with the decrease in Service Difficulty Reports over a comparable period (see Figure 3-4).
- Since these reports generally originate at airports, they may overrepresent the causes of false alarms at such locations somewhat. This situation, however, probably does not measurably affect the overall statistics of ELT false alarm causes because more than 80 percent of all ELT false alarms originate at an airport.
- No detailed geographic analysis was performed, but a sampling of the data suggests that Service Difficulty Reports are representative of all FAA regions.

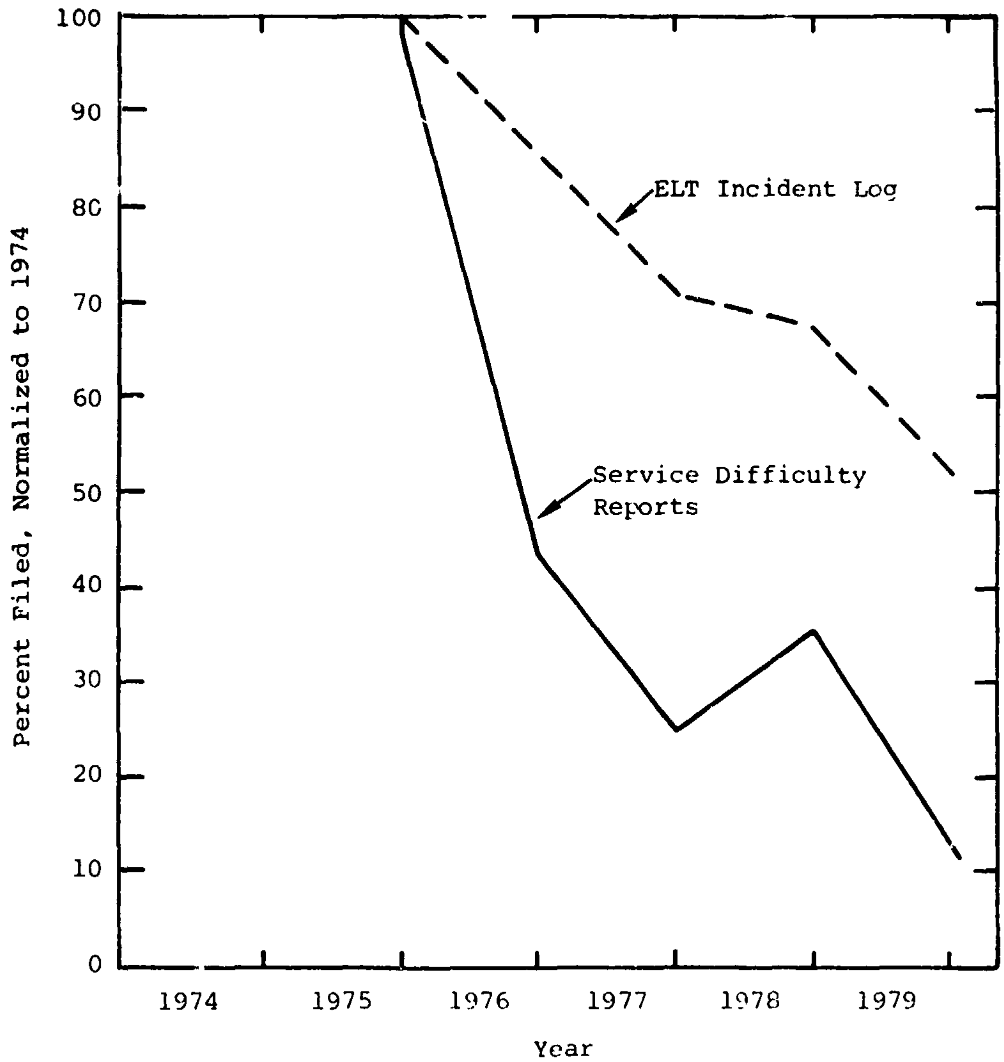


Figure 3-4. LOSS OF INTEREST IN FILING ELT FALSE ALARM REPORTS

CHAPTER FOUR

STATISTICS OF ELT INCIDENT REPORTS

This chapter presents the statistical characteristics of ELT alarm reports. The total of these reports represents a sample of the entire population of ELT alarms. Projections of estimated total alarm population statistics developed from these report statistics are included in Chapter Five.

4.1 TEMPORAL CHARACTERISTICS OF ELT FALSE ALARM REPORTS

4.1.1 Long-Term Trends

Historical data indicate a definite downward trend in filing ELT false alarm reports since 1974. For example, during the first year for which complete records are available (1975), AFRCC received 6,603 reports of ELT incidents from a total population of approximately 160,000 ELTs.* It is projected that in 1979 only 3,526 of these reports will be received from a total population of nearly 200,000 ELTs. This downward trend from 41 incidents to 18 incidents per 1,000 ELTs does not necessarily indicate that the program has matured successfully and overcome its initial start-up difficulties. Unfortunately, false alarms still constitute a substantial majority of ELT broadcasts. The reasons for the decline in reports are not easily verified, but circumstantial evidence indicates that a combination of dead batteries, less rigorous reporting practices, indifference, lack of clear instruction on what and where to report, product improvement, and increased user familiarity with the units have contributed to the decreasing number of reports. However, it is difficult to draw from these figures conclusions as to the trend of actual number of ELT broadcasts. The history of ELT alarm reports between 1974 and 1979 is summarized in Table 4-1. It is noteworthy that during the two years for which NTSB data are available, only about one out of seven accidents resulted in an ELT activation. These activations represent only about 10 percent of the number of total alarms recorded by the AFRCC. Since not all incidents are reported, it is probable that the false alarm rate is substantially higher than 90 percent.

*Since installation of ELTs has been required for most general aviation aircraft, the number of registered aircraft presents an accurate indicator of the number of units in operational use.

Table 4-1. TOTAL ANNUAL ELT FALSE ALARM REPORTS					
Year	Number of Registered Aircraft*	Service Difficulty Reports	AFRCC ELT Incident Log	ELT Activation Resulting from Accidents**	Aircraft Accidents**
1974	153,500	1,014***	No Data	No Data	4,429
1975	161,500	382	6,603	630	4,253
1976	168,500	164	5,681	688	4,207
1977	178,300	96	4,744	No Data	4,286
1978	186,600	139	4,450	No Data	4,489†
1979	198,800	43††	3,526#	No Data	795##

*Source: "FAA Statistical Handbook of Aviation".
**Source: National Transportation Safety Board. (Accidents are occurrences incident to flight resulting in fatality, serious injury, destruction of aircraft, or substantial damage affecting aircraft airworthiness.)
***Based on 741 reports from April through December 1974.
†As of 30 June 1979; investigations still in progress.
††Based on 13 reports from January through March 1979.
#Based on 1,763 reports from January through June 1979.
##Through 26 July 1979; investigations still in progress.

4.1.2 Time Variations

The AFRCC ELT incident logs were used as the primary source of data for analysis. This subsection examines variations in ELT reporting rates and transmission duration as a function of season, day of the week, and time of day.

4.1.2.1 Seasonal Variations

The average daily total alarms, transmission duration*, and number of simultaneous alarms reported are plotted on a monthly basis as shown in Figure 4-1. The daily total alarms represent the average number of incidents recorded in each sample period. Average simultaneous alarms were calculated by counting and averaging the number of ELTs that were active during one-minute segments of each day. Average transmission

*See Subsection 4.1.3 for discussion of transmission duration.

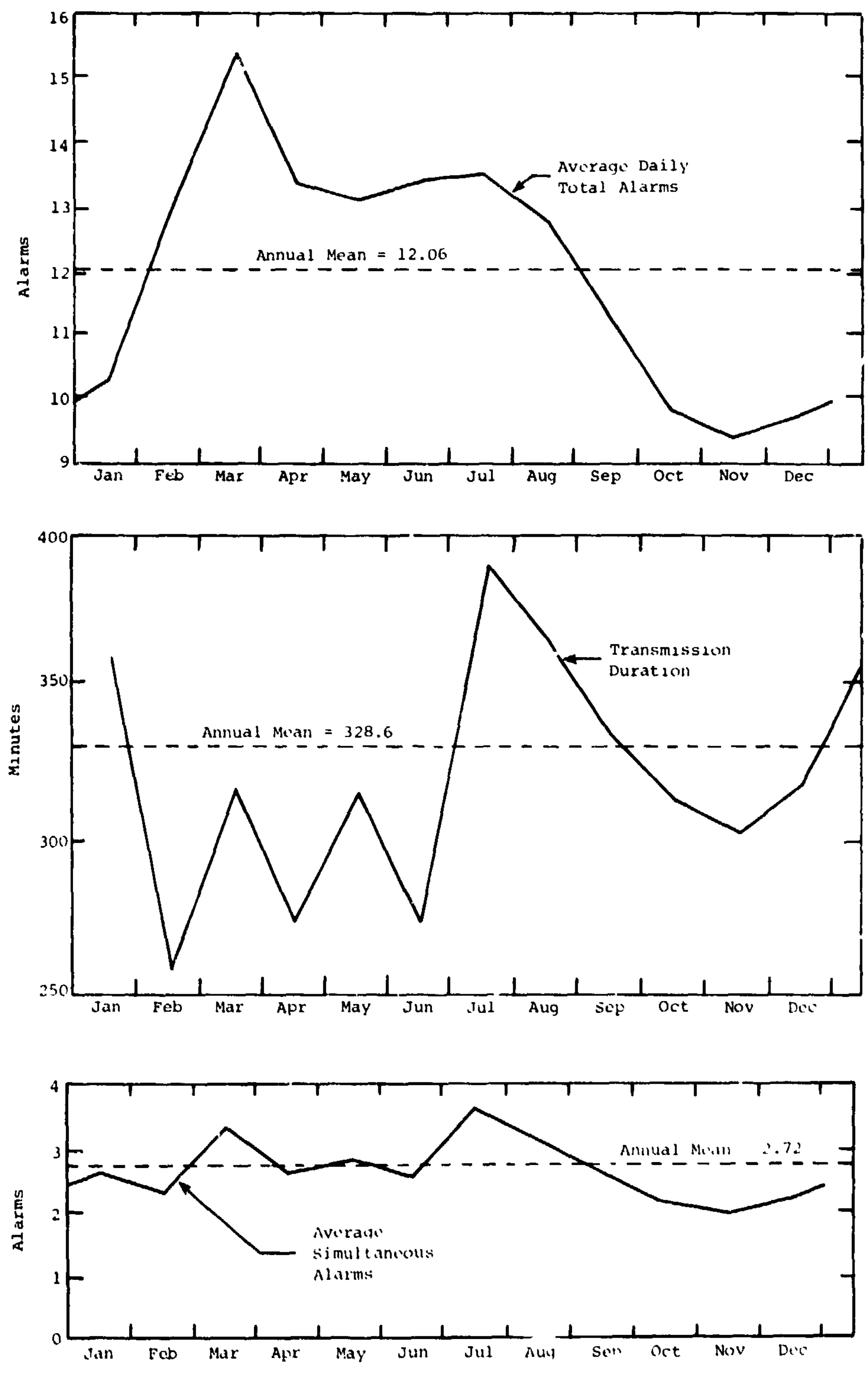


Figure 4-1. AVERAGE ELT ALARM RATE (1978 AFRCC DATA, 1402 SAMPLES)

duration (in minutes) was calculated on the basis of the average number of simultaneously transmitting ELTs and daily total alarms as follows:

$$\text{Average Transmission Duration} = \frac{60 \times 24 \times \text{Average Simultaneous Alarms}}{\text{Average Daily Total Alarms}}$$

As might be expected, ELT activity increases in the spring and summer and decreases in the fall and winter as the weather deteriorates. It is interesting to note that there is a large spike of activity in the month of March, which is 64 percent larger than the minimum activity in November and 28 percent above the average annual level of activity. This large spike might be the result of the onset of spring and concurrent annual reactivation of previously dormant aircraft. Gusty wind conditions during early spring may also contribute to the high alarm rate by violently jostling parked aircraft and triggering ELTs. Variations in the transmission duration and number of simultaneous alarms are substantial but not dramatic. Maximum variation is on the order of ±15 percent.

Figure 4-2 presents another perspective of the seasonal variation of reported ELT incidents. In this case, the percentage of time that a given number of ELTs are transmitting simultaneously is plotted as a function of the exact number of transmitters and season of the year. The summer season includes the period June through August, while winter includes the period December through February. The summer distribution is obviously skewed to the right of the winter season and the annual average distributions because of the higher percentage of time that large numbers of ELTs are transmitting simultaneously. This phenomenon is reflected by the significant differences in the measured mean number of simultaneous transmissions from summer to winter, i.e., 3.12 versus 2.32, respectively.

4.1.2.2 Weekly Variations

Variations between weekday and weekend reporting activity were minimal. The weekend mean of 2.84 simultaneously emitting ELTs is only six percent greater than the weekday mean of 2.67. This difference is inconsequential when compared with seasonal variations. Figure 4-3 is a plot of the probability distribution for simultaneously emitting ELTs as a function of weekend, weekday, and annual average.

4.1.2.3 Daily Variations

The average number of reported alarms was calculated for each 15-minute interval of the day. The results are presented in Figure 4-4. The graph begins at midnight Central Standard Time (CST) and covers a 24-hour period. CST was selected because the AFRCC and the geographic center of the United States are located in Central time. However, the number of simultaneous emitters at any given moment applies to the entire continental United States.

There is significant daily variation of activity about the annual mean. The peak number of transmissions occurs at 6 p.m. CST with 3.78 simultaneous alarms, while the minimum reporting rate bottoms out at

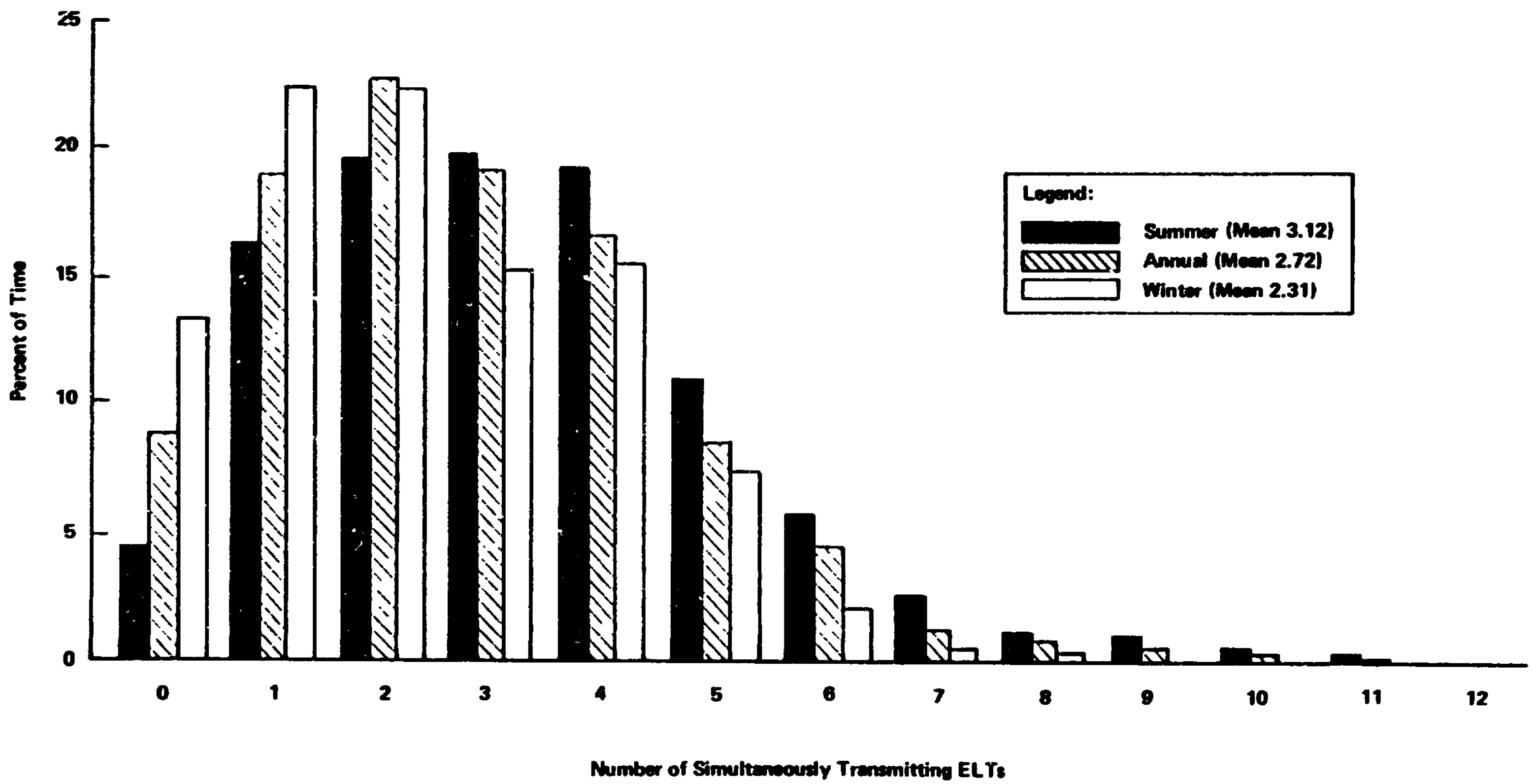


Figure 4-2. ELT INCIDENTS - SEASONAL EFFECTS (1978 AFRCC DATA, 1402 SAMPLES)

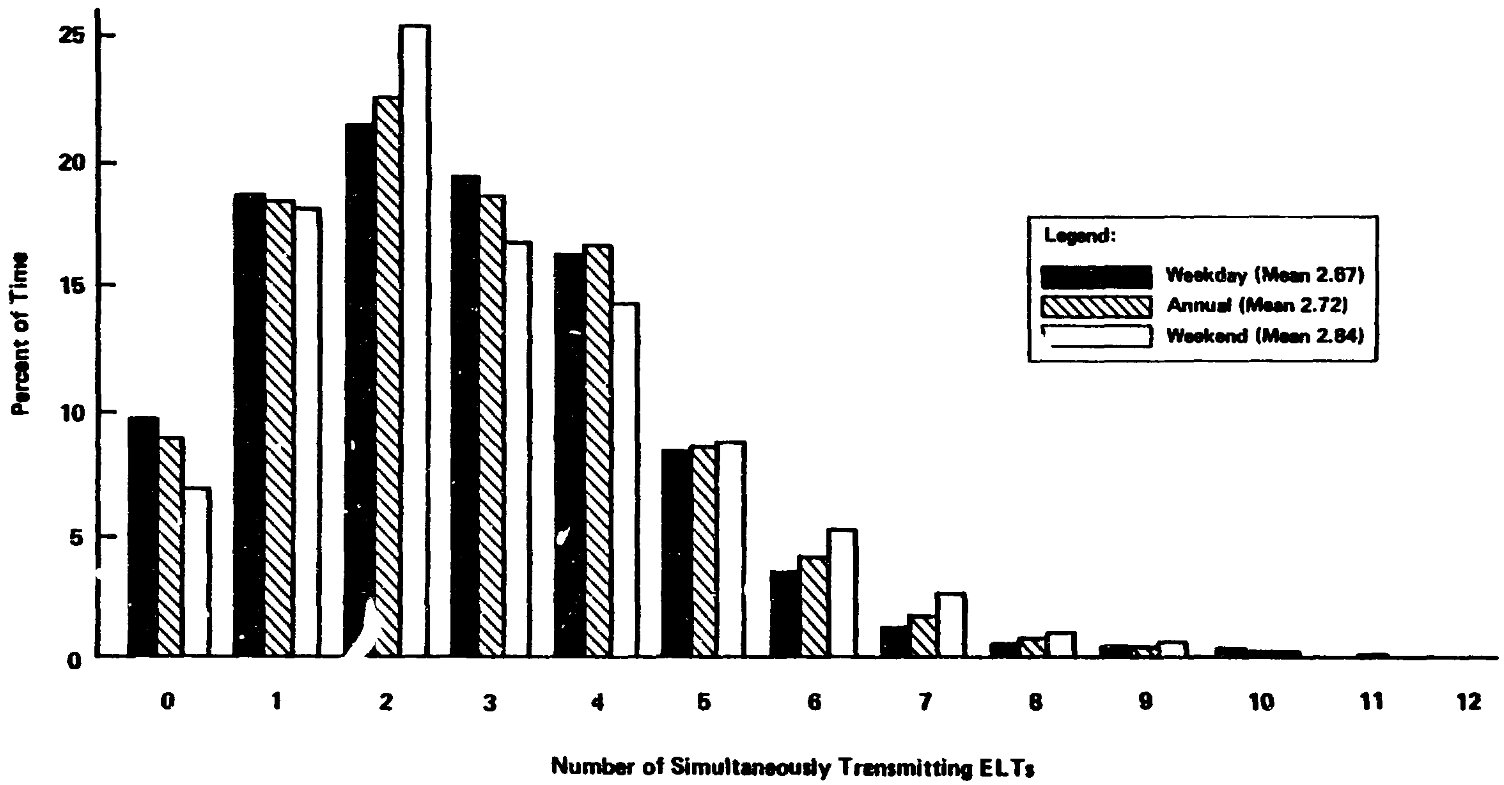


Figure 4-3. ELT INCIDENTS - WEEKDAY/WEEKEND VARIATION (1978 AFRCC DATA, 1402 SAMPLES)

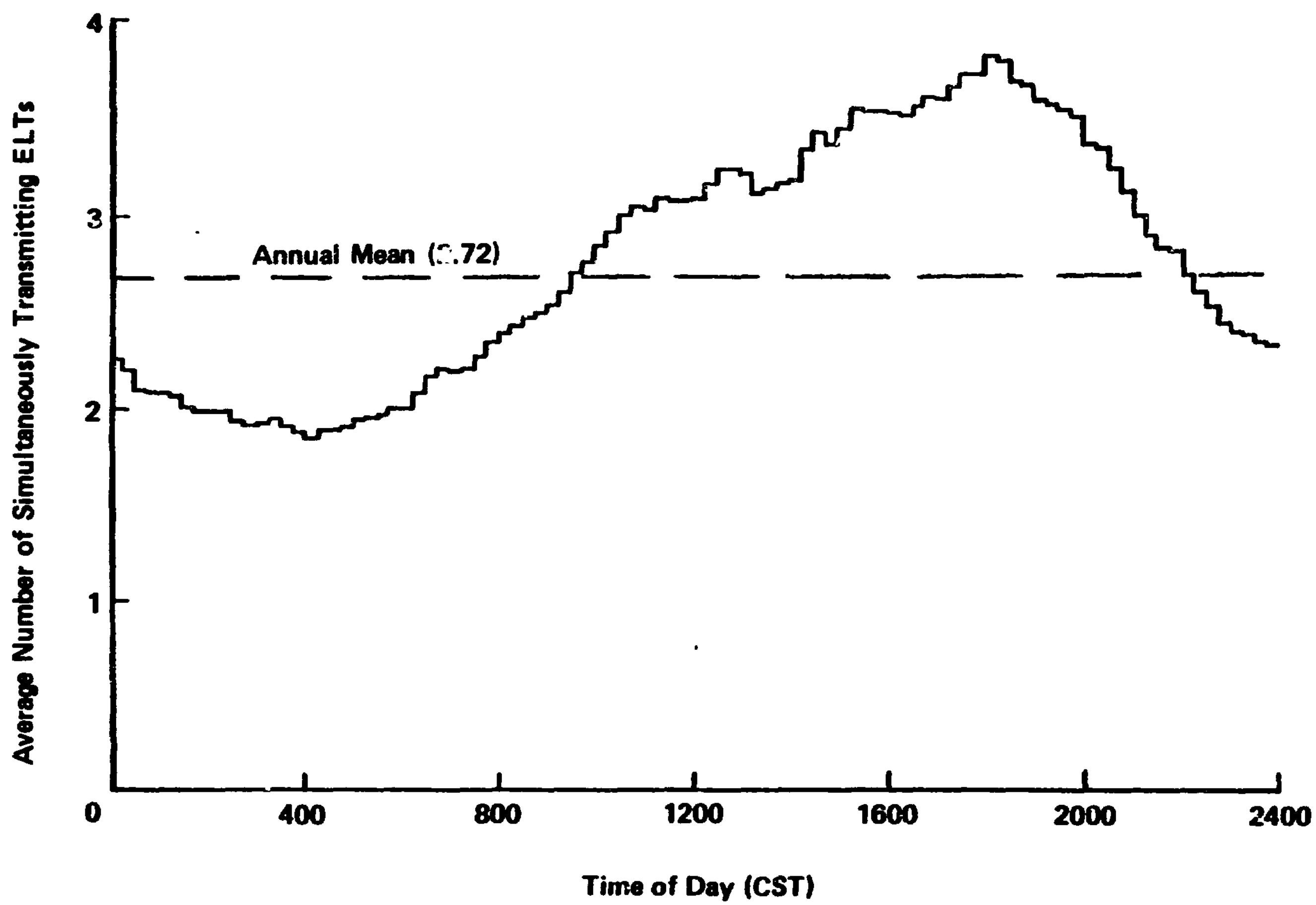


Figure 4-4. AVERAGE SIMULTANEOUS ELT TRANSMISSIONS - DAILY VARIATION (1978 AFRCC DATA, 1402 SAMPLES)

4 a.m. CST with 1.85 simultaneous alarms. This swing in reporting rate represents more than a 2:1 ratio between maximum and minimum as well as a +40 percent, -30 percent variation about the daily mean. The times of high and low activity correspond well to the high and low periods of daily aviation activity.

4.1.3 Duration of Transmission

Duration of transmission is defined as that period between the time of the initial report of an ELT transmission and the time the source is reported to be located and terminated. Both the Frequency Interference Reports and the AFRCC ELT Incident Log contain records of initial reporting time and final termination time.

Range of recorded transmission time is quite large: the shortest transmission period was 3 minutes, while the longest ELT remained active for more than 50 hours. Transmission durations were calculated and grouped into half-hour increments. The resulting distribution is presented in Figure 4-5.

There are significant differences between the distributions based on the FIR data and those based on the AFRCC data, the primary difference being the much shorter durations reported in the FIRs. This difference is reflected in the mean duration of only 142.4 minutes for the FIR records versus 328.6 minutes for the AFRCC records. The causes of this difference are threefold and are important enough to warrant further discussion:

- Delay in receipt of information at the AFRCC
- Geographic distribution of the Frequency Interference Reports
- Different objectives and characteristics of the two data bases

4.1.3.1 Delay in Receipt of Information at AFRCC

All FIRs are completed locally by FAA facilities, and copies of the report are forwarded to a central repository in Washington, D.C., after the incident is closed. Conversely, AFRCC ELT Incident Logs represent reports of emergency transmissions and their dispositions usually received second- or third-hand. Typically, a report on the status of an alarm will be transmitted to a local tower or FSS, from where it will be forwarded to the ARTCC, which reports it to the AFRCC. There is an inherent, significant information-transfer delay in this communications chain while the FIR is filled out by field personnel who are likely to be monitoring the emergency frequency. To measure this delay, FIR data were matched with the AFRCC data so that reports describing the same incident could be compared directly. This process is diagrammed in Figure 4-6. Of the 251 FIRs analyzed, 91 were found to be within the same date range as the Scott AFB data. Of the 91 FIRs, 35 could be matched with reasonable certainty to records in the Scott data base; i.e., the same ELT incident was recorded in both data bases.

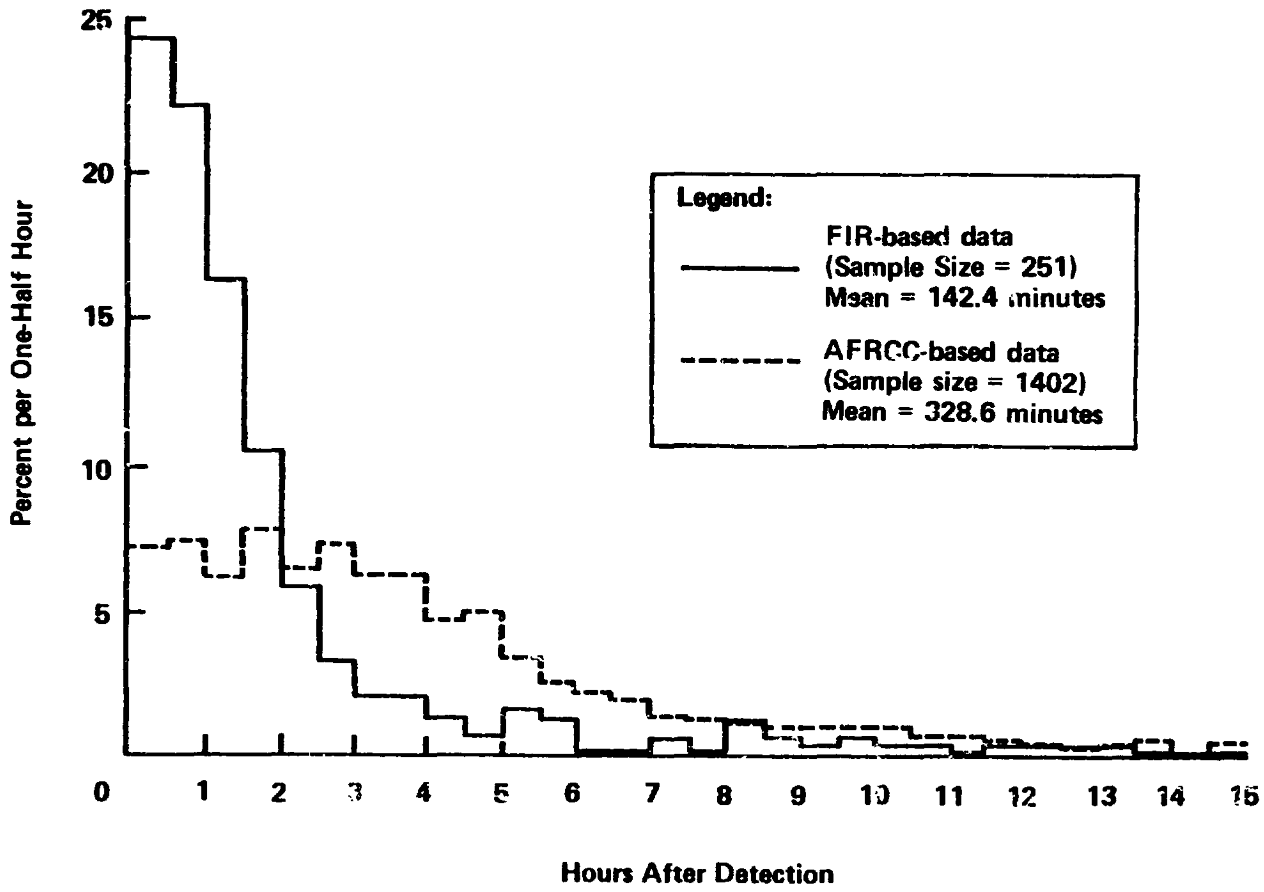


Figure 4-5. DURATION OF ELT TRANSMISSION

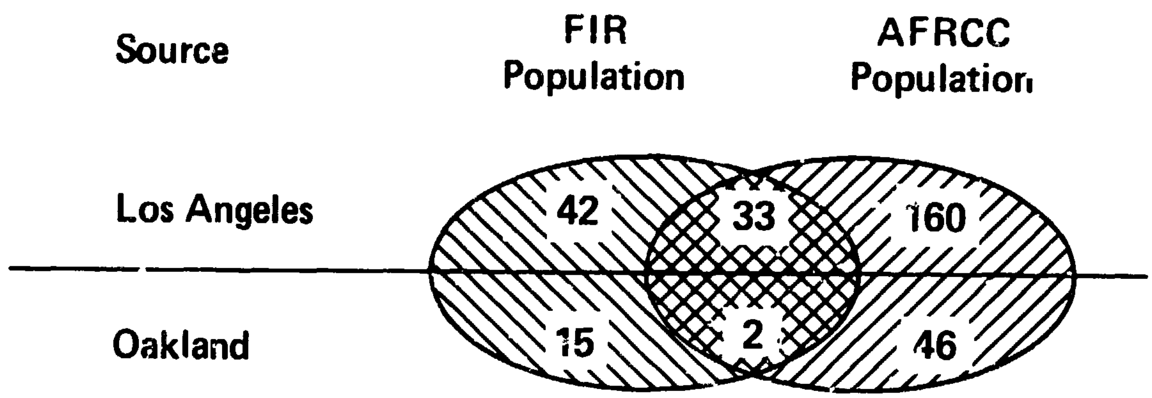


Figure 4-6. MATCHING FIR AND AFRCC RECORDS

It was found that the time of ELT shutoff, as recorded by AFRCC, averaged 79.5 minutes later than the time shown on the FIR. In 19 of the 35 cases, the incident was recorded as "not found" by the AFRCC; therefore, they had to wait for confirmed negative reports before the incident could be closed out. On the other hand, the delay on receipt of the initial reports that an ELT was "on" was only 4.3 minutes. On the basis of this sample, the AFRCC data show an average silencing time of 75.2 minutes (79.5 - 4.3) longer than the FIRs.

In addition, the 35 incidents recorded in both the FIRs and the AFRCC ELT Incident Logs were analyzed for patterns in delay of information receipt. There also appears to be a trend toward an increasing communication delay with increasing transmission duration. The significance of this trend is that a significant portion of the transmission time recorded by AFRCC may be due to slow notification. The true distribution of transmission durations may be more like the FIR curve than the AFRCC curve.

4.1.3.2 Different Geographic Distribution of Sample Populations

California is one of the most diligent states in filing FIRs, with the result that more than 75 percent of FIRs originate in California, as compared with only 20 percent of the AFRCC ELT Incident Logs, as presented in Table 4-2. This disparity in the geographical characteristics of the two data bases may contribute to different perceived transmission durations if California is particularly effective at locating and silencing ELTs.

Table 4-2. COMPARISON OF FIR AND ELT INCIDENT LOGS BY LOCATION		
Location of Incident	ELT Incident Log	FIRs
California	95	195
Arizona and Nevada	18	47
Remainder of United States	439	9

4.1.3.3 Different Sample Captured by the Two Data Sources

All FIRs are filed by FAA facilities to highlight occurrences of frequency jamming. Each occurrence is identified by an FAA facility, usually a control tower or Flight Service Station monitoring with ground-based receivers. The reception range of these receivers is limited by line-of-sight limitations of VHF radio signals. Thus most towers and FSSs receive transmissions only from sources at or very near the airport location. As a result, ELTs recorded on the FIRs are relatively easier to locate than those recorded on the AFRCC reports, which include many signal sources in remote locations as well as those from airports. In addition, AFRCC logs may include records of signals from airports during periods when the tower is closed and is not a factor in quickly detecting and silencing the ELT. This situation is shown in Table 4-3. Thus the two data bases are, in effect, recording the problem from different viewpoints.

Table 4-3. COMPARISON OF FIR AND ELT INCIDENT LOG SOURCES		
Signal Source (Where Known)	Number of Incidents Reported	
	FIRs	ELT Incident Logs
Towered Airport	134	215
Nontowered Airport	17	175
Unknown Airport	0	65
Other	0	98
Total	151	543

4.2 GEOGRAPHIC DISTRIBUTION OF ELT FALSE ALARM REPORTS

As discussed previously, only the AFRCC ELT Incident Logs are filed on a national basis; therefore, the AFRCC data base will be used exclusively as a basis for this discussion.

4.2.1 National Distribution

The AFRCC receives and tracks reports of ELT transmissions principally from FAA Air Route Traffic Control Centers (ARTCCs). Figure 4-7 is a map of the sources of ELT incident reports. One would have expected Los Angeles, Chicago, New York, and Miami to have the largest number of reports submitted to AFRCC because these centers represent areas of heaviest general aviation activity. In fact, there seems to be no particular national pattern for predicting the number of ELT incident reports. It is interesting to note that the Seattle region, which is ranked ninth nationally in total aviation activity, submits the second largest number of reports to AFRCC.

4.2.2 Origin of Located False Alarms

Figure 4-8 summarizes the data reviewed in this effort. More than 80 percent of all incidents that were eventually traced to a specific aircraft were found at airports. In fact, nearly 40 percent of the total 553 records examined indicated that the ELT was physically found at a towered airport. The implications of these data are significant because the average transmission duration at towered airports is only half that from all other origins. Thus the cost of locating these signals should be significantly lower than for all other alarms. It may also be easier to implement workable administrative procedures to control false alarms at towered airports than at the other locations.

If an ELT cannot be located quickly, the AFRCC will initiate a mission, that is, deploy SAR forces to locate and silence the ELT. AFRCC maintains separate records of all alarms for which missions were initiated. One hundred seventy-six of the 1,402 incidents in our sample period resulted in such missions. In 39 of these records the signal terminated before it could be located. One hundred six of the remaining 137 records originated at airports, and the remainder were scattered evenly between miscellaneous origins. The distribution of mission reports by origin is presented in Figure 4-9.

4.3 CAUSES OF FALSE ALARMS

Analysis of the Frequency Interference Reports and Service Difficulty Reports identified four basic reported causes of false alarms:

- Human Error. A preventable false alarm results from someone's carelessness. For example, any signal transmitted by an ELT not mounted in an airplane would be classified as human error

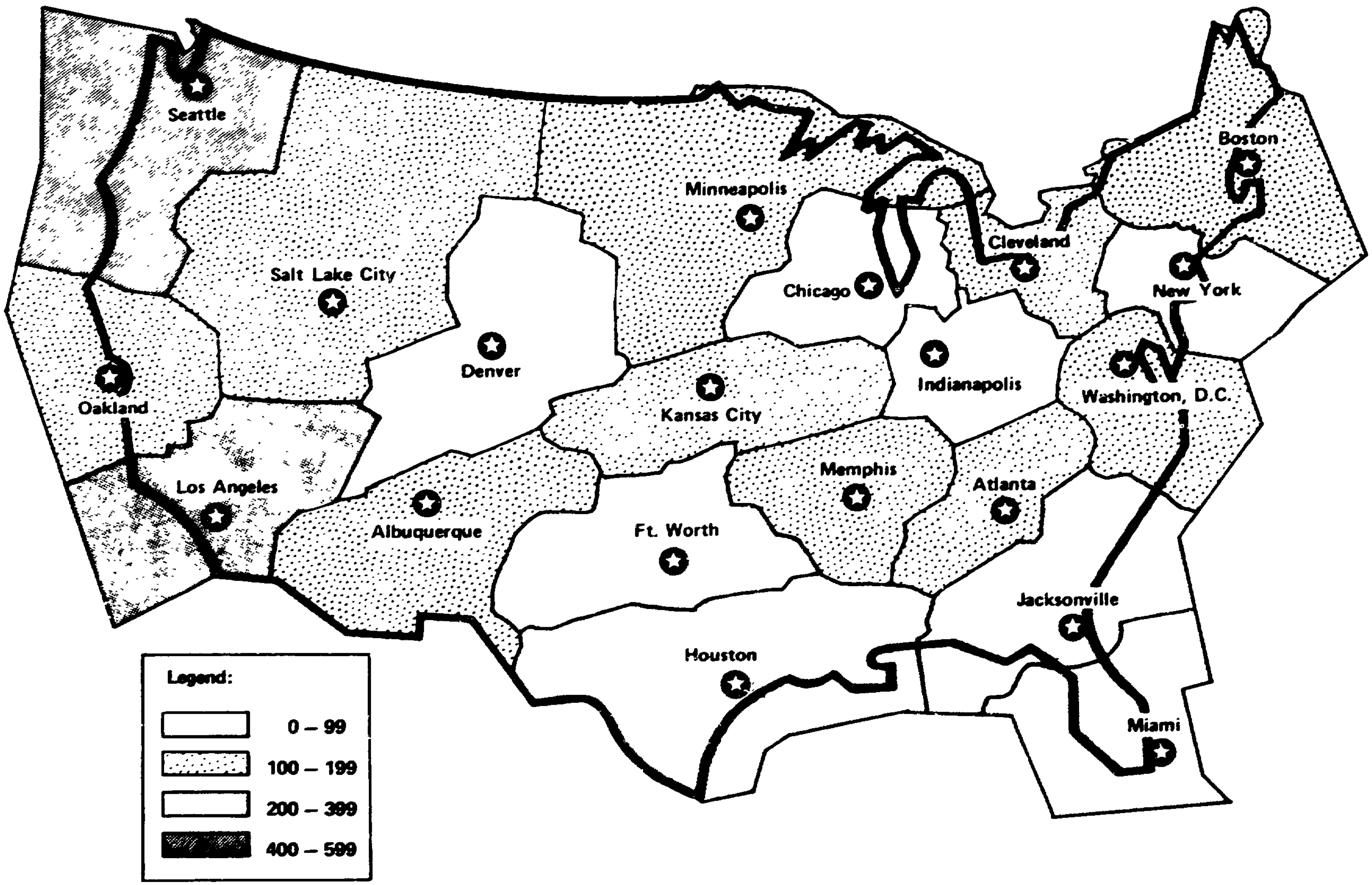


Figure 4-7. ANNUAL ELT REPORTS BY AIR ROUTE TRAFFIC CONTROL CENTER (ARTCC) (1978 AFRCC DATA, 4302 TOTAL SAMPLES)

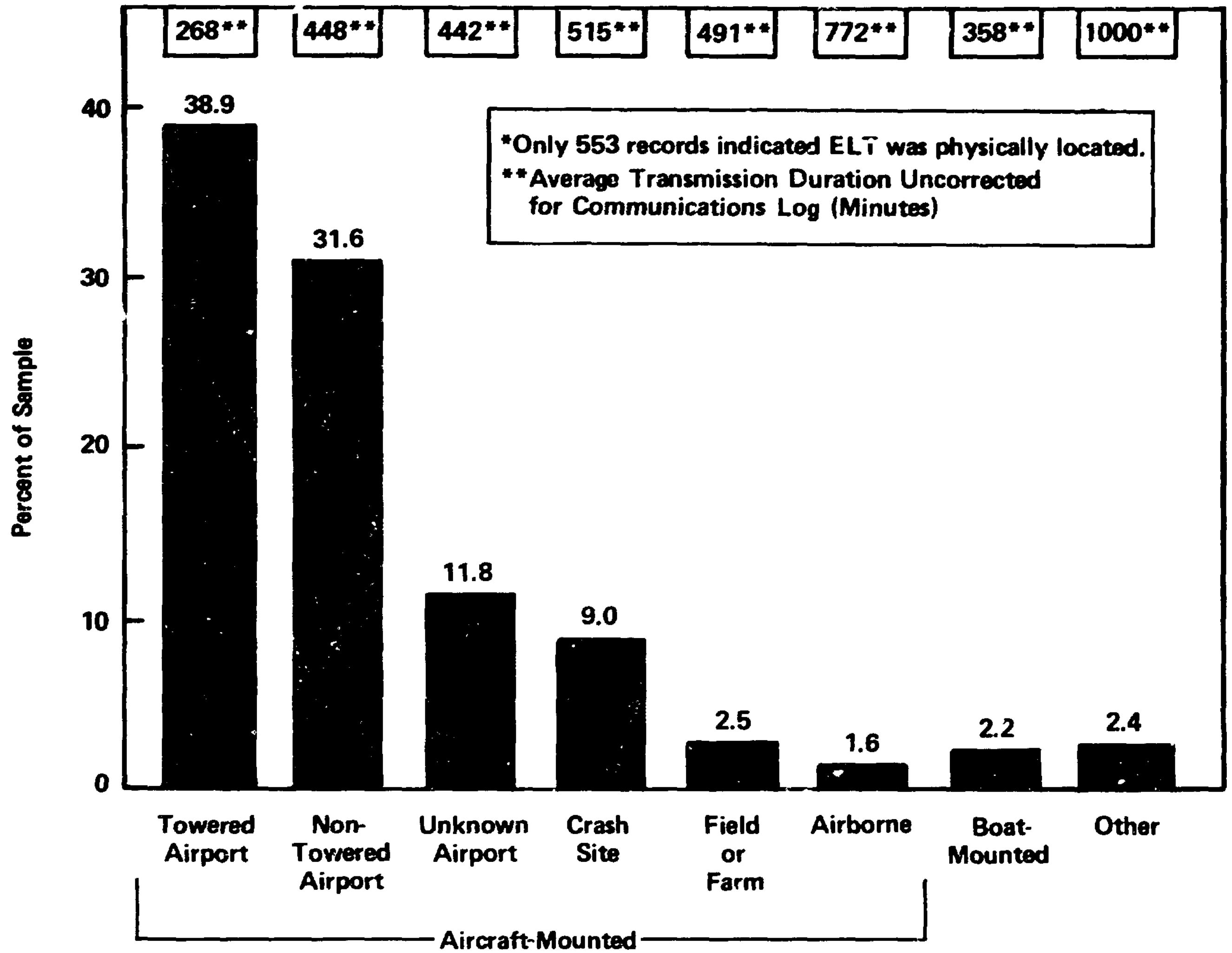
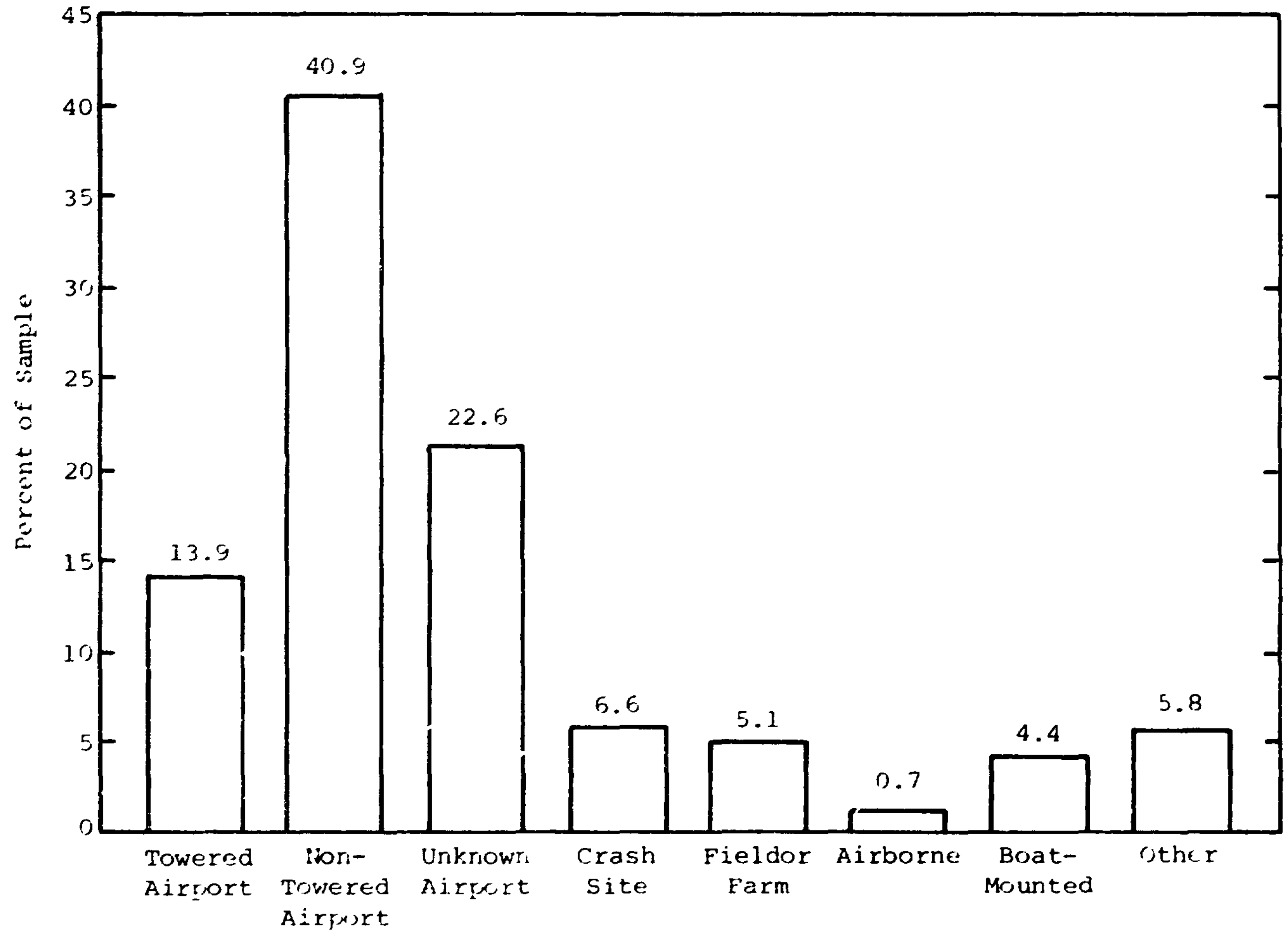


Figure 4-8. ORIGIN OF LOCATED ALARM TRANSMISSIONS (BASED ON 1402 AFRCC RECORDS*)



*Only 137 records clearly identified signal origin.

Figure 4-9. ORIGIN OF LOCATED ALARM TRANSMISSION REPORTS (BASED ON RESULTS OF 176 AFRCC MISSIONS*) since the unit should have been switched to "OFF" prior to removal from the aircraft. Human error may be subdivided into six major causes:

- •• The pilot bumps the G-switch with some part of his body.
- •• The ELT is set off by a shock, such as dropping the unit or throwing baggage against it.
- •• A passenger, or other untrained layman, unknowingly sets off the ELT.
- •• The switch is found in the ON position.
- •• The ELT is installed improperly so as to make it easily triggered.
- •• The ELT goes off while the aircraft is under the care of maintenance personnel

- G-Switch. The deceleration-sensitive switch often malfunctions and sets off the ELT, as follows:
  - •• Jammed -- The switch sometimes became mechanically stuck in the ON position, which is a fairly common occurrence.
  - •• Sensitive -- The ELT is triggered by turbulence, heavy wind, a slammed door, hard landing, or a similar force that should not have been sufficient to activate the ELT.
  - •• Stuck on -- The ELT cannot be reset, or it transmits continuously in the OFF or ARM positions. In these cases the antenna or battery must generally be removed to silence the unit.
  - •• Defective/shorted -- This malfunction represents all other switch-related mechanical or electrical problems, except for corrosion.
- Corrosion. Circuits short or are rendered inoperative by corrosion, which in most cases results from leaky lithium sulfur dioxide batteries. If a corroded switch activates the ELT, it is classified under "corrosion".
- Miscellaneous. These are unusual causes represented by the following:
  - •• Water-activated -- Water or moisture seeps into the ELT and shorts enough components to cause an activation.
  - •• Radio-activated -- ELT is sensitive to the pilot's keying the VHF transmitter.
  - •• Heat-activated -- ELT is exposed to excessive heat, typically absorbing direct sunlight in a closed cabin during the summer.

4.3.1 Analysis of Causes of Service Difficulty Reports

Table 4-4 summarizes the reported causes found in the Service Difficulty Reports from 1974 to 1979. The data base consists of 60 consecutive months from April 1974 to March 1979. Many incident reports show no cause or present insufficient information to determine a cause. These reports are listed as "unknown". For example, an ELT could go off without a sign of careless handling or equipment defect. If the ELT is properly reset and gives no further trouble, the incident is listed as "unknown". Many reports simply state "ELT activated". With the absence of further information, these incidents are also characterized as "unknown".

Table 4-4. SUMMARY OF CAUSES OF ELT INCIDENTS (BASED ON 1,541 SERVICE DIFFICULTY REPORTS)

Cause	Number of Reports by Reporting Period						Total
	1974*	1975	1976	1977	1978	1979**	
Human Error	84	56	20	12	6	0	178
G-Switch	144	62	31	30	38	3	308
Corrosion	46	49	29	29	54	4	211
Miscellaneous	38	11	9	5	6	0	69
Unknown	435	204	75	20	35	6	775
Total	747	382	164	96	139	13	1,541

*April through December.
**January through March.

Table 4-4 demonstrates that the nature of false alarm reports has changed over time. Valuable information may be deduced from the relative magnitudes of the four causes of false alarms.

Figure 4-10 depicts trends in the relative importance of the four main causes of ELT false alarms, excluding "unknown", from the total population for purposes of this calculation. Both the "human error" and "miscellaneous" categories show a definite decline over the years, probably as a result of increasing user familiarity with the equipment. It is also possible that since the ELT itself performed as it should, the filing of the Service Difficulty Report was considered unnecessary. G-switch-related problems remain essentially unchanged since 1974, reflecting a stable technology base. The alarms, because of battery corrosion, have commanded a growing share of false alarm reports as the Li-SO_2 batteries aged. However, it is expected that this trend in battery-related failures should be reversed as a result of the FAA's

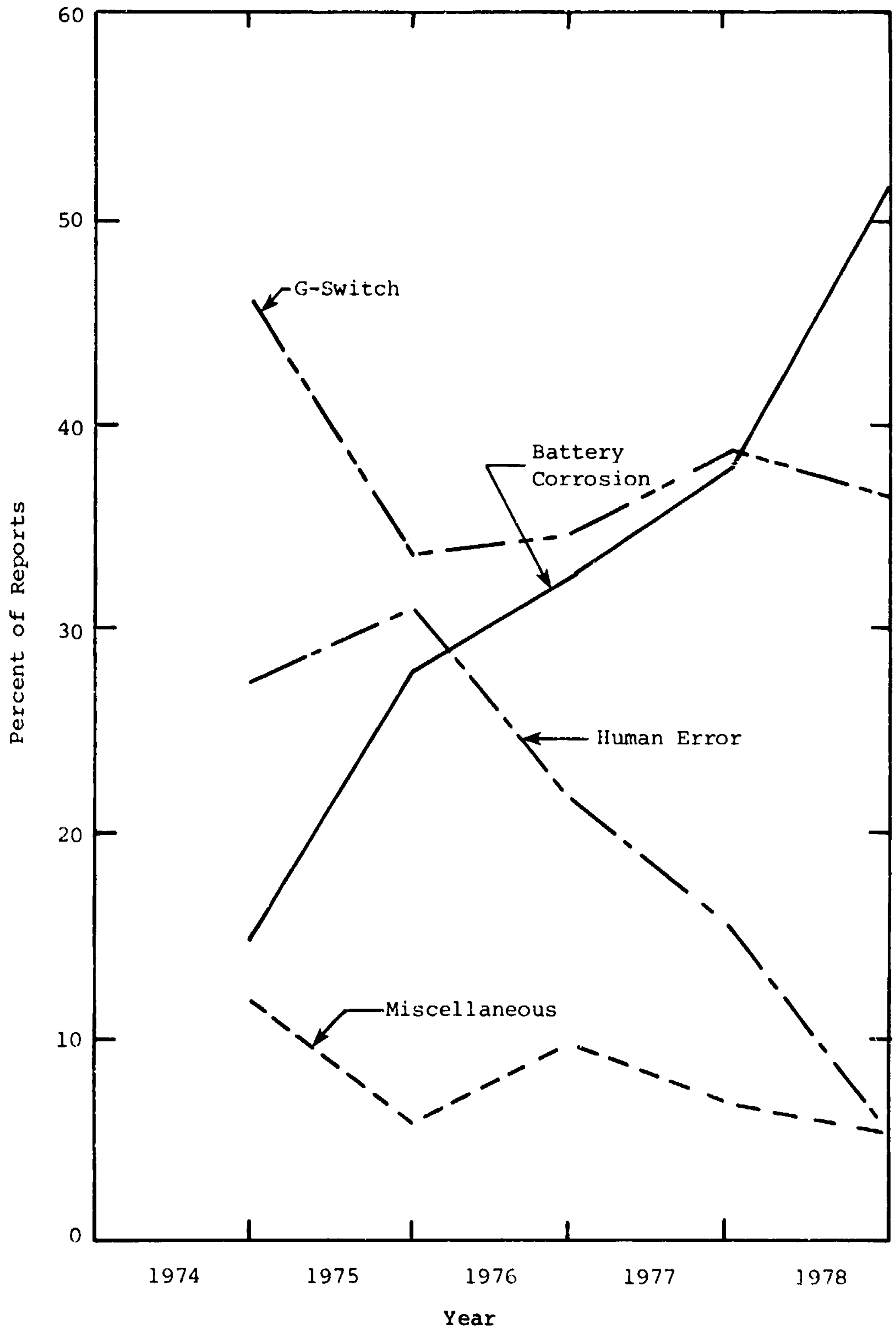


Figure 4-10. TRENDS IN ELT FALSE ALARM CAUSES (BASED ON 1541 SERVICE DIFFICULTY REPORTS)

Airworthiness Directive (AD) requiring removal of Li-SO_2 batteries from ELTs as of 26 February 1979. This directive effectively removed thousands of ELTs from service, and it is expected to result in a dramatic decrease in reported incidents during 1979. A subsequent AD in August 1979 published a new battery specification that is expected to alleviate the corrosion problem.

4.3.2 Analysis of Causes of Frequency Interference Reports

The FIRs are too few in number to provide representative statistical data on causes of ELT false alarms. In addition, the reports are filed primarily in California and may contain some atypical biases in the sample that do not exist for the nation as a whole. The following discussion is intended only to provide a qualitative background in FIR statistics.

Eighty-one of the total number (151) of FIR reports listed the cause as "unknown", leaving 70 reports for which the cause could be identified. Only two reports were categorized under corrosion or miscellaneous, providing a sharp contrast to the Service Difficulty Reports. This contrast can be explained by the fact that FIRs are generally submitted by ATCT or FSS personnel who are not directly involved in the search for a transmitting ELT. When a radiating ELT is located and silenced, the tower will notice only that the frequency has been cleared. The airport staff, who actually found the ELT, will not necessarily call the tower to inform them of the cause, or they may call before anyone has had an opportunity to open the ELT and inspect for damage. As a result, it is not unexpected that so few cases of corrosion were reported. Many of the incidents listed as "unknown" were undoubtedly corrosion-related.

Human error was the most reported cause of a false alarm, accounting for 48 of the known incidents, or 69 percent. Twenty-three of these 48 incidents occurred while the aircraft or ELT was undergoing maintenance; in 18 cases the switch was found "on", and in 7 of those cases the switch was activated, shocked, or bumped. Most of these errors could have been prevented if aircraft owners and maintenance personnel had more respect for the sensitivity of the ELT. The G-switch, theoretically, should not trigger simply because the aircraft is undergoing maintenance, but evidently the stresses resulting from working on the airframe or engine can activate an overly sensitive unit. Disarming the ELT prior to maintenance work would virtually eliminate this problem. The causes of ELT false alarms recorded on FIRs are summarized in Table 4-5.

4.4 MAKE AND MODEL STATISTICS OF ELT FALSE ALARM REPORTS

A significant percentage of the FIRs and SDRs contained specific make or model information. Therefore, the reports were analyzed on a make and model basis to determine if any significant patterns emerged.

Table 4-5. SUMMARY OF CAUSES LISTED ON FIRs*	
Cause	Number Reporting
Human Error	48
G-Switch	20
Corrosion	1
Miscellaneous	1
Unknown	81
Total	151

*Based on 151 Frequency Interference Reports

More than 80 percent of the SDRs filed between 1974 and 1978 were traced to units manufactured by Communications Components Corporation, Emergency Beacon Corporation, Garrett, and Leigh Systems. (It must be remembered that the appearance of a firm's units in many reports does not necessarily indicate poor quality or defective hardware because a disproportionately large number of those units could have been installed.) With one exception, the number of SDRs traced to each manufacturer decreased significantly during that period. For example, Leigh Systems was referenced 459 times in 1974 but only 24 times in 1978. References to Garrett Corporation and Emergency Beacon Corporation decreased from 64 to 20 and 94 to 5, respectively. These data are summarized in Tables 4-6, 4-7, and 4-8. Table 4-9 presents similar data for FIRs.

The specific statistical conclusions that can be drawn from this analysis are limited by a number of factors:

- The number of reports filed per manufacturer/model per year is a small statistical sample, on the order of 20 reports or less. Therefore, annual variations for any given manufacturer may be as much a function of normal statistical fluctuations between samples as of actual differences in performance. However, it could be expected that long-term, multiyear trends will be reflected properly.
- The total population of each manufacturer's product in use at any given time is dynamic. For example, different models may be introduced, upgraded, modified, or discontinued. At the same time, consumer's priorities and interests change, different products gain favor or fall into disfavor, and ELTs are replaced in the field.

Table 4-6. SUMMARY OF ELT INCIDENT REPORT TRENDS (BASED ON 1,541 SERVICE DIFFICULTY REPORTS)

Manufacturer (Model)	Number of Reports by Reporting Period						Total
	1974*	1975	1976	1977	1978	1979**	
ACR Electronic Division (RLB 101, RLB 5)	4	5	1	2	1	0	13
Aero Electric (Pointer 2, 2000, 3000)	7	7	4	5	7	1	31
Aircraft Products (Alert 50)	9	4	5	1	1	0	20
Communications Components Corporation (CIR 10, CIR 11)	12	9	9	18	60	4	112
Dorne & Margolin (DMELT 13, DMELT 52)	16	4	5	5	8	3	41
Edo	1	1	1	3	1	0	7
Emergency Beacon Corporation (EBC 102, EBC 302)	94	56	30	20	5	3	208
Garrett (Rescu 88)	64	45	18	9	20	1	157
Larago Electric Manufacturing (1005)	32	16	10	1	4	0	63
Leigh Systems (Sharc 7)	459	184	70	28	24	1	766
Martech Division (EB 2B)	8	9	2	1	2	0	22
Narco (ELT 10)	11	23	4	3	5	0	46
Pathfinder Company (2052)	24	10	3	0	0	0	37
Radair (Dart 2)	0	0	0	0	0	0	0
Unknown	6	9	2	0	1	0	18
Total	747	382	164	96	139	13	1,541

*April through December.
**January through March.

Table 4-7. CAUSES OF ELT FALSE ALARMS (BASED ON 1,541 SERVICE DIFFICULTY REPORTS)						
Manufacturer (Model)	Number of Reports by Cause					Total
	Human Error	G-Switch	Corrosion	Miscellaneous	Unknown	
ACR Electronic Division (RLB 101, RLB 5)	4	5	1	0	3	13
Aero Electric (Pointer 2, 2000, 3000)	6	5	8	2	10	31
Aircraft Products (Alert 50)	2	8	0	1	9	20
Communications Components Corporation (CIR 10, CIR 11)	4	50	33	0	25	112
Dorne & Margolin (DMELT 13, DMELT 52)	4	9	8	3	17	41
Edo	0	1	3	0	3	7
Emergency Beacon Corporation (EBC 102, EBC 302)	72	35	1	7	93	208
Garrett (Rescu 88)	31	27	14	9	76	157
Larago Electric Manufacturing (1005)	8	21	0	3	31	63
Leigh Systems (Sharc 7)	24	133	123	34	452	766
Martech Division (EB 2B)	3	5	3	1	10	22
Narco (ELT 10)	15	5	5	0	21	46
Pathfinder Company (2052)	2	1	12	7	15	37
Radair (Dart 2)	0	0	0	0	0	0
Unknown	3	3	0	2	10	18
Total	178	308	211	69	775	1,541

Table 4-8. DETAILS OF REPORTS BY MANUFACTURER, CAUSE, AND YEAR (BASED ON 1,541 SERVICE DIFFICULTY REPORTS)

Cause	Number of Reports by Year					
	1974	1975	1976	1977	1978	1979
Communications Components Corporation						
Human Error	1	1	-	-	-	-
G-Switch	4	6	0	12	27	1
Corrosion	-	-	3	5	22	2
Miscellaneous	-	-	-	-	-	-
Emergency Beacon Corporation						
Human Error	30	20	13	6	3	0
G-Switch	12	10	5	6	1	1
Corrosion	-	1	-	-	-	-
Miscellaneous	-	1	3	3	-	-
Garrett						
Human Error	16	11	1	1	2	-
G-Switch	8	8	5	7	3	1
Corrosion	-	-	-	4	10	-
Miscellaneous	4	-	2	-	3	-
Leigh Systems						
Human Error	13	9	2	-	-	-
G-Switch	90	22	12	6	3	-
Corrosion	43	33	22	15	10	-
Miscellaneous	24	4	2	2	2	-

Manufacturer (Model)	Number of Reports by Cause					Total
	Human Error	G-Switch	Corrosion	Miscellaneous	Unknown	
ACR Electronic Division (RLB 101, RLB 5)	0	0	1	0	2	3
Aero Electric (Pointer 2, 2000, 3000)	0	2	0	0	4	6
Aircraft Products (Alert 50)	2	0	0	0	1	3
Communications Components Corporation (CIR 10, CIR 11)	1	3	0	0	10	14
Dorne & Margolin (DMELT 13, DMELT 52)	1	0	0	0	6	7
Edo	0	0	0	0	0	0
Emergency Beacon Corporation (EBC 102, EBC 302)	12	1	0	0	19	32
Garrett (Rescu 88)	4	1	0	0	5	10
Larago Electric Manufacturing (1005)	0	1	0	0	3	4
Leigh Systems (Sharc 7)	6	2	0	1	6	15
Martech Division (EB 2B)	0	1	0	0	3	4
Narco (ELT 10)	6	0	0	0	12	18
Pathfinder Company (2052)	0	0	0	0	0	0
Radair (Dart 2)	0	0	0	0	0	0
Unknown	16	9	0	0	10	35
Total	48	20	1	1	81	151

Table 4-9. CAUSES OF ELT FALSE ALARMS (BASED ON 151 FREQUENCY INTERFERENCE REPORTS)

- The regulatory climate may have significant impact on the actual usage patterns of equipment installed in the field. For example, a recent Airworthiness Directive required the removal of the battery from all units powered by Li-SO_2 batteries. The immediate impact of this directive is expected to decrease the number of reports by about 37 percent.
- The distribution of manufacturers has changed markedly since 1974. Of the 14 manufacturers identified in 1975 as producers of ELTs, less than 5 are actively marketing units today.
- No statistically accurate data were collected that describe either the total population of ELTs in use or the manufacturer's make and model distributions.

4.5 MATHEMATICAL CHARACTERISTICS OF SIMULTANEOUS ELT REPORTS

The distribution of simultaneous transmissions presented in Section 4.1 was compared with mathematical distributions of known characteristics to develop an analytical model of the statistical behavior of simultaneous ELT reports. The ELT population exhibits several characteristics that imply a Poisson behavior:

- ELT activation is a random process.
- For any given ELT at any given moment, only two results are possible -- transmitting or not transmitting.
- The probability of either condition's existing for any given ELT at any given moment is approximately constant throughout the population.
- The number of simultaneously transmitting ELTs at any given moment must be an integer.

It is evident from Figure 4-11 that a Poisson distribution whose expected value (λ) is equal to the average number of simultaneously transmitting ELTs predicts very closely the results gathered from AFRCC records.

The advantage of using a Poisson characterization is that the exact shape of the probability curve depends only on the mean of the independent variable, in this case, the number of ELTs transmitting simultaneously. Thus it is necessary only to calculate the mean to determine the entire distribution. From this value it is easy to calculate the probability that the number of simultaneous transmissions is greater than a given value. This property will be used in subsequent analyses.

4.6 SIGNIFICANCE OF ELT ALARM REPORTS

The data presented in this chapter were derived from a sample of the total number of ELT reports. The ELT reports themselves are actually a

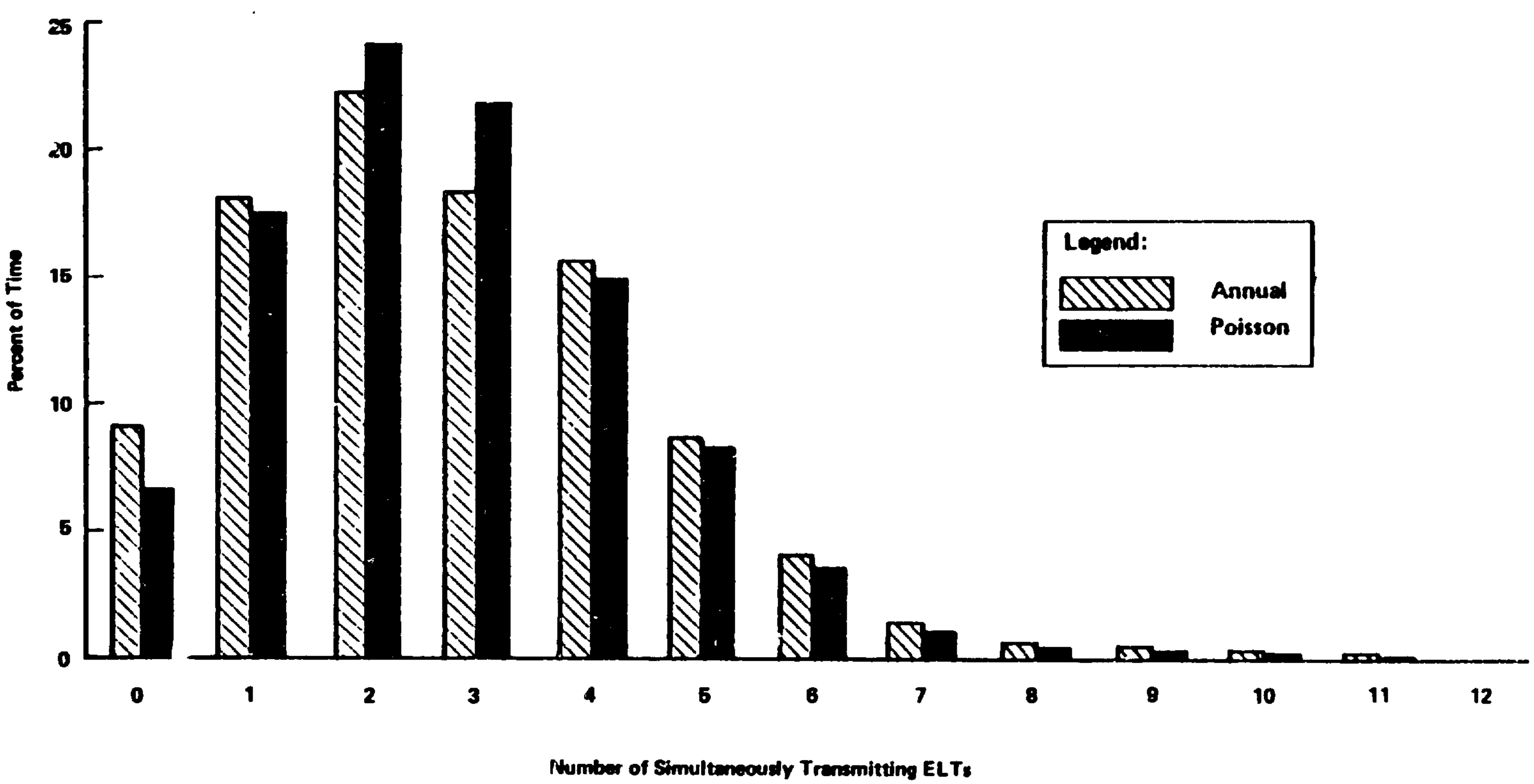


Figure 4-11. ELT TRANSMISSIONS - POISSON AND ANNUAL DISTRIBUTION (1978 AFRCC DATA, 1402 SAMPLES)

sample of the true total number of ELT false alarms that must be calculated on the basis of the parameters compiled in this chapter. Chapter Five presents the necessary calculations and results describing the nature of the total number of ELT alarms.

CHAPTER FIVE

DATA ANALYSIS

5.1 RESULTS OF INVESTIGATION

Chapter Four developed statistical measures describing the nature of ELT alarm reports on the basis of a random sampling of these reports. However, these measures provide only a partial representation of the extent and nature of the total ELT false alarm problem, as illustrated in Figure 5-1.

In Figure 5-1 the dark central region represents the actual report samples selected and studied. The region within the gray boundaries represents the total population of reports as inferred from the random sample and discussed in Chapter Four.

This chapter is a discussion of the estimated characteristics of all ELT alarms, reported and unreported, as represented by the white region in Figure 5-1. These characteristics were calculated as described herein on the basis of data presented in previous chapters. The parameters of primary interest are:

- Number of unreported incidents
- Probability of simultaneous incidents
- Geographic distribution of incidents
- Causes and sources of incidents
- Costs of incidents

These calculations will be used as a basis for cost-benefit analyses of various control strategies presented in the remainder of this report.

5.2 TOTAL REPORTED AND UNREPORTED INCIDENTS

As previously discussed, none of the three data bases contain a record of every ELT alarm nor does the aggregate of these data bases represent all alarms. Therefore, the number of unreported alarms must be estimated to assess the magnitude of the problem, to determine the number of ELT signals that SARSAT may encounter, and to calculate the benefits of each proposed strategy to reduce false alarms.

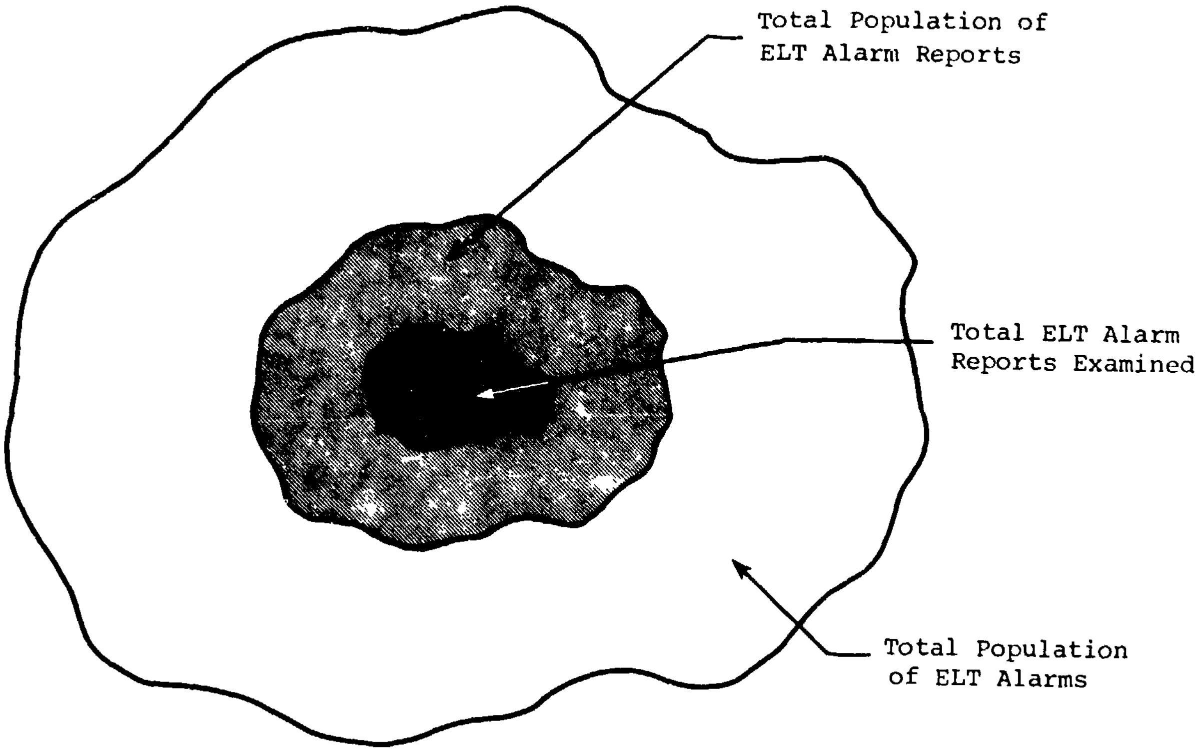


Figure 5-1. RELATIONSHIP OF DATA SOURCES TO TOTAL ELT ALARM POPULATION

The distribution of reports by ARTCC provides a clue in this regard because some centers seem to be more conscientious than others in reporting incidents to AFRCC. For example, the Seattle Center, despite its low population base, has almost twice as many reports as New York and more than six times as many as Chicago. Only the Los Angeles center, with its very large general aviation fleet, filed more reports than Seattle.

If the actual reporting rates at each ARTCC could be determined, or if the efficiency of the most conscientious center could be estimated, then an estimate of the number of unreported incidents could be calculated. Unfortunately, there are no data concerning the reporting efficiency of each ARTCC. Therefore, unreported alarms had to be estimated on the basis of the efficiency of the most conscientious center. Certain critical assumptions were made in this process:

1. Reporting efficiency and the ELT alarm rate are measurable in terms of alarms per unit of aircraft population (i.e., alarms per 1,000 aircraft) and unit of aviation activity (i.e., alarms per 1,000,000 recorded operations -- takeoffs and landings -- at towered airports).

2. The Seattle ARTCC reports the highest percentage of alarms, i.e., 57 percent, which is based on the verbal estimate of a Washington State SAR official. This rate is equivalent to 0.158 alarms per aircraft. Alternative estimates were obtained from the state of Louisiana and from three general aviation airports (Montgomery County, Maryland; Long Beach/Santa Ana, California; Opa Locka, Florida). These alternate estimates ranged from 0.058 to 0.174 and indicate that the Seattle estimate is of the proper order of magnitude.

3. The FIR ELT transmission duration curve given in Subsection 4.1.3 is representative of the characteristics of unreported incidents. Although FIRs are filed primarily in the FAA Western Region, most of the state aviation officials interviewed stated that assistance from AFRCC is not requested unless the ELT cannot be located within an hour. This circumstance, coupled with the nature of the FIR reporting process, supports the validity of such an assumption.

4. Silencing time is independent of geographic location; therefore, a nationally valid, uniform silencing-time curve can be developed.

5. The ELT alarm rate is independent of geographical location. This assumption implies that the calculated alarms per unit of measure for the most conscientious ARTCC can be applied to all other ARTCCs. While there may in fact be some geographical alarm rate variations from center to center (possibly due to weather or manufacturer mix), the variation actually observed (greater than 8:1) is too high to be credible.

5.2.1 Reporting Efficiency

Aircraft registration data as of 31 December 1977 were extracted from the *FAA Statistical Handbook of Aviation*. Data for recorded aircraft operations at towered airports in 1978 were obtained from the publication *FAA Air Traffic Activity*. Both sets of data had been collected on a state-by-state basis; therefore, it was necessary to allocate each state's share to one or more ARTCC. Three different methods were applied to achieve this goal:

- Totals for states entirely within a given ARTCC* were summed completely into the figures for that ARTCC.

*Arizona, Arkansas, Colorado, Delaware, Washington, D.C., Kansas, Maine, Maryland, Massachusetts, Minnesota, Mississippi, Montana, New Hampshire, New Jersey, New Mexico, North Dakota, Rhode Island, South Carolina, Vermont, Virginia, Washington.

- Totals for some states spanning two or more ARTCCs were apportioned on the basis of human population. These states* had aviation communities based primarily in several distinct population centers, obviously within the bounds of a particular ARTCC. Each population center was surrounded by sparsely settled countryside.
- Totals for several of the largest states that cross center boundaries** were apportioned according to detailed data on operations at towered airports. The number of operations at each airport was allocated to a particular ARTCC; the total statewide operations and aircraft registrations were apportioned according to the proportions represented by these totals and are presented in Table 5-1.

The resulting distribution of aircraft and operating rates by ARTCC are presented in Table 5-1. While the above methodology appears somewhat complex, errors in allocation can affect only regional statistics. Once the prevailing false alarm rate is calculated for the highest reporting center, this rate applies to the entire continental United States. Thus, if a given state's aircraft are allocated incorrectly among two or more centers, the errors in the estimate of unreported alarms in those two centers will offset each other. The accuracy of the estimates rests principally on assumptions 1 and 2 above and the accuracy of the FAA statistics on aircraft and operations.

Derived reporting rates for each ARTCC are presented in Table 5-1. The highest reporting rate was exhibited by the Seattle ARTCC. With allowances made for Seattle's 57 percent reporting efficiency, representative alarm rates were calculated at 90.2 alarms per 1,000 aircraft and 330 alarms per 1,000,000 operations. These alarm rates were applied to each ARTCC to develop total alarms per ARTCC using both measures.

The known causes of ELT alarms listed in the Service Difficulty Reports indicate that 77.6 percent of the alarms were traceable to causes proportional to aircraft population and 22.4 percent to causes proportional to operational activity level. By using these weighting factors, the estimates for each ARTCC derived by these two independent techniques were averaged. The results of this calculation are presented as estimated alarm rates by ARTCC in Figures 5-2 and 5-3. It can be seen that there is approximately a 3:1 ratio for alarms predicted in the centers with the largest and smallest number of alarms, Los Angeles and Salt Lake City, respectively. On the average, approximately 966 alarms can be expected for each ARTCC, a significant percentage of which originate in major metropolitan areas such as Los Angeles, New York, Chicago, Cleveland, and San Francisco.

5.2.2 Transmission Duration

Only 4,301 of the total estimated 19,311 alarms were expected to be reported to AFRCC in 1978 on the basis of the 119-day sample investigated. The actual number reported in 1978 was slightly higher (4,450) as a result

*Alabama, Connecticut, Georgia, Idaho, Illinois, Indiana, Iowa, Kentucky, Louisiana, Michigan, Mississippi, Nebraska, Nevada, North Carolina, Ohio, Oklahoma, Oregon, South Dakota, Tennessee, Washington, West Virginia, Wisconsin, Wyoming.

**California, Florida, New York, Pennsylvania, Texas.

Table 5-1. REPORTING RATES PER UNIT OF MEASURE

ARTCC	Incidents Reported to AFRCC		Registered Aircraft as of 31 December 1977	Millions of Towered Airport Operations (1978)	Annual Reports per 1,000 Aircraft	Annual Reports per 1,000,000 Operations
	119-Day Sample	Annual Estimate				
Albuquerque	41	126	7,433	2.263	17.0	55.7
Atlanta	53	163	8,907	2.664	18.3	61.2
Boston	42	129	7,910	3.208	16.3	40.2
Chicago	28	86	14,508	4.441	5.9	19.4
Cleveland	56	172	13,242	3.680	13.0	46.7
Denver	22	67	6,318	2.912	10.6	23.0
Fort Worth	110	337	11,370	3.028	29.6	111.3
Houston	82	252	11,483	4.219	21.9	59.7
Indianapolis	19	58	9,593	2.335	6.0	24.8
Jacksonville	67	206	4,611	2.018	44.7	102.1
Kansas City	43	132	11,794	2.973	11.1	44.4
Los Angeles	193	592	16,763	7.466	35.3	79.3
Memphis	61	187	7,255	1.773	25.8	105.5
Miami	90	276	8,230	4.057	33.5	68.0
Minneapolis	49	150	12,868	2.547	11.7	58.9
New York	117	359	14,489	4.903	24.8	73.2
Oakland	48	147	11,178	5.433	13.2	27.1
Seattle*	186	571	11,114	3.035	51.4	188.1
Salt Lake City	33	101	6,860	1.519	14.7	66.5
Washington, D.C.	62	190	8,254	3.469	23.0	54.8

*Highest reporting rate.

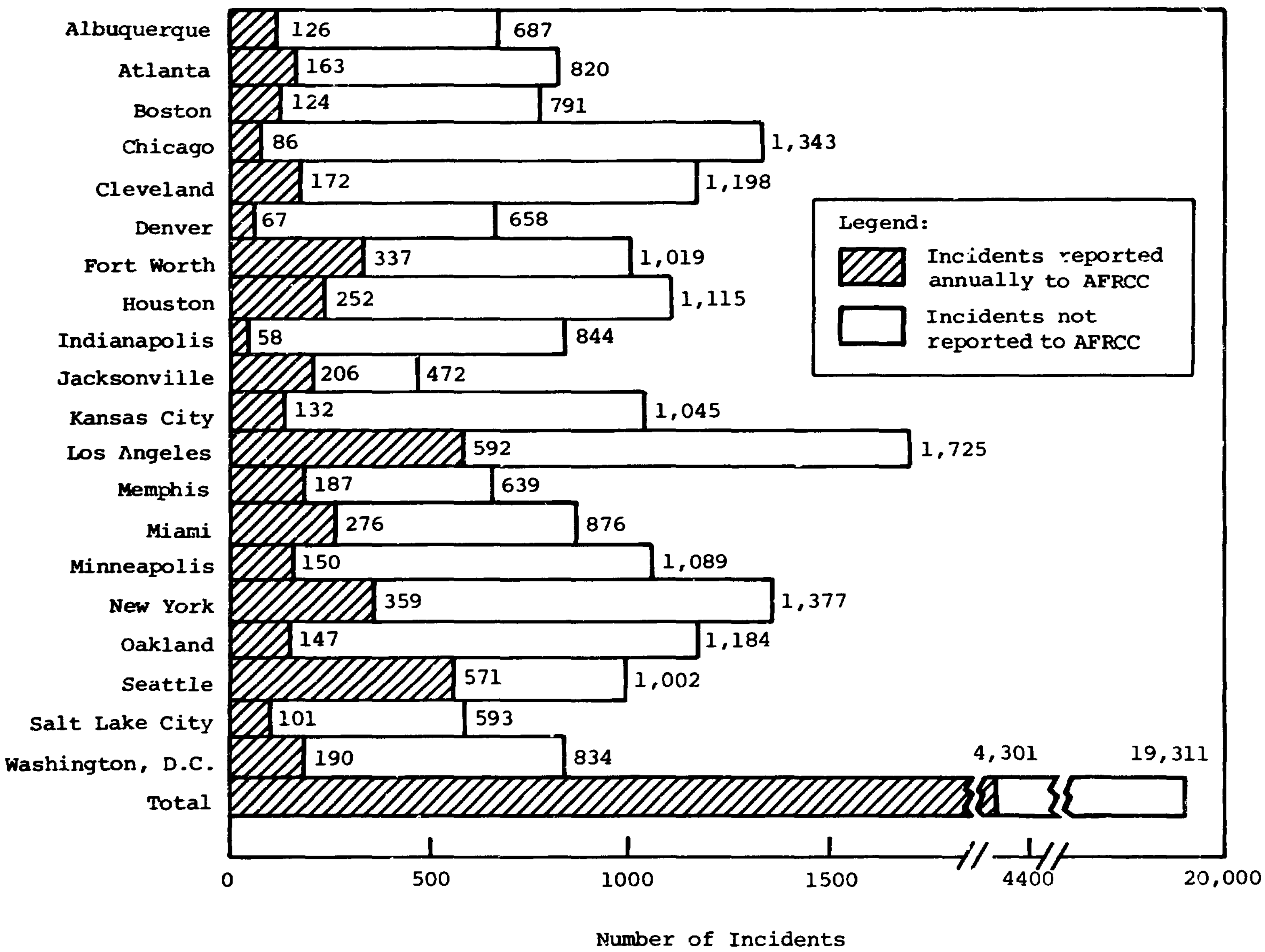


Figure 5-2. ESTIMATED ANNUAL ELT ALARMS BY ARTCC

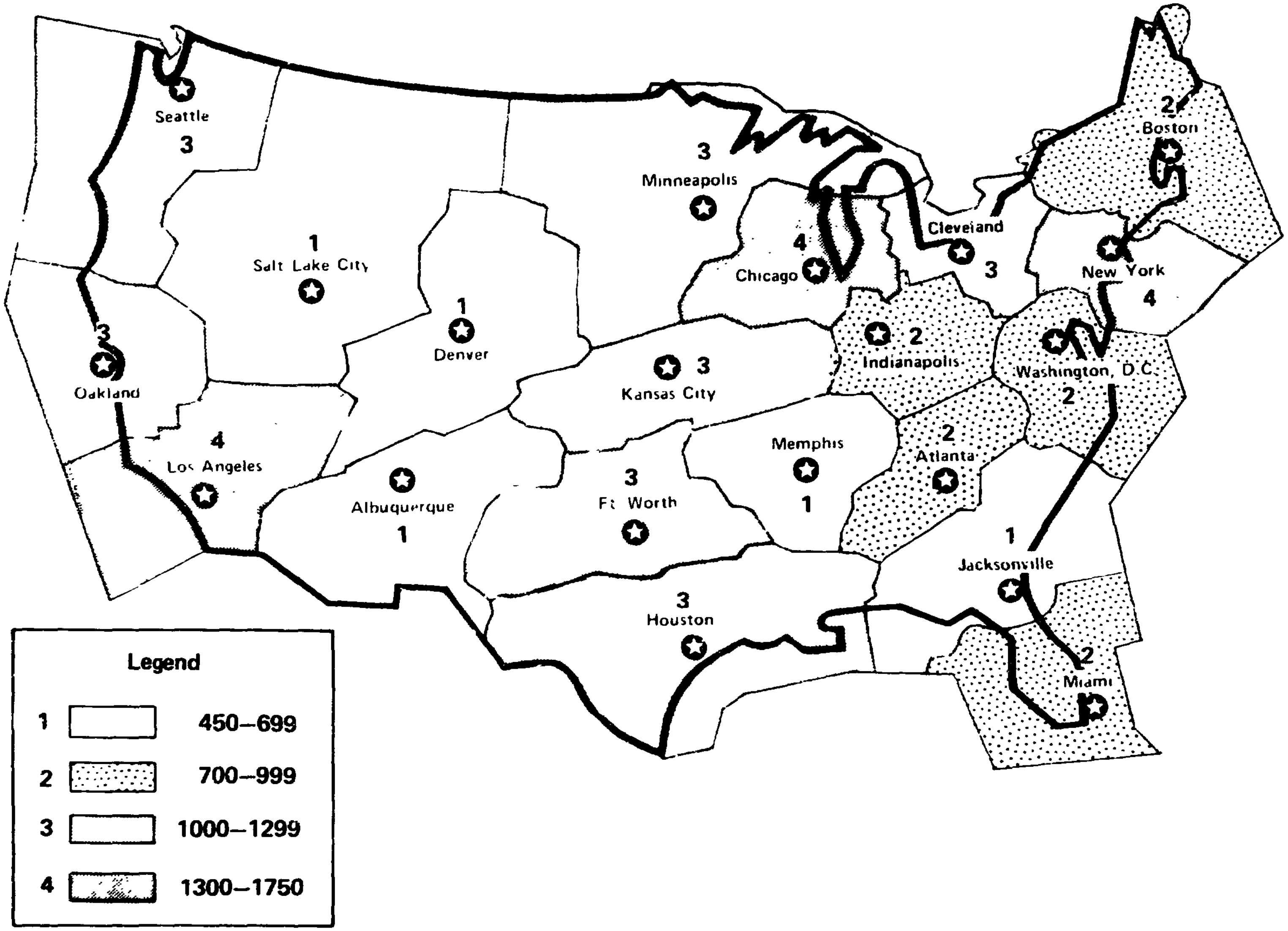


Figure 5-3. DISTRIBUTION OF ESTIMATED ANNUAL ELT ALARMS BY AIR ROUTE TRAFFIC CONTROL CENTER (ARTCC)

of statistical fluctuations. For purposes of consistency, however, the estimated (4,301) figure was used in analyzing the transmission duration and other characteristics of ELT alarms. Figure 5-4 presents the transmission-duration distribution curve for the total estimated ELT alarm population. Values for the curve were derived as a weighted average composite of the AFRCC transmission-duration distribution, representing 4,301 reported incidents (22.3 percent of the total) and the FIR distribution, representing 15,010 unreported incidents (77.7 percent of the total).

More than 50 percent of the alarms are expected to terminate in less than 1.5 hours; however, the small number of long alarms transmitting for 15 hours or longer weights the mean to about 3 hours. The impact of these long duration 10- and 15-hour alarms is significant because the expected number of simultaneous transmissions is directly proportional to the average duration of ELT transmission.

5.3 PROBABILITY OF SIMULTANEOUS INCIDENTS

The probability distribution for simultaneously transmitting ELTs illustrated in Figure 5-5 is a Poisson distribution characterized by an expected value, λ, defined by the equation

$$\begin{bmatrix}\text{Average Number}\\ \text{of Simultaneous}\\ \text{Transmissions}\end{bmatrix} = \frac{\begin{bmatrix}\text{Number of ELT}\\ \text{Transmissions}\\ \text{per Year}\end{bmatrix} \times \begin{bmatrix}\text{Average ELT}\\ \text{Transmission}\\ \text{Duration}\\ \text{(Minutes)}\end{bmatrix}}{[\text{Minutes per Year}]}$$

or

$$\lambda = \frac{19{,}311 \times 176.6}{525{,}600}$$

$$= 6.49$$

The estimated number of simultaneous alarms as calculated above is within the expected capacity of SARSAT. On an annual average, six to seven ELTs can be expected to be transmitting simultaneously throughout the continental United States. Since the distribution is Poisson, the mean determines the entire distribution. Therefore, 10 or more ELTs will be transmitting simultaneously approximately 14 percent of the time. The probability of four or fewer simultaneous transmissions is comparably small, i.e., 20 percent. Of course, there will be more activity (average of more than eight simultaneous transmissions) during the summer and less activity (average less than five simultaneous transmissions) during the winter. This variation in activity level will affect the shape of the distribution somewhat, i.e., shifting it to the right in the summer and to the left in the winter. In addition, the transmitting ELTs are not necessarily distributed uniformly throughout the continental United States, as will be discussed in Section 5.4.

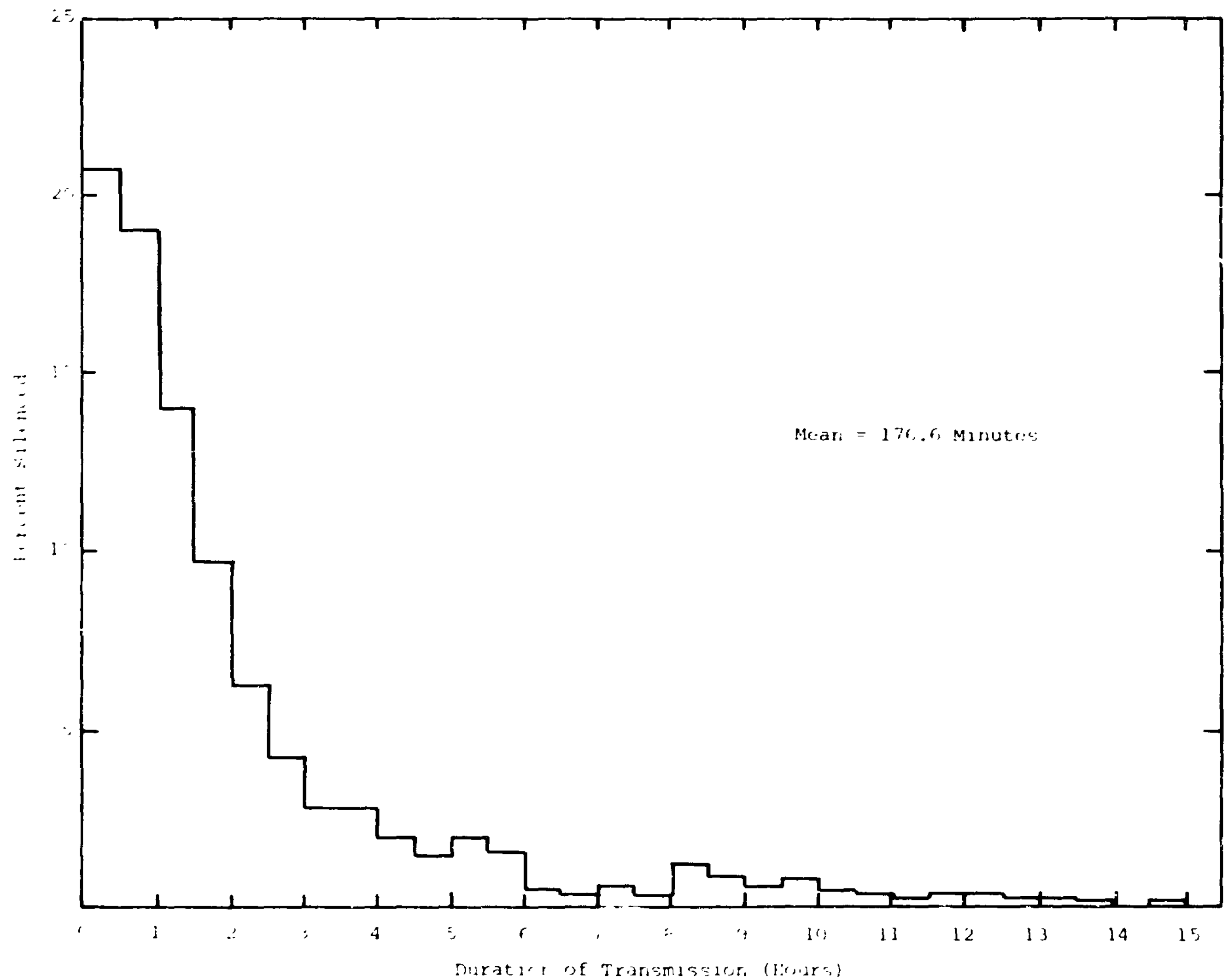


Figure 5-4. ESTIMATED DISTRIBUTION OF ELT TRANSMISSION DURATION (SILENCING TIME)

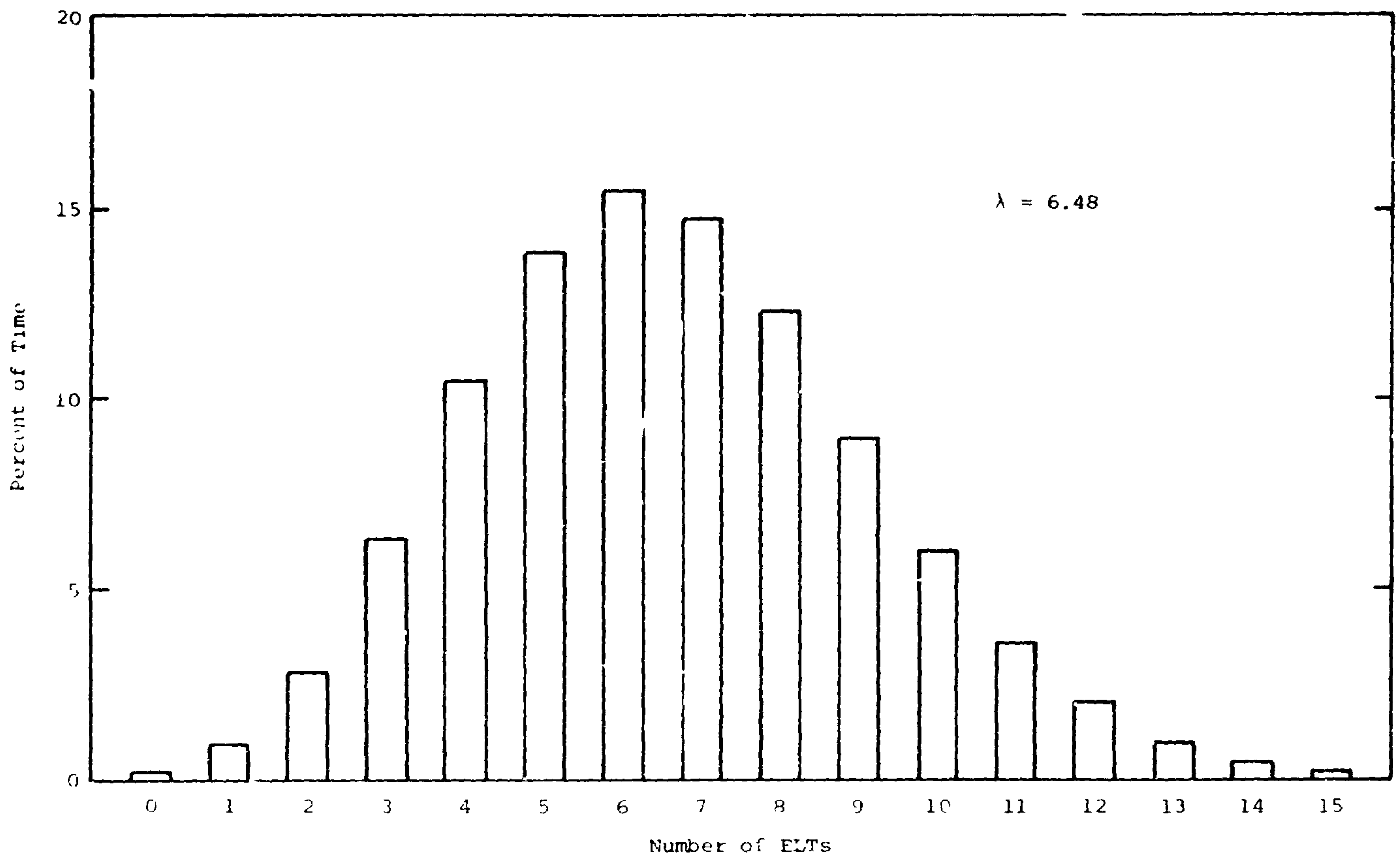


Figure 5-5. PROBABILITY OF SIMULTANEOUS ELT TRANSMISSIONS, CONTINENTAL U.S.

5.4 GEOGRAPHIC DISTRIBUTION OF ALARMS

The performance levels demanded of a satellite ELT detection/location system depend not only on the number and duration of signal sources but also on the spatial distribution of alarms. There are, in fact, significant differences in signal source densities from ARTCC to ARTCC and also within some ARTCCs. This section examines the geographic alarm density distribution on a national scale and the probabilities of simultaneous emissions as a function of alarm distribution within an ARTCC.

5.4.1 Geographic Alarm Density Distribution

More than 95 percent of ELT reports (and thus, it is assumed, more than 95 percent of ELT alarms) originate from land areas (see Figure 4-8). The average geographic density of ELT alarms per ARTCC was calculated on the basis of annual alarm rates of Figure 5-2 and on estimates of land area covered by each ARTCC. FAA estimates of total ARTCC area were used for most centers. In the case of ARTCCs encompassing major bodies of water, the FAA-estimated total area was reduced by an estimate of the water area.

Seven ARTCCs exhibiting alarm densities greater than 10 alarms per 1,000 square miles annually were studied in greater detail. For each of these centers* the total number of alarms was apportioned geographically within the ARTCC on the basis of flight plans filed at Flight Service Stations**. This process is illustrated in Figure 5-6, a map of the Los Angeles ARTCC showing the locations of all the FSSs and the number of flight plans filed at each FSS. A total of 823,200 flight plans were filed in this center. Five of the 25 FSSs corresponding to the Los Angeles-San Diego corridor accounted for approximately 48 percent of all flight plans filed. These five are specifically identified by a star on the map. The area of coverage for these stations was determined by establishing a boundary line that approximately bisects the regions between adjacent stations. ELT alarm rates were assumed to be proportional to flight plans filed; therefore, 48 percent of all alarms are assumed to have originated from within the shaded region and 52 percent from within the unshaded region. Alarm density, in terms of thousands of alarms per square mile, was then calculated on the basis of estimated area of coverage for both the high-density and low-density regions. Calculated in this manner, the density of alarms in the Los Angeles basin (6 percent of area) is estimated to be 92.2 alarms annually per thousand square miles, as compared with an average of 12.7 alarms for the overall Los Angeles ARTCC.

Oakland and Washington, D.C. centers behaved similarly because both centers covered a major metropolitan region surrounded by relatively unpopulated countryside. Suprisingly, activity was distributed fairly

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*New York, Miami, Cleveland, Chicago, Los Angeles, Oakland, and Washington, D.C.

**Barboza, G., *Pilot Briefing Activity Forecasts for Flight Service Stations - 1984*, MTR-6441, July 28, 1973.

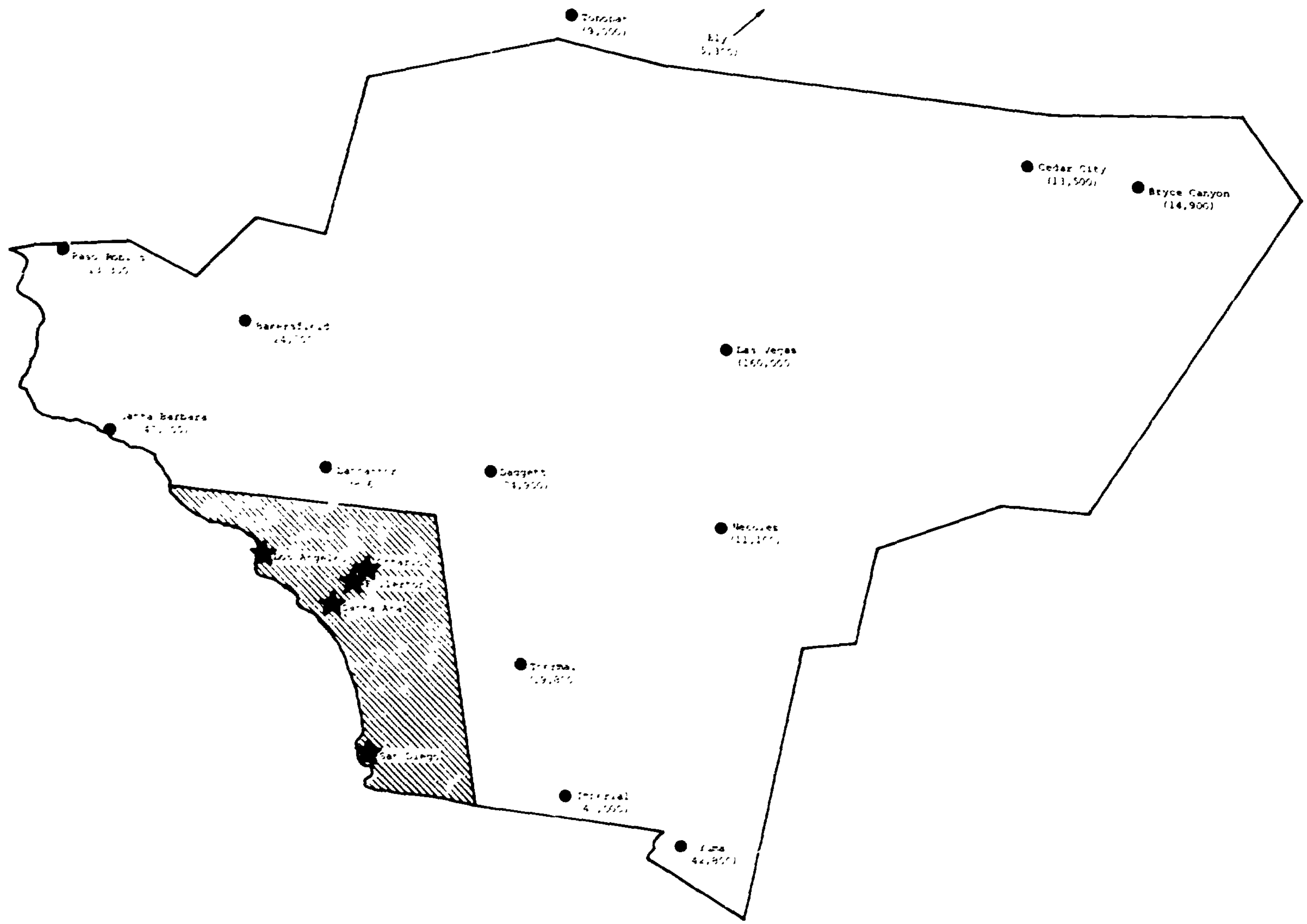

Figure 5-6. DISTRIBUTION OF ALARMS IN LOS ANGELES ARTCC

evenly within the New York, Chicago, and Cleveland centers. The alarm densities in the continental United States are listed in Table 5-2 and plotted in Figure 5-7.

The impact of this uneven distribution of alarms is significant. In the Los Angeles region, for example, the alarm density ranged from a low 7.1 alarms per 1,000 square miles in the rural areas to 92.2 in the Los Angeles-San Diego corridor. Other centers exhibit similar, if not as dramatic, behavior.

5.4.2 Probability of Simulatneous Transmission Within A Specified Area

Alarm densities have a significant, direct impact on the probability of multiple simultaneous transmissions within a specified area of coverage. This probability function is significant because the ability of SARSAT to distinguish simultaneous alarms depends in part on the geographic separation of those alarms. This subsection will examine the probability of simultaneous transmissions over a relatively large area -- such as an ARTCC -- and over a relatively small area -- such as a major city. The number of simultaneous alarms is characterized by a Poisson distribution according to the formula

$$p(n;\lambda) = \frac{(\lambda)^n (e)^{-\lambda}}{n!} \qquad (1)$$

where

$p(n;\lambda)$ = the probability that n ELTs are transmitting simultaneously, given that the average number of simultaneously transmitting ELTs is λ

Now, the probability that two or more ELTs transmit simultaneously is simply

$$p(n \geq 2;\lambda) = 1 - [p(0;\lambda) + p(1;\lambda)] \qquad (2)$$

$$= 1 - \left[\frac{(\lambda)^0 (e)^{-\lambda}}{0!} + \frac{(\lambda)^1 (e)^{-\lambda}}{1!}\right] = 1 - (e)^{-\lambda} - (\lambda)(e)^{-\lambda}$$

If we expand into a series and neglect higher-order terms for small λ (for a single ARTCC, λ is on the order of 0.32; for a metropolitan area, it is much smaller):

$$p(n \geq 2;\lambda) = \frac{\lambda^2}{2} \qquad (3)$$

Since

$$\lambda = \text{Average Simultaneous Transmissions} = \frac{\left[\begin{array}{c}\text{Number of} \\ \text{Annual} \\ \text{Transmissions}\end{array}\right] \times \left[\begin{array}{c}\text{Average} \\ \text{Transmission} \\ \text{Length in} \\ \text{Minutes}\end{array}\right]}{\text{Minutes per Year}}$$

ARTCC	Number of Alarms	Land Area*	Alarm Density (ρ)**		
			Peak	Average	Minimum
Albuquerque	687	220.5	***	3.1	***
Atlanta	820	105.4	***	7.8	***
Boston	791	93.2	***	8.5	***
Chicago	1,343	99.7	←	13.5	→
Cleveland	1,198	71.7	←	16.7	→
Denver	658	271.8	***	2.4	***
Fort Worth	1,019	187.6	***	5.4	***
Houston	1,115	163.4	***	6.8	***
Indianapolis	844	97.2	***	8.7	***
Jacksonville	472	83.4	***	5.7	***
Kansas City	1,045	168.1	***	6.2	***
Los Angeles	1,725	136.1	92.2†	12.7	7.1
Memphis	639	141.1	***	4.5	***
Miami	876	28.5	44.6††	30.7	26.2
Minneapolis	1,089	344.4	***	3.2	***
New York	1,377	43.3	←	31.8	→
Oakland	1,184	105.9	24.5#	11.2	4.5
Seattle	1,002	183.3	***	5.5	***
Salt Lake	593	405.3	***	1.5	***
Washington, D.C.	834	80.0	23.7##	1[illegible]	4.0

*In 1,000 square miles.
**Annual alarms per 1,000 square miles.
***Alarm density assumed constant throughout ARTCC.
†48 percent of total alarms in 6.6 percent of land area.
††35.7 percent of total alarms in 24.7 percent of land area.
#73 percent of total alarms in 33.3 percent of land area.
##74.3 percent of total alarms in 32.7 percent of land area.

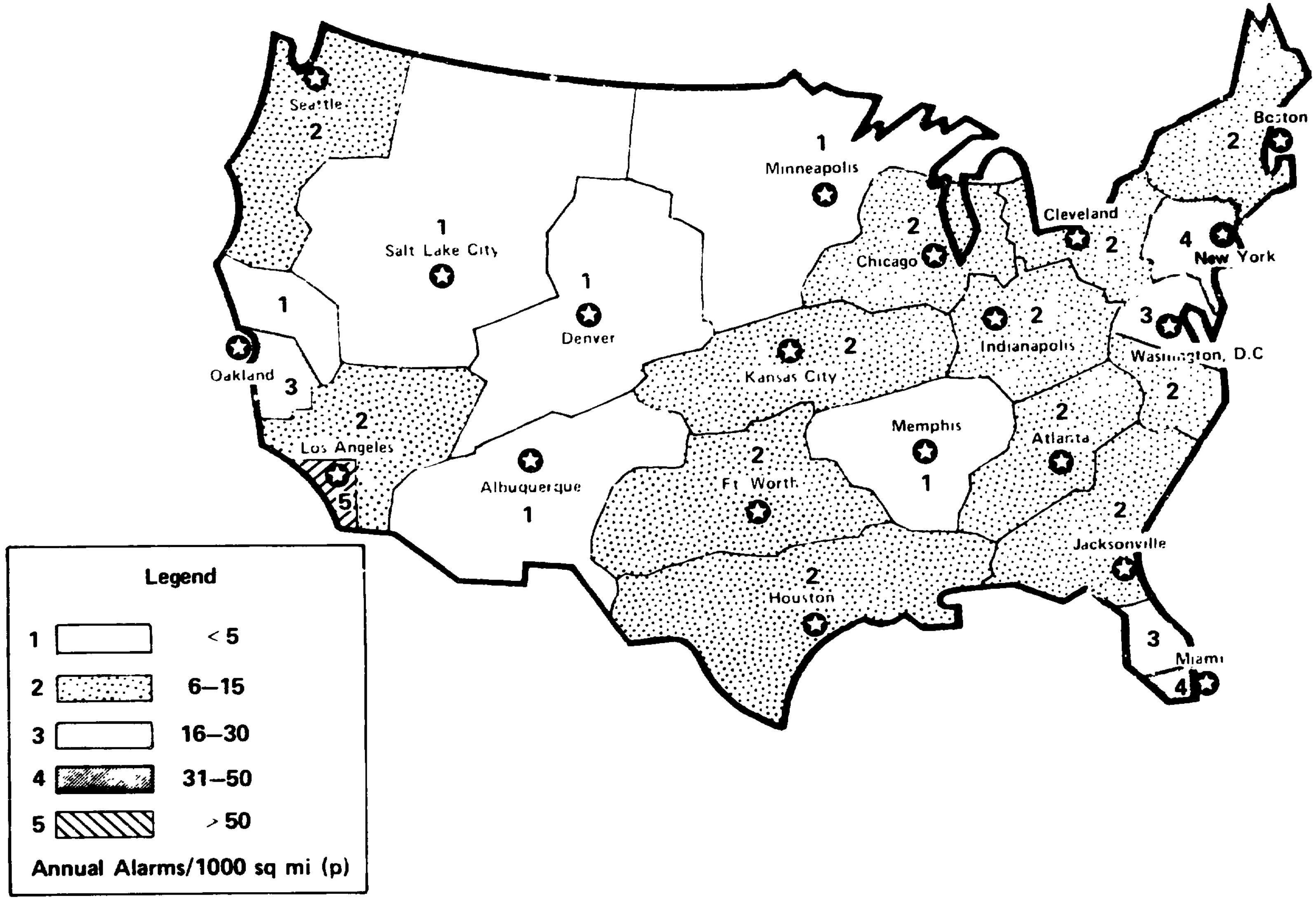

Figure 5-7. GEOGRAPHIC DENSITY OF ELT TRANSMISSION and

$$\begin{matrix}\text{Number of} \\ \text{Annual} \\ \text{Transmissions}\end{matrix} = \begin{bmatrix}\text{Annual Alarms} \\ \text{per 1,000} \\ \text{Square Miles}\end{bmatrix} \times \begin{bmatrix}\text{Specified} \\ \text{Area}\end{bmatrix} = \frac{\rho\pi R^2}{1{,}000}$$

$$\begin{matrix}\text{Average} \\ \text{Transmission} \\ \text{Length in} \\ \text{Minutes}\end{matrix} = 176.6 \text{ (see Figure 5-5)}$$

Minutes per Year = 525,600

$$\lambda = 1.06 \times 10^{-6} R^2 \rho$$

where

R = separation between simultaneously transmitting ELTs (in miles)

ρ = alarm density in region (annual alarms per 1,000 square miles)

Substituting into Equation (3) yields

$$p(n \geq 2; \lambda) = 5.6 \times (10)^{-3} (R)^4 (\rho)^2 \qquad (4)$$

Equation 4 is plotted as a family of curves in Figure 5-8. The left vertical scale provides the probability of simultaneous transmissions during one year as a function of maximum allowable transmission separation and alarm density. The right-hand scales convert these probability figures into total number of minutes and hours per year that two or more ELTs can be expected to transmit simultaneously from a specified region. Each curve is specified by a ρ factor that corresponds directly to the alarm density values presented in Table 5-2. Separation between simultaneously transmitting ELTs is presented on the abscissa in statute miles. The maximum 50-mile separation corresponds closely to the maximum separation distance possible between two ELTs simultaneously transmitting in the same high-density metropolitan area, e.g., Los Angeles.

Figure 5-8 demonstrates that the probability of simultaneous transmissions within a 30- to 40-mile radius is essentially negligible, with the possible exception of the Los Angeles (ρ = 92.2) and Miami (ρ = 44.6) metropolitan areas. Although the probability of simultaneous transmissions in these two areas is still on the order of one percent, daily and seasonal variations* could be expected to increase the probability of simultaneous transmissions in a given year to a peak value on the order of two to three percent.

This annual average three percent probability still provides only a very limited possible interference between two closely spaced ELTs, particularly in view of the fact that the first five minutes of every hour (8.3

*See Subsection 4.1.2. Daily variation is ±39 percent and seasonal variation is ±28 percent.

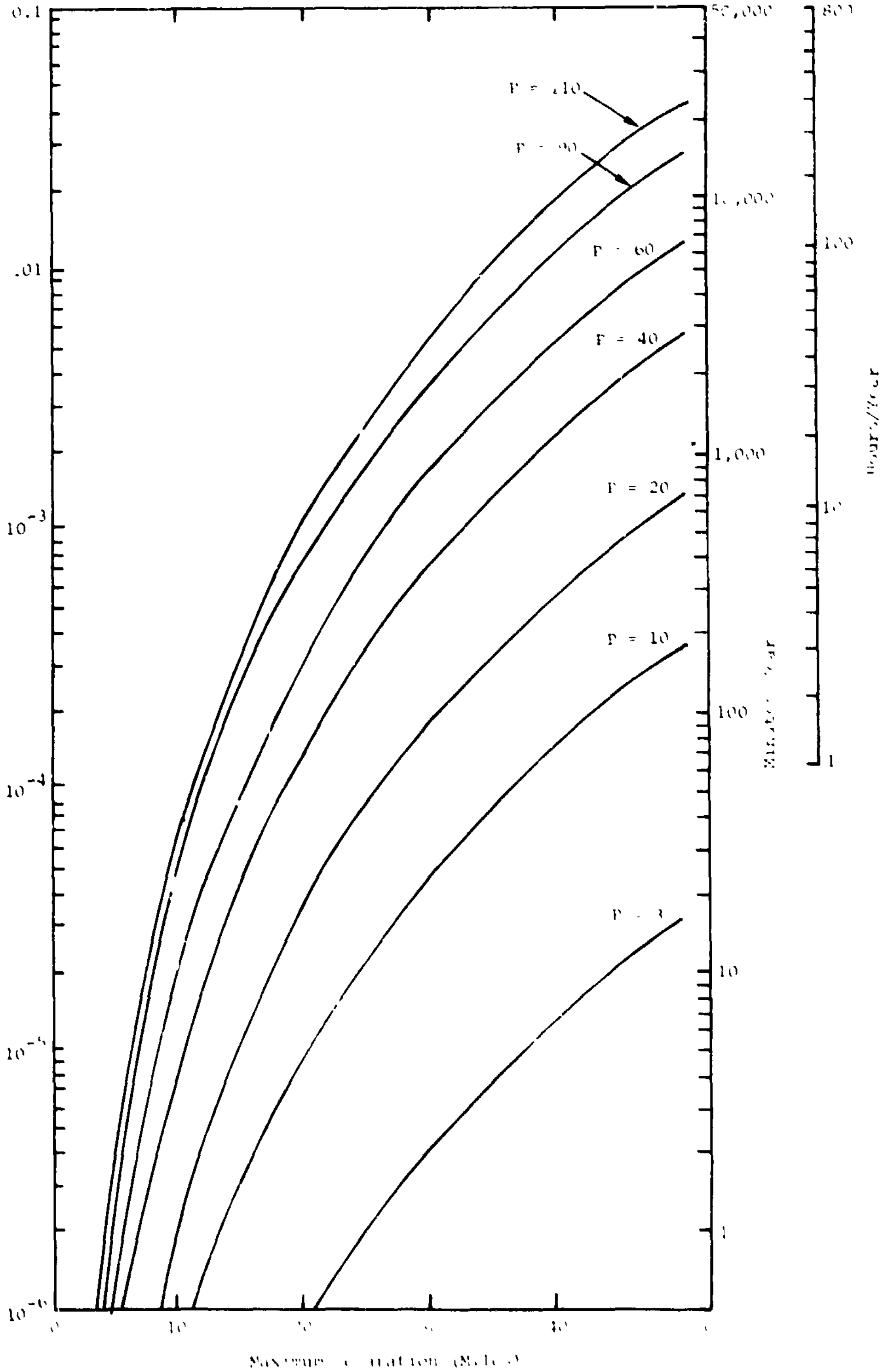

Figure 5-8. PROBABILITY OF SIMULTANEOUS TRANSMISSIONS WITHIN SPECIFIED AREAS

percent of the time) has been set aside for uncontrolled ELT testing. Further, since the probability of closely spaced simultaneous transmissions is highest in densely populated areas, one would expect a minimal possibility of adverse impact on SAR operations from a false alarm's masking of an actual crash.

On the other hand, the probability of simultaneous transmissions from each ARTCC is significantly higher, as shown in Table 5-3. For example, there is an 11.6 percent probability that two or more simultaneous alarms will transmit at a given moment from the Los Angeles ARTCC and a 7.9 percent probability from New York. These values were derived by Equation 3.

In fact, there is a greater than 60 percent probability that at any given time at least two simultaneous ELTs will be transmitting from some ARTCC. Therefore, to avoid frequent occurrences of spatial ambiguity in locating simultaneous alarms, SARSAT must be capable of distinguishing between multiple signals originating from within the same ARTCC.

5.5 ORIGIN OF ELT ALARMS

On the basis of the estimated number of total incidents, 8.4 percent of the estimated total number of ELT alarms are reported to AFRCC and ultimately traced to a specific unit. This is a sufficiently large sample to provide a representative basis for estimating the origins of all alarms, including those which are not reported.

The sources of ELT signals may be categorized as follows:

- Towered airports (44.7 percent)
- Nontowered airports (37.4 percent)
- All other sources, including crash sites, fields, farms, airborne equipment, boats, etc. (17.9 percent)

Each of these signal sources is silenced through a combination of several of five different search and rescue scenarios, illustrated in Figure 5-9.

- Scenario 1: Incident occurs and ELT is silenced through the use of local resources without being reported to AFRCC.
- Scenario 2: Incident is reported to AFRCC but terminates before the alarm is located or a mission is opened.
- Scenario 3: Incident results in an AFRCC mission.
- Scenario 4: Incident at nontowered airport is reported to AFRCC and is located strictly through the use of local resources without an AFRCC mission.
- Scenario 5: Incident at a towered airport is reported to AFRCC but is located strictly through the use of local resources without an AFRCC mission.

Table 5-3. PROBABILITY OF SIMULTANEOUS TRANSMISSIONS

ARTCC	Percent Probability of Two or More Simultaneous ELT Alarms in a Given Year
Albuquerque	2.3
Atlanta	3.3
Boston	3.1
Chicago	7.6
Cleveland	6.2
Denver	2.1
Fort Worth	4.7
Houston	5.4
Indianapolis	3.3
Jacksonville	1.2
Kansas City	4.9
Los Angeles	11.6
Memphis	1.9
Miami	3.5
Minneapolis	5.4
New York	7.9
Oakland	5.2
Seattle	4.7
Salt Lake City	1.9
Washington, D.C.	3.3
Total*	60.7**

*Probability that two or more ELTs will be transmitting simultaneously in one or more ARTCCs in a given year.

**60.7 percent $= 1 - \prod_i [P_i(n \leq 1; \lambda)]$

$= 1 - [(1 - 0.023)$

$\times (1 - 0.033)(1 - 0.031)$

$\ldots (1 - 0.033)]$

The number of alarms associated with each scenario is estimated from the statistics of Figures 4-8 and 4-9 (Chapter Four) as follows: given that Figure 4-8 is representative of all alarms, reported and unreported, the total incidents originating at unknown airports are apportioned between towered and nontowered airports according to the ratio of incidents at towered versus nontowered airports. All nonairport-originated incidents are combined into the "other" category. A similar procedure is used in Figure 4-8 to allocate AFRCC missions. As a result, as shown in Figure 5-10, the majority of unreported alarms originate at airports, particularly towered airports. This last statistic will have enormous impact on the cost of ELT alarms and on selecting priorities in the development of solutions.

5.6 COST OF ELT ALARMS

5.6.1 Cost-Estimating Methodology

This section develops a measure of costs based on the flow chart presented in Figure 5-9; statistical data derived from AFRCC, FIR, and SAR records; and parameter values established through subjective discussions with SAR officials. Five standard assumptions were used in these calculations:

- There is a cost involved with every alarm. This cost is measurable in terms of the resources that could have been used productively elsewhere but had to be diverted to locating ELTs.
- All unreported incidents are solved solely through the application of locally available resources.
- Standard costs are applicable across the board as follows:
  - Manpower. One man-year costs include $25,000 in equivalent salary value, a 50 percent overhead, and 2,000 productive hours for a burdened rate of $18.75 per hour.
  - Aircraft. Average aircraft operating costs, including fuel, are $40 per hour.
  - Ground Vehicles. Ground vehicles travel at an average speed of 20 mph during the search process at a cost of $0.17 per mile, for an hourly cost of $3.40.
- Five possible SAR scenarios exist, as presented in Figure 5-9.
- The distribution of alarm sources described in Figure 5-10 is applicable to pricing the cost of ELTs.

Each step presented in Figure 5-9 was costed independently. The major cost components, as expected, are air and ground searches that use vehicles and aircraft to narrow the initial search area. In fact, while most steps in the search process typically cost less than $100 per alarm, the process of conducting a ground search with vehicles ranged from $109 to $671 over the five categories. If aircraft are introduced, as in a combination

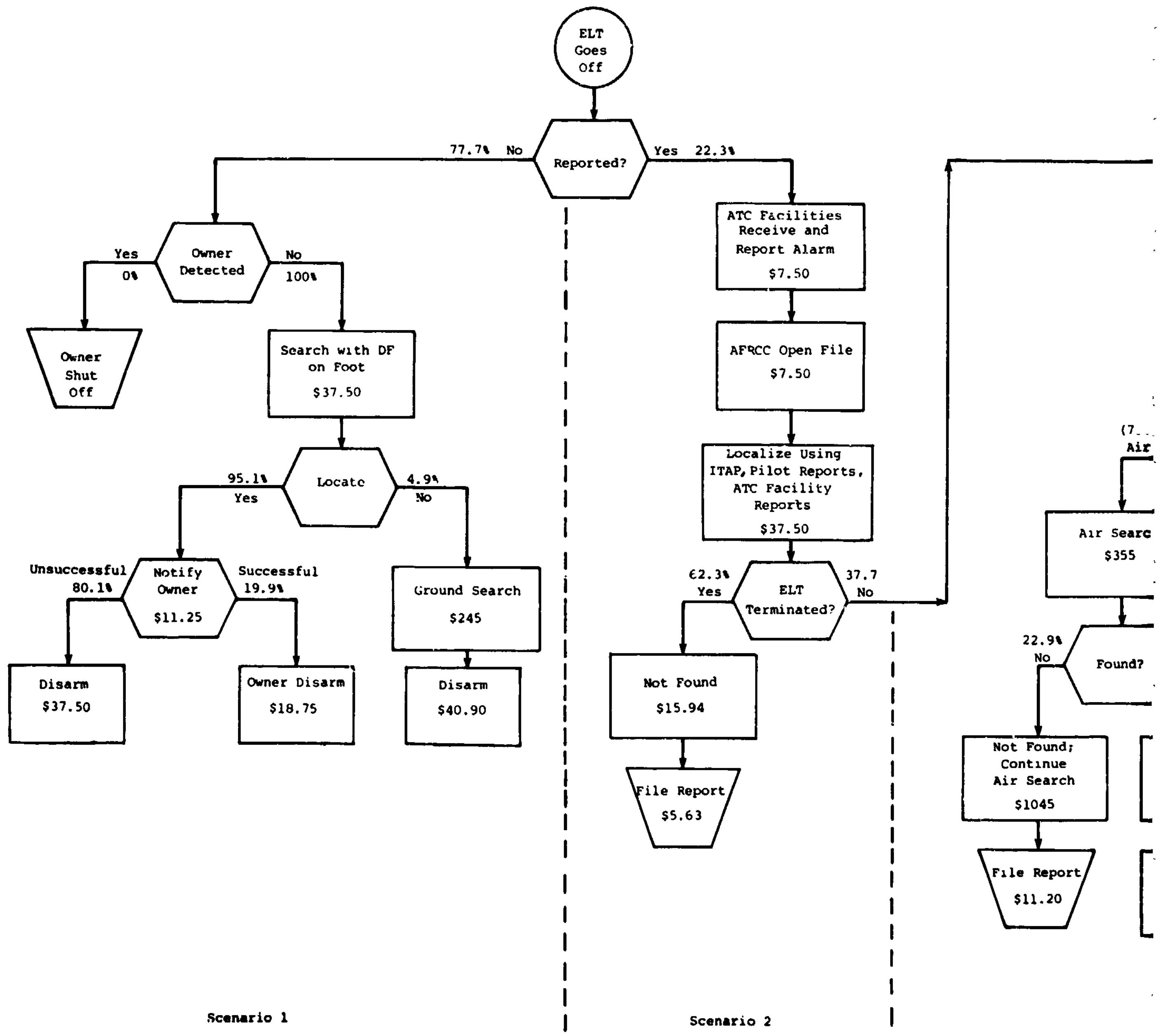

Figure 5-3. F SEARC

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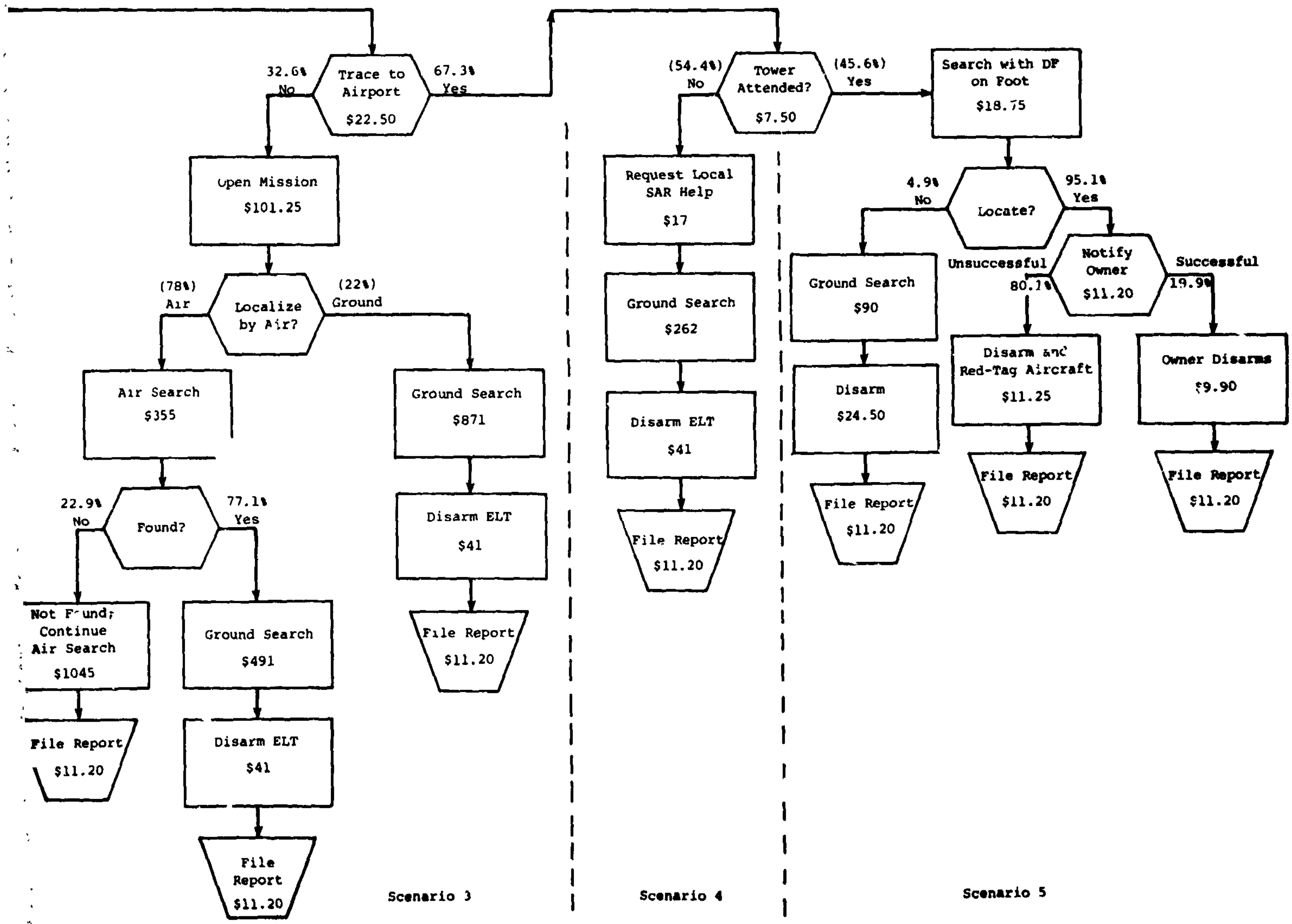

. ELT SEARCH PROCESS MODEL

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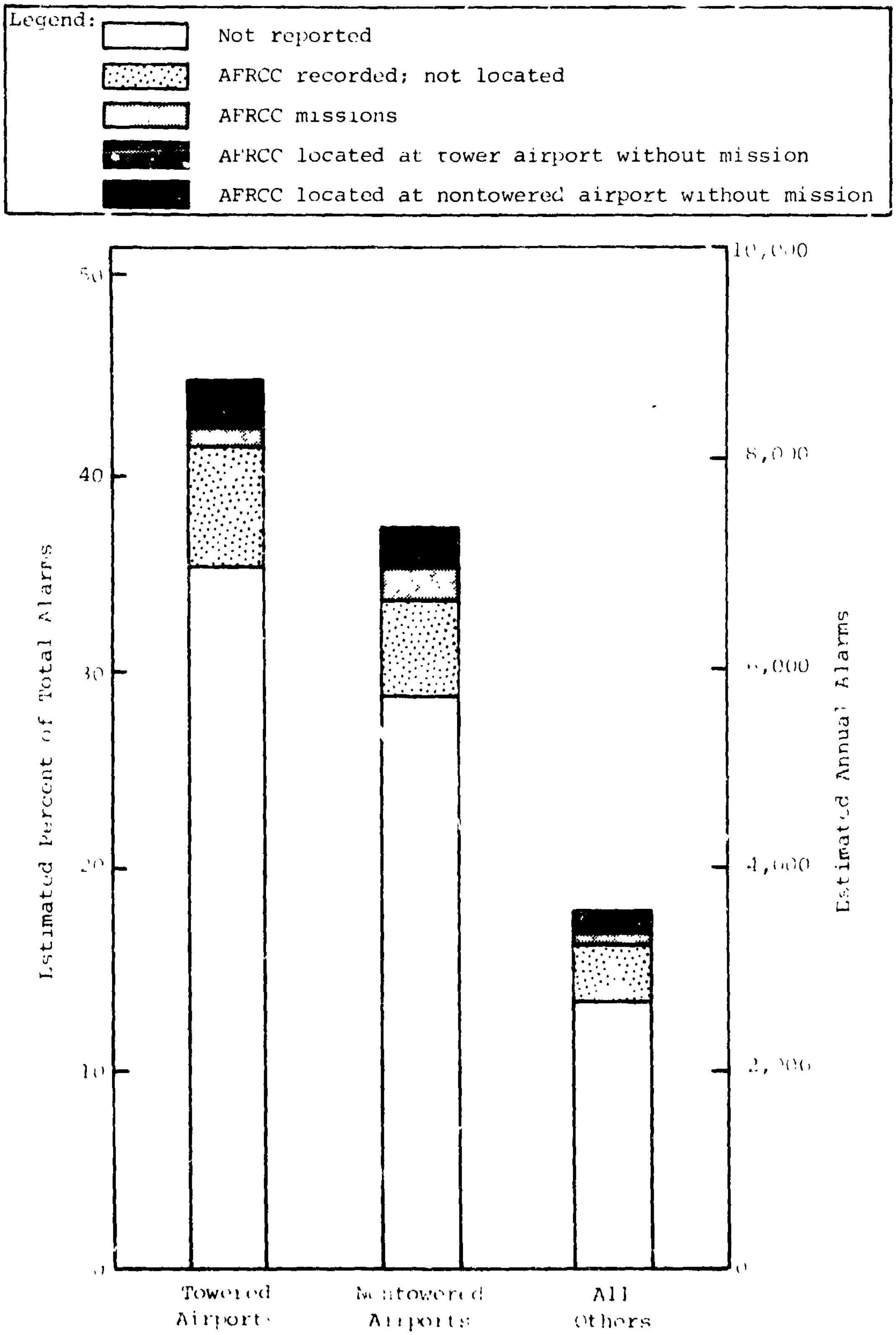

Figure 5-10. SOURCES OF ALARMS

air-ground search, the estimated cost increases to $846 per alarm. The most expensive scenario (at $1,400 per alarm) occurs when an air search fails to locate the ELT. In all these scenarios, logistics and recordkeeping costs must also be added to the costs of any search involved.

5.6.2 Cost Estimates

Estimated costs (including logistics and recordkeeping) are presented in Table 5-4. Note that the lowest-cost disposition of an ELT alarm ($74) occurs when the ELT is terminated prior to any significant field activity. This cost includes expenses incurred in AFRCC processing records, coordinating and monitoring activities, and tracking reports. It is representative of a situation in which the owner discovers the transmitting ELT and silences it before outside search and rescue personnel are dispatched.

The next level of expense occurs with unreported alarms. Typically, the alarm originates in the vicinity of experienced personnel who can quickly proceed on foot and silence the transmission source. Thus only a few personnel are involved for only a short period, thereby limiting costs to $83 per alarm.

There are situations, however, when silencing cannot be accomplished by local personnel alone because the source of the transmission is harder to pinpoint. In particular, if the signal cannot be localized quickly to an airport, AFRCC assistance is requested. This request involves additional personnel to coordinate the search process; therefore, the cost of silencing increases to $139.

If the source still cannot be located, the local SAR teams may be dispatched to the suspected area to locate the signal source, driving the cost of disposition per transmission to $414.

There could also be situations in which the location of the signal source is not known with sufficient accuracy to permit dispatching local SAR teams. In such situations, AFRCC initiates an air search. The estimated $1,128 cost per mission is nearly three times that of the most expensive ground search.

Silencing alarms at nontowered airports requires the most resources, both individually and overall. Two factors account for this situation: First, locating signal sources at nontowered airports requires the application of a disproportionate number of AFRCC-coordinated missions. Second, the local search procedures are more complex than for towered airports.

5.7 CAUSES OF ALARMS

The Service Difficulty Reports provide a statistically adequate sample of the causes of false alarms. In 1978 only about 12 percent of the causes identified were in the human error and miscellaneous categories (see Chapter Four, Figure 4-10). G-switch problems have accounted for a reasonabl_ constant 40 percent of all alarms during the past several years and will probably continue at a comparable level in the forseeable future. All the remaining alarms resulted from battery-corrosion-related effects, which have demonstrated a dramatic increase during the past five years. Approximately 52 percent of all alarms in 1978 were attributed to battery-related phenomena.

Table 5-[illegible] ESTIMATED COST OF ELT ALARMS

Source of Signal	Scenario	How Located	Cost per Alarm (Dollars)	Percent of Total Alarms	Total Cost ($ Thousands)
Towered Airport (44.7 percent)			97*	44.7**	834.7**
	1	Unreported	83	35.3	565.8
	2	ELT terminate	74	6.3	90.1
	3	AFRCC, mission	1,128	0.5	108.9
	5	AFRCC, no mission	139	2.6	69.9
Nontowered Airport (37.4 percent)			145*	37.5**	1,049.1**
	1	Unreported	83	28.6	460.0
	2	ELT terminate	74	5.1	72.9
	3	AFRCC, mission	1,128	1.6	348.4
	4	AFRCC, no mission	414	2.1	167.8
All Others (17.9 percent)			13[illegible]*	17.7**	467.5**
	1	Unreported	83	13.8	221.2
	2	ELT terminate	74	2.5	35.8
	3	AFRCC, mission	1,128	0.6	130.[illegible]
	4	AFRCC, no mission	414	1.0	79.9

*Average for group.
**Total for group.

The statistical indications are that the technical causes of alarms (e.g., battery corrosion) are independent of location (e.g., towered airports). Therefore, a two-dimensional matrix can be readily constructed to break down the origin of alarms with technical cause of alarms. This matrix, presented in Table 5-5, identifies the maximum benefits achievable by entirely eliminating causes or sources of alarms through the application of overlapping goals.

In the examination of possible technical solutions, the high costs associated with problems due to battery corrosion are noticed immediately. Most of these alarms can be expected to disappear as a result of the recent Airworthiness Directive to remove $Li\text{-}SO_2$ batteries from ELTs. The replacement batteries presumably will not be subject to this problem. The only other major technical problem associated with false alarms is the G-switch. Improving this component could reduce false alarms by more than 7,000 annually, for a saving of $870,000 to the aviation community.

Table 5-5. CAUSES AND SOURCES OF ELT ALARMS

Source of Alarm	Alarm Statistics by Cause of Alarm*			
	G-Switch	Battery Corrosion	Human Error and Miscellaneous	Total
Towered Airport	16.5% 3190 $308.8	22.8% 4400 $425.7	5.4% 1040 $100.2	44.7% 8630 $834.7
Nontowered Airport	13.8% 2660 $388.2	19.1% 3690 $535.0	4.5% 870 $125.9	37.4% 7220 $1,049.1
Other	6.7% 1290 $173.0	9.1% 1760 $238.4	2.1% 410 $56.1	17.9% 3460 $467.5
Total	37% 7140 $870.0	51% 9840 $1,199.1	12% 2320 $282.2	100% 19,300 $2,351.3

Possible Benefits of Administrative Solutions

Possible Benefits of Technical Solutions

*Percent of total annual incidents.
Number of annual incidents.
Annual cost per cause/source category in thousands of dollars.

Compared with the G-switch and battery corrosion problems, broadcasts resulting from human error and other miscellaneous causes should be given low-priority treatment because of the small expected benefit.

For solutions based on the origins of alarms, nontowered airports must be first-priority candidates for corrective action because of the high cost of silencing alarms at these airports (due both to the large number of such alarms and to the high cost of locating each offender). Towered airports experience more alarms, but the cost of termination per alarm is significantly lower than at nontowered airports and thus the expected benefit is smaller, making this source of signals a second-priority item.

All other sources of ELT signals, including actual crashes, contribute only 50 percent as many alarms as towered airports. The cost of silencing one of these signals is about the same as for a signal from a nontowered airport, but the possibility of success is low. Thus there seems to be little incentive to consider procedures for reducing these remaining alarms.

CHAPTER SIX

APPROACHES TO REDUCING ELT FALSE ALARMS

This chapter develops a goals structure and implementation plan matrix for alleviating the present ELT false alarm problem. It describes a specific strategy based on the effectiveness and utility of the available tools.

6.1 GOALS

A systematic approach to correcting the present ELT problem must focus on the achievement of two overall goals:

- Reducing the number of false alarms
- Reducing the impact on SAR operations of all remaining alarms

Each of these two objectives may be achieved by satisfying one or more of the subgoals illustrated in Figure 6-1. For example, the number of false alarms may be reduced by solving existing ELT technical problems, preventing the occurrence of new problems, or eliminating the occurrence of repeated problems. Each of these subgoals in turn may be used to establish objectives for proposed programs.

6.2 MEASURES OF EFFECTIVENESS

Some priority objectives contribute more toward the overall goals than others and thus are more significant than others. The significance of each objective can be described quantitatively in terms of the maximum possible saving that could be realized by total accomplishment of that priority objective alone.

Consider, for example, Priority Objective 111 in Figure 6-1 (modify ELT Li-SO_2 battery). Figure 5-10 (Chapter Five) indicates that 51 percent of all ELT false alarms are the result of battery-related problems. Therefore, if all battery-related problems were completely resolved, 51 percent of all alarms (or 9,840 alarms) would be eliminated. This reduction in alarms corresponds to a saving of $1,199,100, for an average of $121 per alarm.

Consider Priority Objective 212 in Figure 6-1 (self-detect and silence alarms at towered airports). If all the alarm at towered airports could be detected by the aircraft operator, then all the alarms currently located at towered airports through AFRCC involvement (Scenarios 2 and 4, Table 5-4) would become, under optimum conditions, alarms that terminate before being located (Scenario 3). Net savings, therefore, may be calculated as $134,500 on the basis of the cost difference between AFRCC-assisted searches and those searches for which the ELT terminates.

6.2.1 Maximum Possible Savings per Plan

The goals structure illustrated in Figure 6-1 describes priority objectives whose achievement will help to reduce the false alarm problem and presents estimates of the maximum savings possible from achievement of each objective. However, this goals structure does not describe how these objectives could be achieved. As a result 33 specific implementation plans were developed, each of which would accomplish one or more priority of objectives. The maximum possible saving attributable to any single implementation plan is equal to the total of all the savings that could be realized from achievement of the specific priority objectives that plan satisfies. The plans considered and the priority objectives that each satisfies are presented in matrix form in Figure 6-2. Consider, for example, Plan 1.4 (include source signature in ELT transmissions). Such a signature embedded in the emergency broadcast would expedite locating all signals from towered airports, nontowered airports, and nonairport sites. Plan 1.7 (connect ELT to anti-collision strobe on aircraft), however, would assist in locating only those signals which originate from airports. The maximum possible saving from Plan 1.4, therefore, is the total of the savings attributable to Priority Objectives 213, 223, and 233. For Plan 1.7, only the savings from Priority Objectives 213 and 223 are included.

6.2.2 Probability that Plan Will Achieve Savings

There are three mitigating factors that may prevent a particular implementation plan from meeting its priority objectives completely:

1. The ability of a plan to satisfy performance goals is limited by the portion of the total possible population it can reach and the extent to which it can solve the priority objectives for that population set.

2. No plan is assured of success if implemented; therefore, a certain amount of technical risk is involved in adopting any particular plan.

3. Some plans may be more acceptable to the user community than others and thus more likely to be successful.

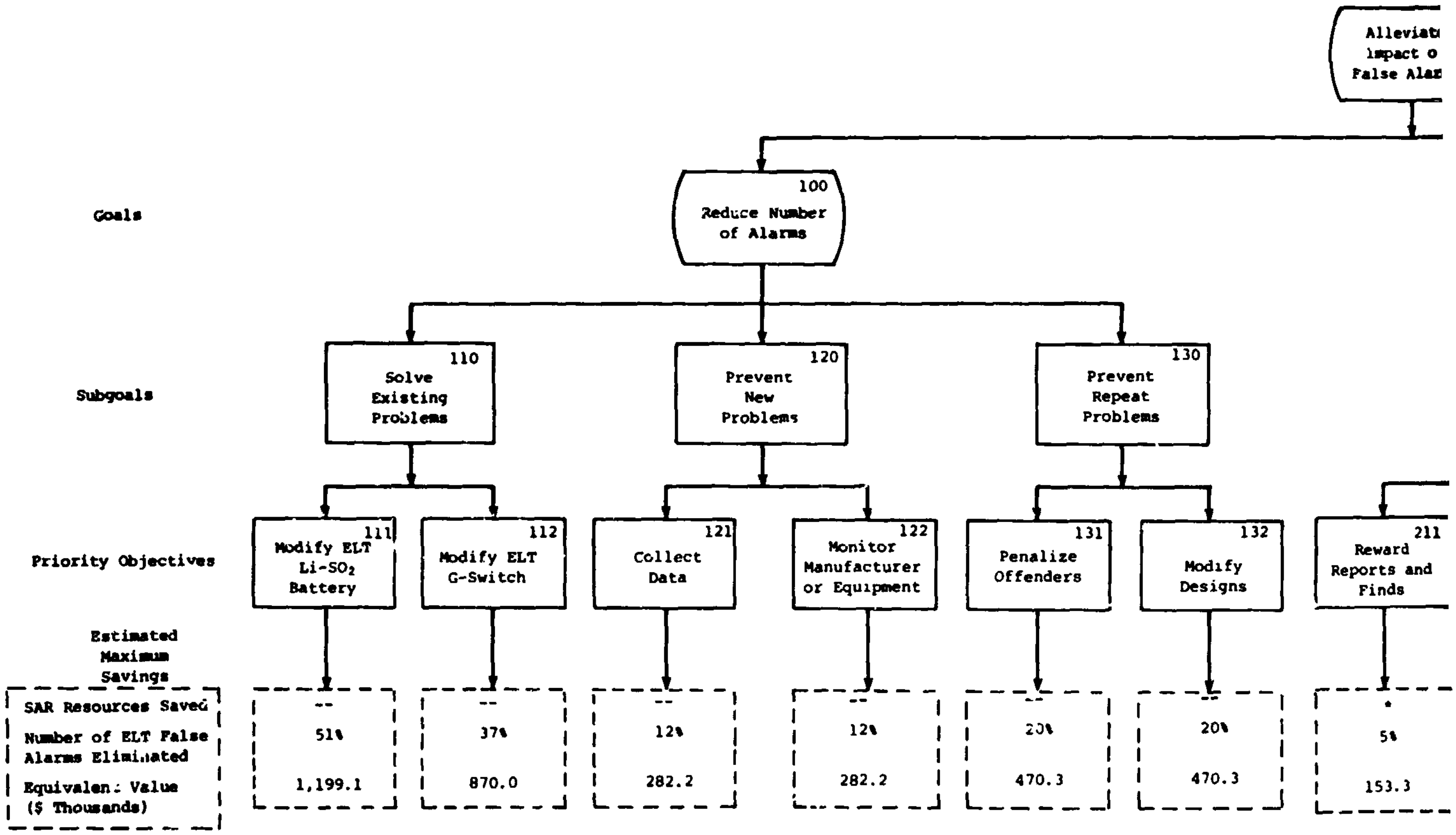

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Figure 6-1. GOAL STRUCTURE FC

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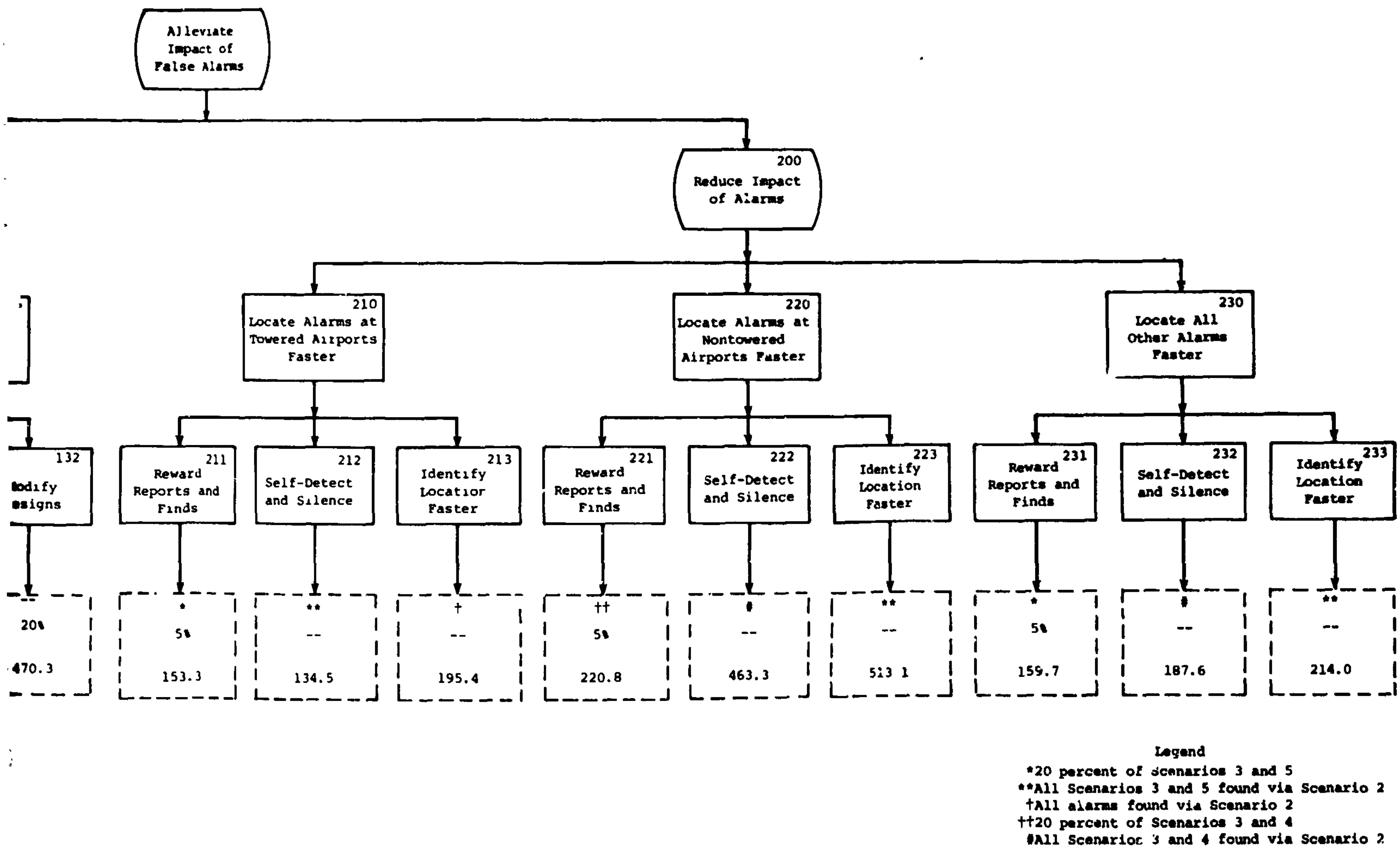

GOAL STRUCTURE FOR SOLVING ELT PROBLEM

FOLDOUT FRAME 2

Implementation Plans	Priority Objectives															Maximum Possible Savings ($ Thousands)
	Modify [illegible] (1.1)	Modify [illegible]	[illegible] (1.1)	[illegible] Manufacturer [illegible] (1.2)	[illegible]	Modify [illegible]	Reward [illegible]	Self-Detect and Silence [illegible]	Identify Location Faster (213)	Reward Reports and Finds (221)	Self-Detect and Silence (222)	Identify Location Faster (223)	Reward Reports and Finds (231)	Self-Detect and Silence (232)	Identify Location Faster (233)	
1.1 Remove Li-SO₂ batteries	●															1,199
1.2 Remove all G-switches		●														870
1.3 Remove defective G-switches only		●														870
1.4 Include source identification signature in ELT transmission format									●			●			●	923
1.5 Include position information in ELT transmission format									●			●			●	923
1.6 Install "ELT transmit" indicator [illegible] of aircraft								●			●			●		765
1.7 Connect ELT to anti-collision strobe on aircraft									●			●				709
1.8 Install cockpit-accessible control switch for all units that currently do not have them		●														870
2.1 Require more frequent ELT inspection and testing				●												282
2.2 Require pilot monitoring of emergency [illegible] before takeoff and after landing								●	●		●	●				1,306
2.3 Require fixed-base operators and [illegible] airports to monitor emergency frequencies												●				513
2.4 Provide rewards for reporting and locating ELT transmissions			●*				●			●			●			534
2.5 License and register all ELTs			●													282
2.6 Require all future radio controls to be designed to step through 121.5 MHz [illegible] or "Off"								●			●			●		785
2.7 Disarm G-switch on parked aircraft		●														870
2.8 Disarm G-switch at all times; manually activate ELT in emergency		●														870
2.9 Specify new type of automatic crash [illegible] for second-generation ELT		●														870
3.1 Ensure full-time ARTCC and FSS monitoring of emergency frequencies									●							195
3.2 Assess existing penalties against repeat offenders					●											470
3.3 Establish production sampling and recertification program at manufacturers' plants				●		●										753
3.4 Establish continuing field sampling and testing program			●	●												564
3.5 Perform a nonrecurring field sampling and testing program			●	●												564
3.6 Perform a joint government manufacturing study of ELT design and reliability			●	●												3,104
3.7 Develop nontariff, nationally uniform ticketing procedure with mandatory correction for offenders		●			●	●										2,257
4.1 Include ELT operating and use procedures in pilot training and certification programs								●	●		●	●		●	●	1,708
4.2 Implement a maintenance personnel ELT awareness program				●												282
4.3 Provide daily reminders of ELT problems to pilots								●	●		●	●		●	●	1,708
4.4 Distribute ELT alarm reports to manufacturers			●			●			●							753
4.5 Include a "check ELT" step in aircraft manufacturers' recommended preflight and postflight procedures								●	●		●	●				1,306
5.1 Establish ELT signal detection and notification at airports									●			●				709
5.2 Distribute DFs to SAR organizations for more extensive use during search operations									●			●				709
5.3 Assume that all ground-detected ELT signals originate at airport of reception									●			●				709
5.4 Develop "model" SAR procedures for national use that illustrate optimum approach to locating and silencing ELTs									●			●			●	923

*Already in savings calculation.

Figure 6-2. MATRIX OF PRIORITY OBJECTIVES SATISFIED BY IMPLEMENTATION PLANS

6.2.3 Net Expected Annual Savings

The three mitigating factors described above were quantified in terms of low (0.2), medium (0.5), high (0.8), and very high (0.95) probabilities and were included in the evaluation of each plan in Section 6.3. The net expected annual saving resulting from each plan's implementation is simply the product of the maximum possible saving, the probability of the plan to satisfy performance goals, the probability of technical risks involved, and the probability of the plan's acceptance by the user community.

6.2.4 Cost of Implementation

Each implementation plan will require the application of some new resources. These resources may be (1) additional Government expenditures for regulatory and administrative machinery or for technical implementation studies, or (2) extra expenditures by the aviation community. Very coarse estimates of these resources were developed for each plan on the basis of present costs.

6.2.5 Payback Period

The measure of the net desirability of any investment is return on investment. If the estimated costs of implementation are considered as "the investment" and the estimated annual savings as the "return" on that investment, the relative effectiveness of the various proposals can be evaluated in terms of payback period in years. The shorter the payback, the more effective and desirable the plan.

6.2.6 Implementation Time and Break-Even Point

In addition, a plan does not become fully effective and operational immediately upon implementation. Some plans with very short payback periods may require as long as 10 years or more to become fully effective. For example, replacement of all present ELTs with perfect units would result in a relatively short payback period. If replacement took place through attrition, however, the plan would require 10 years or more to purge all existing units in the field and become fully effective. Thus the initial break-even point approximately equals the sum of the implementation time and payback period.

These important characteristics of the different possible corrective actions will be discussed in greater detail in the following sections.

6.3 CORRECTIVE ACTION APPROACHES

Five general program approaches have been identified:

- ELT modifications
- Regulatory actions
- Administrative actions

- Education
- Improved SAR procedures

ELT modifications basically address the underlying technical causes of false alarms. Improved SAR procedures accept the inevitable existence of false alarms and attempt to mitigate their impact by reducing the resources required to locate each alarm. The other three programs attempt to treat the symptoms of the underlying technical causes and simultaneously streamline SAR procedures through participation of the aviation community.

6.3.1 ELT Modification Program

The intuitively obvious approach to eliminating all false alarms is to redesign offending equipment. Such a program would provide the ultimate resolution of all problems experienced to date. Unfortunately, an ELT modification program has some significant hidden disadvantages that may offset its desirability.

First, the aviation community is disinclined to spend additional money to modify or replace equipment involuntarily purchased to begin with. Second, wholesale equipment modifications and replacements are likely to result in severe technical dislocations and new unexpected problems. Third, should a technically acceptable set of modifications be developed, the logistics of effective implementation could prove to be difficult, and perhaps unpopular, and probably would require many years to accomplish. Finally, even a simple modification program costing $50 per ELT will be too expensive for cost-effectiveness, since

$$\$50 \text{ per ELT} \times (\text{approximately } 200{,}000 \text{ ELTs}) = \begin{array}{l}\$10{,}000{,}000 \text{ Total}\\ \text{Modification Cost}\end{array}$$

Eight specific implementation plans are considered and summarized in Table 6-1. Analysis confirms the above observations on the cost-effectiveness of hardware-oriented short-term solutions. Note that Plan 1.1 essentially has been accomplished through FAA Airworthiness Directive (AD) 79-05-02. This AD required the removal within 30 days of all Li-SO_2 batteries from ELTs in U.S.-registered civil aircraft. The only other plan that has a reasonably short (0.3 year) break-even period is Plan 1.3 (remove defective G-switches only). This implementation plan would tend to have a comparatively high user compliance rate because the few different types of offending components could be replaced through a mandatory Airworthiness Directive process similar to that used for Li-SO_2 batteries.

6.3.2 Regulatory Program

The success of the ELT concept depends on the performance of the equipment, SAR crew efficiency, and the participation of the aviation community. This community consists of individuals with a variety of needs. The easiest, most effective, and most rapid technique for assuring cooperation from such a diverse population is regulatory action. Regulatory action succeeded in accomplishing, over strenuous objections, the installation of more than

Table 6-1. SUMMARY OF IMPLEMENTATION PLANS FOR ELT MODIFICATION PROGRAM

Plan Number	Plan Description	Maximum Possible Savings ($ 1000)	Probability of: Meeting Priority Objectives	Probability of: Plans' Successful Execution	Probability of: User Community Acceptance	Net Expected Annual Savings ($ 1000)	Estimated Cost ($ 1000): Government	Estimated Cost ($ 1000): Users	Payback (Years)	Full Effectivity Expected After Implementation (Years)
1.1	Remove $Li\text{-}SO_2$ batteries	1,199	M	VH	VH	866	--	2,800 (NR)	3.2	1
1.2	Remove all G-switches	870	M	VH	M	331	90 (NR)	7,000 (NR)	21	4 with AD 15 by attrition
1.3	Remove defective G-switches	870	M	M	VH	331	90 (NR)	1,000 (NR)	3.3	3
1.4	Include source identification signature in ELT transmission format	923	L	L	L	7	200 (NR)	18,000 (NR)	2,600	15
1.5	Include position information in ELT transmission format	923	H	M	L	74	250 (NR)	70,000 (NR)	950	15
1.6	Install "ELT transmit" indicator in cockpit of aircraft	785	L	VH	M	75	--	14,000 (NR)	190	5
1.7	Connect ELT to anti-collision strobe on aircraft	598	L	H	L	19	--	19,000 (NR)	1,000	5
1.8	Install cockpit-accessible control switch for all units that currently do not have them	870	M	H	M	174	--	15,000 (NR)	86	3

Legend:

L = Low, M = Medium, H = High, VH = Very High
NR = Nonrecurring Total Cost, A = Annual Cost

140,000 ELTs in civil aircraft in less than a year. By the same token, regulatory action through issuance of an AD will result in removal of Li-SO_2 batteries from all ELTs within a period of 30 days from publication. (Removal of the batteries does not solve the problem, however, and a technical solution will not be accomplished until at least one year after the AD's publication).

Regulatory action does have some disadvantages, however. Enactment is frequently a difficult, time-consuming process. The regulation cannot expedite the implementation process itself, which may be time-limited by other factors. Frequently, public reaction is negative. Finally, compliance with a regulation is not assured unless the supporting regulatory and administrative machinery is properly installed. Therefore, the application of regulatory solutions must be considered with utmost care.

Nine possible regulatory plans are summarized in Table 6-2. Most of these plans, particularly those which do not demand the establishment of a significant new administrative structure, demonstrate viable short- to medium-term effectiveness against ELT false alarms. Approaches to disarm or deactivate G-switches (Plans 2.7 and 2.8) seem to hold particularly bright prospects for success within a period of about three years. Plan 2.2 (require pilots to monitor emergency bands before takeoffs and after landings) also can be expected to break even within about four years of adoption. Probably the most attractive features of both of these plans are as follows:

- No aviation community cash outlay is demanded.
- No significant Government enforcement machinery is needed for the plans to work.

One of the plans (Plan 2.9, specify new types of automatic crash sensors for second-generation ELTs) holds promise for long-term solutions. The attractiveness of this plan rests partly in the high failure rate of G-switches and partly in the fact that present equipment specifications mention alternative crash-sensing techniques (e.g., oil pressure sensors) but do not consider them to a level of detail adequate for manufacturers to apply in production units. Correcting this problem should encourage manufacturers to apply alternative, more reliable technologies to triggering ELTs.

6.3.3 Administrative Program

The objective of regulatory action can frequently be accomplished through less drastic measures, particularly if the administrative and regulatory machinery already exist. For example, the FAA and FCC already are permitted to take specific punitive actions against individuals who use the emergency airwaves for nonemergency purposes. These punitive actions may range from "red tagging" of an aircraft by the FAA to imposing a fine or revocation of station license by the FCC.

Table 6-2. SUMMARY OF IMPLEMENTATION PLANS FOR REGULATORY PROGRAM

Plan		Maximum Possible Savings ($ 1000)	Probability of			Net Expected Annual Savings ($ 1000)	Estimated Cost ($ 1000)		Payback (Years)	Full Effectivity Expected After Implementation (Years)
Number	Description		Meeting Priority Objectives	Plans' Successful Execution	User Community Acceptance		Government	Users		
2.1	Require more frequent ELT inspection and testing	282	H	L	L	9	200 (NR)	13,300 (A)	∞	2
2.2	Require pilot monitoring of emergency bands before takeoff and after landing	1,305	M	M	H	261	200 (NR)	500* (A)	2.7	1
2.3	Require fixed-base operators at nontowered airports to monitor emergency frequencies	513	M	M	M	64	200 (NR)	1,100 (NR)	20	3
2.4	Provide rewards for reporting and locating ELT transmissions	534	L	L	VH	20	400 (A)	--	[illegible]	2
2.5	License and register all ELTs	282	L	L	L	2	200 (NR)	600 (A)	[illegible]	3
2.6	Require all future radio controls to be designed to step through 121.5 MHz before "On" or "Off"	785	M	M	M	98	200 (NR)	100 (NR)	3.1	15
2.7	Disarm G-switch on parked aircraft	870	H	M	M	174	200 (NR)	--	1.1	2
2.8	Disarm G-switch at all times; manually activate ELT in emergency	870	H	H	M	278	200 (NR)	--	0.7	2
2.9	Specify new type of automatic crash sensors for second-generation ELTs	870	H	M	M	278	100 (NR)	--	0.4	15

*Due to additional time lost by pilots.

Legend:

L = Low, M = Medium, H = High, VH = Very High
NR = Nonrecurring Total Cost, A = Annual Cost

Therefore, more conscientious administration of existing regulations and the addition of new internal procedures within the FAA and FCC can provide the aviation community additional incentive to reduce the number and duration of false alarms. This administrative approach has the advantage of being comparatively easy to implement and control, with relatively little public awareness and short lead times.

Seven specific implementation plans are summarized in Table 6-3. Although the implementation costs of these plans are comparatively low, only four provide sufficient expected savings to offset even these low costs. Of these four possible candidates, Plan 3.3 (establish production sampling and recertification program at manufacturer's plants) requires a long time to full implementation because only newly manufactured units fall under the sampling program, leaving a large number of defective ELTs in the field during a slow attrition process. The most desirable administrative plan appears to be Plan 3.7 (develop nationally uniform nontariff ticketing procedure with mandatory corrective action for offenders). This plan would permit SAR or FAA personnel to issue citations to aircraft that emit ELT false alarms. Copies of the citation would be sent to the FAA at Oklahoma City and to AFRCC. The aircraft owner would be required to submit an ELT inspection and test certificate by an authorized serviceman within 30 days. Noncompliance would result in revocation of the aircraft's airworthiness certificate. This process is conceived to be similar to the citations frequently issued by police to automobiles for safety defects, such as nonworking headlights. A significant consequence of the program would be the establishment of a central data control center in which ELT false alarms and performance could be monitored readily. This data control center already exists by virtue of the FAA Service Difficulty Report data base, which should be relatively inexpensive to augment.

A second desirable administrative plan could be Plan 3.5, a one-time field sampling and testing program to collect operational verification data on existing units and to confirm or deny the make or model distributions developed during this study. This plan could be useful in identifying specific regulatory or technical corrective action plans and in providing the required support for future Airworthiness Directives.

6.3.4 Educational Program

An expanded educational program will not necessarily prevent many false alarms, because the number of alarms directly attributable to human error and miscellaneous causes has been decreasing. However, an educational program can be an invaluable tool for reducing waste of SAR resources in locating false ELT alarms. For example, an aircraft operator who is trained to monitor and inspect his ELT regularly could probably prevent the launching of a search mission by notifying proper authorities more promptly. Proper training of airport and SAR personnel to report all incidents promptly and conscientiously also would permit compilation of a more complete and accurate data base from which undesirable trends could be identified and arrested before they mushroomed into major problems.

Table 6-3. SUMMARY OF IMPLEMENTATION PLANS FOR ADMINISTRATIVE PROGRAM

Plan		Maximum Possible Savings ($ 1000)	Probability of			Net Expected Annual Savings ($ 1000)	Estimated Cost ($ 1000)		Payback (Years)	Full Effectivity Expected After Implementation (Years)
Number	Description		Meeting Priority Objectives	Plans' Successful Execution	User Community Acceptance		Government	Users		
3.1	Ensure full-time ATCT and FSS monitoring of emergency frequencies	195	L	H	VH	30	50 (A)	--	∞	1
3.2	Assess existing penalties against repeat offenders	470	H	L	L	15	--	50 (A)	∞	2
3.3	Establish production sampling and recertification program at manufacturers' plant	753	H	M	M	150	100 (A)	--	0.7	15
3.4	Establish continuing field sampling and testing program	564	H	H	L	72	100 (A)	--	∞	5
3.5	Perform a nonrecurring field sampling and testing program	282	H	H	L	36	100 (NR)	--	2.8	1
3.6	Perform a joint government/manufacturer study of ELT design and reliability	3,104	H	M	M	621	250 (NR)	--	0.4	15
3.7	Develop nontariff, nationally uniform ticketing procedure with mandatory correction for offenders only	2,257	M	M	VH	536	60 (A)	100 (A)	0.3	2

Legend:

L = Low, M = Medium, H = High, VH = Very High
NR = Nonrecurring Total Cost, A = Annual Cost

C-2

Educational programs imply a certain amount of voluntary compliance after training activities are completed. Thus it is reasonable to expect that recommended practices would be less universally adopted than those imposed by regulatory and administrative programs. On the other hand, educational programs preclude the strong negative reactions typically associated with regulations and the limited awareness of administrative actions.

Five specific implementation plans are summarized in Table 6-4. Because of the relatively low cost of educational programs and the possible broad population range of targets, most educational programs appear to be good candidates for adoption. In fact, the only proposed plan with greater than a three-year break-even point is Plan 4.2 (implement maintenance personnel ELT awareness program). The primary reason for this program's comparatively long (8.3 years) payback period is that the FAA already uses notices and advisory circulars as an ELT awareness program. However, we have not been able to determine the program's aggressiveness, level of detail, and effectiveness, and believe that improvements are possible.

6.3.5 Streamline SAR Operations

Another possible method for reducing the cost of false alarms is to improve SAR procedures so that ELT alarms are easier to locate and silence. Streamlining SAR operations can minimize waste of resources. Unfortunately, SAR operating procedures are too varied to permit the development of many comprehensive plans for streamlining operations. However, several possible approaches have been identified; these are presented in Table 6-5.

The first two approaches attempt to reduce the cost of localizing alarms by improving the efficiency of search operations with the aid of additional equipment. Plan 5.1 considers the application of devices that automatically detect and report the existence of alarms at unattended airports. The concept is somewhat similar to a burglar alarm connected to the local police station. Plan 5.2 considers the benefits and costs of providing additional direction finders to search and rescue organizations for use during the localizing process. Both plans require the purchase of a significant quantity of new equipment and thus provide only medium-range break-even on the order of four to seven years.

Another possible approach (Plan 5.3) is based on the savings to be realized by substituting many local airport searches for each air or ground search. For example, all ground-detected alarms could be assumed to originate at the airport from which the report of the alarm was received. Then a search team could be dispatched directly to that airport without an air or ground search. Unfortunately, the additional efforts expended in chasing down alarms that are reported from one airport but are actually located elsewhere far outweigh the expected saving from eliminating air or ground searches.

Plan 5.4 follows an approach commonly practiced by the Federal Government in other areas. Since SAR operations are decentralized, many different procedures exist for locating and silencing ELTs. Each of these special procedures offers unique benefits that may be applied by other jurisdictions,

Table 6-4. SUMMARY OF IMPLEMENTATION PLANS FOR EDUCATIONAL PROGRAMS

Plan		Maximum Possible Savings ($ 1000)	Probability of			Net Expected Annual Savings ($ 1000)	Estimated Cost ($ 1000)		Payback (Years)	Full Effectivity Expected After Implementation (Years)
Number	Description		Meeting Priority Objectives	Plans' Successful Execution	User Community Acceptance		Government	Users		
4.1	Include ELT operating and use procedures in pilot training and certification programs	1,708	M	M	M	213	300 (NR)	--	1.4	2
4.2	Implement a maintenance personnel ELT awareness program	282	L	L	M	6	50 (NR)	--	8.3	1
4.3	Provide daily reminders of ELT problems to pilots	1,708	L	H	H	218	250 (NR)	--	1.1	1
4.4	Distribute ELT alarm reports to manufacturers	753	L	VH	H	114	--	--	0	3
4.5	Include "check ELT" step in aircraft manufacturers' recommended preflight/post-flight procedures	1,306	M	H	H	418	50 (NR)	--	0.1	15

Legend:

L = Low, M = Medium, H = High, VH = Very High
NR = Nonrecurring Total Cost, A = Annual Cost

Table 6-5. **SUMMARY OF IMPLEMENTATION PLANS FOR STREAMLINING SAR OPERATIONS PROGRAM**

Plan		Maximum Possible Savings ($ 1000)	Probability of			Net Expected Annual Savings ($ 1000)	Estimated Cost ($ 1000)		Payback (Years)	Full Effectivity Expected After Implementation (Years)
Number	Description		Meeting Priority Objective	Plans' Successful Execution	User Community Acceptance		Government	Users		
5.1	Establish automatic ELT signal detection and notification at airports	709	H	H	M	227	900 (NR)	--	4.0	3
5.2	Distribute DFs to SAR organizations for more extensive use during search operations	709	M	M	M	80	150 (NR)	--	0.7	3
5.3	Assume that all ground-detected ELT signals originate at airport of reception	709	M	L	L	14	117 (A)	--	∞	1
5.4	Develop "model" SAR procedures for national use that illustrate optimum approach to locating and silencing ELTs	923	M	M	M	115	150 (NR)	--	1.3	5

Legend:

L = Low, M = Medium, H = High, VH = Very High
NR = Nonrecurring Total Cost, A = Annual Cost

but these "optimum" procedures have not been compiled into a unified recommended approach. Therefore, significant savings could be realized through the publication of search and rescue operating guidelines and standards to be applied at the local level. These guidelines would not be mandatory (and localities should not be penalized for not adopting them completely), but they should provide assistance and coordination in minimizing the impact of ELT false alarms.

6.4 CORRECTIVE ACTION STRATEGY

Fifteen of the 33 specific implementation plans discussed will contribute significantly to solving the ELT false alarm problem within the next 15 years. Of course, not all of these can be implemented; even if all fifteen were fully implemented, many of the plans would not be as cost-effective as indicated because of overlaps in coverage. The plans designed to reduce the impact of alarms are especially vulnerable in this regard.

Therefore, it is important to develop a unified corrective action strategy that considers interactive effects. Such a strategy is outlined in the following subsections in approximate sequence of recommended implementation.

6.4.1 Accomplished Plans

Plan 1.1 (remove Li-SO_2 batteries) has already been accomplished through AD 79-05-02, as discussed earlier. The net effect is expected to be a 37 percent reduction in the total number of false alarms.

6.4.2 Short-Term Break-Even Strategy

The following four implementation plans promise short-term break-even in a period less than three years from adoption:

- Distribute ELT Alarm Reports to Manufacturers (Plan 4.4). Plan 4.4 is essentially a "no cost" action that could result in an expected 5 percent reduction in the number of alarms as manufacturers upgrade designs on the basis of the failure reports received.
- Develop Nationally Uniform Nontariff Ticketing Procedure with Mandatory Corrective Action for Offenders (Plan 3.7). Plan 3.7 is a low-cost option that would increase pilot awareness of the necessity of maintaining ELTs in good operating condition, would prevent repeat offenders, and would offer a reliable data base for managing the ELT problem. Savings are expected to be a 10 percent maximum reduction in alarms and a 10 percent saving in SAR resources.
- Provide Daily Reminders of ELT Problems to Pilots (Plan 4.3). This educational program, utilizing both printed and recorded materials, promises to reduce the waste of time and resources by 5 percent in searching for false alarms.

- Require Pilots to Monitor Emergency Bands Before Takeoffs and After Landings (Plan 2.2). Pilot self-detection of ELT false alarm signals and more rapid fixing of transmission sources will reduce the waste of SAR resources by an estimated 6 percent.

6.4.3 Medium-Term Break-Even Strategy

Six implementation plans could achieve break-even within three to six years after adoption. Two of the six plans are somewhat similar and are discussed together. The others are addressed separately.

- Deactivate G-Switch (Plan 2.7 or 2.8). Since armed G-switches are the second most populous cause of false alarms, disarming ELTs while the aircraft is parked (or at all times except in case of emergency) is expected to provide an 8 to 12 percent reduction in the total number of false alarms. The exact reduction will vary depending on the particular implementation plan adopted. Additional information must be developed before this plan can be adopted successfully. First, what are pilot reactions to the possibility of having to worry about one more item (e.g., activating the ELT) during an emergency? Second, how accessible are currently installed units and controls? These questions can be resolved as part of the sampling and testing program discussed next.
- Distribute DFs to SAR Organizations for More Extensive Use During Search Operations (Plan 5.2). Many searches currently are conducted without the aid of adequate direction-finding equipment. Recent technology advances have made available accurate, inexpensive direction finders for use in air and ground searches. In fact, the FAA has been purchasing such equipment to aid in search and rescue operations. The procurement and distribution for use by SAR organizations of more DF equipment will reduce the cost of SAR operations by approximately 5 percent.
- Perform a Nonrecurring Field Sampling and Testing Program (Plan 3.5). The results of this program would be used to identify and remove from service specific units with documented defects. As a result, one percent of all false alarms would be prevented from recurring.
- Include ELT Operating and Use Procedures in Pilot Training and Certification Programs (Plan 4.1). Plan 4.1 would complement two short-term approaches (Plans 4.3 and 2.2). Its effectiveness would be derived from the classroom setting during initial pilot-licensing procedures and from the mandatory examination of all pilots every two years. In combination with the other medium-term break-even plans, this approach is expected to reduce somewhat the total number of alarms by reinforcing the goals of the other two programs and also to reduce wasted SAR resources by approximately three percent.
- Develop "Model" SAR Procedures for National Use That Illustrate Optimum Approaches to Locating and Silencing ELTs (Plan 5.4). Plan 5.4 would take advantage of the experience gained in the more

successful jurisdications (e.g., Alaska, California, Washington) to streamline SAR procedures in other localities. Estimated SAR resources saved nationally would be in the range of two to three percent of present commitments.

6.4.4 Long-Term Break-Even Strategy

The aggressive adoption of short- and medium-term break-even strategies should result in a 60 percent reduction in the number of alarms and an additional 14 percent saving in wasted SAR resources. Quantifying the effects of longer-term strategies is more difficult. Major changes to the ELT concept are expected to occur in the 6- to 15-year period. These changes include the introduction of new, second-generation ELTs with higher reliability and lower false alarm rates, the launching of SARSAT with its more accurate position-fixing capabilities, and perhaps even the introduction of third-generation 406 MHz ELTs. The following plans provide some possibilities for additional improvements:

- Remove Defective G-switches (Plan 1.3). The medium-term strategy undoubtedly missed some defective G-switches because of the lack of user community interest. It is estimated that a rigorously enforced ELT modification program could provide an additional modest reduction in the total number of false alarms, but at great cost.
- Specify Alternate Types of Automatic Crash Sensors for Second-Generation ELTs (Plan 2.9). The deactivation of G-switches may provide an effective interim solution to the false alarm problem. There is, however, considerable uncertainty regarding the necessity for automatic triggers and the mechanisms that should be used for reliably sensing crashes. NASA is currently studying the forces involved in aircraft crashes to define G-switch parameters. Other sensing techniques, such as combinations of engine condition, acceleration, deformation sensors, etc., may provide a more reliable indicator of emergency and should be considered seriously. The potential exists for eliminating more than 25 percent of all false alarms through adoption of this plan.
- Implement a Maintenance Personnel ELT Awareness Program (Plan 4.2). Minimal benefits are expected.
- Automatic Signal Detection and Notification at Airports (Plan 5.1). Given the present statistics of ELT false alarms, an additional three percent of SAR resources could be saved by automatic signal detection and notification. However, the prospect of increasing spatial resolution through SARSAT, the introduction of the new generation of ELTs, and the implementation of short- and medium-term strategies cast serious doubts on the value of this plan.

CHAPTER SEVEN

CONCLUSIONS AND RECOMMENDATIONS

This chapter presents the conclusions and recommendations resulting from this study and addresses critical immediate steps necessary to implement the strategies developed in Chapter Six.

7.1 CONCLUSIONS

This study indicates that the problem of ELT false alarms has not disappeared -- only the causes have changed. It is estimated that in 1978 there were about 19,300 false alarms, the equivalent of one in every 10 units triggering unnecessarily. This rather high and disturbing figure is seasonal and depends heavily on the estimate of the number of unreported false alarms, which are considered to constitute more than 75 percent of all alarms. Even at this high level of false alarms, the expected average of 6.5 simultaneous emissions is well under the anticipated capacity of SARSAT.

Most false alarms can be traced to problems with the G-switch or the Li-SO_2 battery. Since these two major causes of false alarms represent problems with the units themselves rather than with their environment, the rate of ELT alarms should be roughly proportional to the concentration of units in the field. This situation implies that the areas with the highest number of aircraft (i.e., Los Angeles, New York, and Miami metropolitan areas) are the source of the highest density of false alarms. For any given metropolitan area, the maximum probability of two or more simultaneous emissions is estimated to be three percent. Thus the possibility of a false signal masking a true one exists, but this should be a fairly uncommon occurrence.

Most false alarms occur at airports -- approximately 45 percent at towered airports and 37 percent at nontowered airports. The remainder include boat-related incidents (EPIRBs), farms, legitimate crashes, and other miscellaneous sources. Alarms originating from nontowered airports are the most expensive to locate and silence because these fields lack routine monitoring of emergency frequencies. Therefore, the elimination or more rapid location of alarms at airports should be a first priority for proposed solutions.

The average transmission duration for a false alarm is about three hours; however, it is considerably shorter for those alarms which originate at towered airports and longer for those which originate at nontowered airports. This transmission duration is dependent not only on the location of the alarm but also on the method used to locate the alarm. Therefore, some savings in SAR resources may be achieved through streamlining SAR procedures.

7.2 RECOMMENDATIONS

A number of technical and nontechnical short-term solutions are available to correct the causes of problems with ELTs. The most promising of these solutions employ educational and regulatory programs involving manufacturers and active pilots. These short-term solutions, however, will provide only temporary relief and must be supplemented by preparing the groundwork for more thorough medium- and long-term corrective actions. The following recommendations describe a unified, systematic approach to reducing the impact of false alarms on the aviation community. The initial recommendations are designed to lay the groundwork for later strategies by compiling currently unavailable data required for management decisions. The benefits of these recommendations are summarized in Table 7-1.

Table 7-1. RECOMMENDED SOLUTIONS FOR REDUCING ELT FALSE ALARMS

Activity	Benefit*
Review records for defective trigger mechanisms Survey ELT alarm reports to manufacturers	Prepare detailed plan for implementing corrective actions
Distribute ELT alarm reports to manufacturers	Encourage redesign of faulty units
Develop ticketing procedure for offenders	Reduce false alarms by 10 percent Reduce cost of SAR operations by 10 percent
Provide daily reminders to pilots	Reduce cost of SAR operations by 5 percent
Encourage pilots to monitor emergency bands	Reduce cost of SAR operations by 6 percent
Distribute direction-finding equipment to SAR organizations	Reduce cost of SAR operations by 5 percent
Develop alternative triggering mechanisms	Reduce false alarms by 25 percent
Establish automatic ELT signal detector and notification capability at airports	Reduce cost of SAR operations by 3 percent
Develop and encourage use of standard ELT localizing procedure	Reduce cost of SAR operations by 3 percent

*Benefits calculated on the basis of sources and causes of ELT transmissions and estimated costs of locating and silencing.

7.2.1 Review Service Difficulty Reports for G-Switch "No Trips"

Many of the false alarms are caused by defective G-switches. Similarly, many "no trips" also may be related to defective G-switches. The Service Difficulty Reports have extensive records of inoperative or unreliable ELTs, usually detected in the course of the annual aircraft inspection. Make and model correlation of these records with the false alarm data presented here may provide sufficient grounds for recall of specific ELT makes, models, or G-switch types.

7.2.2 Perform Nonrecurring Field Survey

The success of some short-term solutions depends on properly approaching the aviation community for maximum pilot response. Therefore, before any short-term strategies are adopted, it is important to determine pilot attitudes toward using ELTs and providing assistance in locating alarms. This goal could be accomplished through a survey of pilots as part of a nonrecurring field sampling and testing program (Plan 3.5).

In addition, such a survey would provide the necessary quantitative information on the conditions and use patterns of ELTs. This latter information is a critical first step in the decision process to recall certain makes and models of ELTs for noncompliance.

One of the corollary benefits of this survey would be the development of an acceptable set of field test procedures for ELTs. These procedures could be applied by certified mechanics to verify proper functioning of units under Plan 3.7.

7.2.3 Implement Short-Term Corrective Action Strategy

A number of the specific implementation plans contained in the corrective action strategy outlined in Chapter Six require very little Government investment and should begin to show partial results well before 1982, even though "break even" may not occur for several years thereafter. Thus it is highly recommended that the following plans be implemented as rapidly as possible after review of the Service Difficulty Reports for equipment reliability:

- Distribute ELT Alarm Reports to manufacturers
- Develop nationally uniform nontariff ticketing procedure with mandatory corrective action for offenders
- Provide daily reminders of ELT problem to pilots
- Encourage pilots to monitor emergency bands before takeoffs and after landings

7.2.4 Study Alternative ELT Triggering Mechanisms

Other proposed plans, such as Plan 1.3 (remove defective G-switches) and Plan 2.9 (specify alternate types of automatic crash sensors for second-generation ELTs) may require reevaluation of the G-switch concept. This reevaluation may encompass new approaches to achieving the same ends. Conventionality must not limit creativity; ideas such as different transmission formats, different trigger mechanisms, and certainly some equipment redesigns must be considered. It is necessary to develop a set of criteria that are always present in a crash environment and never present otherwise; these criteria can constitute the trigger algorithm for a second-generation unit. Before the aviation community is once again committed to less than optimum approaches and requirements, a creative, unbiased evaluation of the problem is needed.

7.2.5 Improve SAR Procedures

Before more efficient search and rescue operations can be a reality, existing procedures and their faults and benefits must be analyzed in detail in terms of the need for cost-effectiveness, speed of response, prevention of future problems, and other similar factors. With this information available, the impact of any remaining false alarms on SAR can be reduced even further through adoption of proposed plans, such as Plan 5.1 (automatic ELT signal detection and notification at airports), Plan 5.2 (distribute DFs to SAR organizations for more extensive use during SAR operations), and Plan 5.4 (develop "model" SAR procedures for national use that illustrate optimum approaches to locating and silencing ELTs).

APPENDIX

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