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# THE COSTS AND BENEFITS OF A MID-CONTINENT EXPANSION OF LORAN-C

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16. Abstract

The Department of Transportation, Transportation Systems Center (DOT/TSC) conducted a study of the costs and benefits of land uses of Loran-C in the mid-continent region of the United States. Loran-C chains currently in operation or approved for construction will soon cover not only the U.S. coastal and Great Lakes waters, but also 63 percent of the land area and 92 percent of the population of the contiguous 48 states. The mid-continent expansion of Loran-C, representing the completion of nationwide coverage, could be provided at an initial cost of $22 million plus $1.1 million a year in operations and maintenance expenses. These costs would be less than 20 percent of the existing facilities investment already in place and operated by the Coast Guard.
The results of the study indicate $125 million in Loran-C land user benefits as compared to $52 million in user and Loran-C chain costs during the 1982 to 1990 time period. Significant benefits were found in emergency medical services ($52M), rural fire suppression ($22M), police management ($17M), and highway accident location and traffic records ($14M). Using a 10 percent discount rate and benefit estimates restricted to the mid-continent area, other cost-effective applications (benefit-to-cost ratio higher than five) were: nuclear materials security, aerial spraying, biomass inventory, and forest and wildfire suppression. These estimates were obtained through extensive discussions with seven federal agencies (HEW, FHWA, NHTSA, DOE, etc.), many state and local agencies, and industry. The results are conservative and represent only the public (as opposed to private) benefits of a limited number of potential land applications of Loran-C

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## PREFACE

This study of the costs and benefits of a mid-continent expansion of Loran-C was performed by the Department of Transportation, Transportation Systems Center for the Research and Special Programs Administration. The study is a part of a continuing effort to evaluate the needs of land vehicles for a nationwide navigation capability and builds on previous benefit versus cost assessments and analyses of terrestrial requirements and applications. The ground work leading to the estimates of costs and benefits in Section 5, is briefly described here.

<u>Section 1</u>: Identifies the uncovered mid-continent region and its characteristics in the context of the nationwide status of Loran-C and its associated research and development activities relating to land uses.

<u>Section 2</u>: Describes the potential applications and user requirements for Loran-C.

<u>Section 3</u>: Describes the methods used in selecting eight of the most promising mid-continent public applications of Loran-C.

<u>Section 4</u>: Establishes the guidelines for estimating costs and benefits.

The authors wish to express their sincere appreciation to the hundreds of individuals and their organizations who have contributed their advice and effort to this study. From the Department of Transportation, we would like to acknowledge the contributions of Cdr. W. Walker, Cdr. J. Bernard, J. Foley, A. D. Jordan, and particularly Capt. W. Mohin who provided valuable information and program guidance.

Thanks are gratefully given to many individuals in other Federal agencies and the private sector, especially H. Taylor of the U.S. Forest Service, J. Henderson of the Animal and Plant Health Inspection Service, W. Gilbert of the Bureau of Land Management, C. Mosher of the New York State Department of Motor Vehicles, P. Brown of the State of Tennessee Highway Department, D. W. Sherwood of the Energy Research and Development Administration, and J. Stephany.

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In 1980 the U.S. Coast Guard will complete the implementation of fourteen Loran-C transmitter stations to provide the civil marine community with a radionavigation capability in the United States coastal and Great Lakes waters. Loran-C coverage well outside the "two-hundred mile limit" is available from thirteen stations operating in the eastern and western parts of the nation. As shown in Figure ES-1, the 100 kHz Loran-C groundwave signals will also cover 63 percent of the land area and 92 percent of the population of the contiguous 48 states. The existence of these signals and the possibility of obtaining accuracies of better than 150 meters (492 feet) has prompted considerable interest in land uses of Loran-C on the part of Federal, state, and local agencies and private industry. Excluding past efforts and the private sector, there are at least fifteen present or planned Loran-C R&D activities (See Figure ES-1) being sponsored by DOT and other Federal and state agencies. These activities range from large-scale demonstrations of automatic vehicle monitoring (AVM),

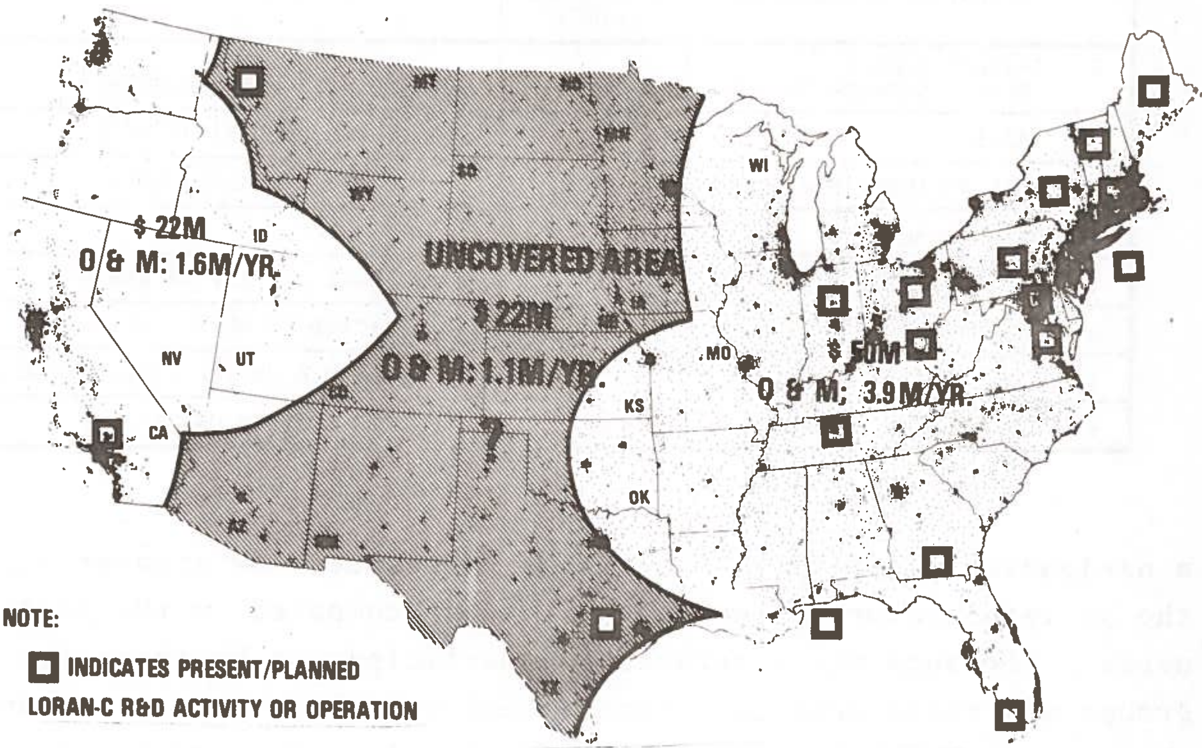


FIGURE ES-1. MID-CONTINENT LORAN-C EXPANSION attitudes of labor unions toward position monitoring of land vehicles, and the division between public and private navigation communications to insure public safety and services.

Considering public uses alone, there are at least 14 potential applications on a realistic "shopping list" for Loran-C. These applications and their associated benefits are listed in Tables ES-2. The first eight applications were selected as the most promising for this study. The study considered the public benefits

TABLE ES-2. POTENTIAL PUBLIC APPLICATIONS AND BENEFITS

| POTENTIAL APPLICATION | POSSIBLE BENEFIT AREA |
|---|---|
| 1. POLICE MANAGEMENT/TRAFFIC ENFORCEMENT | CRIME CONTROL, CITIZEN AID |
| 2. EMERGENCY MEDICAL SERVICES (EMS) | HOUSEHOLD/HIGHWAY MEDICAL AID |
| 3. FIRE SUPPRESSION | FIRE DAMAGE |
| 4. HIGHWAY SAFETY | SELECTIVE ENFORCEMENT, ACCIDENT CONTROL |
| 5. TRANSPORTATION OF HAZARDOUS MATERIALS | CARGO SAFEGUARDS |
| 6. ROAD INVENTORY & TRAFFIC RECORDS | CONSTRUCTION, MAINTENANCE, SITE IDENTIFICATION |
| 7. AERIAL SPRAYING & CROP INVENTORY | SITE LOCATION AND GUIDANCE |
| 8. NATURAL RESOURCE EXPLORATION/ INVENTORY | NATIONAL RESOURCE USE AND CONSERVATION |
| 9. SEARCH AND RESCUE | SEARCH PATTERNS AND COORDINATION |
| 10. NATURAL DISASTER RELIEF | TRACKING AND INTERAGENCY COORDINATION |
| 11. BUS CONTROL & SCHEDULING (AVM) | PASSENGER SERVICE |
| 12. CENSUS TAKING | ENUMERATOR AID IN RURAL AREAS |
| 13. NATIONAL & INTERSTATE LAW ENFORCEMENT | CONTRABAND CONTROL |
| 14. OTHERS (WILDLIFE SURVEY, AIR POLLUTION MONITORING, RIVER BARGE TRACKING, MAIL TRUCK MONITORING, ETC.) | VARIOUS LOCATION EFFICIENCIES (PRODUCTIVITY, FUEL SAVINGS, ETC.) |

which could accrue to the 17 million residents within the mid-continent, recognizing the largely rural character and other unique characteristics of the 13 states involved. Among these were extensive oil, fossil fuel, and mineral exploration, three quarters of the nation's transportation of nuclear materials, large amounts of farm land, a higher per capita number of highway accidents and fatalities, and over one-fifth of its 1.1 million square miles designated as Indian reservations, national forest and parks, and public land.

6. Benefits from the location function were proportioned and estimated on the low side when other advantages (e.g., identification, communications, and control) could be derived from the same system. For example, EMS benefits from reductions in the number of indefinite locations (e.g., emergency calls where imprecise or vague locations such as the "Jones farm", or "Box 248" were given) in very rural areas were estimated at one-half of the total which could be prevented if the household telephone had a central 911 energency dialing service with an automatic address report.

7. Many intangible or unquantifiable benefits were excluded from consideration. Among these were advantages from the Loran-C time reference, police officer safety during criminal emergencies, crime detection and prevention, improvements in search and rescue, and cost savings resulting from the use of a single system both within and outside the mid-continent region.

8. Applications were excluded if the Loran-C costs (receiver, facilities, etc.), benefits, location accuracy, or implementation timetables were not in line with the user requirements or the needs of the responsible public agency.

The results of the cost benefit analysis are summarized along with each public agency in Table ES-3. Major aspects of the findings were:

1. The first <u>four applications (police management, EMS, fire suppression, and highway accident location and statistical records) require coordination and routing of the location information</u> by a central facility. Most of the state and local facility costs for this capability and the Loran-C monitor stations were assigned to the police and highway departments. These four applications required the installation of Loran-C receivers in 8,260 out of 21,000 mid-continent vehicles which are involved in these operations.

death reductions were also estimated for police vehicles equipped with Loran-C as a location identifier in highway accidents where the faster arrival of medical aid minimizes the effects of traumatic injuries (bleeding, shock, etc.) after the accident has occurred.

3. Approximately four-fifths, 32 million dollars, of police management and highway benefits were from reductions in the number of police supervisors and the personnel required to obtain, record, and retrieve highway accident data. The remaining $7 million was mainly derived from the elimination of future milepost installations on 30 percent of the mid-continent's secondary and town roads and from improved operations by state highway accident and road inspection vehicles. The staff savings were selected instead of improvements in crime prevention, selective enforcement, and safety obtainable at the present and increased future levels of service.

4. The last four applications (nuclear materials safeguards, aerial spraying, forest and public land inventories, and wildfire suppression) involve equipping less than 350 land vehicles, helicopters, and aircraft with Loran-C receivers. The associated benefits totaling $18 million were obtained from extensive discussions with officials in the Departments of Energy (DOE), Agriculture (USDA), and Interior (DOI) who generally expressed an immediate need and enthusiasm for Loran-C within the mid-continent. Two agencies, the U.S. Forest Service and the Bureau of Land Management (BLM), have major land jurisdictions in both the mid-continent and west coast regions of the United States and would benefit from a single navigation system rather than employing a different one for each region. This is particularly true for the large-scale combined Forest Service and BLM firefighting operation based in Boise, Idaho. Loran-C benefits to this operation are summarized in Figure ES-2 and include more accurate aerial

helicopters can home-in on households and farms which are long distances from a hospital.

6. Two dramatic applications of Loran-C are safeguarding the transportation of nuclear materials and the extraction and inventorying of a large renewable energy source, called "biomass", from U.S. forest land. The Energy Research and Development Administration (ERDA) is responsible for most of the safeguards and has identified areas where Loran-C receivers in their convoys would improve operations. These include staff savings, improved position reporting, and the deferral of R&D funds for the navigation development programs to other areas requiring attention. The "biomass" benefit was identified from the Federal revenues which can be derived from the leasing and inventorying of U.S. forest lands where at least 1,650 pounds of burnable wood can be removed every year from each acre of woodland without harming the soil nutrients, while at the same time decreasing the danger of fire.

7. A number of road inventory benefits of Loran-C were identified particularly in mid-continent areas where the terrain and road conditions preclude the use of low cost precision odometers. The benefits involved identifying and returning to the site of culvert, road damage, and road hazards needing attention. Widespread use of Loran-C by state highway vehicles may eventually lead to a common latitude-longitude reference system on the nation's roads.

In summary, in present dollars, it is estimated that the expansion of Loran-C to the mid-continent area will produce over $125 million in public benefits as opposed to $51.8 million in user and Federal costs. This results in an overall benefit-to-cost ratio of 2.4 between 1982 and 1990. The benefit-to-cost ratios for the users themselves ranged from 1.9 to 18.8 and were very high in rural and forest land areas, nuclear materials transportation, and

# 1. INTRODUCTION

The objectives of this study were two-fold: First, to re-examine from a conservative point of view (e.g., overstated costs and only explicitly quantifiable benefits) past benefit/cost assessments of land uses of Loran-C; and second, to evaluate only the most promising applications which could be identified from the requirements of Federal, state, and local public agencies.

With the aid of Figure 1-1, this section outlines the central issues in making the decision to expand Loran-C coverage to the mid-continent. The issues are placed in the context of seven questions which were of major concern in the early parts of the study. These questions were:

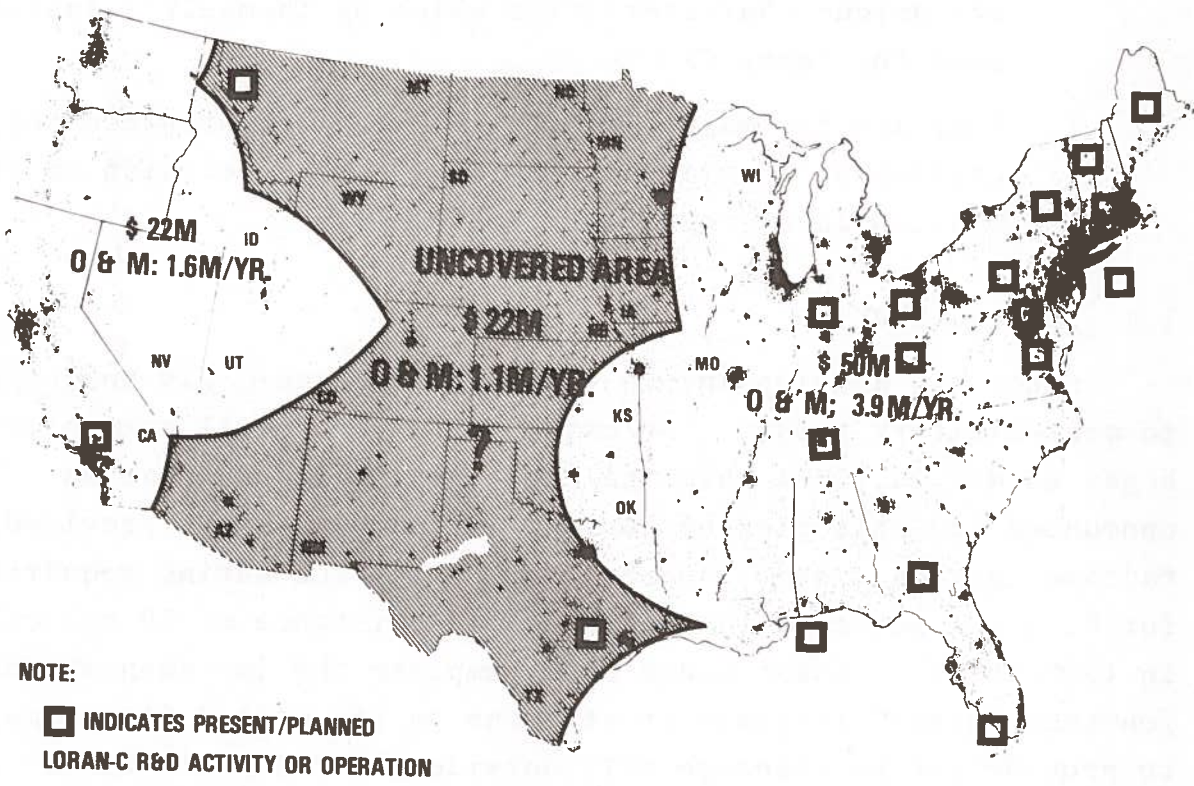


FIGURE 1-1. MID-CONTINENT LORAN-C EXPANSION

1. What will the coverage be when the U.S. Coast Guard completes its implementation of Loran-C for the marine community?

breakdown of these costs into the eastern and western parts of the nation.

The 100 kHz Loran-C groundwave signals from these transmitter stations also cover 63 percent of the land area and 92 percent of the population of the contiguous 48 states. The Coast Guard has provided maps which specify a single fix accuracy (predictability) of better than 92 meters (300 feet), 2 drms in 90 percent of this covered area and 152 meters (500 feet) elsewhere.

## 1.2 EXPANDED COVERAGE TO THE MID-CONTINENT

The expansion of Loran-C to the mid-continent region of the United States will involve three additional transmitter stations at an estimated initial cost of $21.8 million and $1.1 million in annual O&M expenses. These stations would be located approximately 500 miles apart in the vicinities of Salina, Kansas; Caspar, Wyoming; and Midland, Texas. Predictabilities of better than 92 meters would be obtainable in almost all of the mid-continent area except for small areas on the borders of Arixona and Montana where the accuracy would degrade to 152 meters.

## 1.3 LORAN-C DESCRIPTION

A potential land user can take advantage of the basic properties and the newly available precision of Loran-C in the same way as a marine user. As shown in Figure 1-2, a Loran-C receiver mounted in a vehicle will automatically measure the time differences ($t_M$ minus $t_A$ and $t_M$ minus $t_B$) between pulsed radio signals transmitted from a master and two slave stations. The intersection of the hyperbolic lines of position established by each time difference defines the location of the vehicle relative to the stations. At an additional expense, the receivers can provide a conversion of the time differences to a direct readout of latitude and longitude.

As indicated in Figure 1-3, the costs of Loran-C receivers have dropped dramatically over the past eight years. Current prices for most receivers with time difference readouts and automatic encoding range from $3000 down to $990 depending on the manufacturer, the quantity bought, and other special features.

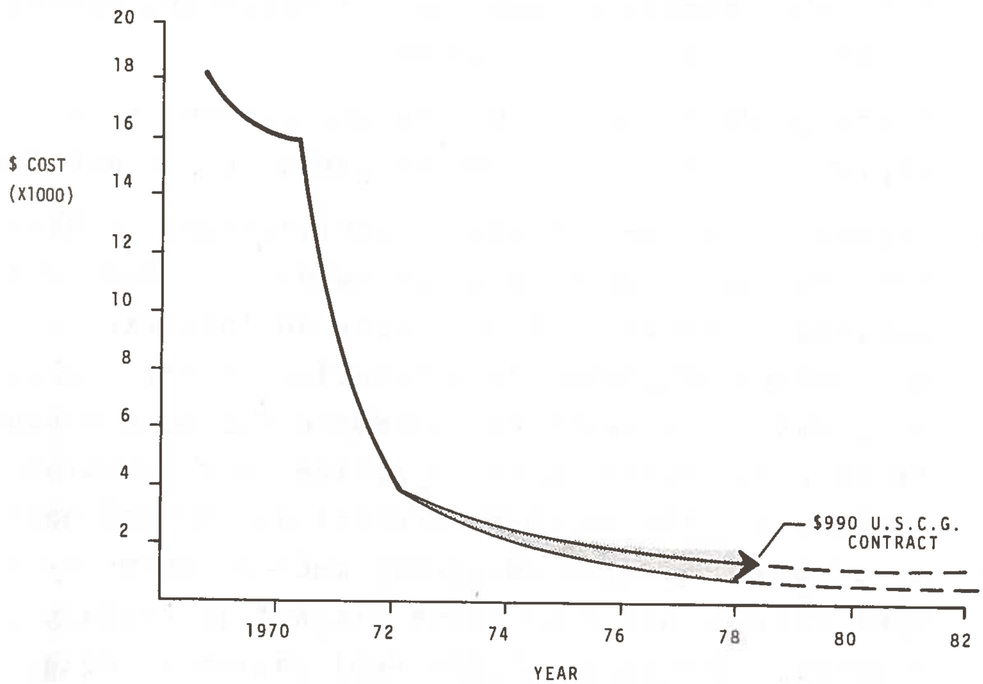


FIGURE 1-3. LORAN-C RECEIVER COSTS

## 1.4 LORAN-C R&D FOR LAND APPLICATIONS

For the past two years there has been a growing number of research and development activities dealing with potential land uses of Loran-C. The extent of these efforts is indicated in Figure 1-1 and ranges from pilot demonstrations for single applications such as aerial spraying to large-scale testing and coordination among groups of users (e.g., emergency medical services and police and highway departments). The smaller pilot demonstrations include flying applications at low altitudes, as well as the ground uses, and are identified as follows:

In addition to these R&D activities two major programs involving Loran-C are to be conducted in New York State and the city of Los Angeles. The New York program starting in late 1979, is being sponsored jointly by the FHWA and NHTSA and will involve extensive Loran-C testing of coordinated police, EMS, and state highway operations. The tests should provide firm data on Loran-C users in rural and suburban areas.

The Los Angeles program is being sponsored by the Urban Mass Transit Administration (UMTA) and will focus on Automatic Vehicle Monitoring (AVM) applications to public transit and, possibly, police and fire suppression uses. The tests will evaluate the random route urban operation of Loran-C to determine the degree of augmentation required from fixed short-range signpost transmitters. An earlier comparison of Loran-C, signpost, and UHF trilateration systems in Philadelphia[4] verfied urban Loran-C accuracies of 325 ($2\sigma$) feet.

## 1.5 PAST LORAN-C LAND ASSESSMENTS

This study utilized information provided in previous papers and reports (References 5 through 10) relating to the potential land applications and benefit versus cost assessments of Loran-C. Four of these documents had a significant effect on the final selection and evaluation of eight land uses. These documents were:

1. A 1978 MIT report[7] on terrestrial radiodetermination applications and technology which mainly addressed automatic vehicle location and monitoring of public transportation and police vehicles. The report emphasized the difficulties in the communication of location information and in quantifying crime prevention benefits from improved dispatching of police cars. It also concluded that in rural areas, Loran-C had distinct cost advantages over signpost (proximity), dead reckoning, or multilateration systems.
2. A 1977 DOT/TSC AVM study[8] of the benefits and costs of alternative automatic vehicle monitoring systems for police cars, buses, and taxis. The study concluded that

of the contiguous 48 states. A comparison with the rest of the nation reveals that the region has a number of special characteristics which by themselves might justify Loran-C. These special characteristics include:

1. Except for eight urban areas, there is a very large amount of land classified as rural (villages of less than 5,000) or very rural (outside of villages), and farm land. The rural areas are particularly suited to the 300-foot single fix accuracy provided by Loran-C.

2. Over one-fifth of the mid-continent is either public land under the Bureau of Land Management (BLM), national forest and parks (U.S. Forest and Parks Services), or Indian reservations. These lands would benefit from the coordination of navigation applications by Federal and State agencies.

3. The amount of oil, fossil fuel, and mineral exploration is considerably higher than in the remainder of the nation. A high percentage of this exploration falls under the jurisdiction of the BLM and Forest Service who authorize exploration sites and lease the land. Both of these agencies have a responsibility to inventory the explored areas and guarantee that they are being left in good condition. One example of this responsibility in road inventory was pointed out by a Forest Service official who said that different explorations sometimes clear a road through a forest which is close to one that had been previously cleared.

4. Two Federal agencies (the Bureau of Land Management and the U.S. Forest Service) expressing a need for a Loran-C or equivalent navigation capability have major land jurisdictions in both the mid-continent and west coast regions of the United States. These and other public and private agencies would benefit from coverage by a single system in order to avoid the additional expense of equipping with two different systems.

3. Will a decision to expand Loran-C to the mid-continent provide the impetus for a nationwide involvement on the part of private industry? This involvement may result in the large-scale production of Loran-C low-cost receivers by the private sector with consequent savings for those Federal agencies having extensive needs for Loran-C.

4. Will nationwide Loran-C coverage provide a common position reference system for the consolidation of the various population, agricultural, and other geographical types of data bases currently employed by many Federal and state agencies?

5. In serving the marine community, what position should DOT (particularly the Coast Guard and the Transportation System Center) maintain toward land users in terms of Loran-C availability, grid calibration, geodetic information, and the provision and updating of accurate geodetic maps? The Coast Guard has already received numerous telephone inquiries from land users on the daily status of Loran-C signals.

6. Loran-C position information in digitized form can be easily transmitted with a slight modification of the mobile communications sets used by police departments and other local agencies serving the public. If the private uses of Loran-C becomes widespread, the possibility of communications congestion may require an early Federal decision on the availability of radio frequencies to meet the needs of both the public and private sectors. The decision will involve weighing the advantages of productivity in the private domain against safety and service benefits (e.g., crime prevention, police officer safety, etc.) in the public sector.

7. Power line telemetry and communication carriers are known to cause Loran-C interference to the point where a stricter enforcement or a compromise of existing FCC regulations on incidental radiation may be required.

# 2. POTENTIAL APPLICATIONS FOR LORAN-C

This section describes in three parts the potential applications and user requirements for Loran-C. The first part is a general discussion of the potential public applications and possible benefits accruing from a precise navigation capability. The second part then combines the larger public uses with two major private user groups (trucking and taxis) in order to present a perspective on the most probable market sizes and the requirements (e.g., tolerable costs, accuracies, and system implementation time tables) of each group. The last part addressed selected public applications which involve a smaller number of vehicles and other special circumstances.

## 2.1 POTENTIAL APPLICATIONS AND BENEFITS

Table 2-1 presents a partial "shopping list" of potential public applications and future benefits which may be derived from the use of Loran-C or an equivalent navigation system. The table lists the most realistic candidates derived from a consensus of previous studies (Reference 5 through 10) and is discussed as follows:

1. The potential benefits generally relate to such factors as lower costs for staffing and vehicle operations or improvements in safety, security, or services. For example, buses using a navigation system can provide better passenger service through schedule and headway control with the additional advantage of locating the bus via an alarm during an emergency or threat to the driver or passengers.[8] The improved control can result in reduced layover (turnaround) times, savings in bus mileage, and increased passenger load factors.

2. Substantial benefits can be obtained from more rapid emergency services for households and highway accidents by police cars, ambulances, and fire engines. Specific benefits include reduced hospitalization and deaths from

on the household's front door via the shortest route. This example also points out the difficulty in determining the extent of the benefits assignable to the navigation function when the application also requires the installation of the 911 service and communications and processing of the location information for vehicle monitoring, dispatching, or guidance. This is especially true when the location data has to be rapidly disseminated or when large numbers of vehicles are involved.

3. Benefits in highway safety can be obtained from the more accurate identification and processing of highway accident locations and potentially dangerous highway conditions by police cars and state highway inspection vehicles. Moreover the use of a common geodetic position reference may lead to improvements in both the speed and coverage of selective enforcement and highway repair activities. Current position identifiers are sometimes so varied (e.g., nearest landmark or street or farm) that the traffic data recording and retrieval is either time-consuming or incomplete.

4. A number of road inventory benefits of a navigation capability can be identified particularly in areas where terrain and road conditions preclude the use of low cost precision odometers (e.g., forests, farm roads, mountainous regions). The benefits may occur in such areas as new road construction, and identifying and returning to the site of culverts, road damages and other obstructions needing repair. Additional benefits may also accrue from the use of a single position reference if these and many other activities are performed together by the same agency (e.g., natural resource exploration and conservation, wildlife surveying, and pollution monitoring).

5. The benefits of a single position reference and its coordinated use among many agencies may be particularly significant during search and rescue or natural disaster

TABLE 2-2. ESTIMATED SIZE OF POTENTIAL USERS

| POTENTIAL APPLICATION | TOTAL NO. OF VEHICLES (X1000) | MOST PROBABLE MARKET SIZE (X1000) & IDENTIFICATION |
|---|---|---|
| 1. PRIVATE TRUCKS (FLEETS GREATER THAN 10) | 2622 | 925 (HEAVIER SIZE CLASSES) |
| 2. TAXIS | 225 | 75 (LARGE FLEETS) |
| 3. MAIL DELIVERY VEHICLES | 300 | 3 (LARGE SHIPMENTS ONLY) |
| 4. URBAN BUSES | 50 | 30 |
| 5. POLICE VEHICLES | 170 | 50 (RURAL AND 33% OF URBAN) |
| 6. AMBULANCES | 44 | 20 (EXCLUDING METROPOLITAN) |
| 7. FIRE ENGINES | 80 | 20 (ONE PER ENGINE GROUP, RURAL) |
| 8. U.S. CENSUS ENUMERATORS | 50 | 4 (RURAL AREAS ONLY) |

high receiver costs (above $2000) and reduced accuracy (152 meters) would be acceptable long before 1982. A number of fleet owners are already expressing an interest in position monitoring to improve the dispatching of utility trucks, intra-metropolitan delivery services, and dock-to-dock hauling. Although it is possible that similar navigation applications may exist for some of the nation's remaining 25 million trucks, these applications have not been included in the most probable market estimates

2. Taxis: Over one-half of the nation's 225,000 taxicabs belong to private fleets of 200 or more cabs.[12] Of these large fleets, approximately 60 percent (or 75,000) may benefit from reduced non-revenue miles and cab running and maintenance costs which are obtainable[14] from improved monitoring and dispatching operations. By 1982 the advantages in selecting and monitoring[8] the nearest taxi to an identified fare and subsequently to a destination may outweigh the $1200 (estimated) upper limit on the industry's acceptable navigation receiver costs. Additional benefits can also accrue to the cab drivers from protective alarms which provide location information during criminal emergencies.

population. Fire departments might restrict their uses to one navigation receiver for each engine group (hook and ladder, pumper, etc.) in rural areas only.

6. U.S. Census Enumerators: It is unlikely that there will be a widespread application of a navigation capability in census taking until a low-cost portable receiver is developed. Cost-effective uses may exist in rural areas where the receiver can be mounted in the enumerator's vehicle as an aid in census location, routing, and verification.[10] Increased use by the U.S. Census Bureau may only occur after 1990 and may depend on sharing the receivers with other agencies (during non-decennial years) and expanding the use of location information in the geographic surveys of population (such as the GBF/DIME file).[15]

## 2.3 SPECIAL PUBLIC APPLICATIONS

Five Federal agencies have special needs for a navigation capability before 1983. The potential applications and public benefits for these agencies are described as follows:

Taken together the jurisdictions of land areas of the Bureau of Land Management (BLM), the U.S. Forest Service, and the Bureau of Indian Affairs (BIA) cover almost 21 percent[16] of the area of the contiguous 48 states. The greatest portion[17] of these land jurisdictions are west of the continental divide and strongly suggest the combined use of a single navigation system by these three agencies. Combined use of Loran-C is already being explored by the BLM and Forest Service at Boise, Idaho,where both agencies have a joint firefighting center. By 1982, a large number of cost-effective applications may be realized by equipping the ground vehicles and aircraft of these agencies with less than 250 navigation receivers. These applications include fire suppression, fire damage assessment, road inventory, inventory of leased lands, and greatly improved police, ambulance, and firefighting services on Indian reservations. Another use which is particularly dramatic is of the shipments within the United States. However, by 1980 it has been estimated that the freight tonnage of radioactive materials will increase[19] to the point where substantial private transport under the jurisdiction of the Nuclear Regulatory Commission may be required. All shipments require elaborate security precautions involving truck and rail convoys along well monitored overland routes. Because of the importance of the safeguards, there is strong present need for improvements in the accuracy and frequency of convoy position monitoring. These improvements can be provided by Loran-C in both the cargo and escort vehicles of the convoys at a cost which can be as high as $4000 per receiver.

# 3. MID-CONTINENT LORAN-C APPLICATIONS

This section describes the steps taken to select eight of the most promising public applications of Loran-C within the uncovered mid-continent region of the United States. These applications are their associated land areas and activities where future Loran-C benefits may be expected are as follows:

1. Police management of police car dispatching operations in rural areas
2. Emergency medical services in rural areas by ambulances and helicopters.
3. Rural fire suppression
4. Highway accident location and record-keeping on rural highways and roads
5. Safeguarding nuclear materials transport by truck convoys
6. Wildfire suppression and road inventory on lands under the jurisdiction of the U.S. Forest Service and the Bureau of Land Management
7. Aerial spraying by the Animal and Plant Health Inspection Service and U.S. Forest Service
8. Biomass leasing and inventory by the U.S. Forest Service

The first step in selecting each of the above applications was to identify areas in the previous studies where additional information or a new approach was needed. This led to an extensive analysis of two aspects of Loran-C: (1) The most probable unit price of a Loran-C receiver; and (2) A comparison of Loran-C costs, accuracy, coverage, and implementation schedules to those of alternative systems such as the Global Positioning System (GPS), Omega, VOR/TACAN, etc. Technical discussions were then held with the responsible Federal, state, and local agencies and often involved cross-checking of one source with another. Whenever possible, the where:

$$\text{Quantity Reduction Factor} = \left[\frac{100}{60}\right]^{\frac{\ln 0.9}{\ln 0.2}} = 0.925$$

$$\text{Tech. Improvement Factor} = (0.95)^3 = 0.857$$

The \$1000 and \$1200 receiver price estimates were also considered reasonable in view of the responses by the manufacturers and the radical improvements in production techniques which might result if the land market exceeded 200,000.

For airborne Loran-C navigators, a price of \$2000 per receiver in 1982 was obtained from a detailed breakdown of receiver component costs by the MITRE Corporation[24] and subsequent discussions of these costs with the manufacturers. Again this price is considered realistic in view of the rapid advances in the recent development and production of Loran-C area navigation equipment. For example, the price of a newly developed Loran-C waypoint navigator has dropped by a factor of more than two over the past year and is now available on direct open sales to the Government in quantities of 100 for less than \$6000.

## 3.2 LORAN-C VS. ALTERNATIVE NAVIGATION SYSTEMS

For the eight applications selected, a comparison was made between the costs, accuracy, coverage, and implementation schedules of a mid-continent Loran-C to alternative navigation systems. The comparison and discussions with the concerned agencies revealed the following:

1. Loran-C would serve as a very useful addition to the VOR/TACAN system for aviation users with low altitude flying requirements and in overland areas where VOR coverage is less accurate or not available.[18] Under these conditions, a need for Loran-C in the mid-continent was identified by APHIS, the Forest Service, the BLM, and emergency medical service helicopters.

selected applications dictated a conservative approach in the comparison of receiver costs and the number of years over which Loran-C benefits could be calculated. To this end, benefits of Loran-C after 1990 were not considered. This resulted in a 1982 to 1990 time period for evaluating costs and benefits of Loran-C. It was concluded that this short time period was reasonable in view of the most recent estimate[25] of $3600 for a 1985 GPS C/A code receiver (in quantities of 3000). It was estimated that improvements in the 100- to 200-meter (estimated) accuracy and in the price of this receiver might make it competitive with Loran-C in the late 1980s.

# 4. BENEFIT/COST GUIDELINES

This section describes the guidelines for evaluating the costs and benefits of the eight most promising public land applications of Loran-C in the mid-continent. The description begins with a reiteration of guidelines inferred from previous sections. It then describes further groundrules which were designed to prevent overstatements of the potential cost effectiveness of Loran-C (eg., optimistic claims of benefits, understated user and Federal costs,and inadequate consideration of facilities and software expenses). The section closes with a general discussion of applications which were eliminated from consideration because of time limitations, programatic constraints, and other reasons such as intangible or insufficient data.

## 4.1 GENERAL BENEFIT/COST GUIDELINES

1. All applications had particular significance for the mid-continent area of the U.S. especially considering its rural character.
2. Whenever possible, the cost and benefit data were obtained from the Federal, state, or local agency which had responsibility for the potential public application of Loran-C.
3. Additional benefits accruing in land areas outside the mid-continent region were excluded even though the users Loran-C equipment might provide a service common to both these areas and the mid-continent. For example, the large forest fire suppression benefits in Oregon and Washington derived from equipping all aircraft the the Boise, Idaho fire center with Loran-C area navigators were not counted.
4. All benefits were calculated over the short nine-year time period from 1982 to 1990. During this period, the standard OMB ten percent discount rate[26] of present

3. Whenever a range of benefit values were obtained from an agency, the lowest dollar value was used, especially in those cases where a Loran-C application produced a savings over an existing agency operation which had to be modified by the introduction of Loran-C. These latter agencies included state highway departments, ERDA, BLM, APHIS, and the Forest Service where special costs for training and retraining personnel were liberally estimated. For ERDA, Forest Service, and highway applications, additional costs were also added for the central facility software, hardware and other expenses which would be required to process the Loran-C data.

4. Although the accuracy derivable from a differential mode of Loran-C operation was not required in all areas of the mid-continent, the monitor station costs to achieve this capability were deliberately included to reflect special needs for more precise position location and mapping requirements. In the case of highway departments, an additional 40 percent of redundant monitor station costs were included to cover cases where local highway districts would not be near the regular monitors or would want their own centralized facility.

5. The Federal costs to provide the mid-continent Loran-C stations included real estate and housing purchases and provision for over two years of additional temporary personnel to insure adequate site preparation prior to and during the initial stages of operation. It was also assumed that there would be no recovery of real estate or Loran-C equipment costs after 1990.

## 4.3 EXCLUDED BENEFITS

During the course of the discussions with each of the concerned agencies, a number of additional benefits accruing from the fixed complement of Loran-C equipment assumed for these agencies

# 5. MID-CONTINENT LORAN-COSTS AND BENEFITS

This section provides the detailed estimates of the costs and benefits for the eight public applications of Loran-C in the mid-continent. The section starts with the estimates of the Federal costs for the Loran-C stations. This is followed by estimates of the costs and benefits to each of the public users along with a brief description of their present operations and the methods used to obtain the data. Appendices have been provided to cover extensive analysis and other more detailed data and information. The Federal and user costs and benefits in 1982 dollars are then summarized and discussed in terms of a benefit-to-cost ratio and additional economic considerations. Finally, a sensitivity analysis is conducted to examine the impact of variations in the key assumptions used in the calculation of Loran-C related benefits.

During the course of this study, discussions were held with over three hundred individuals in order to obtain advice and information on Loran-C and its applications. Appendix B provides a partial list of these individuals grouped by their organizations. Additional information may be obtained from the authors on those sources which have been omitted for confidential reasons.

## 5.1 FEDERAL MID-CONTINENT LORAN-C COSTS

The Federal costs to install and operate three Loran-C transmitter stations were provided by the U.S. Coast Guard in April 1978 and were specified for three stations in the vicinity of Salina, Kansas; Caspar, Wyoming; and Midland, Texas. Two of these stations and two others outside the mid-continent would be double rated to provide time-shared Loran-C transmissions in two master plus two slave chains. Initial costs were given in 1980 dollars and included the installation of the two mid-continent slave stations in 1980, the master in 1981, and expenditures for temporary personnel. Expressed in millions of dollars (M) and by calendar year these costs were:

TABLE 5-1. SUMMARY OF MID-CONTINENT LORAN-C BENEFITS AND COSTS

| APPLICATIONS | USER | BENEFITS* TOTAL ($M) | COSTS* ($M) | USER BENEFIT-TO-COST RATIO |
|---|---|---|---|---|
| 1. POLICE MANAGEMENT | STATE/LOCAL GOVERNMENT | 17.6 | 9.2 | 1.9 |
| 2. EMERGENCY MEDICAL SERVICES | HEW, NHTSA, STATE & LOCAL | 52.1 | 3.7 | 13.4 |
| 3. RURAL FIRE SUPPRESSION | STATE/LOCAL GOVERNMENT | 22.5 | 3.3 | 6.7 |
| 4. HIGHWAY ACCIDENT LOCATION & RECORDS | FHWA/NHTSA | 14.4 | 4.6 | 3.1 |
| 5. NUCLEAR MATERIALS TRANSPORT | DOE | 4.7 | 0.8 | 5.6 |
| 6. BLM WILDFIRE SUPPRESSION & ROAD INVENTORY | DOI | 1.7 | 0.3 | 5.6 |
| 7. APHIS AERIAL SPRAYING | USDA | 4.9 | 0.3 | 18.2 |
| 8. FOREST FIRES, ROAD & BIOMASS INVENTORY | | 6.9 | 0.9 | 8.0 |
| TOTALS $125.5M BENEFITS ÷($23.2M USER + $21.8M, CHAIN + $6.8M**) = 2.4 | | | | |

*PRESENT VALUE AT 10% DISCOUNT FOR 9 YEARS

**PRESENT VALUE AT 10% DISCOUNT FOR 9 YEARS, $1.1M/YEAR CHAIN O&M COST

### 5.2.1 Police Management

A pictorial description of Loran-C applications in police cars is shown in Figures 5-1 and 5-2. These figures point out three ways in which Loran-C vehicle location data can be reported and processed. These are:

1. Highway accidents and other incidents are described on prepared forms which are generally filled out by the police officer immediately after all emergency needs are attended to. A Loran-C receiver mounted in the police

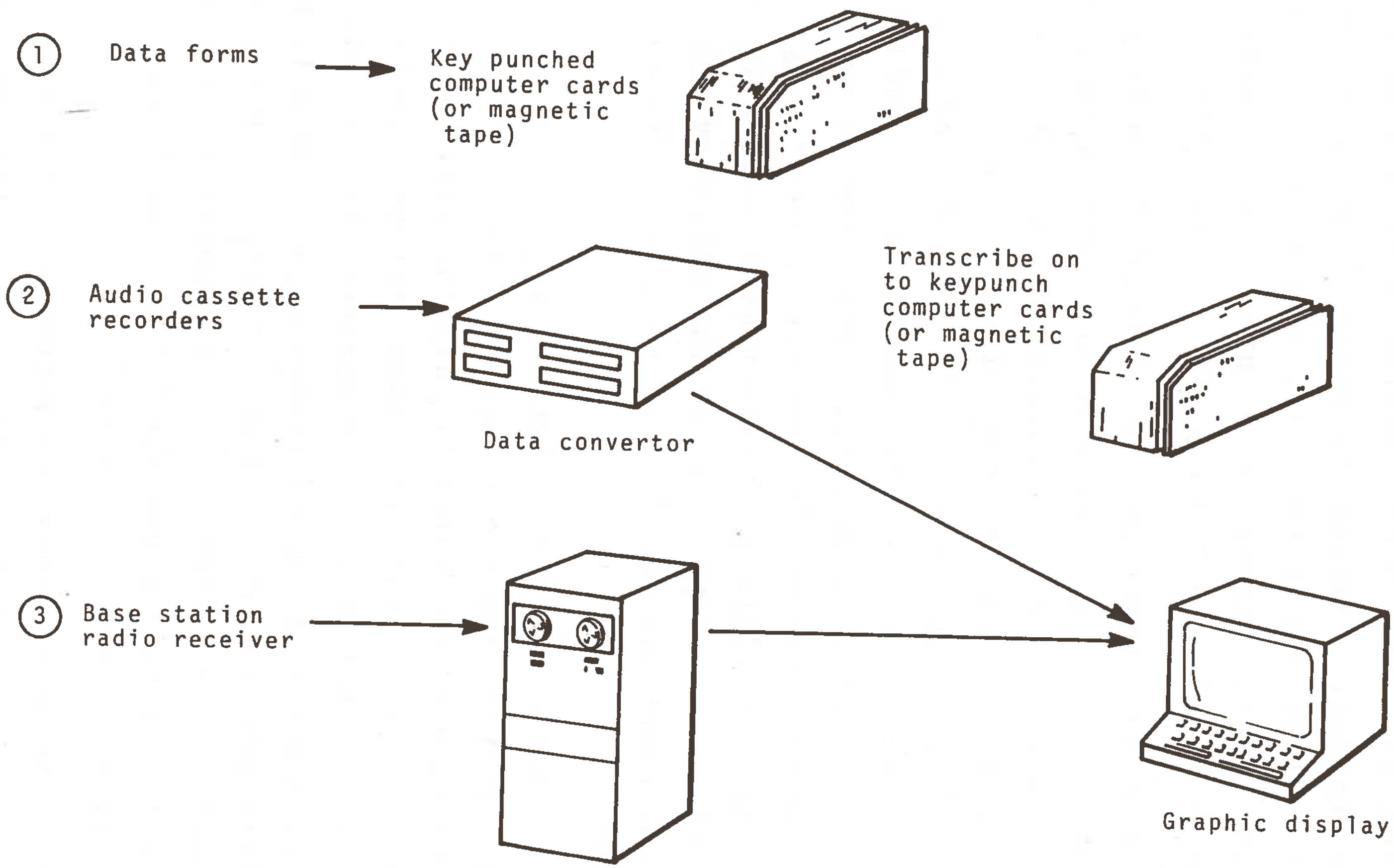


FIGURE 5-2. PROCESSING OF POLICE DATA

accident data used in state and Federal highway safety programs. The second, and more important, reason is to introduce the requirement for coordinated routing of accident and other emergency information and locations between the local police, fire, and ambulance services. Since the police departments usually act as the central facility in coordinating this information, it was decided to assign the costs of the local monitor stations (mentioned earlier in Section 1.3) to the police management application rather than estimating the proportionate share of these costs to be paid by fire departments and ambulance services. Differential corrections from these monitors made once every two hours to vehicles equipped with Loran-C would provide an accuracy of better than 45 meters (150 feet).[28,29] In 1982, it was estimated that 100 of these monitor stations spaced at correlation distances of 160 km (100 miles) apart would be more than adequate to cover the entire mid-continent. At an estimated cost in 1982 dollars of $10,000 each, the monitors would consist of two latitude-longitude receivers with automatic encoding, antennas, a microprocessor and keyboard, a display, a casette recorder, and interfaces with existing police communications equipment.

The increased accuracy provided by the local monitor stations led to the consideration of Loran-C benefits which could be derived by residents of households and farms, particularly in rural areas (villages of less than 5000) and very rural areas (outside of villages). It was envisioned that the combined police, fire, and ambulance application of Loran-C in these areas and in the suburbs of the eight mid-continent metropolitan areas would operate in the following manner:

1. A minimal number of local police vehicles would be equipped with Loran-C receivers in order to provide each household or farm with its latitude and longitude in the form of a tag which could be pasted on the home telephone. Alternatively, the ten-to-twelve digit latitude-longitude number could be recorded by the telephone company when it installs or repairs the phone. The Loran-C location could

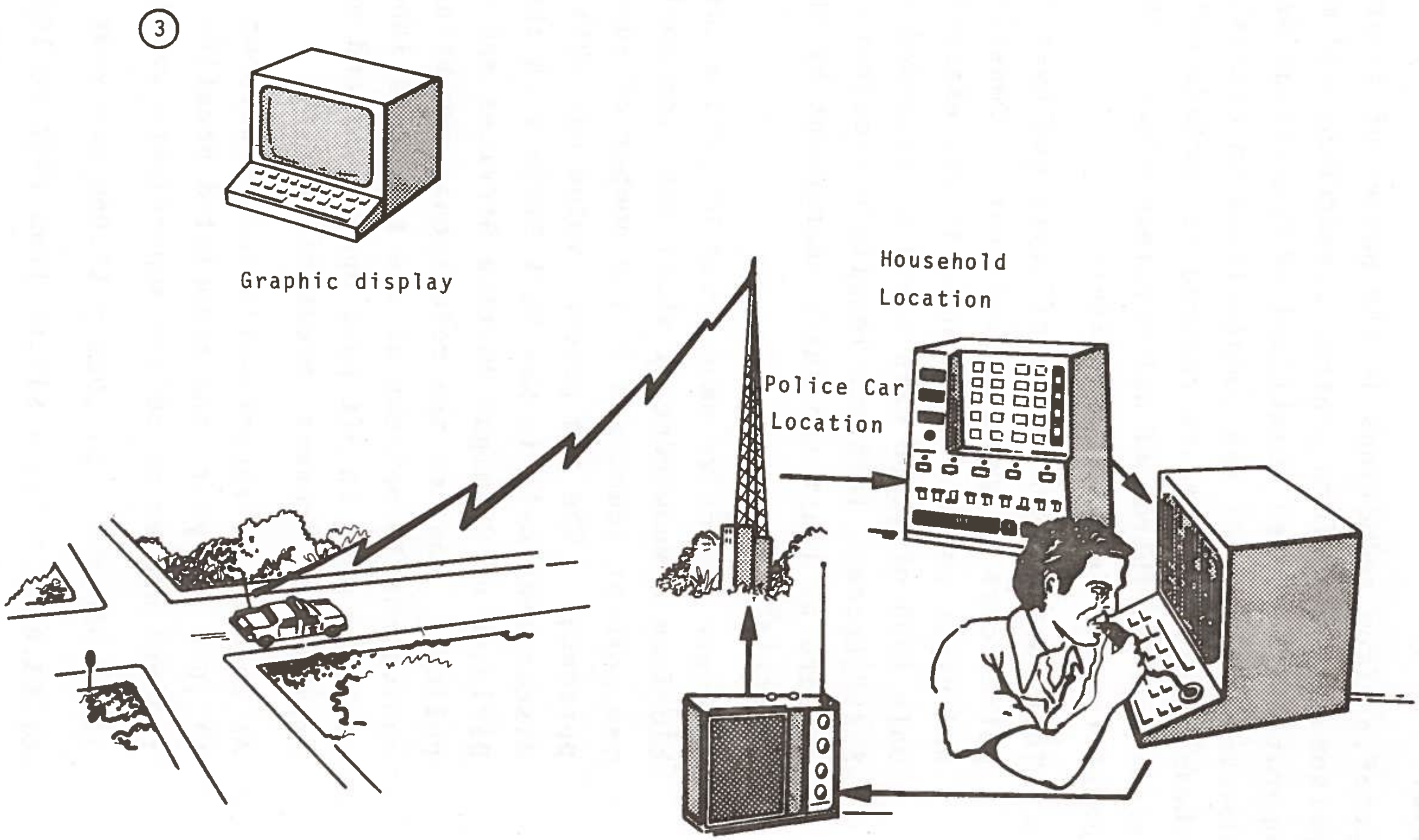


FIGURE 5-3. EMERGENCY VEHICLE DISPATCHING

latitude-longitude receivers, (2) the initial costs for the 100 monitor stations, and (3) Annual operations and maintenance costs calculated at 10% per year of the initial investments in both the receivers and the monitor stations. These costs were:

Initial Receiver Costs in 1982 = 4000 x $ 1,200 = $4.8M

Monitor Station Costs in 1982 = 100 x $10,000 = $1.0M

O&M from 1982 to 1990 = 0.10 ($4.8M+$1.0M) 5.759 = $3.34M

Total Police Management Costs = $9.2M

The benefit-to-cost ratio to the police users was 1.9.

### 5.2.2 Emergency Medical Services

Extensive personal and telephone interviews were held with a large sample of the Emergency Medical Services (EMS) community in order to assess the use of Loran-C in ambulances and a smaller number of helicopter medical services. The findings and data are covered extensively in Appendix C and revealed a significant improvement in ambulance services over the past four years, particularly in the areas of ambulance standards and reporting.[33] Aspects of the findings obtained from over 40 different individuals and agencies and a study of pertinent literature (References 31 through 43) were used to estimate the size and nature of EMS in the mid-continent, namely:

1. By 1982 there will be at least 3500 vehicles and 270 aircraft providing EMS in the mid-continent. Of these 2000 vehicles and 100 aircraft will be used in rural areas.
2. Each year, there are over 750,000 calls for emergency medical services from households, highway accidents, and other sources in the mid-continent. At least 22,000 of these will be in rural areas (towns of less than 5000 population) and an additional 120,000 will be made from very rural areas outside of towns and villages.
3. Fifty-nine percent of the calls are time-critical to the extent that an additional delay of 10 to 12 minutes in the

e. The costs to equip 2000 EMS vehicles and 100 aircraft with Loran-C were estimated to apply to the rural and very rural areas even though these vehicles might also serve urban areas.

f. Reduced deaths and hospitalization benefits from Loran-C only applied to the small percentage of hospitalizations (i.e., 16% very serious and 20% trauma) which were time-critical (59%) and also would have the 10-12 minute indefinite location problem for 1% of the rural and 10% of very rural fraction of these cases. The product of each of these three small percentages established four "Loran-C Aid" factors which were used in the computation of benefits. The factors are computed as shown in Table 5-2 and form the basis for the following statements:

   1. Reduced hospitalization will occur from the use of Loran-C in 1.18% of the very rural EMS calls and 0.118% of the rural calls.

   2. Loran-C will reduce the number of deaths in very serious medical emergencies by 0.944% in very rural areas and by 0.0944% in rural areas.

The next step in the computation of benefits was to obtain estimates of the extent of the hospitalizations and deaths which were eligible and could therefore by multiplied by the Loran-C Aid factors. For hospitalizations, a large majority of the EMS people interviewed stated that the 10 to 12 minute reduction in the delay would result in at least 10 days less hospital time at a cost of over $100 dollars a day. These savings would apply to the number of EMS calls which did not result in a death (the latter restriction being made to avoid double counting).

The number of accidental deaths were extrapolated from data supplied by four states, NHTSA, the National Safety Council,[42] and discussions with the American Heart Association and heart specialists. An eligible total of 3325 very rural deaths and 8160 rural deaths was obtained from a detailed breakdown (See Appendix C) which included a number of conservative criteria. Among these were, the assignment of all highway accidental deaths to the lower benefit rural areas, exclusion of three-quarters of the deaths from heart attacks for those over 65 years of age, and the exclusion of many other causes of death which might have a time critical aspect. Using the standard DOT value of $200,000 for the cost of death and the Loran-C Aid factors, the annual benefits of reduced deaths in rural and very rural areas are:

Very Rural Areas:

0.00944 x 3325 deaths x $200,000 = $6.277M per year

Rural Areas:

0.000944 x 8160 deaths x $200,000 = $1.54M per year

The additional benefits from reduced hospitalization were computed in a similar manner from the number of EMS calls minus all deaths as follows:

Very Rural Areas:

0.0118 x (120,000 calls-16,875 deaths) x $100 per day x 10 days

= $1.217M per year

Rural Areas:

0.00118 x (22,000 calls-3510 deaths) x $100 per day x 10 days

= $0.022M per year.

In these calculations the number of rural deaths were estimated to be the sum of one-quarter of all deaths from highway accidents and all rural deaths from heart attacks and other accidental causes.

Summarizing, the application of Loran-C to EMS vehicles in the rural and very rural areas of the mid-continent will result in a benefit of fewer deaths of $7.817 million involving 39 people each year. The additional benefits from reduced hospitalization will be $1.239 million each year and will affect an annual total of 1238 hospital patients. The sum of the benefits of fewer deaths consistent with alternative methods which compared the benefits of heart attack, trauma, and highway accidents on a one-by-one basis.

One last point worth noting is that, even though the number of highway deaths seems high compared to other accidental deaths, their overall effect is low because they were assigned to rural areas where the Loran-C Aid factor was ten times lower than for very rural areas. As shown in Appendix C, when all highway accidents are excluded from consideration, the $52.1 million in benefits are reduced to $45.3 million. In fact, Appendix C shows that if all highway injuries and deaths are not considered the overall benefit is still $42.7 million.

### 5.2.3 Rural Fire Suppression

The location problems in connection with very rural fire suppression were much the same as those for EMS. Discussions held with Chiefs of largely volunteer, rural fire departments, the Department of Commerce National Fire Prevention and Control Administration, and the Insurance Service Office, Inc. of Boston echoed the responses of the EMS people. Again areas with rapid growth, rapid turnover of people, or a large number of transients (e.g., tourists) experienced severe location problems.

The results of the interviews are summarized in Table 5-3 and are discussed as follows:

1. It was estimated that Loran-C would reduce delays incurred by indefinite location of reported fires in at least ten percent of the very rural cases, and the reduction in the delay would average 10 to 12 minutes.

2. Average running time to very rural fires is already in the 12 to 15 minute range so additional delays of 10 to 12 minutes significantly increase damage. Typical interview responses referred to "involvement of the whole house rather than one room." A consensus of five knowledgable fire suppression personnel indicates that such delays about double the damage. This 50% factor has been utilized in calculating benefits. Actual additional damage

from additional delays in particular fires range from moderate to several times the damage incurred without delay. Some location difficulties, which could readily be avoided with Loran-C, prevent apparatus from arriving in time to prevent a total loss. However no hard data was available to evaluate any additional damage but all of the interviews indicated that the doubling factor was reasonable.

4. There are roughly 5000 fire trucks in the rural and very rural areas of the mid-continent. This estimate was obtained by extrapolation in terms of the rural population of the estimates provided by the interviews. However, there was a general consensus that only one fire truck would be equipped with Loran-C in small towns which have more than one piece of fire apparatus. Therefore, it was estimated that Loran-C would have to be installed in 2000 fire trucks to provide coverage in the rural areas.

The percent reduction in fire damages in very rural areas due to Loran-C was estimated at 5% from the product of the 10-12 minute delay reduction for indefinite calls (10%) and the 50 percent of $78 million in total fire losses in the very rural areas of the mid-continent. The $78 million was estimated as the sum of farm and non-farm fire losses as follows:

1. Data from the National Safety Council indicated that the annual loss in the United States due to farm fires was 300 million dollars. This total loss was multiplied by the 13 percent mid-continent proportion of the U.S. farm population (obtained from U.S. Census data) to establish a 39 million dollar mid-continent farm fire loss estimate. This fire damage estimate is considered low because it only applied to dwellings, barns, machinery, and produce and therefore does not include any benefits from the saving of lives.

2. The proportion of very rural fire losses in areas which do not involve farms was also estimated to be $39 million.

The need for improved position location in each area is described in the context of present operations as follows:[44]

1. Highway Traffic Records: The positive identification of precise position locations through the use of non-standard description narratives (as opposed to a common Loran-C position reference) has always been a problem in the acquisition, processing, storage, and retrieval of highway safety data. Further problems are also encountered in associating the descriptions of reported accident locations with roadway characteristics maintained in highway inventory files. The problems arise because street names, addresses, road landmarks, and other narrative descriptions are sometimes ambiguous and often do not lend themselves to computerized storage and retrieval. For example, a traffic officer's description of an accident location is basically composed of a group of words which are subject to individual interpretation and cannot be easily standardized on accident report forms. Without a definite close-by landmark, such as a highway milepost, the precise spot of an accident is hard to find.

2. Highway Inventories: State highway departments could benefit from a standard coordinate system and reduced costs to install, maintain, and update location identifiers used in their highway inventories. Many different types of inventories are now conducted to identify roadway and roadside hazards, road features (route mileages, bridges, signs, traffic control devices), highway design characteristics, and locations requiring selective traffic enforcement. These inventories rely on fixed location identifiers ranging from route mileposts, photographic log data, and strip maps to mile-points measured by precision odometers in highway vehicles. The costs of the identifiers often precludes their use on most roads except for the main highways, especially for mileposts where the installation and yearly renewal expenses are high. Loran-C

mile at a total cost of over $4 million. Moreover, 20 percent of these markers had to be renewed each year at an additional cost of 850,000 dollars per year. The renewal rate was so high because many of the markers were knocked down when they were placed near enough to the edge of the road so that a police officer could read them.

c. Excluding the Federal-aid primary roads, there are 890,000 miles of county and township roads and other types of roads (e.g., Federal domain, state parks) in the mid-continent region which is not covered by Loran-C. The area also includes 104 State Highway districts and approximately 260 highway inspection vehicles. These estimates were obtained through a state-by-state population extrapolation of FHWA data to the mid-continent and are described in Appendix D.

d. The Tennessee Highway Department stated that their recording of highway accidents is very time consuming and now requires a staff of ten people to process location, damage, injury, and death information for the 8300 miles of Federal-aid primary roads under their jurisdiction. 12,300 miles of their Federal-aid secondary roads and township roads cannot be treated precisely in accordance with FHWA guidelines[46] because 50 percent of the staff time is used on the location information aspect of the records. A similar type of problem also exists for their highway inventory where only 80% of the primary roads and 50% of the secondary roads have location identifiers. Moreover, 20 to 30 percent of the received accident reports cannot be identified to within one mile of the actual location and 40 to 50 percent of the secondary locations are, in effect, guesses with errors greater than one mile. Considering the number of times and purposes for using the location data, the general conclusion from the State of Tennessee was that Loran-C could provide a positive and automatic recording of highway accident and inventory data which would enable them to expand their

b. Savings in milepost renewal at an 8% per year renewal rate for nine years (from 1982 to 1990):

0.08 x $4.009M x 5.759 = $1.847M

The total of the mileposts savings (in 1982 dollars is $6.317 million.

2. Highway Accident Data: Benefits of Loran-C will be derived from improvements in obtaining, recording, and retrieving highway accident data. These benefits are described as follows:

a. Estimates obtained from the FHWA and the States of New York and Tennessee indicated that economies in the operations of the 260 state highway inspection vehicles could be obtained with the aid of Loran-C. The economies are derived from reductions in vehicle moving costs and the time required to perform the site identification of accidents, road conditions, areas needing repair, and areas needing selective enforcement. The reductions in personnel were conservatively estimated to accrue from a staff savings of 5 percent for the (average of) four people in each of the 104 highway districts. At a yearly cost (salary and overhead) of $30,000, the savings over the nine year period from 1982 to 1990 are:

0.05 x $30,000 x 4 people x 104 districts x 5.759

=$3.593M

b. The additional savings in fuel, tire wear, and other moving costs of the 260 mid-continent state accident inspection vehicles were estimated to be ten percent of the $4000 in annual running expenditures for each vehicle. The benefits from 1982 to 1990 are:

0.10 x $4000 x 260 x 5.759 = $0.599M

c. Estimates obtained from NHTSA and the State of Tennessee indicated the use of Loran-C in police and

0.25 x $0.172M x 5.759 - $0.247M

4. Provide additional local monitor stations in 40 percent of the 104 state highway districts to reflect instances where the districts would need their own monitors or are not near the previously costed monitors in the central police stations. At $10,000 per monitor, and considering a 1981 installation, these costs are:

   0.40 x $10,000 x 1.1 = $0.44M

5. Account for operations and maintenance expenses at 10 percent per year of the sum of the initial costs for the Loran-C receivers and the monitors. Over the nine year period from 1982 to 1990, these costs are:

   0.10 x ($0.343 + $0.44) x 5.759 = $0.451M

6. Provide automatic Loran-C data recording, road and map correlation capabilities, and digital data communications sets in each of the highway districts. These modifications along with software changes in each center's computer facility will permit local monitor corrections and a mixture of automatic Loran-C data entries with other manually derived data. It also provides for the semi-automatic processing of police accident location data in a local map coordinate system which would be used as a reference for other information relating to the accident. The costs for these modifications in 1982 dollars were estimated to be $22,000 for each of the 104 highway districts:

   $22,000 x 104 = $2.288M

7. Revise the data entry and retrieval software in each of the 20 state highway departments in 1981. At an estimated cost of $27,500 per state, these costs in 1982 dollars are:

   $27,500 x 20 x 1.1 = $0.605M

8. Revise two million accident forms to facilitate the entry of Loran-C location data. At 5 cents per form, these costs are:

a final correspondence containing estimates of costs and benefits (see Appendix E). The results of this effort are summarized as follows:

Since 75 percent (or 25 of the 33 convoys) of their nuclear materials transportation is in the uncovered mid-continent region, ERDA was very interested in an early expansion of Loran-C. It would provide accurate and automatic position reporting every five minutes instead of the present less frequent and more labor-intensive manual observation of highway routes, landmarks, etc. Moreover, a receiver could be used in both the cargo and escort vehicles to guard against theft by an insider and maintain location contact during emergencies. Benefit estimates confirmed by ERDA fall into three categories:

1. Saving in R&D expenditures allocated for the upgrading of the convoy location function. These savings would be $0.56 million a year from 1979 through 1981 and $0.152 million per year from 1982 to 1988.

2. The elimination of the need for that part of the courier service which is now solely devoted to each convoys location function. At a courier cost of $165 a day over a use time of 100 days a year, the total annual savings for the 25 convoys are:

   $165 x 100 x 25 = $0.412M per year from 1982 to 1990.

3. A reduction of one labor year in the central facility staff required to manually track the positions of the convoy. At a salary of $20,000 per year and a 50 percent overhead rate, these savings are $30,000 a year from 1982 to 1990.

Using 1982 as the base year, the sum of the above benefits at the 10 percent discount rate is calculated as follows:

a. Sum of yearly savings:

   1979-1981: $0.56M

0.10 ($0.2M + 0.22M) 5.759 = $0.242M

4. Provide ten days of training on the Loran-C system for 10 people in both the central facility and the five communications relay stations. At $150 per day, these costs are:

   $150 x 10 days x 10 people = $0.015M

5. Provide three days of training for five couriers in each of the 25 convoys. At $165 per day, these costs are:

   $165 x 3 days x 5 couriers x 25 convoys = $0.062M

The sum of the above costs are $0.739 million. Considering that the Loran-C investments are made in 1981 one year before the mid-continent Loran-C becomes operations, the equivalent cost in 1982 dollars is:

$0.739M x 1.1 = $0.813M

In summary, the application of Loran-C to the public transportation of nuclear materials will result in a benefit of $5.34 million and a cost of $0.81 million. The benefit-to-cost ratio is 6.59. The benefit estimates are very conservative for the following reasons:

1. Nuclear material shipments will at least double by 1982 and may be much greater thereafter.
2. The open market value of only one cargo is classified information but will be substantial if stolen.
3. The blackmail value of a terrorist bomb threat would be astronomically high.
4. Additional benefits from public confidence in the security of interstate nuclear material shipments cannot be quantified.
5. Substantial safeguard benefits (e.g., protection from theft by insiders, less visible tracking by the escort vehicle) from the two-receiver, inter-convoy monitoring of the cargo vehicle by the escort vehicle have not been included.

The wildfire suppression operations include air detection, initial attack using ground forces, smoke jumpers and helitrack crews,retardant airdrops, and back-up and support from large supply centers, suppression, and rehabilitation. From the latest available data the BLM wildfire related costs to maintain these operations in the mid-continent are:

1. Fire presuppression; i.e., permanent personnel, equipment purchases, training, etc., in FY78 were 1 million.
2. Emergency presuppression; i.e., temporary personnel, seasonal rentals, detection, aircraft guarantees, supplies, etc., in FY78 were 2 million.
3. Fire suppression; i.e., salaries, equipment use, rehabilitation for fire suppression-related damages, Boise Interagency Fire Center support, etc. in FY76 were $5.5 million.
4. Resource damage in calandar year 1975 was $2.1 million.

Discussions with over ten people involved in various BLM fire suppression activities indicated that Loran-C would improve their operations in five possible areas. These were:

1. More rapid and accurate identification of fire locations by aerial detection and a consequent faster initial attack.
2. Tracking and directing retardant bombers, helitrack crews, transport aircraft, and smokejumper groups carrying portable batter-powered Loran-C receivers.
3. Pinpoint recovery of personnel, including injured people and other rescues , by helicopter.
4. Improved location and coordination of crews on large fires.
5. More rapid and accurate mapping of fire perimeters and resource damages.

The total benefit for the fire suppression application from 1982 to 1990 was calculated from the lowest amounts of the annual savings which were actually quantified. Namely:

(0.02+0.04+0.105+0.094) 5.759 = $1.49M

Estimates of the associated fire suppression costs were made by BLM and DOT/TSC in five areas. There were:

1. Forty $1200 Loran-C latitude-longitude receivers plus $300 per receiver for portable encasements and batteries would be required for ground operations:

   40 ($1200+$300) = $0.06M

2, Training costs for 120 ground personnel for one day each and at $65 dollars per day would be:

   120 x $65 = $0.008M

3. $2000 Loran-C area navigation sets would be required in forty aircraft serving all BLM and other land areas in western part of the United States:

   40 x $2000 = $0.08M

4. Training costs for two pilots per aircraft for two days each and at $200 per day would be:

   2 x 40 x $200 = $0.032M

5. O&M expenses at 10 percent per year of the initial ground and air Loran-C costs would total:

   0.10 ($0.06M+$0.08M) 5.759 = $0.08M from 1982 to 1990

The sum of the above costs were $0.26 million dollars. The benefit-to-cost ratio for the BLM fire suppression users was 5.73.

The second Loran-C area where firm estimates were obtained from the BLM was road inventory. The BLM now maintains 56 highway districts covering its nationwide total of 100,000 miles of road. Nineteen districts are operated in the mid-continent for 34,000 miles of road which require periodic inventory. Of these, 16,976 are now on record to require "log-mile" data to identify the

1. Initial 1982 receiver costs:
   $1200 x 19 = $0.023M

2. Two days training to two people per district at $90 per day:
   2 x 2 x 10 x $90 = $0.07M

3. O & M at 10% per year of initial receiver costs:
   0.10 x $0.023 x 5.759 = $0.013M

The total of the above costs is $0.043M. This results in a benefit-to-cost ratio of 4.86 for the BLM road inventory application. It is interesting to note that this ratio is only slightly higher than a 4.37 benefit-to-cost ratio obtained independently in the state highway road inventory application of section 5.2.4, i.e., without the local monitor costs:

State highway inventory benefits = $3.593M + $0.599M = $4.192M

State highway inventory costs = $0.343M + $0.172M + $0.247M + 0.10(0.343M)5.759 = $0.960M

Benefit-to-cost ratio = 4.37

In conclusion, the sum of the BLM wildfire suppression and road inventory benefits and costs are respectively 1.694 and 0.303 million dollars. The overall benefit-to-cost ratio for the BLM is 5.59.

### 5.2.7 APHIS Aerial Spraying

A series of interviews and working sessions held with the Department of Agriculture's (USDA) Animal and Plant Health Inspection Service (APHIS) revealed a very beneficial use of Loran-C area navigation in aerial applications for agricultural, insect, and pest control. Aspects of these meetings pertaining to the estimates of benefits and costs for APHIS in the mid-continent are covered in detail in Appendix G and are summarized as follows:

1. Each year APHIS sprays at least seven million areas in the mid-continent. This acreage was estimated from existing APHIS records and correspondence (see Appendix G) and involves many different types of quarantine programs

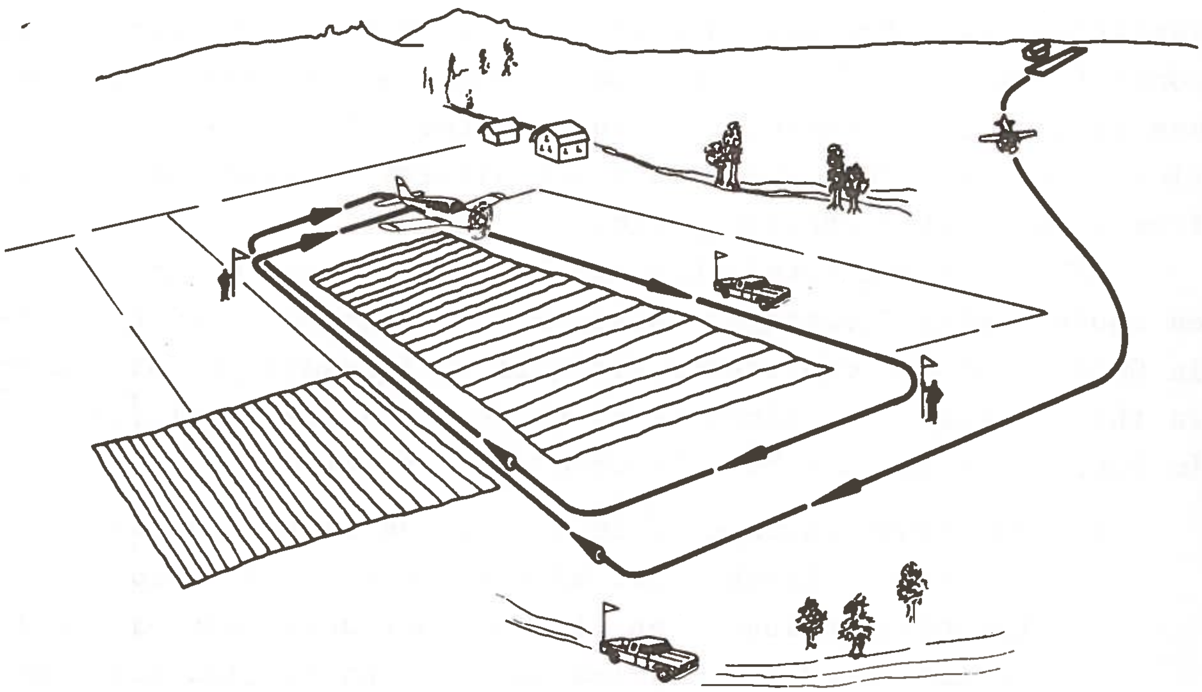

FIGURE 5-5. AERIAL SPRAYING OPERATIONS

caterpillar treatment. The remaining benefits were derived from a similar 30% savings in the 17.5 cents per acre material cost for grasshopper treatment and a smaller 10% savings in respraying operations for fire ants.

3. An annual savings of $0.116 million resulting from savings in en-route flying time to the spray site and to the spray depots. This benefit involved roughly 40 aircraft and was based on a 25% savings in flight time which, because of the large mid-continent land areas, was 50% of the total spray time.

The sum of the benefits of the Loran-C application to APHIS aerial spraying was $857,300 per year and did not include additional savings which might accrue from other smaller APHIS control programs and large amounts of spraying in the private sector. The total benefit from 1982 to 1990 is:

$$\$0.8573M \times 5.759 = \$4.94M$$

The costs to achieve the above Loran-C benefits are also treated in detail in Appendix G and are summarized in five areas as follows:

1. Equip 26 PV-2 and 14 Ag-Truck (or equivalent) two-man aircraft with $2000 Loran-C area navigators. The initial costs in 1982 are:

   $$40 \times \$2000 = \$0.08M$$

   It is noted that the above costs are conservative since a smaller number of Loran-C equipped aircraft may be able to satisfy all of the PV-2 requirements in fire ant, grasshopper, and range caterpillar treatments in each year.

2. Equip the two Cessna Ag-Cat single-pilot aircraft used in fire ant mop-up spraying operations with a $2500 Loran-C area navigator, an extra waypoint storage capability, and a $1500 heads-up display. The initial costs are:

   $$2 \times (\$2500+\$1500) = \$0.008M$$

3. Provide twenty-four hours of initial training for 80 pilots at a conservatively high wage rate of $40 dollars an hour.

pyrolytic converters, it may be possible to derive ten percent of the nation's future energy needs from forest lands.[53,54,55] To put this statement in perspective, it is first necessary to consider the increasing use of wood as an energy source in the face of the rising costs for fossil fuels. For example, the city of Burlington, Vermont has recently switched from coal to wood burning for their electrical power generation and is saving 40% in the costs of electricity after amortization of the costs of conversion. In another example, the rising costs of a cord of wood and the need to clear some forests of surplus biomass, has enabled the State of Massachusetts to institute a "pick-a-cord" program where citizens can obtain their own wood from state forest for a permit charge of four dollars. These examples are provided to emphasize that the biomass exists and it is a source of public revenue which should outweigh the Federal and State inventory costs to insure that the woodland is not permanently damaged. The public inventory responsibility is necessary because only 50% of the biomass can be removed without depleting the soil nutrients and, at the same time, decreasing the danger of fire. The Forest Service estimated that 40 million acres of mid-continent U.S. forest land is suitable forest land which could supply one-third of a cord of wood each year with a dry oven weight of between 1650 and 2850 pounds.

By 1982, the recent private and U.S. Forest Service efforts[56] to achieve an efficient and economical removal of biomass from forest lands should produce a profit in recoverable fuel of at least 0.1 cents per pound after all costs for striping, removal, and transportation have been included. These efforts involve forest residue machines for timber stand improvement, better extraction methods, and relatively smoke free pyrolytic converters to produce methane and other gases. For the known converter efficiency of 85%, the total value of this biomass is at least:

$$40M \text{ acres} \times 1650 \text{lbs} \times \$0.001 \times 0.85 = \$56M \text{ per year}$$

To calculate the benefit of the application of Loran-C to biomass inventory it is estimated that the commercial enterprise profit will be 10% of the total biomass worth and the Goverment will particularly for the combined BLM and Forest Service fire-fighting operations at the Boise, Idaho Fire Control Center. Because of this similarity, the Forest Service stated that the BLM Loran-C benefits could be extrapolated to obtain corresponding savings on mid-continent U.S. forest lands. The extrapolation was based on the sum of the lowest benefits provided by the BLM, the ratio of Forest Service to BLM lands, and a 3.33 ratio of Forest resource value and frequency of fires versus corresponding BLM values as follows:

1. The minimum annual fire suppression benefit to the BLM in Section 5.2.6 was $105 thousand. This total involved $20K a year in fire presuppression cost reduction, $40K a year in fire suppression savings, and $105K a year in reduced resources damage.
2. The mid-continent has 73 million acres of U.S. forest land and 60 million acres under BLM jurisdiction.
3. The aggregate number of fires and fire damage loss in forest lands is at least 3.33 higher than on BLM lands. This value is reasonable in view of the worth of timber as opposed to grazing land as a natural resource especially for some sparse mid-continent areas where it is difficult to grow trees. Moreover, from a purely ecological point of view, it should be noted that in every year an acre of forest land produces 2000 tons of molecular oxygen and purifies 20,000 gallons of water.

Given the above considerations, the annual benefits of Loran-C in the forest fire suppression and damage assessment application are calculated as follows:

$\$0.15\text{M} \times \frac{73}{60}$ acre ratio x 3.33 value ratio = $0.668M per year

The costs to achieve these benefits are:

1. Provide 30 latitude-longitude Loran-C receivers at a cost of $1200 plus $300 per receiver for portable encasements and batteries for ground fire fighting operations:

$$30\ (\$1200+\$300) = \$0.045\text{M}$$

Loran-C would save 20% of these latter costs for only the second helicopter in the team. Taken together, these factors yield an annual benefit of:

0.45M acres x \$8 x 0.50 x 0.20 x 0.50 = \$0.18M per year

2. The cost elements are \$2000 each for eight helicopters, 5 days of initial training of 16 pilots at \$200 a day, and annual O&M and retraining at the 10% rate. The elements yielded an initial cost in 1981 of \$0.035 million dollars and an annual cost of 0.0032 million per year.

The totals of the benefits and costs from 1982 to 1990 were respectively \$1.037 and \$0.054 million. The resulting benefit-to-cost ratio in the aerial spraying application of Loran-C for the Firest Service was 19.3. This ratio was reasonably close to the 18.2 ratio obtained by different methods in section 5.2.7 for the four other types of spraying performed by APHIS.

The last application of Loran-C for the Forest Service involves its use in road inventory. In this area, it is of interest to note that the yearly road mileage construction on Forest Service cognizance is higher than any other single State or Federal agency. For example, the Forest Service has 54,000 miles of road in the mid-continent compared to 24,000 miles under the jurisdiction of the BLM. 2056 miles of new road were built in 1976 in forest lands which include rugged terrain generally without recognizable landmarks. Loran-C could serve a very useful function in inventory vehicles covering roughly 80% of these roads once every two years. The inventory would be particularly valuable in identifying the locations of existing roads for mineral exploration in order to avoid such cases as a new road bieng cleared within short distances of existing roads. Other benefits similar to those described for the BLM in section 5.2.6 (e.g., locating culverts, water sources, and major trail entrances) can also be derived from Loran-C.

The estimates of the road inventory benefits of Loran-C were obtained in three areas by extrapolation from BLM data which were discussed with Forest Service personnel. The first two areas were based on the ratio of Forest Service roads to BLM roads under the

The total cost from 1982 to 1990 is \$0.106 million. The benefit-to-cost ratio from the application of Loran-C to the Forest Service's road inventory program is 3.4

To summarize, there are four major applications of Loran-C with favorable benefit-to-cost ratios for the USDA Forest Service. The benefits (B), costs (C), and benefit-to-cost (B/C) ratios for these applications are listed together as follows:

1. Biomass inventory:
   B = \$1.612M, C = \$0.531M, B/C = 3.1
2. Fire suppression:
   B = \$3.847M, C = \$0.168M, B/C = 22.9
3. Aerial spraying:
   B = \$1.037M, C = \$0.054M, B/C = 18.2
4. Road inventory:
   B = \$0.359M, C = \$0.106M, B/C = 3.4

The overall total of the above estimates for the Forest Service are a benefit of \$6.855 million, a cost of \$0.859 million, and a benefit-to-cost ratio of 8.0. The overall ratio should provide a strong incentive for the Forest Service to develop these applications rapidly, especially considering the number of intangible benefits which were not quantified but could be derived without additional Loran-C connected costs. Among these are benefits from search and rescue and other emergency services and advantages of better resource management.

a. Net Annual Benefits: \$20.72M-(1.186M+1.41M) = \$18.124M per year

b. Net Initial Costs: \$21.8M+\$15.03M-6.158M = \$30.672M

c. The write-off or payback year, n, at 10% is calculated from:

$$\frac{30.672}{18.124} = \frac{(1+0.1)^n-1}{0.1(1+0.1)^n} \text{, Therefore, } n \approx 2$$

If present investments accrue 10% interest each year, the payback period is only slightly extended from 2 years to 2.3 years. The latter payback is equivalent to an internal rate of return (discount rate for zero net benefits) of 62%.

3. The benefit-to-cost ratios and payback periods resulting from ±20% changes in the cost and benefits are listed in Table 5.4 under the following conditions:

   a. ±20% changes in the Federal costs for the Loran-C transmitter stations. These changes were made to reflect the range of estimates provided by the U.S. Coast Guard.

   b. ±20% changes in user costs which may result from different costs for the Loran-C receivers, central facilities, training, and annual operations and maintenance expenditures.

   c. ±20% changes in the public benefits accruing from the application of Loran-C. In view of the conservative approach employed in this study, the lower benefits are considered unreasonable unless severe operational problems occur in the initial implementation of Loran-C.

The table shows that the benefit-to-cost ratios and payback periods are almost equally sensitive to individual 20% changes in federal costs, user costs, and benefits. For these cases, there was a relatively small variation in the benefit-to-cost ratios (ranging between 1.5 and 2.3) and all payback periods were less than 2.3 years. The last two sets of changes were calculated for the extremes and resulted in a lowest value of 1.6 in the overall benefit-to-cost ratio. Although these extreme cases are considered highly improbable, the "worst case" view of Loran-C still pays for itself within 3.6 years.

### 5.3.2 Confidence Limits on Benefits and Costs

A "devil's advocate" position on the successful implementation of Loran-C to the eight public uses reported in this study might ignore its conservative criteria and apply the following pessimistic engineering judgements to the baseline estimates of costs and benefits:

1. The benefits of reductions in police supervisor's time may be too high if Loran-C is not widely accepted on an operational basis. Moreover, full acceptance does not guarantee a saving in the supervisory staff unless there is a reduction in force or a reassignment to other duties. For these reasons, the benefits should be reduced by a factor of three (to $1.06 million per year) while the costs should be reduced by only 40 percent (to $2.8 million initially and $0.29 million annually). Assuming that all of the monitor stations are still needed for the other applications (e.g., EMS, rural fire suppression, etc.), the resulting benefit-to-cost ratio to the police users in Section 5.2.1 will be lowered to 1.0.
2. Without full participation by the police, the EMS benefits from reduced hospitalization and deaths in highway accidents may not materialize. The most extreme case where all of these benefits are excluded was considered in Appendix G and resulted in a lower benefit to the EMS users of $42.7 million. The corresponding benefit-to-cost ratio for the same Loran-C EMS costs is 11.6.

these profits to be paid to the Government for its inventory and leasing operations may be difficult to determine. Therefore, the biomass benefits and the corresponding Loran-C receiver costs should be reduced. Deletion of these benefits and costs lowers the Forest Service benefit-to-cost ratio to 6.4.

The above revisions to the benefit and cost estimates and the reasons for these "less confident" values are summarized in Table 5.5. The main effect of the extreme changes is to reduce the overall benefits from $125.5 million to $89 million at a slightly lowered cost of $48.4 million. The benefit-to-cost ratio is reduced from 2.4 to 1.8.

The last "confidence" issue to be addressed relates to the estimated price of Loran-C receivers in 1982. Although it is believed that the price estimates developed in Section 3.1 are on the high side, a "what-if" exercise on even higher prices may surface from more cautious judgements. This exercise would take the following form:

1. In all of the applications considered, a total of 8474 Loran-C receivers and 260 area navigation sets were to be purchased in 1982. Of these, 4000 were $1000 time-difference receivers and 4362 had latitude-longitude readouts with automatic encoding at a per unit price of $1200. When the remaining 120 special types of more expensive receivers are included, the average price of the ground receivers becomes $1126.

2. The manufacturer's price estimates in Section 3.1 were reduced by 10% to reflect a doubling of their proportionate shares of the present marine market of 45,000 units. If a corresponding land market for receivers almost identical to those used by the marine community does not materialize, the estimated price would not include the 10% reduction factor. This would increase the average price to $1251.

3. Additional costs may be involved in the modification of the marine receivers to suit the land environment. The modifications would address such issues as increased man-made noise (particularly in metropolitan areas) and the higher speeds and possibly special installations required for the different types of ground vehicles. Although this study was mainly restricted to rural areas in the mod-continent, it is likely that the manufacturers would want their modifications to apply to both rural and urban regions. If so, the estimated costs of each receiver should be increased by $350. These additional costs would increase the 1982 receiver price to $1601, which is high enough to satisfy even the most cautious considerations.

4. The additional costs for an increase in the average price from $1126 to $1601 for 8474 receivers involve initial purchases in 1982 and the 10% per year O&M expenditures from 1982 to 1990. These additional costs are:

$$(\$1601-\$1126)\ 8474 \times 1.5759 = \$6.34M$$

When the above cost increase is also combined with a generous $1000 increase in the 1982 cost of the 260 Loran-C area navigators (originally priced at $2000 each), the overall costs are raised from $51.8 million to $58.5 million. This causes a 12.5% reduction of the benefit-to-cost ratio from 2.4 to 2.1. The reduction is considered small when compared to the 42% increase in receiver price.

In summary, the combined effect of all of the most pessimistic engineering judgements on the benefits and costs of Loran-C in the mid-continent are:

1. Benefits = $89M
2. Costs = $48.4M + $6.7M = $55.1M
3. Benefit-to-cost ratio = 1.6

TABLE 5.6. BENEFITS AND COSTS IN RESTRICTED CASES

| LORAN-C APPLICATION DESCRIPTION | BENEFITS, B ($M) | COSTS, C ($M) | B-TO-C RATIO |
|---|---|---|---|
| 1. POLICE PROVISION OF LORAN-C POSITION TO RURAL HOUSEHOLDS (1982) | 0 | 2.9 | 0 |
| 2. EMS FOR RURAL HOUSEHOLDS | 33.5 | 3.7 | 9.1 |
| 3. RURAL FIRE SUPPRESSION | 13.2 | 5.0 | 2.6 |
| 4. NUCLEAR MATERIALS TRANSPORT (NO CHANGE) | 5.3 | 0.8 | 6.6 |
| 5. COMBINED BLM AND U.S. FOREST SERVICE WILDFIRE SUPPRESSION | 5.3 | 0.4 | 14.6 |
| 6. COMBINED APHIS AND U.S. FOREST SERVICE SPRAYING | 5.9 | 0.4 | 18.2 |

# APPENDIX A

## ESTIMATES OF POPULATION AND LAND AREA NOT COVERED BY LORAN-C

Table A1 lists 19 states within the mid-continent region of the United States which are not covered by Loran-C. The table also lists estimates of the uncovered population and land areas for each states. The total uncovered land area of 1,118,361 square miles is 31 percent of the 3,028,886 area of the contiguous 48 states. The total uncovered population of 16,916,000 is 8.1 percent of the 207,976,452 population of the contiguous 48 states. An analysis of U.S.Census data also provided the following mid-continent population estimates in rural areas:

a. 550,000 in rural areas calculated from villages with populations of less than 5000

b. 1,340,000 in very rural areas (outside of towns) which are on farms.

c. 1,672,000 in other very rural areas involved in logging and mining operations.

# APPENDIX B

## LIST OF MEETING AND TELEPHONE CONTACTS

During the course of this work many people in various organizations furnished an abundance of data and discussed pertinent and related information at length both in meetings and in telephone discussions. These contacts are listed below grouped by major divisions of this cost study. Of course, in many cases discussions involved topics related to more than one grouping. For example, emergency dispatching covers police management, emergency medical services, and rural fire suppression. For simplicity, each individual is listed only in the one grouping most closely related to discussions involved.

The cooperation and help given by all of these people is very much appreciated.

George Ajimine Orange County, CA. EMS

Kenneth Russell, Arizona Dept. of Public Safety, EMS

Howard Adams, Central Arizona EMS, Inc.

Ms. Janis Griffin, Central Arizona EMS, Inc.

Duane Moore, Illinois State Dept. of Transportation - (Helicoptors)

Ms. Karen Cabot, Illinois Dept. of Public Health EMS

Don Pool, Illinois Dept. of Public Health EMS

James Stoffels, Minnesota Dept. of Public Health EMS

Henry Fruns, Minnesota State Dept. of Transportation

Paul Anderson, Idaho Dept. of Health and Welfare EMS

Jack Cvitanovic, Washington State Dept. of Health EMS

Howard Fordyce, Washington State Dept. of Health EMS

Harold Hopkins, Texas Dept. of Health Resources EMS

Truman Hopkins, New Mexico Dept. of Health EMS

Arthur Harmon, Alabama Health & Welfare EMS

Ned Butler, Alabama State Director of Communication

David Fletcher, Colorado Dept. of Health EMS

Joseph Stephany, Southwest Georgia EMS Inc.

Charles Detweiler, Pennsylvania Dept. of Health, EMS

Raymond Hashold, Wisconsin Dept. of Health & Social Services EMS

Ms. Toni Engstrom, Wisconsin Dept. of Health & Social Services EMS

Jay Crawford, Duval County, Florida EMS.

Prof. William Brundage, Southern Mississippi University

Mr. Duane, American Heart Association (Boston)

Royce Britton, American Heart Association (Dallas)

Salisbury Adams, Arthur Young Company, (Boston)

Janet Mitchell, PHD, Boston City Hospital

Sumner B. Chansky, DOT/FHWA (HHS-12)

Vincent Nowakowsky, DOT/FHWA (HHS-12)

Lyle Saxton, DOT/FHWA (HRS-32)

A. Dewey Jordan, DOT/NHTSA (NTS-24)

Richard Smith, DOT/NHTSA (NRS-24)

Clarance Mosher, New York State Dept. of Motor Vehicles

James C. Murdock, New York State Dept. of Motor Vehicles

Malcom Abrams, New York State Dept. of Motor Vehicles

Philip Brown, Tennessee Highway Dept.

F. W. McMichael, Tennessee Highway Dept.

James Daves, Tennessee Highway Dept.

Charles Sanders, Tennessee Highway Dept.

Prof. Paul Tutt, Univeristy of Tennessee

Prof. Frederick Wegmann, University of Tennessee

NUCLEAR MATERIALS TRANSPORT

Ralph Shull, Dept. of Energy (Germantown, MD)

Dr. D. Wayne Sherwood, Dept. of Energy (Germantown, MD)

Angelo Giarratana, Nuclear Regulatory Commission

Wayne Olsen, Sandia Corp.

Clay Ericson, Sandia Corp.

AGRICULTURAL APPLICATIONS

Raymond Lueffe, USDA, Statistical Reporting Service

Paul Cook, USDA, Statistical Reporting Service

Ralph Bernstein, International Business Machines Corp., Gov't System Div. & Service

Norman Meyer, USDA, Animal and Plant Health Inspection Service

Richard Dyer, USDA, Animal and Plant Health Inspection Service

Garry Spate, DOI/Bureau of Land Management

Thomas Paterson, DOI/Bureau of Land Management

Ronald Voss, DOI/Bureau of Land Management

Lee Montoya, DOI/Bureau of Land Management

Grover Torbert, DOI/Bureau of Land Management

Roy Perceval, DOI/Bureau of Land Management, Reno, NE

Dale Vance, DOI/Bureau of Land Management, Denver, CO

Dennis English, DOI/Bureau of Land Management, Denver

General

Richard Schwietzer, DOC/Bureau of the Census

Jerry Post, DOC/Bureau of the Census

Bernard Ambroseno, Epsco, Inc.

Carl Andren, Navigation Systems Inc.

Stanley Piasecki, Navigation Systems Inc.

Billy Watkins, Navigation Systems, Inc.

Mel Barney, Texas Instruments, Inc.

George Burrell, King Radio Inc.

John Currie, Internav, Inc.

Robert Goddard, Internav, Inc.

Harry Halamandaris, Teledyne Systems Co.

Robert Janc, Motorola, Inc.

William Judge, Amecom D.W./Litton, Ind.

Charles Malaquias, Digital Marine, Inc.

William Marchall, Offshore Navigation, Inc.

Edward McGann, Megapulse, Inc.

William E. Simpson, Operations Research, Inc.

# APPENDIX C

## EMERGENCY MEDICAL SERVICES

## INTERVIEW DATA AND ANALYSIS

It is apparent that EMS ambulance services are rapidly improving and developing much higher standards of advanced life support systems. Data on EMS is beginning to become more standardized and more comprehensive. Cross fertilization of new techniques, ideas and procedures between the various states, countries, EMS districts, etc., is proceeding rapidly with HEW and DOT/NHTSA (e.g., Standard 11, 35) guidance and support. However, at the present time, the data is not uniform as gathered from the various states, counties, hospitals and other private and volunteer ambulance services. Thus it must be carefully interpolated. The reasons for this can be appreciated when it is recognized that laws governing EMS standards and inspection are rather recent and are just going into force in some states. For example, Massachusetts EMS laws were passed in 1973, went into effect in 1974, inspections began in 1975 and 1976 and the full benefit is just now being realized. This shows up in quality of reports, improved response times and by the rapid percentage increase in serious cases using EMS vehicles to get to a hospital. The improved ambulance standards not only provide better medical care but also minimize unskilled care and patient movement where such care is inadvisable, as in cases of fractures of the neck and back. Previously many Massachusetts ambulances were hearses with nothing more than a driver, an oxygen bottle and a stretcher. Utilization of EMS was very low. Wisconsin's new EMS standards are just now going into effect. It is obvious that the tremendous resources now going into EMS are rapidly having an impact.

In view of the difficulty in obtaining uniform data, extensive telephone interviews and working sessions were held with approximately forty persons (including division chiefs in 20 EMS districts in states and counties, five HEW and NTHSA personnel, two American Heart Association people, and three MD's.) The results

# TABLE C-1. INTERVIEW DATA

| PLACE OR ORGANIZATION | PERSONS CONTACTED | POPULATION (x1000) | NUMBER OF VEHICLES AND AIRCRAFT | VEHICLES PER MILLION POPULATION | CALLS PER YEAR (X1000) | CALLS PER VEHICLE EACH YEAR | CALLS PER THOUSAND PEOPLE | PERCENT TIME-CRITCAL EMS CALLS | EMS PERCENT OF HOSPITAL PATIENTS | PERCENT VERY SERIOUS EMERGENCIES USING EMS | PERCENT OF CALLS IN TRAUMA | % INDEFINITE LOCATION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TENNESSEE | ACKER, PHILLIPS, LAND | 3924 | 347+8 AIRCRAFT | 90 | 180 | 518 | 46 | | | 80-90 | 35 | 40 |
| MASSACHUSETTS | MANSFIELD POTTS | 5689 | 1100 | 190 | 200 | 182 | 35 | 59 | 8-10 | ABOVE 80 | 40 | 0.8 IN URBAN |
| WASHINGTON | CVITANOVIC, FORDYCE | 3409 | | | 150 | | 44 | ABOVE 50 | | | 34 IN RURAL | 10 |
| IDAHO | ANDERSON | 713 | 150 | 210 | 30 | 200 | 42 | | | | 30 | (YES) |
| ORANGE, CA | AJIMINE | 1420 | | | 40 | | 28 | | | | 22 | URBAN VERY LOW |
| INLAND COUNTIES, CA | BARKER | 1232 (29 RURAL) | | | | | | | | | | 30-40 RURAL |
| COLORADO | FLETCHER | 2007 | | | | | | | | | | 10-20 |
| UTAH | WHARBURTON | 1059 | | | | | | | | | | NONE |
| NEVADA[43] | CHAPPELL | 489 | 102+8 AIRCRAFT | 210 | | | | 30 URBAN 70 RURAL | 10 | | 45 | HIGH RURAL |
| TEXAS | H. HOPKINS, PETERS | 11196 (1733 RURAL | 1934 | 173 | 344 (70 IN RURAL) | 178 (40 RURAL) | 30.5 (40.5 RURAL) | 60 RURAL | | 60 RURAL | | 20 PROBLEM AREAS |
| KANSAS | ECKHART | 2249 | | | | | | | | | | PROBLEM AREA |
| ARIZONA[39] | RUSSELL, ADAMS, GRIFFIN | 1500 | | | 110 | 73 | | | | | | ABOVE 10 RURAL ABOVE 1 URBAN |
| MINNESOTA[40] | STOFFELS, BRUNS | 3805 | 458+28 AIRCRAFT | 150-170 | 231 987 CRITICAL) | 153 CRITICAL | 60 RURAL | 59 | | | 20 | |
| ILLINOIS | POOL, MOORE | 11113 | | | | | | | | | | HIGH FOR AIRCRAFT |
| WISCONSIN[41] | NASHOLD, ENGSTROM | 4417 | 1000 | 226 | 92 | 92 | 20 | 58 | 7 | 43 | 24 | SOME PROBLEM |
| N. MEXICO | HOPKINS | 1016 | | | | | | | | | | PROBLEM EXISTS |
| LYNN, MA | DR. WASCO | 90 | | | | | | | | 85 URBAN | | |
| UNIV.OF FLORIDA | DR. CREVASSE | | | | | | | | | | | 30-40 |
| SOUTHWEST GEORGIA | STEPHANY | 560 | 65 | 116 | 33 | 510 | 59 | | 20 | 65 | | 70 |
| MISSISSIPPI | SURATT | 2216 | 245 | 110 | 78 | 145 | 35 | 50 | LOW | 50 | 26 | 40 |
| ALABAMA | HARMON, BUTLER | 3444 | 600+5 AIRCRAFT | 175 | | | | 50 | | HIGH | 30 | MODERATE |
| DUVAL COUNTY, FL | CRAWFORD | 570 | | | | | | 50 | | 90 | | 35-40 |

Note: Interview data is private and should not be quoted or utilized except for this evaluation of benefits and costs of Loran-C.

have been saved if the EMS vehicle had arrived 10 to 12 minutes earlier. This was particularly true for those patients in the early stages of a heart attack and in accidents where shock, bleeding, respiratory and other traumatic after-effects were severe. A 16% life saving benefit, applying only to time-critical cases, was finally selected for the 10 to 12 minute reduction in EMS delays as the product of the 80% using EMS vehicles and the 20% estimated from the interviews.

7. The percent of EMS calls for those patients suffering less severe trauma requiring hospital stays of more than a week varied from 20 to 45 percent, and was estimated to average 22 percent.[40,41] The discussions with the EMS people uniformly indicated that a 10 to 12 minute improvement in response time would reduce the hospitalization time of these cases by at least ten days of reduced hospitalization were selected to apply only to time-critical cases.

8. An analysis of reduced delays which would result from the application of Loran-C in EMS vehicles led to a distinction between a "definite", as opposed to an indefinite", knowledge of the locations of emergency calls from households, highway accidents, and other sources. It was concluded that, even though there were benefits from Loran-C in the majority of cases when the locations of emergency calls were known (i.e., definite), these benefits could not be quantified. It was virtually impossible to determine the time saved when other important parts of the services (such as communications, dispatching, etc.) were also being performed. Moreover, one study 7 ha concluded that, for police dispatching, the average reduction in the delay from the location function alone would be no more than two minutes. However, even though the EMS people interviewed were strongly cognizant of exaggerations falling under the title of the "delay horror story" syndrome,

N.Y. over one hundred miles away. Other studies indicated that better than 15% of the EMS vehicles proceed in the wrong direction and that about 17% of the telephone emergency reports do not give adequate location information even in urban areas.[9,29] It is likely that these higher percentages can be reduced significantly with a local 911 emergency dialing service at, say, a central policy station.[29] However, on the basis of the interviews it was conservatively estimated that, without the addition of a 911 automatic address location system, Loran-C would solve 1% of the indefinite location problems in rural areas and that the time due to the use of Loran-C would be higher than 10 to 12 minutes.

c. Very Rural areas (outside of towns and villages) had indefinite location problems ranging from 20 to 40 percent of the EMS runs. The interviews indicated that a Loran-C location capability especially in aircraft would reduce the delays by at least 12 minutes in a large number of these cases. Special time saving benefits of Loran-C were also found on forested lands and on the many mid-continent Indian reservations where well trained volunteer emergency medical technicians and paramedics are almost completely unfamiliar with locations. Again considering the range of the estimates and the separate advantages of a local 911 system, it was concluded that Loran-C would solve at least 10% of the very rural indefinite location problems and that the average time saved would be at least 10 to 12 minutes.

Excluding urban areas, a summary of the key factors in the analysis of the interview data of Table C-1 is presented below:

## TABLE C-2. LORAN-C AID FACTORS

Loran-C Aid factor = Percentage of EMS cases with reduced delays of 10-12 minutes due to application of Loran-C in EMS vehicles and aircraft

1. <u>Reduced Hospitalization in Very Rural Areas</u>:

   Aid Factor = 59% time-critical x 20% of calls x 10% Response Time Reduction = 1.18%

2. <u>Reduced Hospitalization in Rural Areas</u>:

   Aid Factor = 59% time-critical x 20% of calls x 1% Response Time Reduction = 0.118%

3. <u>Reduced Death in Very Rural Areas</u>

   Aid Factor = 59% time-critical x 20% of calls x 16% of cases x 10% Response Time Reduction = 0.944%

4. <u>Reduced Death in Rural Areas</u>

   Aid Factor = 59% time-critical x 16% of cases x 1% Response Time Reduction = 0.0944%

2. There were 1,800 rural and 9,800 very rural deaths from heart attacks in the mid-continent. However, since only one-quarter of these (450 and 2,450) occurred for persons under the age of 65, these latter totals were used as a more conservative estimate.

3. There were 390 deaths from farm accidents and 485 other accidental deaths (on logging, mining, and other sparsely populated regions) in the very rural areas of the mid-continent. There were also 160 accidental deaths (outside of farms) in the rural areas.

Finally, the annual benefits derived from the application of Loran-C to EMS vehicles in the mid-continent were computed in four categories using $100 per day for the cost of hospitalization and the standard DOT value of $200,000 for the cost of death. The $100 per day hospital cost was on the low side of the cost estimates made by a majority of the EMS people interviewed. The four categories of benefits were computed using the Loran-C Aid factors as follows:

1. <u>Benefits of Fewer Deaths in Very Rural Areas</u>:

   0.00944 x 3325 deaths x $200,000 = $6.277M per year

2. <u>Benefits of Fewer Deaths in Rural Areas</u>

   0.000944 x 8160 deaths x $200,000 = $1.540M per year

3. <u>Benefits of Reduced Hospitalization in Very Rural Areas</u>

   0.0118 x (120,000 calls - 16,875 deaths) x $100 per day x 10 days = $1.217M per year

   In these calculations the number of deaths is conservatively taken as the sum of all deaths from highway accidents (6200) all very rural deaths from heart attacks (9800), and other very rural accidental deaths (875).

4. <u>Benefits of Reduced Hospitalization in Rural Areas</u>:

   0.00118 x (22,000 calls - 3510 deaths) x $100 per day x 10 day = $0.022M per year

c. O&M at 10% of \$0.2M per year times 5.759 = \$0.115M

Summarizing, the application of Loran-C to EMS vehicles and aircraft in rural and very rural areas of the mid-continent will involve a total cost (in 1982 dollars) of \$3.687 million. The overall benefit-to-cost ratio to the EMS users is 14.1

During the course of the study, three alternative methods of estimating some of the major components of the EMS benefits were examined as a cross-check on the results. The first of these was an assessment of heart-related benefits which was based on a rather large extrapolation to the whole mid-continent area from one year of data in the Nevada Emergency Medical Services Plan of 1977.[43] The extrapolation and comparison to the calculations used was performed in the following way:

1. The Nevada Plan report[43] stated that 140 lives could be saved from cardiac failure if the EMS vehicle had arrived 10 to 12 minutes earlier. From American Heart Association data, only 1/4 of these, or 35, could be saved by Loran-C.

2. The 35 cases were extrapolated to the entire mid-continent region by taking the ratio of rural and very rural populations (See Appendix A) to the population of Nevada, i.e.:

$$\text{Rural: } \frac{550^k}{489^k} \times 35 = 39.4 \text{ cases}$$

$$\text{Very Rural: } \frac{3012^k}{489^k} \times 35 = 215.6 \text{ cases}$$

3. Since the 39.4 rural and 215.6 cases were already defined as time-critical cases using EMS which could be saved at the 20% hospital rate, the effect of Loran-C is simply the number of these cases multiplied respectively by the 1% rural and 10% very rural Loran-C improvements in response times. This multiplication yielded 0.4 rural and 21.6 very rural cases.

4. The equivalent number of cases used in the primary benefit calculations are obtained by multiplying the number of rural (450) and very rural (2450) heart attacks by their respective Loran-C Aid

that the lower $1.17 million value was more appropriate.

Two last points are of interest in a sensitivity analysis. The first, is that, even though the number of highway deaths seems high compared to other accidental deaths, their overall effect is low because they were assigned to rural areas where the Loran-C Aid factor was ten times lower than for very rural areas. If the 6200 deaths from highway accidents are excluded the benefits of fewer deaths in rural areas must be reduced to:

0.000944 x 1960 x $200,000 = $0.37 instead of $1.54M

The net effect of this exclusion is to reduce the overall benefit from $52.1 million to $45.3 million.

The second point worth considering in a sensitivity analysis is the additional exclusion of all reduced hospitalization benefits which could be derived from the faster arrival of an EMS vehicle at the scene of a highway accident. The most extreme criterion in this exclusion would be to subtract all of the 302,000 non-fatal injuries in mid-continent highway accidents (supplied by NHTSA) from the total number of EMS calls. When extrapolated to rural and very rural areas, the resulting deletion of highway injuries and deaths yields the following benefits:

1. Benefits of Reduced Hospitalization in Very Rural Areas: 0.0118 x (73,775 calls - 10,475 deaths) x $1000 = $0.747M per year

2. Benefits of Reduced Hospitalization in Rural Areas: 0.00118 x (13,500 calls - 1960 deaths) x $1000 = 0.014 M per year

The combined effect of the exclusion of both highway injuries and deaths is to reduce the overall benefit from $52.1 million to $42.7 million.

# APPENDIX D
## RURAL ROADS AND HIGHWAY DISTRICTS

The Federal Highway Administration (FHWA) provided estimates of the mileage of rural roads and the number of state highway districts with the mid-continent area of the United States which is not covered by Loran-C. These estimates are listed by State in Table D-1. The mileage estimates total 890,981 miles and were prepared in two steps:

1. The mileage of county and township roads, roads under Federal domain, and state park roads were listed for each state which had all or part of its area in the uncovered region. All Federal-aid primary and secondary road mileages were not included.

2. The mileage of each state was then multiplied by the percent of its population within the uncovered region (See Appendix A for those percentages).

The estimates of the number of state highway districts were also obtained through a similar extrapolation of each state's population within the uncovered region. This yielded a total 104 highway mid-continent highway districts. Since each of these districts involves an average of 2.5 state accident investigation vehicles, the application of Loran-C to highway traffic safety would involve 260 of these vehicles.

# APPENDIX E

## ESTIMATING LORAN-C BENEFITS AND COSTS IN NUCLEAR MATERIALS TRANSPORT

This appendix contains a working paper and a follow-up memorandum which were used as a prime sources of information in estimating the costs and benefits in the application of Loran C to the transportation of nuclear materials. The working paper was sent to the ERDA Division of Military Applications after initial discussions were held with that division and contractor personnel in a visit to DOE. For security reasons, information of a classified nature has been omitted.

The follow-up memorandum quantifies the costs and benefits which were used in the main body of this report.

# ESTIMATING LORAN-C COSTS AND BENEFITS IN THE SHIPMENT OF NUCLEAR MATERIALS

## WORKING PAPER, JANUARY 30, 1978

is working paper describes a method for estimating the benefits obtainable from the e of Loran-C in the DOE program to protect shipments of nuclear materials within e United States. The method is based on three key assumptions:

The potentially catastrophic nature of inadequate protection will insure the same high level of DOE program funding for many years to come.

When a significant improvement in one component of the total program is to be obtained, this component receives a greater portion of the available funds than other components in which performance is considered adequate. For example, the vault-like reinforcement of the vehicle carrying the nuclear materials may be considered adequate enough to intensify program efforts and resources to other areas such as communications.*

Although research and development efforts will continue in all areas of the program, a major enhancement in any one area, which is assumed to be at state-of-the-art, may not reoccur for three to four years.* Significant factors in this delay may be awaiting the development of a new technology or the implementation of a more advanced system.

ven the above assumptions, the first step in estimating the benefits is to list the rect and indirect costs in each subprogram area for the past five years in the llowing categories:

Present investment in one road convoy, including cargo and all equipment except that used for position location. Include past research and development costs.

Cost of position location equipment in each convoy, if any. If position location is manual, estimate the percent of operator trip time required to verify and communicate position data. Do not count costs of communications equipment in this item (Count it in category 1 above).

Planned R&D development funding to augment current position location techniques with radionavigation capabilities (e.g.: Omega, Loran-C).

Average time convoys are being used each year where "use time" involves convoy setup, loading, transport, unloading, and breakdown for storage. Provide separate estimates for road and rail convoys, if possible.

Average yearly costs of convoy personnel during "use time" defined in category 3. Include salary, benefits, and overhead.

Present investment in all road and rail vehicles involved in transportation. Include all security vehicles, cargo, all equipment, and past R&D costs.

---

ndicates TSC assumption on system functions and modes of operation misinformation of convoy position) Helicopters will also be equipped with the hybrid system and will automatically receive the last known or current convoy position during an emergency. Within the convoy, additional surveillance of the cargo vehicle will be obtained from differential Loran-C signals with an accuracy which varies from an average of 75 feet (1 sigma) to 225 feet (3 sigma). This feature will result in a precise knowledge of the cargo vehicle position by an accompanying escort vehicle, providing three advantages: (1) More flexible and less obvious escort vehicles within the convoy; (2) greater insurance of cargo vehicle theft by an insider, and (3) secret tailing of a stolen cargo vehicle after it was taken over.

In the uncovered mid-continent area, position determination will be made manually with the Omega receiver to an accuracy ranging from an average of 1 1/2 miles (1 sigma) to 5 miles (3 sigma). The Omega lane ambiguity will be resolved manually with the Loran-C receiver through the use of its skywave signal. Once resolved, the convoy position will be verbally communicated every thirty minutes to the central station.

System 2: A Nationwide Loran-C System not requiring an Omega receiver will be used throughout the United States after January, 1982. The system operation and accuracies will be the same as that described in System 1 in the areas already covered by Loran-C and will include 5-minute automatic position updates, helicopter rendezvous, and interconvoy surveillance. The estimated reliability of the transmitted signal will be better than 99.97% with signal outages never exceeding 100 minutes. A DOE Loran-C signal survey vehicle will be used to determine the received signal accuracy over the very small number of prearranged route locations where the absolute position data might be off by more than 1000 feet.

Between January 1980 and January 1982 operation in the mid-continent area will involve the use of the Omega/Loran-C System 1 as previously described. After January, 1982, the Omega receivers may be maintained for redundant operation in those few instances (99.97%, 100 minute) when a master station outage or a major error in position location is automatically identified by the Loran-C receiver.

third and last step is to estimate the benefits between System 1 and 2 which will ie in the mid-continent area each year after January, 1982. Recalling the three assumptions and relevant items in the first step of this paper, specific benefits be listed in the blank spaces provided in the following categories:

Reduced central station labor force = ___________. (DOT/TSC estimates 1 labor year)

Reduced convoy guard personnel labor force for those convoys operating within the mid-continent area (See item 8) = ____________. (TSC estimates 1 labor year for each such convoy).

Research, development, and operations funds deferred from guarding and cargo physical security efforts to other program areas (such as advanced R&D, "black hat", etc.). These deferrals will result from the position location advantages provided by the Loran-C system. Among these are: quicker emergency detection, more reliable convoy location information,more rapid rendezvous, and improved tracking by an escort vehicle. The deferred funds are the total of items a, b, and c, below:

U.S. DEPARTMENT OF TRANSPORTATION

TRANSPORTATION SYSTEMS CENTER
KENDALL SQUARE
CAMBRIDGE, MASSACHUSETTS 02142

In reply refer
to: DTS-534

April 17, 1978

W. Sherwood
Facilities and Safety Branch
Division of Military Applications
DOE, Mail Stop A-362
Washington, D.C. 20545

REF.: DOT/TSC Memorandum dated 1-30-78

This memorandum estimates the costs and benefits of using Loran-C in the DOE transportation of muclear materials. The estimates have been made on the basis of guidelines in the referenced memo and information supplied from your office. The analysis is as follows:

The Division of Military Applications will continue to invest $3.8M per year in Safeguards R&D, $700K of which is now being spent on location systems. A decision to provide mid-continent Loran-C coverage would enable DOE to use a nationwide system and result in the following savings:

1. From 1979 to 1981: 80% of the $700K or $560K each year will be set aside for another Safeguards R&D Program area which does not relate to a location function. In accordance with the three key assumptions in the referenced working paper, the $560K is considered a benefit for these three years. The remaining 20% or $140K would be applied to R&D for more advanced location systems (e.g.: GPS NAVSTAR) for implementation after 1990.

2. From 1982 to 1988: 10% of the $3.8M Safeguards R&D, or $380K, will be spent on location systems. If the Loran-C system were operational on a nationwide basis, 40% of the $380K in R&D funds (or $152K in yearly benefits) would not be spent while the remaining 60% ($228K) would be devoted to increased R&D efforts on the advanced systems.

3. After 1988, all of the $380K will be spent on R&D for the advanced location system. No monies would be saved on Loran-C.

The use of Loran-C will also reduce the DOE labor force required for the transportation of muclear materials. These benefits are:

A. One labor year reduction in central station labor costs resulting from nationwide use of Loran-C at a salary of $20K and a 50% overhead rate = $30K per year from 1982 to 1990.

3. Net Savings:

   1979-1981: $560K per year
   1982-1988: $152K + $442K = $594K per year
   1989-1990: $442K per year

4. Present Worth of Savings at 10% Discount (using 1981 as the base year):

   1979-1981: $560K x 2.487 x 1.21 = $1685K
   1982-1988: $594K x 4.868 x 0.909 = $2627K
   1989-1990: $442K x 1.736 x 0.5132 = $393K

   TOTAL PRESENT WORTH = $4705K

5. The total costs if the Loran-C system is installed 1 year prior to full operation in 1982 are:

| | | |
|---|---|---|
| $477K x 1.1 (one year, 10%) | = | $525K |
| 48 x 1.1 x 5.759 | = | 304K |
| | TOTAL | $829K |

6. The benefit-to-cost ratio is:

   $4705K ÷ $829K = 5.6

NOTE: These estimates are very conservative for the following reasons:

1. Nuclear material shipments will at least double by 1982 and may be much greater thereafter.

2. The open market value of only one cargo is classified information but may be in excess of $1M if stolen.

3. The blackmail value of a terrorist bomb threat would be astronomically high.

4. Additional benefits from public confidence in the security of interstate nuclear material shipments cannot be quantified.

5. Substantial safeguard benefits from the two receiver interconvoy monitoring of the cargo vehicle by the escort vehicle have not been included.

Robert Wiseman

# APPENDIX F

## PRELIMINARY ESTIMATES OF LORAN-C COSTS AND BENEFITS OF WILDFIRE SUPPRESSION IN PUBLIC LAND AND ROAD INVENTORY APPLICATIONS

This appendix contains the initial correspondence relating to costs and benefits from DOT/TSC to the Bureau of Land Management. The correspondence was intended to obtain more information on two of the most promising Loran-C applications which were selected from at least six possibilities identified in two previous conferences with a wide spectrum of BLM personnel. The main part of the correspondence is a working paper which describes the first steps in obtaining more detailed information on the operational aspects and the cost and benefit estimates for Loran-C. Subsequent review of the paper by BLM indicated that its guidelines were reasonably sound except for an error in the identification of the Denver Interagency fire station. (There is no such center.)

The final BLM response on the Loran-C applications in fire suppression and road inventory was received by DOT/TSC in written form as a telecopy in March 1978. The costs and benefits contained in the response were used in the main body of this report.

# ESTIMATING LORAN-C COSTS AND BENEFITS IN BUREAU OF LAND MANAGEMENT ROAD INVENTORY AND FIRE PROTECTION APPLICATIONS

## WORKING PAPER, FEBRUARY 28, 1978

This working paper describes a method which may be used by the Bureau of Land Management to estimate the costs and benefits of Loran-C location information within two of its major program areas: (1) Inventories of roads and lands on Federally-owned territory under BLM responsibility; and (2) Fire protection and damage prevention on BLM lands. Among the many BLM candidates studied by DOT/TSC, these two program areas have been determined to require location information under accuracy and cost constraints which are uniquely satisfied by Loran-C. That is, given the requirements for location predictability within approximately 1000 feet (2d rms) and repeatability in the neighborhood of two hundred feet, it is the purpose of this paper to refine cost and benefit estimates for these programs. These estimates are prepared under the following guidelines:

a. Generally, costs and benefits are computed for only the U.S. mid-continent area not presently covered by Loran-C. Since most of the BLM lands are westward of a latitude line through the Oklahoma panhandle, the coincident area pertains mainly to the States of Arizona, Nebraska, New Mexico, Montana, and Wyoming. The uncovered area also includes western Kansas, western Texas, and North and South Dakota.

b. Benefits for all federal lands both inside and outside the mid-continent area (e.g.:Oregon, Washington, California, etc.) may be computed for savings in equipment rental costs in cases where the equipment serves large multi-state and multi-agency areas. For example, rental cost reductions derived from more efficient location by aircraft primarily located in the Boise Interagency Fire Center may be computed for large project fires for all agencies and for all of the States served.

c. Loran-C station costs, receiver costs, survey costs, etc. will be estimated by DOT/TSC and will not include the costs of digital communication or specialized central data bases or monitoring/dispatching systems. These latter costs are omitted for the following reasons:

   1. The costs of digital augmentation of voice communication are minimal and are more than offset by the advantages from increased speed and pre-formatting of location data for automatic entry.

   2. Individual program benefits from and costs of centralized data bases and more automatic monitoring and dispatching systems may only form a small part of a larger multi-purpose system. These factors require extensive analysis of system size and coverage under the assumption that the current operation may not be adequate. Moreover, the costs of centralization of a single function is small compared to the purchase costs of large quantities of receivers and may be absorbed in the normal year-by-year upgrading of operations in the larger centers (e.g. Boise and Denver). For these reasons, it is assumed that the Loran-C location

The second step is to compare the present system location cost factors and the possible future Loran-C improvements in all areas of the two programs:

C. Road Inventory: The present system for road inventory involves land automobile examination of BLM roads for culverts, bridges, fences, cattleguards, and many other road survey, maintenance, and repair activities. The road quality prevents the use of precision odometers in the inventory automobiles or vans in ______ percent (Please estimate) of the total mileage. Instead, the usual automobile odometer is used to measure distance from ground identified or aerial photographed landmarks which have an average absolute offset error of __________miles (Please estimate). Also, over the average distance of _________miles (Please estimate), the automobile odometer mileage calibration and cumulative error can average ____________miles (Please estimate). The combination of these errors causes a ___________percent loss (Please estimate) of the time spent for road inventory and subsequent maintenance and repair efforts. The lost time involves difficulties in the finding the road and its landmarks and subsequently locating the inventory item.

Loran-C receivers mounted in the BLM ground vehicles and the photo-mapping aircraft would provide reference position (in latitude and longitude) from map to map and for all landmarks within each map. Daily variations in predictable accuracy could then be corrected on the ground with a calibration at one or two landmarks and total differential operation (repeatable accuracy) to all other landmarks and inventory items. It is estimated that this Loran-C technique would save ________percent of the time lost with a resulting_______ percent in the ground vehicle costs per mile (See Item A1). A Loran-C area navigation capability (included in the TSC costing) would save ________percent of the flying time for aerial photography through more direct paths to each map site and between sites. (See Item A3). The time to retrain a total of _____________(Please estimate) BLM or contractor ground vehicle personnel in the use of the Loran-C is _________days per person (TSC estimates 2 days) at a salary and overhead rate of ___________ per day. The training of ________ pilots will require ________days (TSC estimates 3 days) at a salary and overhead of $______ per day.

D. Fire Damage and Protection: The present system to minimize fire damages involves identification, control, and assessment in three major BLM activity areas: (1) Local centers within each State; (2) The Denver Service Center; and (3) The Boise Interagency Fire Center. The cost and benefit factors in each of these areas are described as follows:

1. The local BLM fire center activities involve fire watches, fire fighting, and fire damage assessment. There are three ways in which Loran-C could be used by these centers. The first would involve more rapid aerial or ground identification of fire locations for fire fighting crews, especially during times when the visibility is limited. The second would involve more efficient location and coordination of each fire crew unit during the progress of the fire. Each unit would carry a small portable Loran-C receiver weighing less than three pounds in order to communicate its position and the direction of movement of the

# Appendix G

## AERIAL SPRAYING BENEFIT AND COST COMPONENTS

This appendix provides a detailed breakdown of the benefits and costs of Loran-C in four aerial spraying applications areas for the Animal and Plant Health Inspection Service (APHIS). The four spraying applications are; (1) fire ants, (2) grasshoppers, (3) cotton insects, and (4) range caterpillars. The final estimates were obtained with the aid of APHIS cost accountants in a working meeting with APHIS aircraft operations personnel. Previous visits to APHIS, their initial response, and a working paper leading to these final estimates are included in the end of this appendix. The breakdown for each application expressed in thousands of dollars (K) are as follows:

1. Fire Ant Treatment: An average of two million of the annual nationwide total of ten million acres are in the mid-continent.

   A. Benefits of Loran-C are derived from three sources:

      1. Savings in the costs of aerial navigation provided by ground-based Decca or Loran-C systems. These navigation costs are presently roughly 11 cents per acre. Therefore, the annual benefits accruing from the use of Loran-C area navigation sets in all aircraft involved in fire ant treatment are:

         2M acres x $0.11 per acre = $220K per year

      2. The current navigation capability requires APHIS to re-spray approximately 10% of the acreage in a follow-up operation. APHIS pilots have indicated that navigation with Loran-C would eliminate this re-spraying requirement and also greatly reduce the amount of overspraying which is an important concern to the Environmental Protection Agency. Since this latter benefit could not be quantified, the only savings taken were those from the reduced re-spraying. These were:

multiple way point capability and a $1500 heads-up display:

2 x ($2500 + $1500) = $8K

It is noted that the extra $1000 Loran-C cost for additional waypoints is needed to avoid in-flight waypoint entries when single-pilot aircraft are involved in spray operations per pilot

3. Provide 24 hours of initial training for 20 pilots at an estimated per pilot cost of $40 per hour:

   20 x 24 hours x $40 = $19.2K

4. Provide for yearly maintenance at 10% per year of the total initial equipment and training costs:

   0.10 x ($20K + $8K + $19.2K) = $4.7K

5. Provide annual retraining of 10% of the labor force 0.10 x $19.2K = $1.9K

The total initial investment for the Loran-C fire ant spraying application is $47.2K. Annual costs from 1982 to 1990 are $6.6K per year.

2. <u>Grasshopper Treatment:</u> An average of two million of the annual nationwide total of three million acres are in the mid-continent

   A. Benefits of Loran-C are derived from three sources:

      1. The present system for grasshopper treatment involves ground crew guidance of aircraft from flagmen and vehicle operating at the spray site. This ground guidance is illustrated in Figure G-1 which also shows the previously discussed uses of Loran-C in direct en-route flying to and from the spray material depot. APHIS pilots have demonstrated that the guidance obtained from a Teledyne 424 Loran-C area navigator is more accurate than the current methods and would eliminate the need for half of the ground crews and vehicles. The ground guidance requires 12 people for one and one-half weeks to cover 280,000 acres or:

12 x 1.5 weeks x 40 hours per week ÷ 0.28M acres = 0.00257 hours per acre at a cost of ten dollars per hour for salaries, per diem, and vehicles, the resulting annual savings for two million acres are:

$10 x 0.00257 x 2M acres = $51.4K

2. APHIS stated that Loran-C would also reduce the amount of wasted spray materials due to over, under, and repeat spraying. They estimated that 30% of the spray material costs would be saved. At a $2.80 material costs per 1.6 acres, the resulting annual benefit for two million acres is:

0.25 x $2.80 ÷ 16 x 2M = $105K

3. An additional savings of 25% in the en-route flying time (which were again estimated at 50% of the total spray time) of 8 two-man PV-2 or DG4 (or equivalent) aircraft were also estimated. At a flight time cost of six cents per acre, these aircraft spray 175 acres per minute. The resulting annual benefit is:

0.25 x 0.50 x $0.06 x 2M = $15K

The sum of the annual benefits of Loran-C in grasshopper treatment are $171K.

B. The costs to achieve the above benefits in grasshopper treatment fall into three categories:

1. Equip an additional eight PV-2 aircraft with $2000 Loran-C area navigation sets:

8 x $2000 = $16K

2. Provide 24 hours of initial training for 16 pilots at an estimated cost of $40 per hour:

16 x 24 hours x $40 = $15.4K

3. Provide yearly maintenance and pilot retraining at the 10% rates:

0.10 x $16K + 0.10 x $15.4K = $3.1K

B. The costs to achieve the Loran-C benefits in cotton insect treatment fall into three categories:

1. Equip 14 aircraft with $2000 Loran-C area navigation sets:

   14 x $2000 = $28K

2. Provide 24 hours of initial training for 28 pilots at an estimated per pilot cost of $40 per hour:

   28 x 24 hours x $20 per hour = $26.8K

3. Provide yearly maintenance and retraining at the 10% rates:

   0.10 x $28K + o.10 x $26.8K = $5.5K per year

   The total initial investment for the Loran-C cotton insect treatment application is $54.8K. Annual costs from 1982 to 1990 are $5.5K per year.

4. Range Caterpillar Treatment: Two million acres per year are treated in New Mexico.

A. APHIS has estimated that the benefits of Loran-C in range caterpillar treatment are substantial, especially for savings in spray material and are described in three areas as follows:

1. Since the same ground crews and vehicles are used to provide aircraft guidance as those in grasshopper treatment, the savings are 0.00257 man hours per acre at a cost of 10 dollars per acre:

   $10 x 0.00257 x 2M acres = $51.4K per year

2. The savings in en-route flight time are identical to those for grasshopper treatment and involved the same number of PV-2 two-man aircraft. Therefore, the annual benefit from a 25% reduction in flight time, which is 50% of the total spray time, at six cents per acre in aircraft costs is:

   0.25 x 0.50 x $0.06 x 2M = $15K per year

TABLE G.1. SUMMARY OF APHIS LORAN-C BENEFITS AND COSTS

| APPLICATION AREA | MILLIONS OF ACRES | ANNUAL BENEFITS (x $1000) | | | COSTS (x $1000) | | AIRCRAFT NUMBER & TYPE |
|---|---|---|---|---|---|---|---|
| | | GUIDANCE | SPRAY | FLIGHT TIME | INITIAL | ANNUAL | |
| 1. FIRE ANT | 2 | 220 | 22 | 35.5 | 47.6 | 6.6 | 10 PV-2<br>2 AG-CAT |
| 2. GRASSHOPPER | 2 | 51.4 | 105 | 15 | 31.4 | 3.1 | 8 PV-2 |
| 3. COTTON INSECT | 1 | 57.6 | - | 50.4 | 54.8 | 5.5 | 14 AG-TRUCK |
| 4. RANGE CATERPILLAR | 2 | 51.4 | 234 | 15 | 31.4 | 3.1 | 8 PV-2 |
| TOTALS: | 7 | 380.4 | 361.0 | 115.9 | 165.2 | 18.3 | -- |

Note: Total Annual Benefits are $857.3K

Many millions of acres have been treated for gypsy moth, Japanese beetle, and cotton insects during the past several years. A conservative estimate of the needs on these and similar programs requiring aircraft guidance is 2 million acres per year. Aircraft would be the same as those mentioned in items 1 and 3 above.

5. Yearly costs for flagmen per acre and type of spraying (i.e., gypsy moth).

Flagging methods vary considerably from merely marking block corners to marking each swath with one to several flaggers. One cost study for the imported fire ant program indicated that the cost was approximately $.10 per acre.

6. Percent of time lost in not flying direct to plots.

This is normally not a critical factor; probably not over 20 percent.

7. Amount of total spraying in mid-continent region where there is presently no Loran C coverage.

Approximately 50 percent of the areas involved in our pest control programs do not currently have Loran C coverage.

We trust this information will be useful in your determinations and will look forward to additional discussions on radio guidance of agricultural aircraft.

Sincerely,

Harry J Moore

Harry J. Moore
Acting Staff Officer
Aircraft Operations

Lastly, in order to prepare our presentation, it is imperative that we receive your response to this memorandum by March 22, 1978. To facilitate this, I have structured the paper so that you can fill in underlined blank spaces in most of your estimating.

Sincerely yours,

Robert Wiseman

Robert Wiseman

Enclosure

5. Percent of service time, e.g.: (actual spraying time) saved with Loran-C in cases where aerial navigation is not required. For example, this saving would result from the elimination of retracing some swaths or respraying when inadequate spraying was identified.

6. Estimated percent of flying time saved from Loran-C enroute area navigation, site servicing, etc. in items 4 and 5 above. Express by aircraft type if applicable.

7. Estimated time to train pilots in the use of Loran-C (DOT/TSC estimates 4 days( and their average salary and overhead rates).

In order to facilitate the estimating process, abbreviated forms of the above categories are provided in the following pages. (Types of service may be combined when the estimates are similar):

A. Fire Ant Treatment

1. Average acreage treated: ______________ million acres.

2. Average Costs for present aerial navigation: ________ cents per acre

3. Number of aircraft, aircraft type, and costs of flight time:

   a. ________ of _________________ at $______ per hour

   b. ________ of _________________ at $______ per hour

   c. ________ of _________________ at $______ per hour

4. Average flight time to and from service site (mid-continent and other areas):___________ hours.

5. Percent of on site service time saved with Loran-C in cases where aerial navigation (flagman, Decca, etc.) not required: ___________%

6. Percent of total flying time saved in enroute and site servicing: _______%.

B. Grasshopper Treatment

1. Average acreage treated: __________ million acres.

2. Average costs for present aerial navigation: __________ cents per acre

3. Number of aircraft, aircraft type, and costs of flight time:

   a. ________ of _________________ at $______ per hour

   b. _______ of __________________ at $______ per hour

   c. ______ of ___________________ at $______ per hour

E. Cotton Insect Treatment

1. Average acreage treated: _________ million acres.

2. Average costs for present aerial navigation: ________ cents per acre

3. Number of aircraft, aircraft type, and costs of flight time:

   a. __________ of ____________________at $_________ per hour

   b. __________ of ____________________at $_________ per hour

   c. __________ of ____________________at $_________ per hour

4. Average flight time to and from service site (mid-continent and other areas):__________ hours.

5. Percent of on-site service time saved with Loran-C in cases where aerial navigation (flagman, Decca, etc.) not required: ___________%.

6. Percent of total flying time saved in enroute and site servicing: ______%.

F. Other treatments such as caterpillars, black grass bugs, West Texas boll weevil, etc. Please copy and fill in the above abbreviated forms where applicable.

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