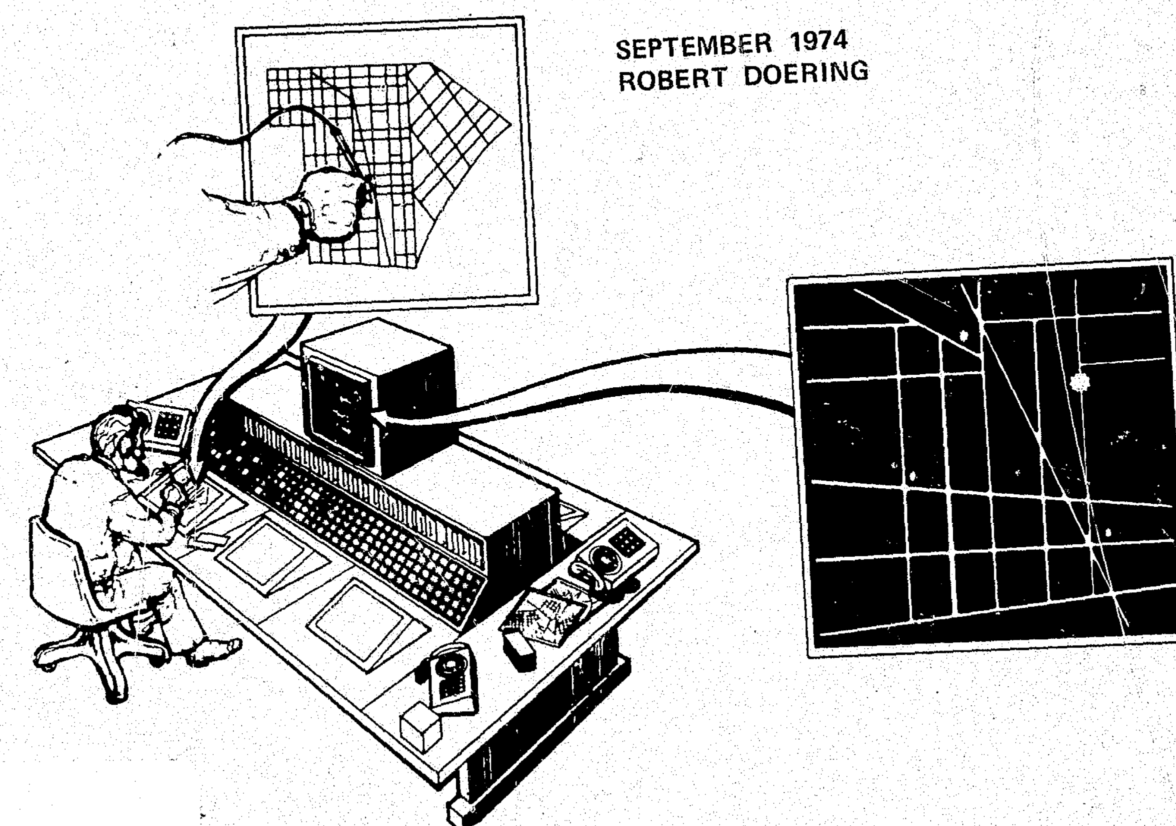
APPLICATION OF AUTOMATIC VEHICLE LOCATOR SYSTEMS IN POLICE OPERATIONS

SEPTEMBER 1974
ROBERT DOERING



PROCEEDINGS OF FIRST ANNUAL POLICE AND INDUSTRY CONFERENCE LAW ENFORCEMENT TECHNOLOGY

FLORIDA TECHNOLOGICAL UNIVERSITY

Sponsored By
BUREAU OF CRIMINAL JUSTICE PLANNING AND ASSISTANCE
TALLAHASSEE, FLORIDA

Proceedings

Of

Symposium , Sept. 10-11, 1974

APPLICATION OF AUTOMATIC VEHICLE LOCATOR SYSTEMS IN POLICE OPERATIONS —

September 10, 11, 1974

Florida Technological University

Orlando, Florida

Edited By

Robert D. Doering, PhD., P. E.

Associate Professor

College of Engineering

Sponsored By

Bureau of Criminal Justice Planning and Assistance

Tallahassee, Florida

SYMPOSIUM PROGRAM

TUESDAY, SEPTEMBER 10, 1974

10:30 a.m. - Registration - FTU Engineering Auditorium
- 12:00 noon
12:00 noon - Buffet Lunch - FTU Cafeteria
1:00 p.m. - Session I: Introduction to AVL Systems - Dr. Robert D. Doering, Chairman
1:15 p.m. - Welcome - Dr. Robert Kersten, Dean, College of Engineering, FTU; Director Robert Chewning, Division of Public Safety, City of Orlando
1:35 p.m. - Opening Remarks - Mr. J. N. (Nat) Cole, Law Enforcement Science Officer, Bureau of Criminal Justice, Planning and Assistance, Tallahassee, Florida
1:45 p.m. - Command/Control in Police Operations - Dr. David E. Clapp, IEMS Department, FTU
2:30 p.m. - AVL Systems Operations/Economics - Dr. Robert D. Doering, IEMS Department, FTU
3:30 p.m. - Break
3:45 p.m. - AVL System Field Test - Mr. Dennis Symes, Research and Development, Urban Mass Transportation Department, Washington, D. C.
5:00 p.m. - Adjourn
6:30 p.m. - Dinner/Address - Ramada Inn - Mr. George Shollenberger, Manager of Eqpt. Development, National Institute of Law Enforcement and Criminal Justice, LEAA, Washington, D. C.

WEDNESDAY, SEPTEMBER 11, 1974

9:00 a.m. - Session II: Operational AVL Systems - Session Chairman: Dr. Klaus L. Lindenberg, IEMS Department, FTU
9:15 a.m. - Proximity System LOCATES, Montclair, California - Mr. Robert B. Fleming, Vice President, Products of Information Systems, Costa Mesa, California
10:00 a.m. - Trilateration System, Philadelphia, Pennsylvania - Mr. Basil Potter, President, Metroscan Inc. (Sierra Research Corp.) Buffalo, New York
10:45 a.m. - Coffee Break
11:15 a.m. - Dead Reckoning System FLAIR, St. Louis, Missouri - Mr. Joseph Henson, Program Manager, Boeing, Wichita, Kansas
12:00 noon - Buffet Lunch - FTU Cafeteria
1:15 p.m. - Panel Discussion - Panel Members: Dr. R. D. Doering, Mr. R. B. Fleming, Mr. B. Potter, Mr. J. Henson, Dr. D. E. Clapp
3:00 p.m. - Break
3:15 p.m. - Resume Discussion
4:30 p.m. - Concluding Remarks - Dr. Klaus L. Lindenberg, IEMS Department, FTU
5:00 p.m. - Adjourn

Preface

This symposium on Application of Automatic Vehicle Locator Systems in Police Operations was the result of a study conducted during 1973-4 by the College of Engineering at Florida Technological University for the City of Orlando under LEAA Grant (No. 72-14-09) from the Bureau of Criminal Justice Planning and Assistance, Tallahassee, Florida. The objective of the study was to identify AVL devices and determine the feasibility of incorporating an AVL system into the Command/Control operations at the Orlando Police Department. Although addressed to a specific application, much of the information which was assembled in the Final Report had general application to other law enforcement and public safety operations.

Mr. James Nathan (Nat) Cole, Law Enforcement Science Advisor, Bureau of Criminal Justice Planning and Assistance, recognized the technology transfusion gain which could be effected by dissemination of this information. Accordingly in discussions with the Principal Investigator, Dr. Robert Doering and the Research and Development Officer, Lt. Bernard McCrystal, at OPD it was decided to propose a 2 day symposium during which the Report information of general interest could be presented to other law enforcement agency representatives. This plan was adopted with the enthusiastic support of Chief of Police James Goode and Robert J. Chewning, Director of Public Safety in Orlando. All Sheriff's offices and Municipalities with populations over 5000 within the State of Florida were invited to attend. In addition, major law enforcement agencies in the remaining other southeast states were encouraged to participate. Registration was without charge to the officials and their designated representatives.

The Symposium was held on 10, 11 September 1974 in the Engineering Building Auditorium on the Florida Technological University campus. Careful consideration was given to preparation of the schedule to encourage participation. The initial session was scheduled after lunch on the first day to allow time for those who might be driving from 200-250 miles away to reach the campus. Also the latter part of the closing session on the second day was an informal session. This permitted those most interested to pursue questions relating directly to their operations while those having to drive long distances could break away with a minimum of confusion.

The primary objective of the symposium was to provide public safety officials with current information and an understanding that would enable them to evaluate the potential advantages which AVL may provide in their operations.

Automatic Vehicle Locator (AVL) technology has matured to the point where it can automatically and continuously determine the location and status of vehicles within a given environment. Accordingly, AVL systems now appear to offer attractive possibilities for improving the effectiveness and/or reducing the costs in operating, police, emergency and service vehicles.

The symposium reviewed the recognized AVL techniques and how these technologies could be applied in various municipal and county law enforcement operations to establish a background in AVL systems for the attendees. This involved a discussion of Command/Control in police operations, the basic technology used in AVL systems and the potential economic and operational advantages which AVL can contribute.

The second day featured representatives from industry whose firms are presently engaged in installation of police AVL systems. Each presented a different technological approach to the problem- Proximity, Trilateration and Dead Reckoning, which they have developed. At the conclusion of these sessions, the meeting was opened to questions and comments from the floor with all speakers responding.

To reinforce the understanding gained by the attendees during the final part of the Symposium, Proceedings were prepared which contain the text of all papers delivered by the speakers. The Proceedings were furnished to all attendees without charge.

Acknowledgement and thanks are due those from law enforcement and industry who supported and contributed to this first Symposium on Application of Technology to Law Enforcement Operation. It is hoped that its success will permit it to be repeated on an annual basis, each year explaining a new phase of technology and how it can contribute to law enforcement.

DIGITAL COMPUTER SIMULATION OF COMMAND/CONTROL OPERATIONS

by

David E. Clapp, Ph.D.,P.E.
Assistant Professor of Engineering
Florida Technological University
Orlando, Florida 32816

Abstract

This paper describes a digital computer simulation study of the Orlando Police Department Command/Control System. The system operating procedures are described and a simulation model is developed closely patterned after the structure of the actual system. The collection of data from the actual system is presented along with results from a statistical analysis of that data. The data forms a basis for the execution of a digital computer simulation model under several proposed study conditions. These conditions include an examination of operations under growth conditions expected in the next decade, the impact of an enlarged complaint officer role, and a study of the effectiveness of an automatic vehicle locator system.

Introduction

This paper describes the results of a computer simulation study of the Command/Control System operated by the Orlando Police Department in Orlando, Florida. The study was motivated by the importance of the Command/Control System in police operations. The objectives of the study were to establish a valid computer model of the existing system operation. Given this model, an analysis was undertaken of the influence of the projected population growth of the region upon the system effectiveness in future years. Also, the feasibility of combining the complaint officer/radio operator was tested as a viable operating alternative. Finally, the feasibility of an automatic vehicle locator was examined toward discovering any improvements which might be realized in the actual system.

The presentation begins with a definition of command/control and its role in police operations. Next, the specific operation of the command/control system at the Orlando Police Department (OPD) is briefly described to introduce the actual structure of the operating system. Following this description, the computer simulation model is presented including a discussion of the collection and analysis of necessary data. The analysis of the collected data produced some important conclusions which are presented in summary form. Finally, the results of the computer simulation are discussed in the three areas:

1. The impact of projected rapid growth in the Central Florida area in the Command/Control System.
2. An analysis of the effectiveness of combining the functions of complaint officer and radio operator
3. The feasibility of an automatic vehicle locator in the Command/Control System.

Command/Control in Police Operations

Purpose and Importance

Command and Control is a term used to describe the activities associated with planning, directing and controlling operations. A Command/Control System, in turn, can be defined as "an organization of personnel and facilities to perform the functions of planning, situation intelligence force status monitoring, decision making and execution."[7] All management activities whether industrial, military, or law enforcement require some type of Command/Control System to perform these functions.

In most police departments, the Communications Center is the focal point of all public calls and other inputs to the system. The Center houses the personnel and equipment necessary to retrieve and integrate all information pertaining to routine or emergency situations and control and coordinate the men and equipment needed to respond to a given situation. Personnel stationed in a typical center include Complaint Officers and Radio Operators. The complaint officers receive the incident calls, assess the force status situation and assign the appropriate response. Radio operators, on the other hand, communicate with forces in the field. The communications system consists of an integrated network of radio circuits and land lines linking the Center with the public. Key components in such a system include phone lines, VHF/UHF radio and control console, teletype links to other agencies, a force status display board, and a computer information display terminal. In a computer augmented system additional capability may be provided to integrate all pertinent information on a complaint call with the nearest available unit.

Any Command/Control operation must have the inherent capability of rapid and complete information assembly, decision making and execution. In police operations, response time is keyed to the effectiveness of the Command/Control System. Here, response time is defined as the period from the receipt of a complaint call until a patrol vehicle arrives at the incident scene. Studies of the Los Angeles Police Command Control System[7] showed that the communications delay accounted for 30-50% of the total response time on emergency calls. It was further determined from the Los Angeles Police data that with a response time of less than 1 minute, 62% of the emergency calls ended in an arrest. As the response time was increased, the apprehension probability rapidly decreased and with a response time of 14 minutes only a 44% arrest probability can be expected.

Importantly, response time is affected by delays both in the Communications Center and in vehicle travel to the incident scene. This study addresses potential improvements in both phases of operations with principal emphasis on the communications function. A later study examines in detail the impact of an automatic vehicle locator (AVL) system in the improvement of vehicle dispatch operations. In the following section, the specific operation of the OPD Command/Control system is described.

OPD Command/Control System

The Command/Control Center for the Orlando Police Department reports to the Lieutenant in charge of the Records and Communication Section. This section is charged with providing an effective communications interface between the person calling for service and the field forces, between various units of the Department, and other law enforcement and emergency agencies. The Center is responsible for manning telephone, teletype, telegraph, computer terminal and radio communication facilities necessary to provide effective Command/Control communications capability within the Department. Thus, the unit has both an operational and technical orientation.

The organization structure consists of three operational areas--Complaint Desk, Radio Dispatch and Teletype as shown on the Organization Chart in Figure 1. Personnel staffing consists of both civilians and sworn personnel. Typically the Radio and Teletype Operators are civilians and the Complaint Desk position utilizes both sworn and civilian personnel.

The Command/Control Center Supervisor is responsible to the Lieutenant for the effective operation of the unit. The duties of this position include management functions such as planning, organizing, staffing, directing, and controlling. It is noted that the planning and organizing functions are unique in that the internal policies and operating procedures of the unit must directly reflect and complement the operational field forces procedures.

It is important to note that the Command/Control Center has been assigned functional authority in dispatching the field forces. This is necessary to preserve the unity-of-command principle which is essential for effective response. The line responsibility for response by the field forces however remains within the Uniformed Bureau and the watch or sector commander may modify a dispatch order based on his assessment of the field situation. When this procedure is used, the field commander must realize that he is interrupting the normal event chain and is now assuming responsibility for dispatch. He must ensure that he is aware of all service needs and can respond to them appropriately. He also has the responsibility to inform the Command/Control Center via the Radio Operator of the new dispatch assignments and that he is now returning fuctional authority to the Center.

Under the Supervisor in direct line command are the Complaint Desk personnel. When the Supervisor is not in the Command/Control Center, the responsibility of command rests with one of the Complaint Desk officers. In the general functions of the Command/Control Center, the Complaint Desk coordinates the Radio-Dispatch and Teletype operations to ensure a smooth orderly flow of information and assignments to the field units. Unusual telephone inputs or incidents are reported to the Supervisor or acting supervisor for disposition.

The Radio-Dispatch and Teletype Operators also report to the Supervisor. Each has direct responsibility within the total Command/Control function and must advise the Supervisor of unusual communications and/or incidents. Both Radio-Dispatch and Teletype interact with field forces and with the Complaint Desk. All broadcasts received from NCIC and FCIC must be approved by the Complaint Desk before Teletype can relay the information to Radio-Dispatch. This ensures that there is no unintentional repetition in information broadcast to the field units.

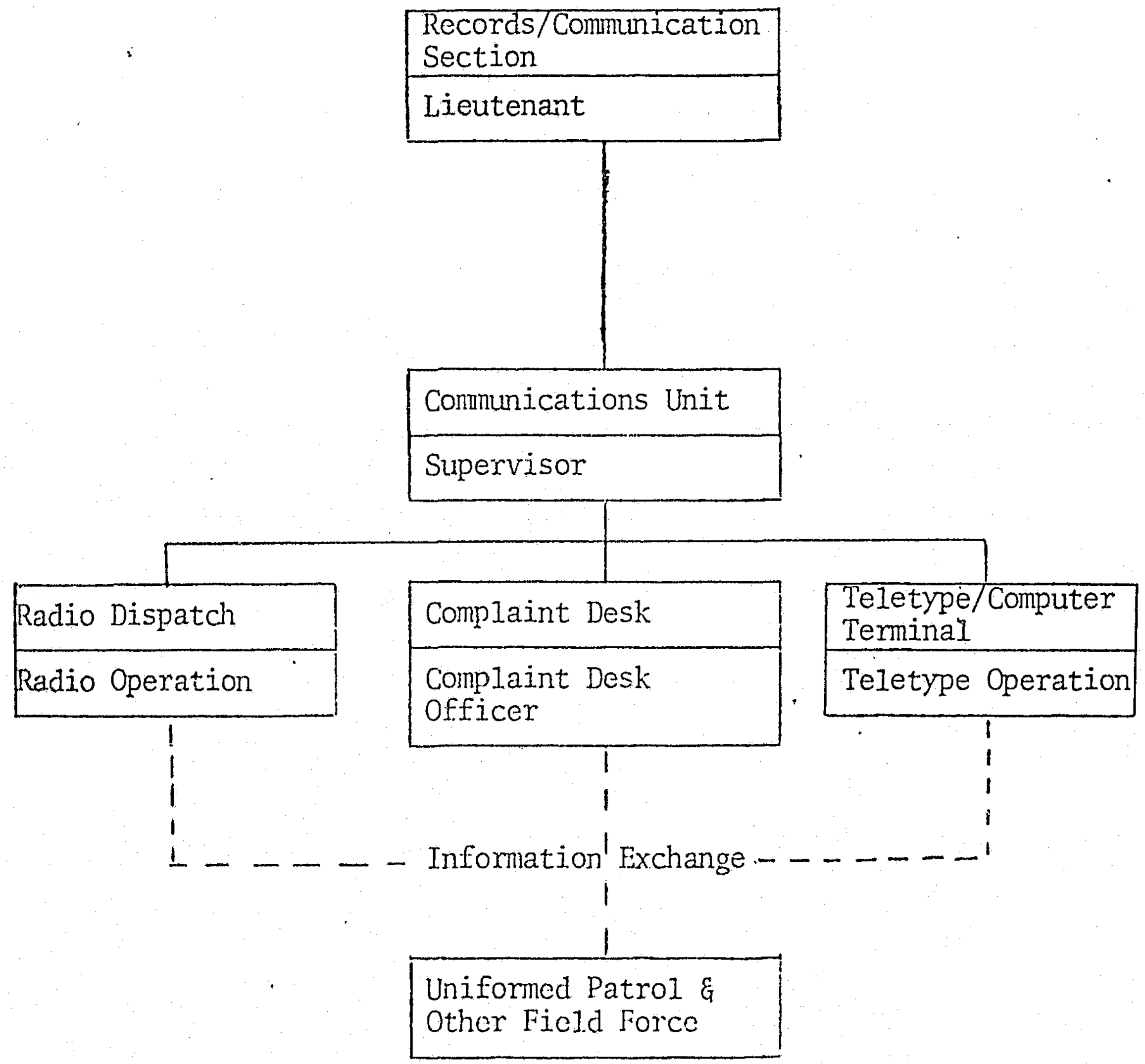


Figure 1. Organization chart of the Command/Control Center.

OPD Response Capabilities

The response of the Orlando Police Department is keyed to a district system. The City is currently divided into 18 Districts which have been designed such that the work load, based on number of incidents and serivce time requirements, is relatively equal. One uniformed patrol car is normally assigned to each district and is responsible for all complaint calls within that district. There are also four zone cars manned by Assistant Squad Leaders (ASL) who act as backup when required. All district cars are supervised by four squad leaders (Sergeant) who patrol each of the zones.

There are also special service patrol cars such as K-9 and traffic control which are used to handle special incidents. Two accident investigation cars, AI 42, AI 43, are available to handle traffic incidents. Investigative

and motorcycle units move in all districts but are dispatched to complaints only under emergency conditions. The primary assignment of the motorcycle units is traffic control and these units typically focus on traffic problem areas.

Under normal conditions the standard operating procedure is to dispatch the district patrol car to service a complaint which occurs within the district. If the primary car is unavailable the squad leader may move in to answer the call followed by special assignment cars, investigative and motor units generally in that order. Since the Communications Center does not have information on the specific whereabouts of field units, except within his assigned district, this appears to be the best method of operation; it assures primary and backup coverage for each complaint.

The Orlando Police Department averages 29 Uniformed Bureau patrol units per watch. The three shifts change at 6:30 am, 2:30 pm, 10:30 pm and are scheduled to provide a 30 minute overlap to assure continuous field coverage. Because of illness, vacations, or car repair, all patrol units may not be available for duty during the watch. This requires reassignment of the units to cover all districts.

OPD Complaint Officer Function

Telephone calls from the general public account for approximately half of all the calls answered by the Complaint Officer. The remaining calls are from other activities within the police department and other law enforcement agencies such as the Florida Highway Patrol and Orange County Sheriff's Department.

The general public calls the Police Department when it needs emergency aid, wishes to report a crime or suspicious activity, or many times simply desires information. In Orlando, the Police Department "emergency" number is on the front inside cover of all telephone directories and on every "marked" patrol unit. Dialing this number will automatically place the caller in contact with a Complaint Officer at the Command/Control Center. Although the caller may never see this officer, his very life could depend on the officer's decisions and actions. To this citizen the complaint officer is the Police Department; how he conducts himself over the phone will be equated with the actions of all uniformed police.

Until it is determined otherwise, a call to the Complaint Officer's desk must be considered an emergency. The call must be answered, information obtained, all requisite forms completed and a patrol unit dispatched if required, within the shortest possible time. How the information is obtained is based on training and experience, but the same general information is required of every incoming call before any decisions may be made.

The Complaint Officer must determine:

- Name and location and telephone number of the caller;
- Location of the incident;
- Nature of the call, that is, to report a crime or disturbance, to report an accident, or to request information;

- o Names of any involved persons;
- o Whether the call required immediate or emergency assistance, such as an ambulance.

With this information the Complaint Officer determines if the location of the need is within the Orlando Police Department jurisdiction, whether a patrol unit should be sent, an ambulance or other assistance should be dispatched, and if a case number for a permanent police record is required. These decisions may have to be made for all incoming calls, although the order in which they are made vary by Complaint Officer.

If a call comes into the Complaint Desk where the Orlando Police Department has no jurisdiction, the Complaint Officer may either record all the information and then relay it to the appropriate agency, or the Complaint Officer may interrupt and give the caller the telephone number of the appropriate agency if it is a non-emergency call.

If a call does require a police unit, the complaint officer will complete either a 602-09 or a 602-03 form. These forms summarize the information pertinent to the call and enable the complaint officer to indicate the patrol district and patrol unit to be assigned if available. The 602-03 form is completed whenever a patrol unit is required. The 602-03, however, has a sequenced record number in the top right corner and is completed when a police report file will be created on the incident. When either form is used, the time of day and date is electronically stamped on the card before it is deposited in a conveyor belt, which transports it to the Radio Operator.

Table 1 lists the Complaint Officer's responsibilities and shows that he has duties other than answering the telephone. All "messages" or "local-look-outs" must be approved by the Complaint Officer. This is done to minimize the broadcast of repetitive information on the field units. He is also responsible for informing owners of businesses where burglaries have been attempted, and notifing other law enforcement agencies of the incident which could effect communities outside of Orlando. He is the advisor as to which field unit to dispatch and the source of information to the field unit relative to pertinent information on the incident, such as the general mood of the caller. The Complaint Officer interfaces with all other functions within the Command/Control Center, the Orlando Police Department, other safety agencies and the general public.

TABLE 1

LIST OF FUNCTIONS PERFORMED
BY THE COMPLAINT OFFICER

- o MONITOR AND ANSWER ALL PHONE EXTENSIONS WITHIN A SPECIFIC NUMBER OF RINGS
- o ASCERTAIN NATURE OF CALL
- o ASCERTAIN JURISDICTION
- o DETERMINE THE NATURE OF ASSISTANCE REQUIRED
- o COMPLETE 602-03 OR 602-09
- o LOCATE DISTRICT IN WHICH REPORT PERTAINED
- o RECORD TIME RECEIVED AND TIME GIVEN TO RADIO OPERATOR
- o COMPLETE 602-03 FROM FIELD REQUEST
- o CONTACT RESPONSIBLE PERSONS OF BURGLAR ALARMS OR REPORTED B & E'S AT THEIR PLACE OF BUSINESS
- o NOTIFY LAW ENFORCEMENT AGENCIES OF SERIOUS CRIMES -
- o COMPLETE "LOCAL-LOOK-OUT" FORM FROM T/T OR PHONE INFORMATION
- o SIGN T/T "MESSAGE" FORMS FOR BROADCAST
- o CONTACT LOCAL NEWS MEDIA OF INFORMATION FOR BROADCAST TO PUBLIC TO ASSIST POLICE

OPD Radio and Teletype Operations

A continuous flow of information must be exchanged quickly and reliably between the Communication Center and Field Forces in order for the Command/Control System to operate effectively. The Radio Operator relays dispatch assignments and information to the Department patrol units and receives request for clarification and/or additional information via four channel UHF radio. Additionally this position can communicate via radio and direct telephone lines with other regional law enforcement agencies and fire and ambulance services.

Inputs to the Radio-Operator may originate from four sources:
- o A form completed by the Complaint Officer,
- o Monitoring the city wide alert channel,
- o A "message" from the Teletype Operator through the Complaint Officer, and
- o Field force requests via radio.

The actions by the Radio Operator keyed to the respective input sources are summarized in Table 2. These operational steps are designed to assign a patrol unit, investigative vice unit, K-9 or "motor" unit to the area of need as quickly as possible. To facilitate determination of the nearest available patrol unit a Force Status information system is used which indicates all units assigned on the particular watch together with their primary assigned district and their immediate status.

When a card is received via the conveyor belt, the Radio Operator checks the Force Status Board and calls the designated unit if available. The time at which the unit is called, and the time when the Radio Operator has completed transmitting the information to the unit are recorded on the form by time stamp. This card is then filed in the numbered slot corresponding to the number of the unit dispatched. This action causes a light keyed to the unit on the Force Status Board to change from green, which signifies the unit is available, to red, which signifies the unit is on a call and not available.

TABLE 2

FUNCTION RESPONSIBILITIES OF THE RADIO AND TELETYPE OPERATORS

RADIO FUNCTION	o OBTAIN 602-03
	o ASSIGN NEAREST FIELD PATROL UNIT OR UNITS TO INVESTIGATE REPORTED INCIDENT
	o RECORD DISPATCH TIME, UNIT ARRIVAL TIME, AND UNIT CLEAR TIME
	o PERFORM UNIT STATUS CHECK
	o MONITOR CHANNELS FOR UNITS REQUESTED CHANGE OF STATUS OR REQUESTING AID OF INFORMATION
	o RELAY INFORMATION TO THE FIELD UNIT AS REQUESTED
	o MONITOR STATUS BOARD TO KEEP IT ACTIVE
	o COMPLETE 602-03 PER UNIT REQUEST FROM FIELD FOR CASE NUMBER
	o MONITOR "INTERCITY" RADIO FREQUENCY AND COMPLETE "LOCAL LOOK OUT" FORM
	o BROADCAST INFORMATION FROM "LOCAL LOOK OUT"
	o SEND "LOCAL LOOK OUT" FORM TO COMPLAINT DESK
	o BROADCAST INFORMATION FROM "MESSAGES" TO ALL CHANNELS FOR ALL UNITS
	o RELAY BY PHONE IF FIELD UNIT REQUESTS SPECIAL UNITS (NON O.P.D.)
TELETYPE FUNCTION	o RELAY INFORMATION TO FIELD UNITS VIA CHANNEL 1
	o RECORD "MESSAGES" FROM T/T OR PHONE
	o SEND "MESSAGES" TO COMPLAINT DESK
	o BROADCAST VIA T/T TO OTHER LAW ENFORCEMENT AGENCIES INFORMATION REQUESTED
	o BROADCAST TO NCIC AND FCIC INFORMATION REQUESTS AND ANSWERS TO INFORMATION REQUESTS

When the unit arrives at the incident site it calls the Radio Operator and reports 10-6 or "at the scene". The Radio Operator then removes the form from the status file slot, stamps the time reported 10-6, and replaces the form in the status file. At the discretion of the Radio Operator, a status check of that unit may be instituted by calling the unit and determining if it requires assistance. A status check is recorded on the reverse side of the form. This status check is routine when an "in progress" crime call is answered or when an unusually long time has passed before the unit has cleared the scene. When the unit has completed the assignment it reports code 10-8 to the Radio Operator; this time is also stamped. The Radio Operator is also

notified when a unit requests a change of status. This may be instituted to indicate unavailability due to mechanical difficulty or investigation of observed suspicious activity, for example. When this request is made, a form with the unit number and location is stamped and put in the status file and the corresponding light for that unit shows red on the Force Status Board.

Input to the Teletype (T/T) Operator may occur from a Departmental field unit, the National Crime Information Center (NCIC) or the Florida Crime Information Center (FCIC). When a field unit request information, it calls on a UHF channel, other than the dispatch channel, directly to the T/T Operator. If T/T Operator has the requested information on file, the response is immediate. A query is always made as to NCIC and/or FCIC and the results transmitted via radio to the unit by the T/T Operator.

NCIC and FCIC also communicate to all law enforcement agencies information on stolen items, persons wanted and other pertinent information. The T/T Operator receives this information, updates the appropriate files and relays the pertinent information to the Complaint Desk, or other Bureaus as appropriate.

Computer Simulation Model

Model Construction

The criteria used for the selection of an appropriate computer language to be used for a given simulation model involve several interlocking considerations. Perhaps the foremost of these is the inherent suitability of the language for implementation of the particular set of operating data and structural information available for the system under study. In the case of the Orlando Police Department Command/Control System project, a detailed flow chart of the operating procedures has been developed previously to support the computer work. In addition, statistical data in the form of means, standard deviations, and graphical distributions had been developed for the various times associated with the operation of the Command/Control System. These two factors suggested the use of a block-oriented simulation language to minimize the programming effort required to achieve a working model. Such language was available in the IBM GPSS/360 and this system was used for all subsequent computer runs on this project. GPSS/360 is one of the so-called user-oriented languages. This means that much of the internal operation of the program is transparent to the user of the language, and the analyst can construct a simulation model simply by selecting one language element, or command, for each block in the flow chart of the real-world system.

Consider the flow diagram in Figure 2. It represents a summary of the basic simulation logic used in the computer simulation model. The block along the left of the page represent activities in the servicing of a typical call through the Command/Control System. Calls arrive at the system according to some pattern depending on such factors as the time of day, the present level of criminal activity in the community, the weather, etc. Complaint Desk clerks answer the phones, gather the information as to the location and severity of the incident being reported, and if necessary, generate an Orlando Police Department form 602-03 or 602-09 for subsequent Radio Operator use.

Information-only requests and other calls not requiring field unit attention are not documented on a form. A conveyor transports the completed forms to the Radio Operator who in turn contact the appropriate field unit to service the call by consulting the duty roster and field unit assignment map board. The field unit assigned to a particular call must then travel to the location of the request and perform any necessary investigative and action services. When this processing is completed, the calls are removed from the system by the Radio Operator.

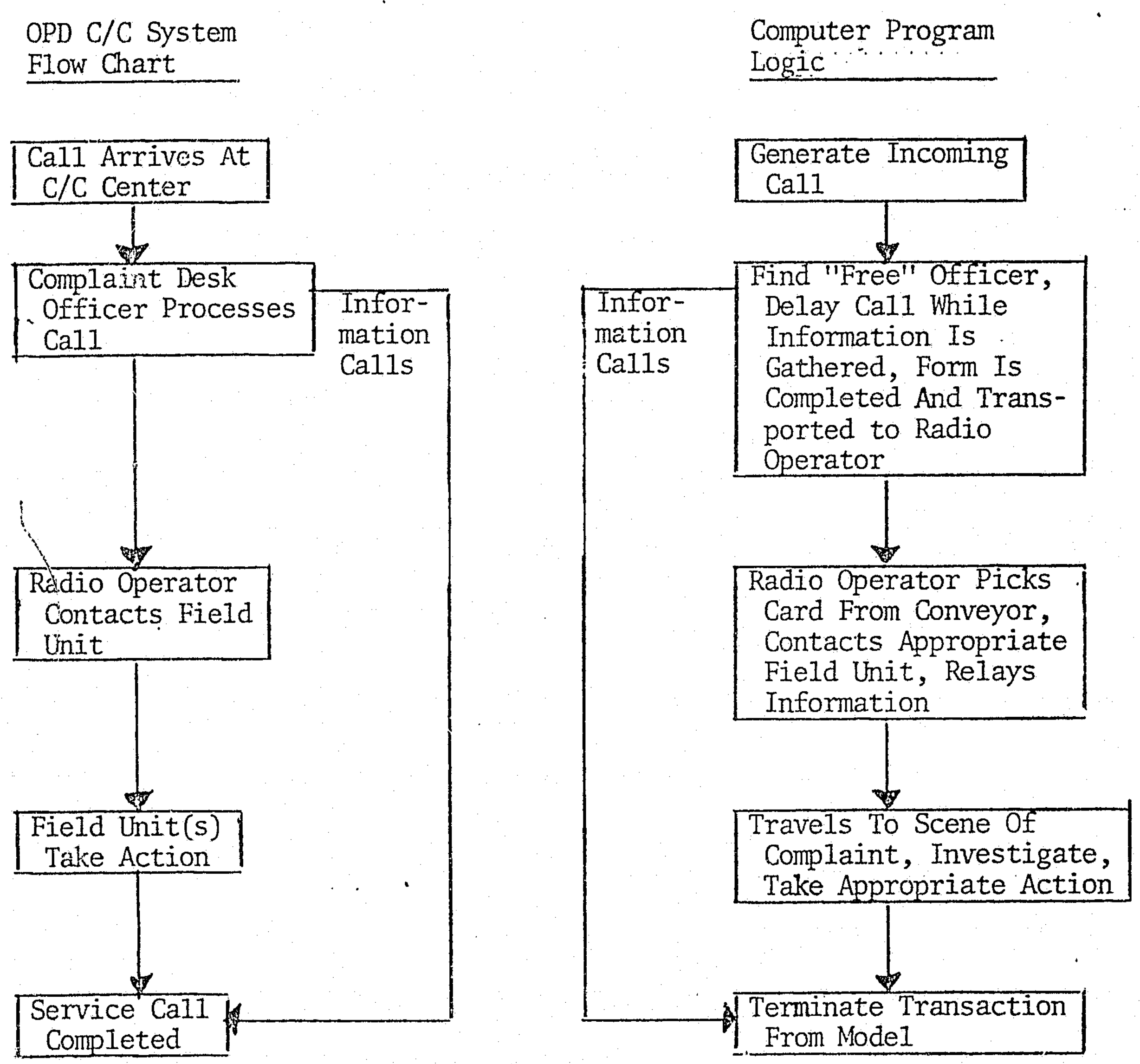


Figure 2. The comparison of GPSS/360 Program Logic Blocks to Flow Chart of actual system.

The corresponding system operation in the computer model is accomplished by the use of program devices called "transactions". These may be thought of as individual calls passing through the system. The computer uses statistical call arrival information from the real system to produce service requests at random intervals from the "generate" command. The resulting transactions pass through the remainder of the model just as the service calls would pass through the actual system, e.g., when a transaction passes through a Complaint Desk officer, it encounters a time delay determined by statistical sampling of the time delays encountered by real-world service calls at the complaint desk. This correspondence of model/system activity is maintained throughout the simulation process, and thus allows statistical data observed from observing and timing on transactions to be used to predict these numbers for calls passing through the actual system. Along with these statistics, GPSS/360 simultaneously generates output statistics on the performance of structural components of the model, e.g., the percentage of time during an eight-hour shift that a unit was "busy".

Data Collection

To generate representative behavior in the simulation model, actual data was collected from the operating system. Key elements were identified for the collection of time lapse data. The choice of these elements was determined by four factors: ease of measurement, completeness of the operation times, independence from other elements and the total of all the elements must be representative of the entire operation.

It was important that the elements chosen be easily measured. The data logging was to be accomplished by Orlando Police Department trainees who were not familiar with engineering time study techniques. Prior to their assignment they were instructed in a special class in continuous stopwatch techniques. In addition, special data forms were designed to facilitate actual data logging and minimize confusion of the trainee.

The initiating point of each timed element must have an audio or visual cue and a clear and unmistakable termination so that personnel taking the data can accurately measure the elapsed time. Each element must measure one specific activity subset of activities in the total operation which must be completed before another begins. In this manner each element is independent of preceding elements so that the summation of timed elements will actually describe the total operation of the Command/Control System.

To analyze the Complaint Desk operation three elements were timed. These were designated "D1", "ANFO", and "F1". They measure, respectively, the time delay in answering the telephone, the time necessary to gather all required information as well as the decision time and finally, the time to complete the appropriate form given that one is required. The element "RAD" is a measurement of the travel time for the form to reach the Radio-Operator and an information recheck time used by some Complaint Officers prior to placing the form in the conveyor. The elements separating each of these parameters is either an audio cue, such as a teletype ring or electronic stamp, or the visual cue of the telephone receiver at the ear of the Complaint Officer.

Three elements were also used to time the Radio-Dispatch function. The "D2" parameter indicates the time delay once the form is available to the Radio-Operator and the time for the unit assignment decisions. The total time for the Radio-Operator to give the information to the field unit was measured by parameter "CALU". The last parameter which is a measure of the Radio-Operator is "D3", the delay time occurring from a unit Status Check. The audio cues for the elements defining these parameters were principally the voice of the Radio-Operator calling the assigned unit.

The three remaining parameters are "TRVL", "ANV1", and "ANV2" which are a measure of the time for the assigned unit to travel to the location of need and the investigation time required to clear the incident. The audio cues are the electronic time stamp when the Radio-Operator records the 10-6 time and 10-8 time in the appropriate locations on the Complaint Card.

A maximum of ten elements were timed and subsequently analyzed statistically. The number of parameters that will be timed for any given call, depends upon the type of form completed at the Complaint Desk.

TABLE 3

ACTIVITY ELEMENTS SELECTED FOR STATISTICAL ANALYSIS

Element Number	Name Assigned in Computer Program	Element Description
1	D1	Time delay in answering telephone.
2	ANFO	Information gathering and decision time for telephone call.
3	F1	Total time to complete the necessary forms if one is required.
4	RAD	Travel time or delay in completed form reaching the Radio-Dispatcher.
5	D2	Radio-Dispatcher delay in assigning unit.
6	CALU	Unit information gathering time from Radio-Dispatcher.
7	TRVL	Unit travel time to address given.
8	ANV1	Investigation time.
9	D3	Status check delay time.
10	ANV2	Investigation time.

Raw data on 8710 randomly selected inbound telephone calls was recorded from February 28 through March 31 and from May 15 through June 30, 1972. This data was reduced statistically to obtain information which could be used in the simulation.

Initially the elapsed time for each element was determined by subtracting the times of the two defining event elements and recording this on the Time Study Sheet. The resulting data was transfered to computer cards where each line of the time study sheet represented a timed telephone call. A special computer program was then used to determine the mean and standard deviation for each parameter by day of week, by shift and by total time to 10-6 and to 10-8.

The results of the computer analysis for all sample data is shown in Table 4. The two investigation elements ANV1 and ANV2 were combined to give a more accurate description of total time involved. The status check delay time "D3" occurred so infrequently that these statistics were omitted. The mean standard deviation and sample size for all other parameters by day and by shift are shown. The smallest sample size (74) occurs in the cell "Investigation Time" on Saturday. Although this sample is relatively small, it is statistically significant. The population parameters μ and σ are approximated by $\bar{\bar{x}}$ and $s_{\bar{\bar{x}}}$ shown in the "Total" row. Each was determined using the formulas:

$$\bar{\bar{x}} = \sum_{i=1}^{N} \bar{x}_i \Big/ N \quad \text{and} \quad S_{\bar{\bar{x}}} \sum_{1}^{N} \sqrt{\frac{\sum_{i=1}^{n} (x_j - \bar{x})^2}{(n-1)}} ,$$

where n = sample size
N = number of samples

Analysis of $S/\bar{\bar{X}}$ ratios indicates relatively flat distribution for all parameters. If each day of the week is assumed to be a separate sample, the range of the $\bar{x}$'s for each parameter are closely grouped and normally distributed about the corresponding $\bar{\bar{x}}$. It is noted that in at least one entry for each parameter the standard deviation is much larger than the other values by day of week, and therefore dominates the estimate of the population standard deviation, $S_{\bar{\bar{x}}}$.

TABLE 4

DESCRIPTIVE STATISTICS FOR TIMED ELEMENTS BY DAY OF WEEK AND WATCH

Day of Week / Shift		Response Time to Ring of Phone mins.	Information Gathering Time mins.	Form Completion Time mins.	Travel Time To Radio Operator mins.	Radio Operator Delay mins.	Unit Response Delay mins.	Travel Time To Get To Area mins.	Investigation mins.	Total Time to 10-8 mins.	Total Time to 10-6 mins.
MON	$\bar{X}$	.047	.924	.945	.373	.822	.392	4.535	14.851	22.890	8.039
	S	.039	.935	1.118	.511	1.532	.457	3.588	17.146	17.658	4.221
	N	893	885	206	198	188	164	161	110	896	896
TUES	$\bar{X}$	.046	.913	.894	.459	.649	.432	4.943	17.244	25.582	8.338
	S	.031	1.038	.797	.679	.908	.600	3.525	16.568	17.038	3.973
	N	1507	1497	300	287	270	238	220	118	1507	1507
WED	$\bar{X}$	.053	.911	.900	.597	.872	.402	4.800	13.948	22.483	8.535
	S	.110	1.007	1.941	.772	1.402	.428	3.349	11.533	12.320	4.330
	N	1513	1496	265	248	239	218	199	100	1515	1515
THUR	$\bar{X}$	.052	.864	.825	.504	.709	.416	4.602	17.357	25.329	7.972
	S	.050	.964	.880	.631	1.120	.421	3.219	15.240	15.689	3.729
	N	1297	1284	242	229	216	190	182	92	1301	1301
FRI	$\bar{X}$	.086	.914	.985	.328	.764	.466	4.785	15.580	23.908	8.328
	S	.094	1.084	.724	.496	1.054	.590	3.509	18.199	18.665	4.146
	N	1333	1316	229	220	215	198	180	77	1333	1333
SAT	$\bar{X}$	.054	.997	1.112	.380	.574	.372	4.146	15.307	22.943	7.635
	S	.063	1.037	.885	.563	.755	.514	2.905	18.358	18.667	3.384
	N	1210	1225	212	205	190	179	163	74	1233	1233
SUN	$\bar{X}$	.051	1.094	1.020	.421	1.010	.496	4.421	17.524	26.036	8.513
	S	.048	1.291	1.093	.562	2.033	.806	3.175	16.198	16.776	4.364
	N	923	910	183	184	175	167	153	88	924	924
1st Shift	$\bar{X}$	.077	.945	1.105	.524	.830	.413	3.993	13.958	21.845	7.888
	S	.994	1.121	.988	.749	1.399	.451	2.883	15.958	16.398	3.775
	N	1993	1973	353	341	321	316	288	174	1995	1995
2nd	$\bar{X}$	.050	.859	.891	.379	.657	.421	4.984	18.506	26.747	8.241
	S	.061	.954	1.379	.523	1.313	.675	3.512	18.606	19.073	4.195
	N	3177	3145	625	618	588	504	478	207	3181	3181
3rd	$\bar{X}$	.049	1.004	.915	.464	.837	.436	4.658	15.378	23.741	8.363
	S	.043	1.088	.933	.633	1.200	.484	3.381	14.057	14.634	4.070
	N	3506	3495	632	612	584	534	492	278	3533	3533
TOTAL	$\bar{X}$	.056	.945	.955	.438	.772	.425	4.605	15.973	24.167	8.194
	S	.120	2.796	2.959	1.611	3.494	1.480	8.815	43.178	44.458	10.431
	N	7	7	7	7	7	7	7	7	7	7

Observations Resulting from Statistical Analysis

A number of observations resulted from collecting and analyzing the operational data. These observations are summarized to include:

- Almost half (49%) of all 602-09's completed by the Complaint Desk personnel are a result of interdepartment communications. An example would be a personal request that a officer or field assignment call the originating party. It appears this type of traffic could be received and handled by the Bureau watch commander. If it affected the status of the field unit, he would so notify the center by radio or callbox.

- In addition 79% of all interdepartment calls handled at the Complaint Desk do not require subsequent action. These are information queries and could be answered by the Information Desk Sergeant.

- 64% of all calls from other agencies result in no Orlando Police action. This indicates that the information pool among Police agencies within the immediate area must be upgraded.

- 46% of all calls to other agencies made by the Radio Operators are a result of no Police activity, since any telephone activity concerning Police business must be as a result of a 602-09 or a 602-03.

- Further, of those calls from the public requiring processing by the Complaint Desk Officer, only 45% result in a patrol unit being dispatched. It appears that the Public expects more service and is prone to upgrade an incident beyond what it actually requires. It is realized however, that this situation cannot be readily changed and the Complaint Office must continue to respond to these calls.

- There is no significant difference in response time performance of the Command/Control Center by day of week or by shift. This indicates an uniform operation not subject to differences of day or shift.

- The Time To Answer Phone Variable DL has a flat distribution. The Complaint Desk personnel answer 73% of the calls within three rings or 0.13 mins.

- The Information Gathering Time Variable ANFO is characterized by a flat distribution. However, the mean and standard deviation for a 602-09 and a 602-03 are $\bar{x} = 0.73$ and $s = .74$ and $\bar{x} = 1.014$ and $s = .786$ respectively. Both of these distributions are considerably more peaked indicating that, once the decision to dispatch a unit has been made by the Complaint Officer, a routine of information gathering is followed. A longer average time for a 602-03 is indicative of the additional information required by the form.

- The Form Completion Time Variable F1 has a mean and standard deviation for a 602-03 greater than that of a 602-09, indicating a longer time required to complete a 602-03. This parameter is also a good indication of time which under present operation is wasted due to work duplication. In a great many cases F1 time is information transfer time. The appropriate work was not being completed while the caller was still on the telephone. This is an indication of improper procedure since most of the F1 time could be eliminated by completing the required form while gathering the information.

- The Travel Time To Radio Operator RAD is governed by the belt speed of the card conveyor. Typically .12 min. is required for the card to reach the Radio Operator's station. The remaining 0.32 min. is spent double checking the information on the form. The extremely large standard deviation would indicate poor procedures in completing the form, that is, no consistent pattern is followed when completing a type of form.

- The Radio Operator Delay D2 has a relatively high mean time and indicates the decision process of assigning the nearest available unit. the very high standard deviation indicates high traffic on the radio, as well as, a delay in recognizing a form is in the conveyor belt. Better designed work station would greatly reduce both the mean and standard deviation of this parameter.

- The Unit Response Delay CALU includes both transmission time and delay in unit response. The use of "10 codes" and signal codes should convey all pertinent information including the address within .25 min. The additional time is dead air time awaiting the unit reply to the call by the Radio Operator. The relatively large standard deviation indicates congested air traffic, repetition of information and delay of the unit to respond to its initial call.

- The Travel Time To Get To Area TRVL shows no significant difference in the mean by shifts which indicates traffic conditions are not the primary delaying factor but rather the units relative location within the patrol district. The average travel time per call could be significantly reduced by a car locator system and possible realinement of the patrol districts.

- Investigation Time ANV1 has a uniform distribution whose mean is dependent upon the nature of the investigation. However, possible procedure changes are indicated because the function of the patrol unit is to patrol. When a unit is detained for up to one and one half hours with investigations another unit must cover that patrol area.

- The 602-03 total response time to 10-4 is $\bar{\bar{x}} = 3.72$ and $s = 2.11$ mins. 54% of the mean time is involved with gathering the information and transferring to the 602-03 form.

- The 602-03 total response time to 10-6 is $\bar{\bar{x}} = 8.19$ and $s = 10.56$ mins. 55% of this average time is unit travel time.

- The 602-03 total response time to 10-8 is $\bar{\bar{x}} = 24.17$ and $s = 44.45$ mins.

- The 602-03 unit response time (time from unit called by Radio Operator to time reported 10-6) is $\bar{\bar{x}} = 5.27$ and $s = 3.39$ mins.

- Variables D1, ANFO, F1, D2, CALU, and TRVL have the desired characteristics of a Type I or α error less than 10% and a Type II or β error such that the mean of the parameter will not be less than 10% of the population mean more than 10% of the time.

- Variable D1 has the desired characteristics of both α and β errors are less than 10%.

- The grand mean $\bar{\bar{x}}$ for each parameter is the "standard time" for that parameter. Therefore, the work load of the Complaint Desk personnel may be evaluated and staffing by work load could be realized.

System Response to Projected Requirements

Statistical projections relating to Orlando population data indicate additional service call input activities of 30% and 80% in 1976 and 1980, respectively, over current levels. The Command/Control System simulation model was used to evaluate system performance for the present system for all three cases. In addition, alternate systems with car locator capabilities and geographically-oriented complaint officer/radio operator stations were tested with the model. The basic results of this testing are presented herein, and should be considered preliminary and tentative at best, requiring additional computer runs and analysis before committing Orlando Police Department resources to implement these new concepts on an operational basis.

Analysis of the computer model runs for the present system indicates that the Command/Control System is operating well within its capabilities for handling service calls during "normal" operating conditions, and "fails-soft" or starts to become unacceptably loaded in field unit utilization by 1980. For example, individual field unit "precentage busy time over an 8-hour shift" data from the simulation runs projected numbers in the 70% range in several instances. This result should be studied and confirmed as it indicated a potential need for additional field patrol units by 1980. It should be noted that the model can answer projected resource requirement questions such as how many additional cars are needed in 1980 by making repeated runs with varying levels of resources, and comparing the resulting predicted values for the system operating parameters with the predetermined management goals for these conditions.

The project time frame did not allow the experimentation necessary to model system saturation, e.g., the case where all system components are buried for extended periods of time. However, the normal input rate for calls entering the system was doubled for all shifts for one series of runs to test what has been termed the "Heidi Effect." This generic name refers to a recent television network decision to suspend broadcasting of a professional football game to allow a children's program to be seen at its scheduled time, resulting in a temporary public reaction of telephoning public agencies such as police departments to express their dissatisfaction. The term has come to mean any situation which causes similar call generations to occur, for example, the occurrance of a sonic boom over a populated area. The model response to this stress condition was primarily seen in the extreme waiting time for calls processed in Command/Control center. This resulted in an increase in system call processing time of up to 2 minutes. This condition peaked at 10 minutes after onset of stress condition and call processing returned to normal approximately 15 minutes after removal of the stress condition. The stress environment was designed to last 30 mintues. Field unit responses were not affected materially, as would be expected.

Combined Complaint Officer/Radio Operator

In the earlier discussion of operational statistics it was shown that only 43% of all calls handled by the Complaint Desk result in Police action. On an average day, 423 calls answered by the Complaint Desk could be handled as an information call by the Desk Sergeant.

It is observed that the Complaint Desk station exists primarily for information gathering purposes. Once recorded, the information must again be assimulated by the Radio Operator so that it can be communicated to the Field Units. This suggests that it may be feasible to combine the Complaint Desk and Radio Operator stations in order to expedite and improve the communications link in the System. In essence this is the configuration used during the emergency mode when the Radio Operator monitors the Complaint Desk call as it progresses. Accordingly two operating configurations both of which combined the functions of the Complaint Officer and Radio Operator were developed and evaluated by computer simulation. This proposed operational unit consisted of four complaint-dispatch personnel each having responsibility of gathering the information for unit assignment in one quadrant of the City. This also required assignment of one radio channel to each station. It is noted that the personnel manning these stations must be well trained in the proper procedures of information gathering and dispatch.

In the first alternative, one additional Information Desk Officer was used to answer all incoming calls. His function was to quickly determine the type of call and which quadrant of the City the reported incident occured so that it could be transferred to the Complaint-Dispatcher for that quadrant for processing. Only those calls which require police action would be forwarded to the Complaint-Dispatcher. Information type calls would be screened and transferred to the Information Desk Sergeant. Clearly the officer screening the calls must be well qualified and experienced to ensure minimum delay in assigning the proper Complaint-Dispatcher.

The second alternative evaluated was the same as the first except two screening officers were used to prevent any delay in answering the incoming calls. Both alternatives were evaluated against incident rate projected for 1972, 1976 and 1980.

The quadrants of the City were determined by dividing City North and South by Central Avenue and East and West by I-4. Table 5 summarizes the data for the two alternatives against the capabilities of the present system through 1980.

The response time of the Command/Control Center under the persent system shows no significant increase in 10-4 process time through 1980. In each of the alternatives, the process time increases with the most significant change occuring in the Alternative 1. By 1980 the 10-4 time of the Alternative 1 is 0.8 minutes longer than the projected 10-4 time of the present system. Alternative 2 shows only a slight increase in process time, and is substantially longer than the present system. If just the total time to process the calls is the decision criteria, the Alternative 2 offers a significant advantage over the present system.

A more detailed analysis of the queues developed by Alternative 2 however shows some disadvantage to this system. The total number of calls which must wait either because the two screening officers are busy or the appropriate quadrant dispatcher is busy, is twice that of the present system by 1980. The duration of the delay is also greater than the present system in all cases.

TABLE 5

COMPARISON OF TIME TO 10-4 FOR ALTERNATIVES COMBINING COMPLAINT OFFICER/RADIO OPERATOR FUNCTIONS WITH PRESENT SYSTEM

Year	Present System	Alt. 1 One Screening Officer	Alt. 2 Two Screening Officers	Total Time For A Call In A Queue To Receive Action		
				Present	Alt. 1	Alt. 2
1972	3.13 min.	3.15 min.	2.72 min.	1.09*	1.89*	1.16*
1976	3.11	3.81	2.76	1.06	2.74	1.49
1980	3.06	3.84	2.82	.98	2.76	1.70

*Minutes.

The two alternative systems exhibit marginal improvement in 10-4 time over the projected present system by 1980 such that the addition investment in communications consoles could not be justified. The present system is very workable up through 1980 and a reduction of 10-4 time can probably be realized more readily by intensive training of the Complaint Desk Personnel.

Feasibility of an Automatic Vehicle Locator System

Continuous force status monitoring is typically one of the most effective methods of improving the Command/Control operation since it provides a dynamic display of information combining offense locations and displayment/availability of patrol units. Without the aid of a vehicle locator system, the Orlando Police Department dispatching procedure requires that a patrol unit operating in as assigned district be dispatched to an emergency call if it happens in his district. If he is unavailable alternate units from adjoining districts may be dispatched. The weakness of this system is that there is a relatively high probability that a unit in an adjacent district may be closer than the assigned district unit. To overcome this problem the Radio Operator may query all units in the vicinity and dispatch accordingly; however, this would delay the 10-4 response and introduce considerably more radio traffic.

There are a number of vehicle locator system designs which may be applicable. Each has inherent performance capabilities which depend on the operating environment and sensor subsystem used in the design. Consequently, a system analysis is a primary requisite to identify the most cost effective system for a specific police application. For the purposes of this study, however, only the accuracy requirement is important since a number of systems are available. Studies presented in the Science and Technology Task Force Report[7] showed that almost all value of a locator system was obtained with a specified accuracy of 0.2 mile. This work also presented the relationships between AVL system accuracy and the average extra patrol unit distance traveled. This information was incorporated in the simulation model to represent the effect of an AVL system with 0.2 mile accuracy on the operations of the Orlando Police Department Command/Control System.

The quantitive evaluation was based on a comparison of average travel time delay with and without AVL system at varying incident loadings representing 1971, 1976, and 1980. The travel time in each case was obtained as the difference between the 10-6 and 10-4 times generated by the computer simulation model. The resulting data is presented in Table 6.

Since the number of simulations were limited by the computer funding available, the data has been presented as a distribution of values. This permits a better evaluation of the results based on a statistical confidence level. The mean system travel time is bracketed by the 90% confidence limits. Comparing the travel time for the Basic and AVL augmented systems generates values at maximum and minimum predicted travel time which may be saved as a result of incorporating the AVL system. The data presented represents output from three computer simulation runs each using a different incident demand rate as noted earlier.

TABLE 6

COMPARISON OF PREDICTED TRAVEL TIMES WITH AND WITHOUT AUTOMATIC VEHICLE LOCATOR SYSTEM

	Base Travel Time Min.	AVL Travel Time Min.	Travel Time Saved Min.	Improvement %
Min. (5%)	3.52	3.24	.28	8.0
Mean	4.12	3.85	.27	6.6
Max. (95%)	4.72	4.46	.26	5.5

Considering the summary data, it is safe to conclude that at least 0.26 minutes travel time can be saved by use of a AVL system with the present district assignment operations. As the City expands it can also be expected that this predicted improvement in travel time will improve markedly. The reduction in travel time which the AVL might thus afford translates to a percentage improvement of between 5.5% and 8.0%.

It is noted that this analysis includes all response incidents. The largest improvement would probably occur in the lower priorty incidents since emergency incidents are typically answered by at least the nearest available patrol unit which arrives first regardless of its apparent position to the

dispatcher. However, this typically results in extra units converging on the site which would be more effective remaining on their own beats or being strategically deployed along likely escape routes, especially in event a chase is anticipated. The AVL also affords additional safety for the field officers since the Communications Center has information at all times on the patrol unit location. Additionally the AVL system can be equipped with an "Officer Needs Assistance" signal device which the officer can use to unobtrusively summon help in an emergency.

Conclusions

This study has shown the value of a computer simulation study of Police Command/Control systems. The advantages of experimentation with a computer model of a system rather than the real system are significant and include:

1. The real system can be accurately represented in a computer model through the selection and collection of representative data.

2. A wide range of experiments may be formulated and tested with a simulation model without disturbing the actual system.

3. The effects of operations over an extended period may be tested in a short period with a computer model. For example, a year of police operations may be analyzed in a few seconds of computer time.

4. The cost of testing alternatives with a computer model are far less expensive than experimenting with the actual system. Although computer time is expensive, the costs of extensive alternative testing is modest when compared with the costs of organizational and operating changes in the actual system.

The computer simulation results included in this paper have shown that the Command/Control system in the Orlando Police operation is reasonably effective and should be able to handle a reasonable increase in activity produced by anticipated growth in the Central Florida area. The analysis of a combined complaint officer/radio operator function has shown only marginal improvement over the present operating system and is not recommended as a cost effective alternative. The use of an automatic vehicle locator (AVL) in Command/Control systems, on the other hand, shows great promise. The results of this study may only be classified as preliminary, but an AVL system is certainly feasible and may serve to moderate the effects of anticipated growth in this regional area. The significance of the AVL results has led to an additional, expanded study of the OPD Command/Control system which is reported in a separate research effort.

The requirement for analyzing the existing system as well as collecting pertinent data has been an important by-product of this research. The data collection section of this paper includes comments which have arisen from observations of the collected data as well as study of operating methods. These observations suggest a wide range of improvements which may be instituted to improve the system operation. Perhaps a principal by-product is the importance of the Complaint Desk Officer. This officer essentially controls the effective deployment of police resources and is a key element in effective police operations. The occupant of this position should be carefully selected and trained and the position should receive the focus of management attention. Toward this end, a future research project is planned which will produce a Complaint Desk Officer Training Model to insure effective and constant training of individuals occupying this position.

References

1. Bussard, D. L. Los Angeles Police Department Operations Simulation TP. 69-16-29. Fullerton, California: Hughes Aircraft Company, Ground Systems Group, August, 1969.

2. Churchman, C. West, Ackoff, Russell L. and Arnoff, E. Leonard. Introduction to Operations Research. London: John Wiley & Sons, Inc., 1957.

3. Clapp, D. E., Doering, R. D., Steinberger, E. A. and Strumpler, K. R. "Engineering Management Methodology Applied to Police Department Operations." Police. June, 1972.

4. Doering, R. D. A Statistical Study of Orlando Police Department Operations. Report to the Administrative Services Bureau, Orlando Police Department, Orlando, Florida, April, 1971.

5. General Purpose Simulation System/360 User's Manual. H20-036-2. International Business Machines Corporations, 1968.

6. Hughes Aircraft Company. Design Study and Master Plan for an Improved Command/Control Communications System Serving the Emergency Service Departments of the City of Los Angeles. Springfield, Virginia: National Technical Information Service, January, 1971.

7. Institute for Defense Analysis. Task Force Report: Science and Technology. Washington, D. C.: President's Commission of Law Enforcement and Administration of Justice, 1967/

8. Maisel, Herbert and Gnugnoli, Giuliano. Simulation of Discrete Stochastic Systems. Chicago: Science Research Associates, 1972.

9. Miller, Irwin and Freund, John E. Probability and Statistics for Engineers. Englewood Cliff, New Jersey: Prentice Hall, 1965.

10. Surkis, Julius, Gordon, Gilbert R. and Hauser, Norbert. "A Simulation Model of New York Police Department's Response System." Digest of the Second Conference on Application of Simulation. December, 1968.

AUTOMATIC VEHICLE LOCATOR SYSTEM ORLANDO POLICE DEPARTMENT

by

Robert D. Doering, Ph.D., P.E.
Associate Professor, Engineering
Florida Technological University
Orlando, Florida

The primary objective of this research was to identify feasible Automatic Vehicle Locator Systems and evaluate them against the operating requirements of the Orlando Police Department in order to determine several of the more promising for possible incorporation into the Command/Control System.

Initially a survey was conducted to determine the state-of-the-art in AVL Systems by mailing a questionaire to 150 potential suppliers. The mailing list was compiled from a literature review and included firms and agencies engaged in developing systems and equipment in performing related services. Approximately 30% responded.

Based on the interest and capabilities indicated by the completed questionaires, 3 firms representing Proximity, Dead Reckoning and Trilateration based systems were selected for further consideration. Each was contacted individually and specific requirements of OPD were discussed with their engineers. On this basis they furnished performance information in their respective systems and how they could be integrated into the OPD Command/Control System.

A prototype system using the Proximity technique was also installed on a limited scale in two selected districts of the City for demonstration purposes. This system was designed and fabricated at Florida Technological University using off-the-shelf-components. Two patrol cars were equipped to show that the system could distinquish individual vehicles. A large backlighted city map was used as a display with L.E.D. at intersections to identify the car locations. The prototype was used to obtain field operational data from which problem interfaces associated with integration of an AVL System into the existing Command/Control operation could be identified.

A computer simulation model of the OPD Command/Control System was used to assess the value of introducing an AVL capability. The model was exercised for System accuracies of ± 0, ± 500, and ± 1000 feet to determine the effect of accuracy on the Command/Control System performance. The study showed that incorporation of an AVL System would improve the efficiency of the field forces such that they could be reduced by two patrol cars and still maintain the same response time. An economic analysis using the operating savings to be realized from reducing the field force by two cars was then performed. This showed that assuming 5% return investment and 10 year life, there savings would justify a capital expenditure of over $900,000.

Introduction

All police departments utilize some system by which they direct and control their field forces in a dynamic response environment. This system of Command and Control must have the inherent capability of rapid and complete information assembly, decision making and execution which assures rapid response to the threat situation and minimizes the danger to both citizen and police officer.

Continuous force status monitoring is one of the more effective methods of improving the Command/Control function since it provides a dynamic display which combines offense locations with deployment/availability of patrol units. Typically continuous force status monitoring information improves command decisions which in turn improves operational efficiency of the system by:

- reducing response time
- dynamically deploying patrol units
- maintaining better administrative control of patrol units

An AVL System provides the key to a quicker response because it enables the Command/Control Center to dispatch the nearest available patrol units. Also to be considered is the increased safety afforded the field officer; at all times the Command/Control Center has knowledge of his location and can respond if assistance is needed.

In addition the AVL System provides the command officers with locations of their forces during major civil disturbances or disasters. Typically the police must rely on their force mobility to extend their limited field capabilities in responding to such emergencies. The ability to concentrate on trouble spots and control them is worth many additional units in the field. Knowing the locations of patrol units also improves administrative control and avoids over or under responses that may inadvertently leave sections of the city without protection.

The primary thrust of this study was focused on identifying feasible Automatic Vehicle Locator Systems and evaluating them against the operating requirements of the Orlando Police Department in order to recommend the most promising configuration for incorporation into their Command/Control System.

A number of vehicle locator systems for police operations have been conceived and some have undergone prototype evaluation. It is evident, however, from the review of the literature that the locator technique must be carefully selected and the system designed to satisfy not only the police operational requirements but also the physical and environmental conditions in which it must operate.

Command/Control Operations

The Orlando Police Department uses a response system keyed to 18 patrol districts which have been configured such that the work load, based on number of incidents and service time requirements, is relatively equal. One uniformed patrol car is normally assigned to each district

and is responsible for all complaint calls within that district. There are also four zone cars manned by Assistant Squad Leaders (ASL) who act as backup when required. District cars are supervised by four squad leaders (Sergeants) who patrol each of the zones. There are also special service cars, such as K-9 and Accident Investigation, which are used to handle special incidents. Investigative and motorcycle units move in all districts. The Orlando Police Department averages 32 Uniformed Bureau patrol units per watch. The three shifts change at 6:30 a.m., 2:30 p.m., 10:30 p.m., and are scheduled to provide a 30-minute overlap to assure continuous field coverage.

The map of the City, Figure 1, shows the districts and their relationship to the two major freeways. These freeways, I-4, which runs north-south and the East-West Expressway, effectively divide the City into four sectors since they restrict free passage across them.

Under normal conditions the standard operating procedure is to dispatch patrol car to service a complaint which occurs within its assigned district. If the primary car is unavailable , the car in an adjacent district may be dispatched or the squad leader may move in to answer the call followed by special assignment cars, investigative and motor units generally in that order. Since the Communications Center does not have information on the specific whereabouts of field units, except within its assigned district, this appears to be the best method of operation; it assures primary and backup coverage for each complaint.

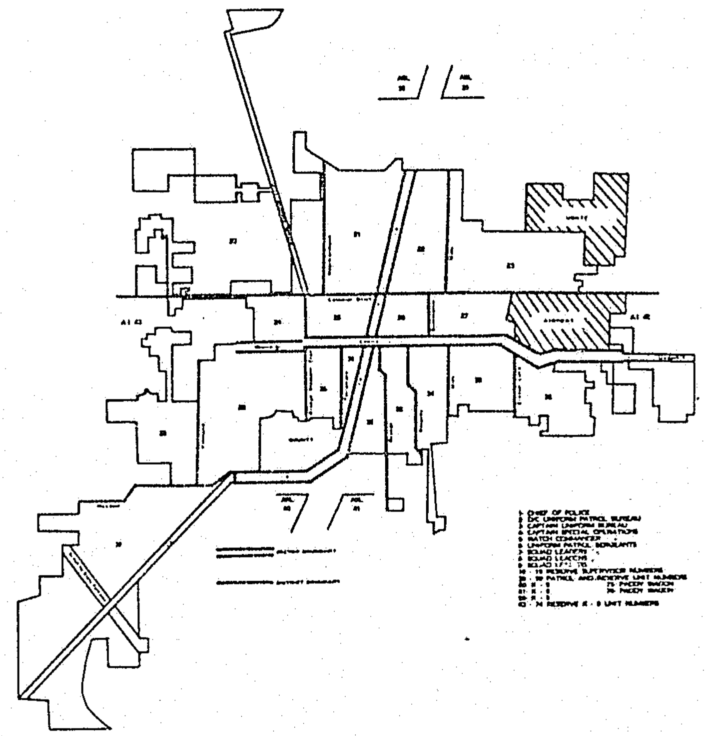


Figure 1 Reduced Scale Map of the City of Orlando Identifying Police Patrol Districts.

A key element in this operation is the Command/Control Communications Center. It provides a point contact between the outside world and the field forces, integrates the sources of information and has functional authority to direct and coordinate the field activities. Input to the Center can be initiated by the public via telephone, other law enforcement or public service agencies via telephone, radio or teletype and field units via radio or telephone. Typically an input to the system requires a data screening and analysis at the Complaint Desk station, and additionally may require information dissemination at the Radio and Teletype stations and/or information retrieval at the Teletype station.

An average watch manning includes a Supervisor, two Complaint Desk Officers, one Teletype Operator and two Radio Operators. Personnel are trained in the functions of each work station so that they can relieve each other as required.

The field patrol units are organized under a Watch Commander with four Sector Commanders supervising the Patrol Units in their sector. A patrol unit recieves and responds to a dispatch order from the Communications Center. All assignments, however, are monitored by the Sector Commander who may modify the dispatch order based on his knowledge of the field situation. His countermand may range from a simple designation of an alternate field unit, if the district is engaged, to redeployment of several field units to meet a stress situation. A vital part of this procedure is to ensure the Communications Center is fully aware of the new assignments; unity of command must be maintained at all times.

Industry Survey

Primary information on feasible AVL Systems was obtained through use of a simplified questionnaire which was mailed to a list of approximately 150 industrial firms and government agencies. The list was compiled from a literature search to identify firms engaged in developing systems and equipment, or performing related services applicable to the use of Vehicle Location Systems. It is noted that, since this is a relatively new field, there were very few references which directly related vendors and AVL Systems. Accordingly, reports on funded AVL studies were the primary sources used to compiling the list.

The questionnaire was constructed to obtain technical information in four basic areas. Potential suppliers were queried concerning their experience, availability of equipment and performance parameters of their respective systems. These are identified in Figure 2 which is a reduction of the information pages of the questionnaire. The third page asked if the firms were interested in setting up a demonstration at Orlando Police Department, if they could be contacted for additional detailed information, and whether their information could be included in the report. This page also provided space for identification of the firm and person responding. A cover letter and information sheet on the Orlando Police Department operations accompanied each questionnaire to aid those responding.

Approximately 30% of the firms responded to the questionnaire, and of these more than half indicated some specific interest in the project. Eight returned completed forms giving detailed information concerning their system. Of the 150 letters mailed, 32 were returned

ORLANDO POLICE DEPARTMENT SURVEY FORM
AUTOMATIC PATROL VEHICLE LOCATOR SYSTEMS
FLORIDA GOVERNOR'S COUNCIL ON CRIMINAL JUSTICE

PROJECT 72-14-09

ATTENTION: Dr. Robert D. Doering,
Florida Technological University
College of Engineering
P. O. Box 25000
Orlando, Florida 32816

1. INTEREST OF OUR FIRM IN AUTOMATIC VEHICLE LOCATOR (AVL) SYSTEMS

System Supplier ( )
Component Supplier ( )
Other ________

2. EXPERIENCE OF OUR FIRM IN AVL SYSTEMS

Research ________
Design ________
Prototype ________
Operating Systems ________

3. SYSTEM DESCRIPTION

Sensor Type
- Officer Update ( )
- Proximity ( )
- Dead Reckoning ( )
- Trilateration ( )
- Triangulation ( )
- Loran-Decca-Omega ( )
- Other ________

Vehicle Electronics ________

Base Station Electronics ________

Data Link ________

1

Base Station Display ________

Dispatchers CRT Console Display ________

System Computer ________

System Documentation ________

Personnel Training ________

System Equipment Maintenance (annual) ________

Additional System Capabilities ________

Other Notes on System ________

4. SYSTEM PERFORMANCE DATA DESIGN ( ) FIELD TEST ( )

Accuracy ________
Capacity ________
Update Time ________
Frequency ________
Band Width ________
Power Levels ________
Sites ________
Coverage Area ________
Advantages ________
Limitations

Figure 2

unopened due to obsolete addresses; 45 were returned with some type of response and the remaining 73 were not returned.

Analysis of the survey data showed that of the four main types of Automatic Vehicle Locator Systems, the proximity system can claim the greatest development activity. Eight companies indicated their engineering efforts were in this area. This can probably be attributed to lower development costs and lower equipment costs. Six companies reported work being done in the Dead Reaconing area of AVL Systems. Triangulation/Trilateration types of systems and the navigation (Loran) systems were reported as areas of activity by three companies in each area. Of the firms responding, some stated that they were exploring more than one type of system and had actually parallel efforts going in two to three different systems including some hybrid variations.

Figure 3 presents the response distribution by type of system. As the chart shows, no one technique clearly dominates; however, the Proximity System is slightly favored. This distribution seems to verify the assumption that the approach may more directly be a function of experience and initial application, rather than a purely scientific approach to the problem. A listing of the companies which responded by systems type has been indicated in the Figure.

Based on interest and capabilities indicated on the survey questionnaire, three firms associated with the systems judged most feasible for OPD were selected for in-depth discussions. This was effected by the Principal Investigator visiting their plants, viewing the equipment in operation, and specifically reviewing the OPD requirements with their engineers. All then furnished information on conceptual designs for OPD.

Proximity System

The Applied Technology Division of Product of Information Systems, Costa Mesa, California, has developed an operational Proximity System, LOCATES, for the city of Montclair, California. This was accomplished as part of a study project funded by the California Council on Criminal Justice under Grant Number 192 and final report on the Phase I effort was issued in March, 1972. The demonstration LOCATES system provides Automatic location of police vehicles on a map grid display at the

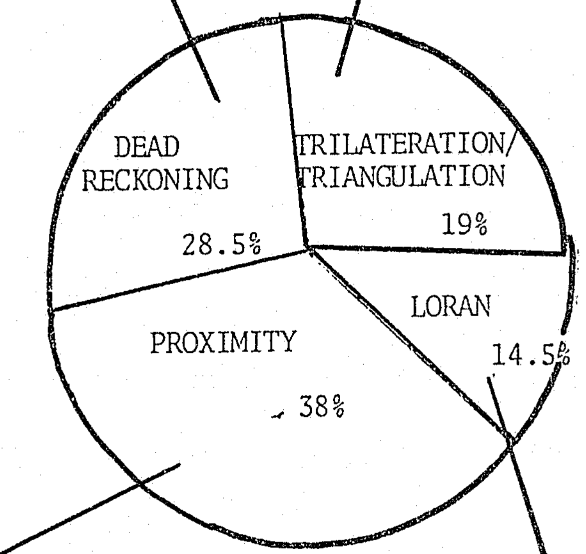
Command/Control Center using an active signpost sensor, and also includes capability of digital communications between officer in the patrol vehicle and the dispatcher. In addition an integral part of the system is the capability for the officer while away from his vehicle to unobtrusively transmit an emergency alert message to the dispatcher. The scenario shown in Figure 4 illustrates the LOCATES application.

Dead Reckoning Systems

Lockheed Corp. Electronics Division
AGA Corp.
Boeing Corporation*
Bendix Corporation*
Marconi, Ltd.
Martin Marietta Corp.

Triangulation/Trilateration Systems

Sierra Research Corporation*
Sanders Associates, Inc.
Marconi, Ltd.
Cubic Industrial Corporation



Proximity Systems

Applied Research Corporation*
Products of Information Systems*
Capitol Science Corporation
Sanders Associates, Inc.*
Marconi, Ltd.
RCS Associates, Inc.*
Mitre Corporation
Bendix Corporation*

Loran (Navigation) System

Lockheed Corp./Electronics Division
Teledyne Systems Co.
Hazeltine Co.

Figure 3: Survey Response Distribution By Firm Shows That Most Favor The Proximity Type System.

As shown in Figure 4, police units are automatically located by wayside emitters which are strategically placed throughout a prescribed geographic area. These wayside emitters transmit, via a specified radio frequency, digitally coded location identification data to police vehicles as they pass within proximity of the emitters. Each police unit, in turn, retransmits this location data and its identification to the police Command Center (Headquarters). At the Command/Control Center, the location of each vehicle in the system is automatically displayed for the dispatcher. Display techniques include large wall-type map displays, as well as console displays for use by individual police personnel.

Status messages are digitally transmitted via a radio frequency communications link to and from the patrol vehicles by convenient small size keyboards which are located in the patrol vehicles and the Command/Control Center. Incorporated with these keyboards are display panels to enumerate messages received by the patrol vehicles and by the dispatcher at the Center.

In addition to vehicle location and status reporting capabilities and LOCATES System provides for emergency signal by a police officer while away from his patrol vehicle. A miniature belt unit enables the officer to transmit a signal to the police vehicle, which re-transmits the message to the Command/Control Center.

Applied Technology is now working with the Montclair Police Department on Phase II of the study which has been funded by the Governor's Council. This effort involves installation of a fully operational LOCATES System for the Montclair and Chino. To date, the System has been installed and is being evaluated for its operational maintenance effectiveness.

The performance of a proximity system is largely a function of the number of signpost emitters and how their data is encoded and transmitted to the Command/Control Center. Accuracy for example is not dependent on the precision of the emitter/sensor circuitry. This contrasts directly with other AVL systems where accuracy is dependent on precision components and design of inherent correction feedback loops. In the LOCATES System inexpensive low-power emitters are used to communicate with the existing mobile radio in the patrol vehicle. The mobile radio then completes the relay link ot the Center. The performance cost trade-off in this type system is between the number of sensors and their installation/maintenance cost.

The LOCATES System typically is designed for a density of about 10 locators per square mile. These are strategically located along the most frequently travelled streets and at "choke" points which the

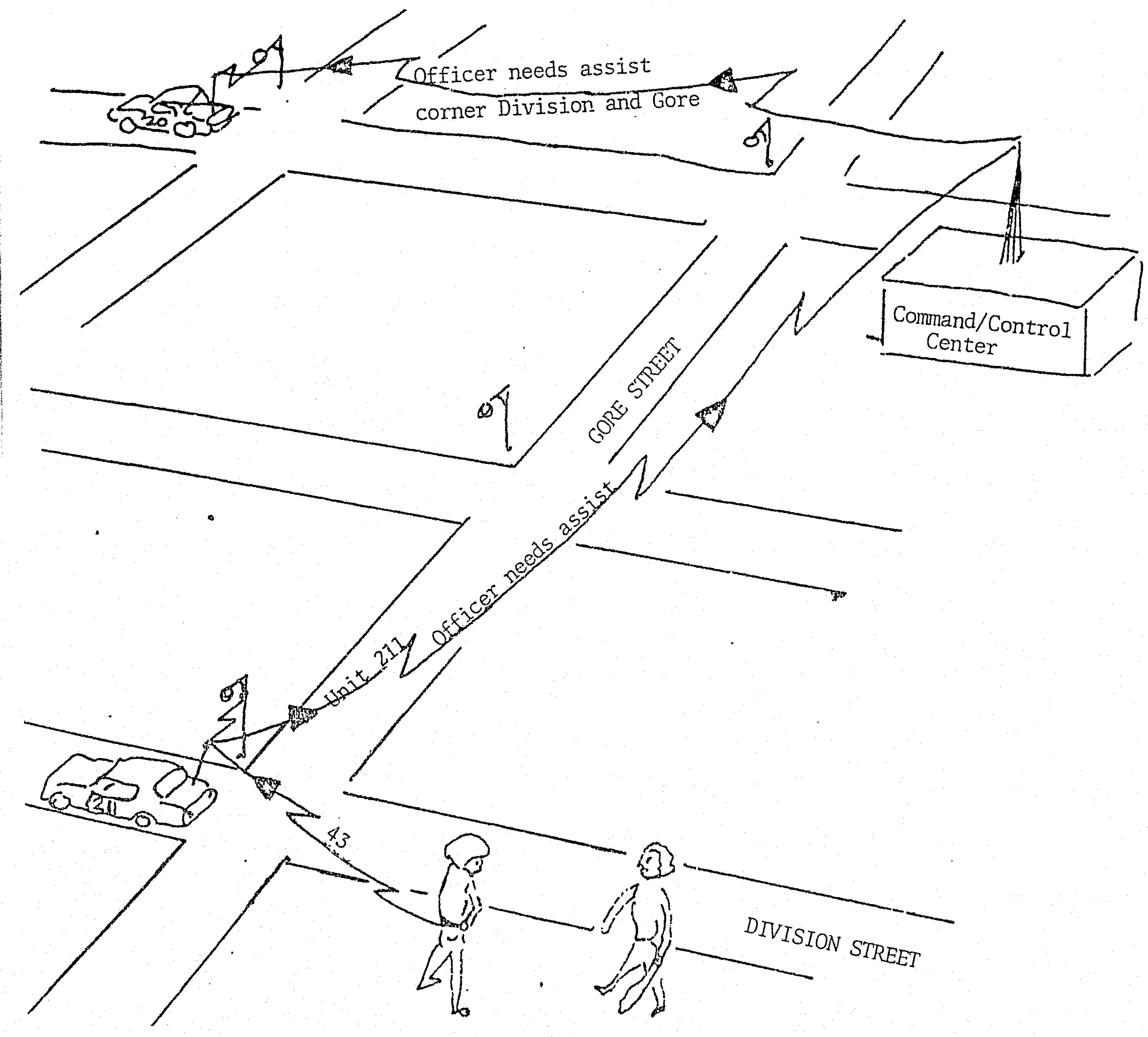


Figure 4: LOCATES Proximity System Operational Scenario

vehicles must pass. In a purely random patrol assignment 10 emitters per square mile may not be adequate to maintain required contact with the patrol vehicle. Additionally some districts are more active than others and greater accuracy and contact would be desirable. Each system must be examined and designed to satisfy the requirements.

Another significant operational characteristic which is related to the performance is the method of transmitting the location data to the Command/Control Center. Utilization of the normal voice channel imposes an additional load which is a direct function of the number of emitter locations. Recoding of the location information in digital format would reduce air time. Hard Wire transmission can also be used and might be feasible in districts which have a high density of call boxes, such as the inner core of Orlando. Also to be considered is the utilization of the Cable TV network which exists in Orlando. The franchise agreement provides that the City can use it without charge.

Trilateration System

Sierra Research Corporation of Buffalo, New York, has developed and demonstrated a practical Automatic Car Locator System under a contract DOT-WT-10024 from the Urban Mass Transportation Administration of the United States Department of Transportation. The demonstration was conducted in Philadelphia, Pennsylvania, under the supervision of DOT and results were documented in Final Report TR-0932 issued February 1973. The results of this demonstration were that on over 5,000 locations in the dense high rise area, Sierra was able to "track" a vehicle within an RMS accuracy of 650 feet. The location information is presented at the Command/Control Center on a display unit designed to complement the existing dispatch system and enables the dispatcher to determine the closest available vehicle to an incident. In addition to the basic car location function, the Sierra system also has the ability to transmit 8 standard messages in digital format from the vehicle to the Center. This includes unobtrusive transmission of an "officer-needs-help" signal.

The Sierra System Concept is shown in block diagram form in Figure 5. This configuration is designed for locating 20 to 30 vehicles. The system utilizes the phase (time) difference of arrival of a vehicle-transmitted UHF signals (location time) as received at a number of sensor stations. The location tone, after demodulation at the various satellite sensor stations, is transmitted via dedicated telephone lines to the Command/Control Center. The relative times of arrival of the location tone from the various satellites are compared at the Center with the aid of a computer to determine vehicle location.

The display utilizes a cathode ray tube on which the vehicle location is shown on a grid map. To correlate the vehicle location with the incident the dispatcher uses an electronic "press-board" which has an over lay of an area map. By pinpointing the incident location on the press-board with an electric pen, an expanded scale display is created with the incident at the center. The computer then searches out the nearest available vehicles and displays their positions and vehicle numbers for reference. Available or assigned status of the vehicle is indicated by colored light on the display.

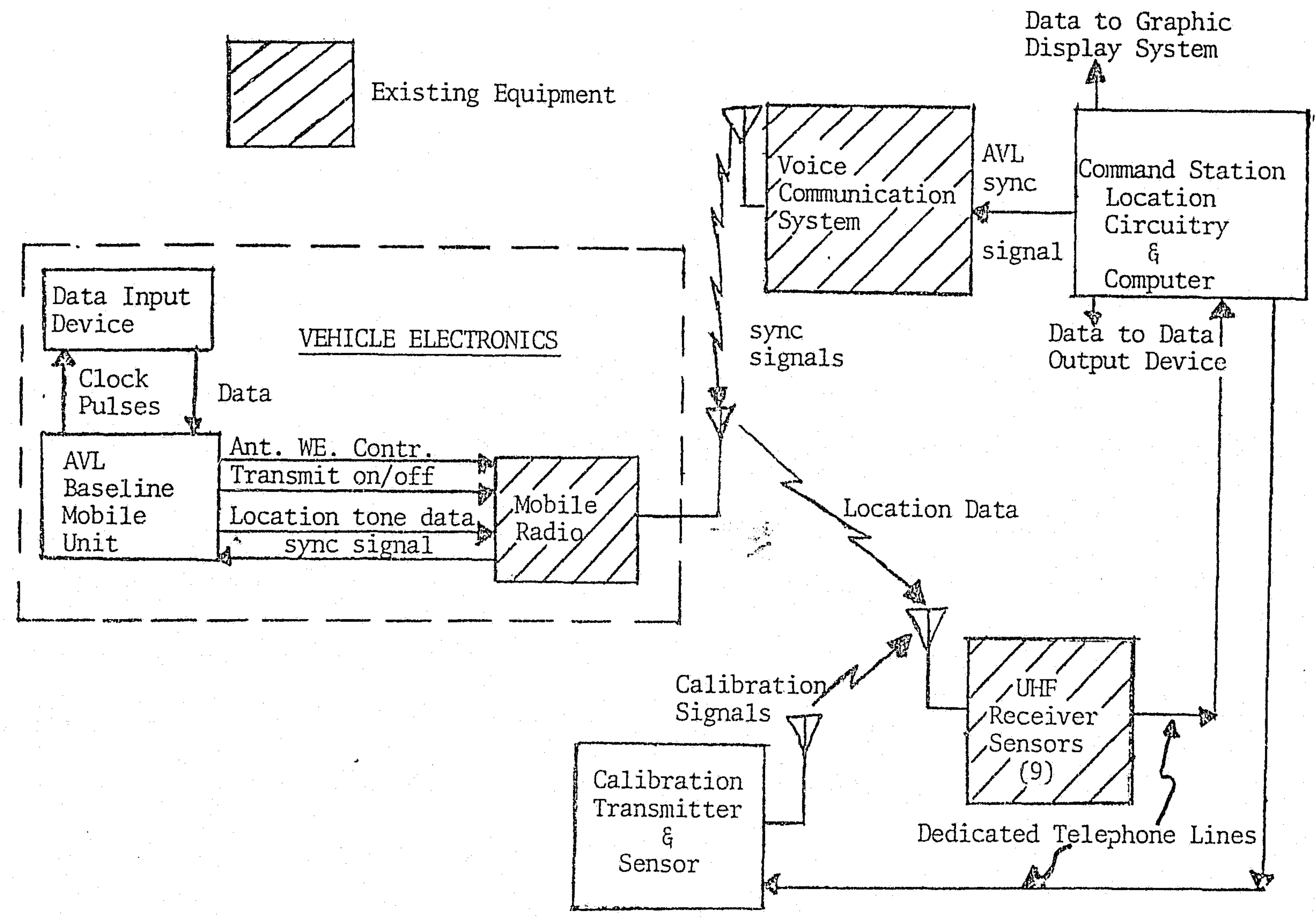


Figure 5: AVL System Block Diagram Shows Compatibility with Existing PREP System

In Figure 5 the blocks representing existing equipment have been shaded to show how the Sierra System has been designed to incorporate and interface with equipment comprising a typical policy system. Typically, the system can utilize existing communications equipment without compromising normal voice tranmissions. In operation, voice communications would be handled in the normal manner on duplex frequencies with the minor exception of a sync signal to the vehicle for 1/10 of a second every 3.3 seconds on the dispatcher frequency. All data/location tones from the vehicles plus other housekeeping signals would be transmitted on a single independent frequency.

It is noted that this approach offers a high degree of compatibility with a PREP (Personal Radio Equipped Police) communications system. The PREP system typically uses low power field transceivers and satellite receivers located at strategic elevated sites throughout the city. At the present time the Orlando Police Department PREP system has 9 such satellite receiver stations which have proven signal coverage. By using existing channel frequencies these receiver stations could function as the sensors required by a Trilateration system.

One of the most difficult problems inherent in a Phase Trilateration System is associated with RF multipath propagation and signal blockage effects. Due to the nature of the time difference of arrival locations technique, perturbations of the transmitted signal up to the transmitting antenna of the vehicles are cancelled because they are common to all vehicle-sensor links. However, the individual perturbations in the different links are not cancelled and errors can be introduced in the location estimation by error in the measurement of time phase of arrival of the time at each sensor station. These problems make it difficult to assign general performance parameters; each system application should be analyzed. It is noted, however, that the system should be near its peak effectiveness in Orlando because of the flat terrain and minimum grouping of large buildings.

In order to conserve radio spectrum the Sierra System is designed to operate in two standard land mobile radio channels (25 KHz in the 450-512 MHz region) and on a time multiplexer basis, rather than a polled basis, to reduce the number of channels required. The system uses standard commercial FM land mobile voice transceivers and utilizes a general purpose digital mini-computers for all control and operational functions.

The baseline system is designed to locate up to 680 vehicles on each land mobile radio channel used. This channel is time multiplexed into 4000 time slots with the entire 4000 slot format being repeated once per minute. Thirty-four hundred slots are assigned to specific vehicles. The remainings slots are used for calibration, synchronization and as special assignments to provide a higher sampling rate for vehicles in an emergency or critical situation; a silent alarm function is also provided by these special slots.

Dead Reckoning System

Over the past two years, the Boeing Company in cooperation with

the Wichita, Kansas, Police Department has developed a prototype police vehicle locator system known as FLAIR (Fleet Location and Information Reporting). FLAIR is based on the dead reckoning location technique and updates the location of each vehicle every 2 seconds. This information is displayed on a video map at each dispatchers control console. It also has the capability of digital transmission of up to 99 different "10 code" messages and an emergency "officer needs help" call.

The system concept is shown in Figure 6 and consists of four basic units. The Vehicle Locator Unit works on the fundamental navigation principle that if the original location of vehicle is known, its location at any later time can be determined if heading and distance changes are added to the original location. The heading and incremental distance moved for each 2-second period are transmitted from the Vehicle Locator Unit to the Command/Control Center Unit which interfaces with the Computer Unit to update the vehicle location. The Display Unit receives the vehicle location information from the computer and presents it at the proper position, in the form of bright dots on a video map displayed on a TV monitor located in each control console.

The dynamics of the display are such that the dispatcher can estimate the cars travel rate and observe when they stop. Each dispatcher can individually select a portion of the city for detailed observation and "zoom in" to read street names on the video map display. Also, each dispatcher may choose to selectively display a single precategorized group of officers or any combination of the categorized officer groups.

In order to locate the cars closest to an incident, the dispatcher slews the map until the point of interest is under his cursor. The four cars in order of proximity to the cursor are continually displayed and the location and number of the eight cars closest to the incident are displayed if requested by the dispatcher.

Since the dispatcher can view the continuous movement of the field forces, communication security can be provided by directing a car to an incident by travel route rather than by incident address. The dispatcher can also use this information to direct cars around barriers, such as street construction, and to assist a car in finding an address.

In a similar manner a car in trouble can be located and the nearest available cars dispatched to assist him. Car location is initiated through Display Unit controls which cause the map location of the car to be positioned under a cursor displayed at the center of the TV monitor. In addition to the car number, the numbers of the three closest cars in order of proximity are instantaneously displayed. If the dispatcher desires that more than three cars be sent to assist an officer in trouble, the location and number of the eight cars closest to the incident can be displayed on the video map. Map display of car numbers is initiated by the dispatcher depressing a control switch. Cars from any combination of categorized groups can also be selected for display. The dot on the video display which is placed at the location of the car blinks slowly

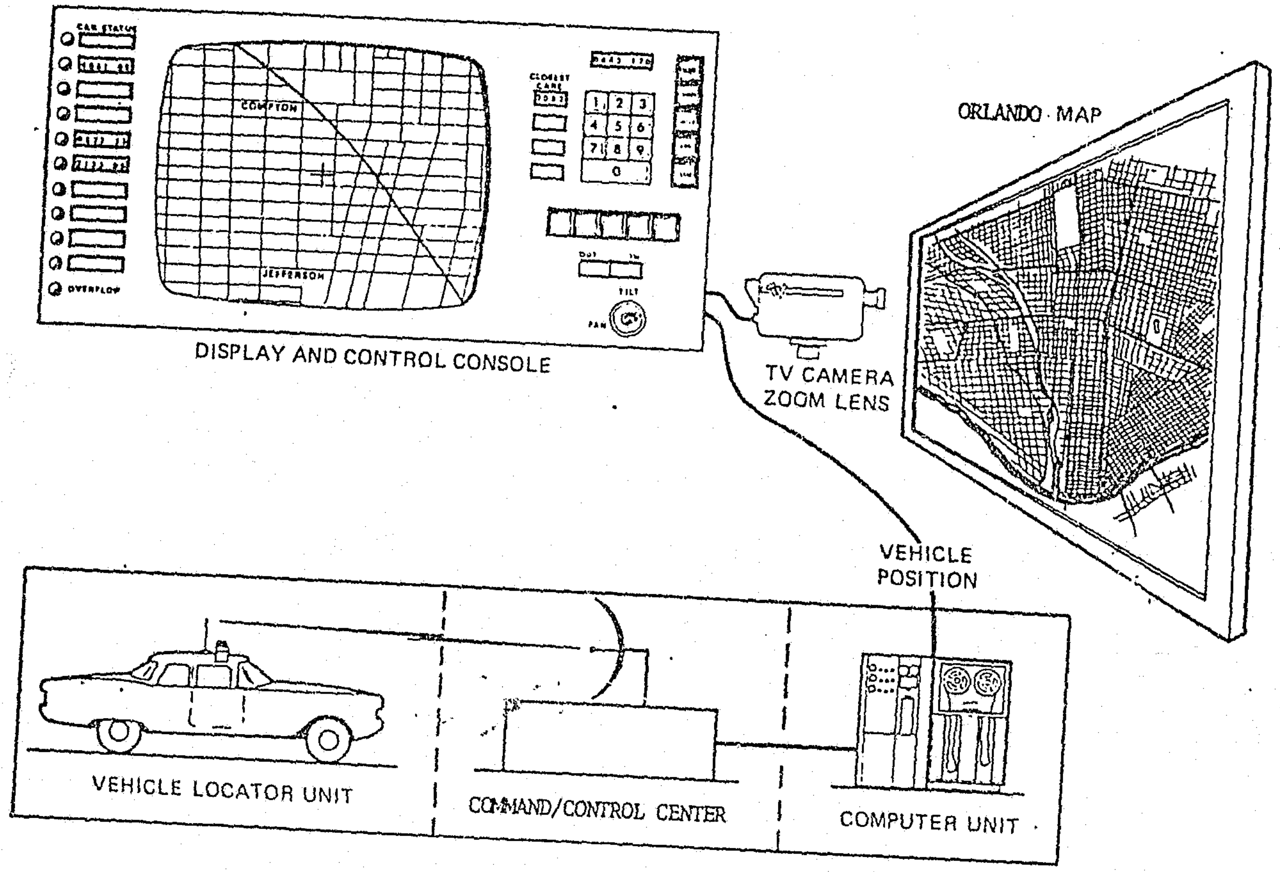


Figure 6: FLAIR System Concept Shows Major Functional Components and their Interrelationship

for cars "in service and on call", is steady for cars "in service and not on call", and blinks rapidly for cars relaying an emergency status.

The dead reckoning location technique has many features which make it attractive; however its performance characteristics are largely dependent on the components and/or the sytems configuration selected. Typically dead reckoning navigation is subject to a cumlative error buildup which must be minimized. This can be accomplished by use of high precision sensors in the vehicle or by augmenting less precise sensors with some type of corrective feedback loop in the system configuration. Inherently, then, there is a performance/cost tradeoff between precision sensors and feedback system.

The FLAIR system features inexpensive on-board components augmented by a computer at the Command/Control Center which periodically provides corrective feedback data to enhance the field data. After receiving the location data from the vehicle, the Center computer evaluates and corrects the data and applies geographic (street, etc.) constraints to the vehicle location. This approach has an obvious advantage for large fleets where inexpensive components can be used in the vehicle and only one control computer is needed.

When cars are driven off of roadways, alleys, or parking lots (normal drivable surfaces) the FLAIR system utomatically reverses to a secondary mode of operation termed "open loop". Under such conditions (such as a high speed chase across a large open field) the dispatcher will still know and have displayed the general location of the car. Any time the system reverts to an "open loop" condition for any reason, including Vehicle Locator Unit malfunction, the dispatcher will receive an automatic indication on the Situation Display Unit which will indicate that the dispatcher should verify by voice the position and status of that car. Once the car returns to a normal drivable surface, reinitialization of the car can easily be performed by the dispatcher.

The design goal of the FLAIR system is to provide the dispatcher with the capability to locate each police car within ± 50 feet 95% of the time. Test data conducted with FLAIR prototype equipment to date provides a high degree of confidence that this accuracy is achievable under all normal police operation conditions. The system is designed to be operated with conventional communications support equipment.

It is noted that performance information to date reflects extrapolation of prototype development data obtained while working with Wichita Police. The Boeing Company is presently under contract , however with the St. Louis Police Department to set up a development program Phase I of which includes monitoring 50 police cars operating in a selected portion of the City.

AVL System Evaluation

A computer simulation model of the Orlando Police Department Command/Control System was used to assess the value of incorporating an AVL capability. The model was structured to match the basic design of the actual system and operates as a dynamic, Monte-Carlo simulation by generating calls from measured statistical distributions, passing these calls through each processing step a call would encounter in the real system, and then compiling data on designated system components as well as the overall operations. Typically a computer simulation model does not exactly duplicate the real world operations, but rather serves as a close approximation which acts the same as the real system. The long run statistical averages to model outputs and real system historical data, however, are typically close enough to permit management to make use of model outputs in analytic and decision-making applications.

Assumed Dispatching Disciplines

The Orlando Police Department operates four major classifications of uniformed patrol units; individual cars operated by patrolmen, Evidence Technician, Sergeants, and Lieutenants, and motorcycle units, which are principally assigned to traffic duty. Cars operated by Sergeants and Lieutenants are supervisory but these units do respond to incident calls under certain conditions. The rules applied in the computer model are discussed below under the major operating categories of the computer model. In the "present system" the decision rules correspond approximately to the current methods in use at OPD. Under the Automatic Vehicle Locator System the postulated assignment discipline was modified to take advantage of the vehicle location information.

Existing Assignment by District

When an incident occurs, the computer attempts to dispatch a car in the district in which the incident has occurred. If no unit is available in that district, then the district north and/or south of the incident district is searched for a free unit. If no unit is available in those districts, then the district east/west of the incident district is searched for a unit which can be dispatched. If no available unit is located through this 360 ° search, the Evidence Technician, (ET), Sergeant and motorcycle units are interrogated for dispatch. If no unit is located, the call is delayed and is inserted into a queue for accomplishment when an unassigned unit is available. On high priority calls in a queue situation, the higher priority (emergency) incident bumps lower priority incidents into the queue.

Automatic Vehicle Locator (AVL) System

Dispatch decisions in a system using AVL are made by computing actual distance from an incident scene to available field units. The closest available field unit is then assigned (excluding Lieutenants and motorcycles). If a unit manned by a patrolman is not available, the closest ET, Sergeant or motorcycle unit is dispatched. As with the present system, if no available units are found the call is placed in a queue to await the first available unit. In calculating distances in the computer model, the operating area was overlaid with a system of 50-foot grid lines providing coordinates of any point. These coordinates were used to determine the rectangular distance (as with city streets) between any two points of interest. Distances computed in this manner become highly important in experimentation with the simulation model. Since locations and distances are known exactly, the influence of accuracies of various AVL systems can be evaluated in terms of incorrect dispatches and the attendant unnecessary distance travelled.

The simulation model of the Automatic Vehicle Locator System was run with accuracies of ± 0 feet, ± 500 feet, and ± 1000 feet. Four runs of the model were made with each run processing 500 incidents which corresponds to approximately 2-3 days of normal operations. In order to insure steady state conditions, 1000 incidents were processed through the model prior to collecting performance statistics. As a further control on variability between runs, each set of four runs were averaged to obtain the results graphed in Figures 7 and 8.

The first graph, Figure 7 shows the average distance traveled by an incorrectly dispatched unit as approximately 0.4 mile with an AVL of ± 500 foot accuracy. An incorrectly dispatched unit is defined as a unit which is not the physically closest available unit to the incident being processed. Physical distance in the model is measured in horizontal and vertical (X,Y) distances. In the model design, it was assumed that X-Y travel most closely approximates actual travel of a vehicle through city streets. As an illustrative example, consider two points A and B with coordinates (X_1,Y_1), (X_2,Y_2) respectively. The following simple formula relates the distance between these points

$$\text{Distance} = \left| X_1 - X_2 \right| + \left| Y_1 - Y_2 \right|$$

where the vertical bars designate absolute value. In Figure 8, distances measured by this equation for incorrectly dispatched units averaged approximately 1.0 mile for the AVL System with ± 1000 foot accuracy. It will be noted that the distance travelled increases more sharply with decreased AVL System accuracy. Computer runs with ± 50 foot accuracy showed little difference from ± 0 foot accuracy but distance increases rapidly as accuracy is degraded to the ± 500 and ± 1000 foot levels.

For each of the accuracies in Figure 8, the number of incorrect dispatches increases as the accuracy of the AVL System is decreased. An incorrect dispatch is defined as the selection of a unit for assignment which is not physically closest to the incident scene. The selection of this parameter relates to the assumption that incorrect dispatches obviously degrade overall system response time. In the Figure 8, the number of incorrect dispatches almost doubles as the accuracy goes from ± 500 feet to ± 1000 feet, increasing from 17 wrong dispatches at the ± 500 feet accuracy to 30 for the ± 1000 feet accuracy system.

To interpret the system behavior under various accuracies, a means of comparison to the present system was needed. For the purposes of this study, it was deemed appropriate to increase the number of units in the present system to a point where both systems would be equivalent in average response time. Thus if the AVL System response time were less than the existing District Dispatching System, more patrol vehicles would be added until the existing system obtained the same reduction in response time.

Under this procedure, the model of the present system was run with the same number of vehicle (34) as assumed in the Automatic Vehicle Locator System. More vehicles were added, one at a time, to the model of the present system. The simulation was run again and the results noted. This was carried out repeatedly until the 10-6 time equalled or was less than, the 10-6 time of the Automatic Vehicle Locator System. As vehicles

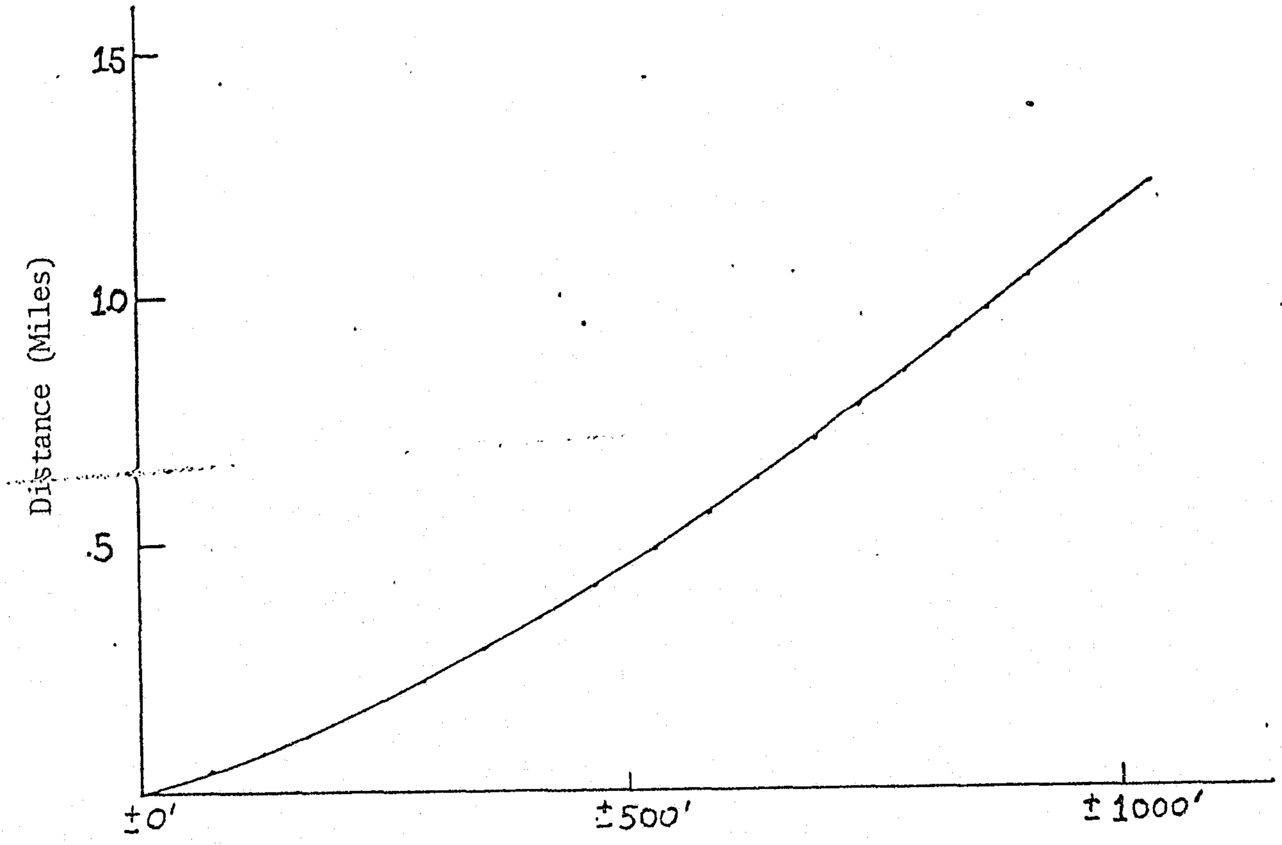


Figure 7: Average Distance Traveled Due To Wrong Dispatch

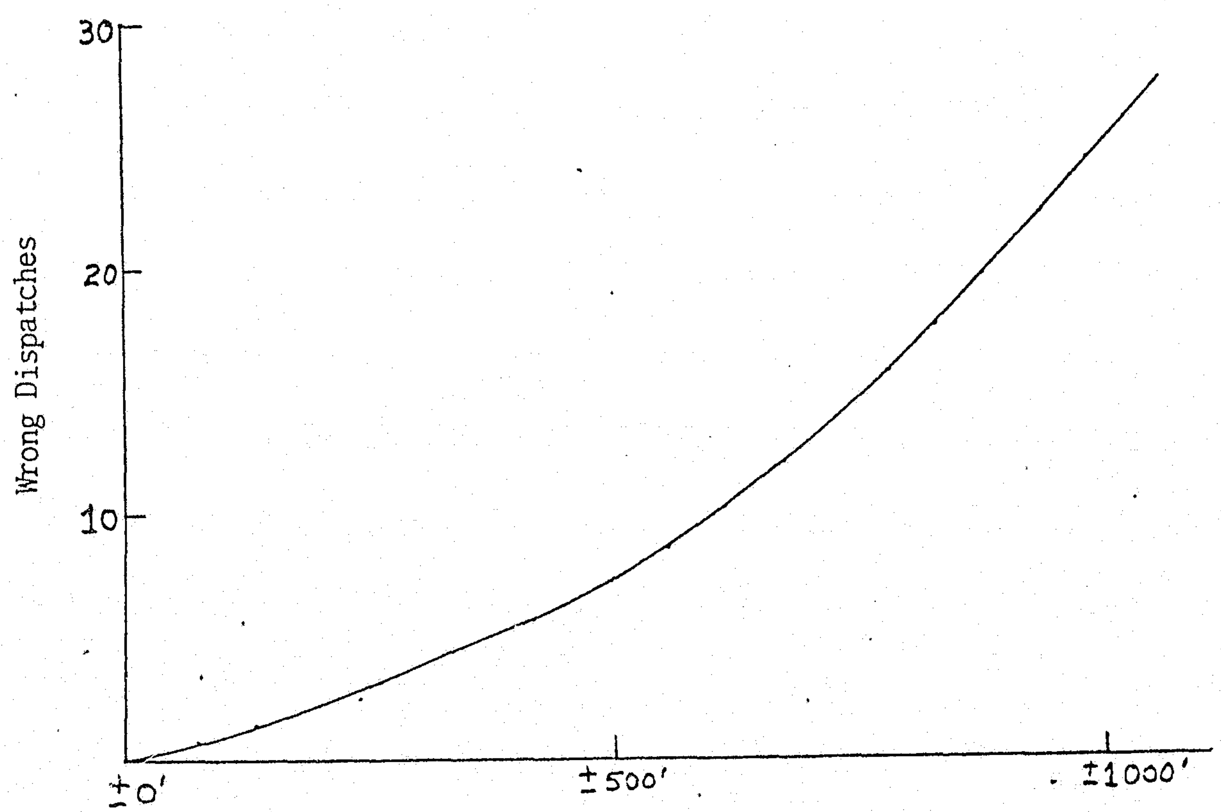


Figure 8: Number Of Wrong Dispatches

were added to the present system, they were placed in districts showing the most activity in the previous run.

A graphic comparison of the two systems is shown in Figure 9. Some of the observations which can be made from this information include:

- A perfect Automatic Vehicle Locator System ±0 feet accuracy will operate as well as the present system with 37 vehicles.
- A 500 foot accuracy Automatic Vehicle Locator System has the performance of the present system using 36 vehicles.
- The two systems are approximately equal with an Automatic Vehicle Locator System of 900 feet and the present system with 35.8 vehicles.

On an overall basis, it may be concluded that the cost of operating 1.8 vehicles (rounded off to 2 vehicles) may be compared with an AVL system with 900 feet accuracy.

Economic Justification of AVL System

A basic engineering economics analysis was used to estimate the capital investment which could be justified for an AVL System based on its response efficiency expressed an equivalent patrol vehicles. The analysis showed that for each patrol unit so replaced $501,000 was justified.

The Orlando Police Department is currently experiencing expenses of $450 per month for the operation and maintenance of each patrol car. This includes depreciation, gas, oil and maintenance. To estimate the personnel costs a single officer car was assumed together with an average salary of $10,500 per year for the officer. Three shifts per day, 7 day/week, including holidays and vacations would then require 5 equivalent men and amount to $52,500 dirct cost per year in operator salaries for each car in the field. If we include overhead and administrative support this would increase by an estimated 100%. The Orlando Police Department, therefore, experiences total average costs per year of $115,000 including officer salaries overhead/support and operation and maintenance costs for each car in the field.

Although the initial cost of an Automatic Vehicle Locator (AVL) System for Orlando is unknown at this time the capital outlay justified by a reduction in field units can be determined. This can be used to determine the threshold of capital outlay where an AVL System becomes a good investment. Examining the cash flow diagram in Figure 10, the cost of an AVL System has been labelled as "X" or unknown. Annual operation and maintenance costs were assumed to be 10% of first cost or .10X, as shown in the diagram. The investment of these amounts for an AVL System then will produce savings because of fewer patrol units in the field. For example, if one field unit is eliminated through the use of an AVL System an annual savings of $115,000 will result. This amount is shown as the upward (cash inflow) arrows on the diagram. The net "profit" from installing an AVL System

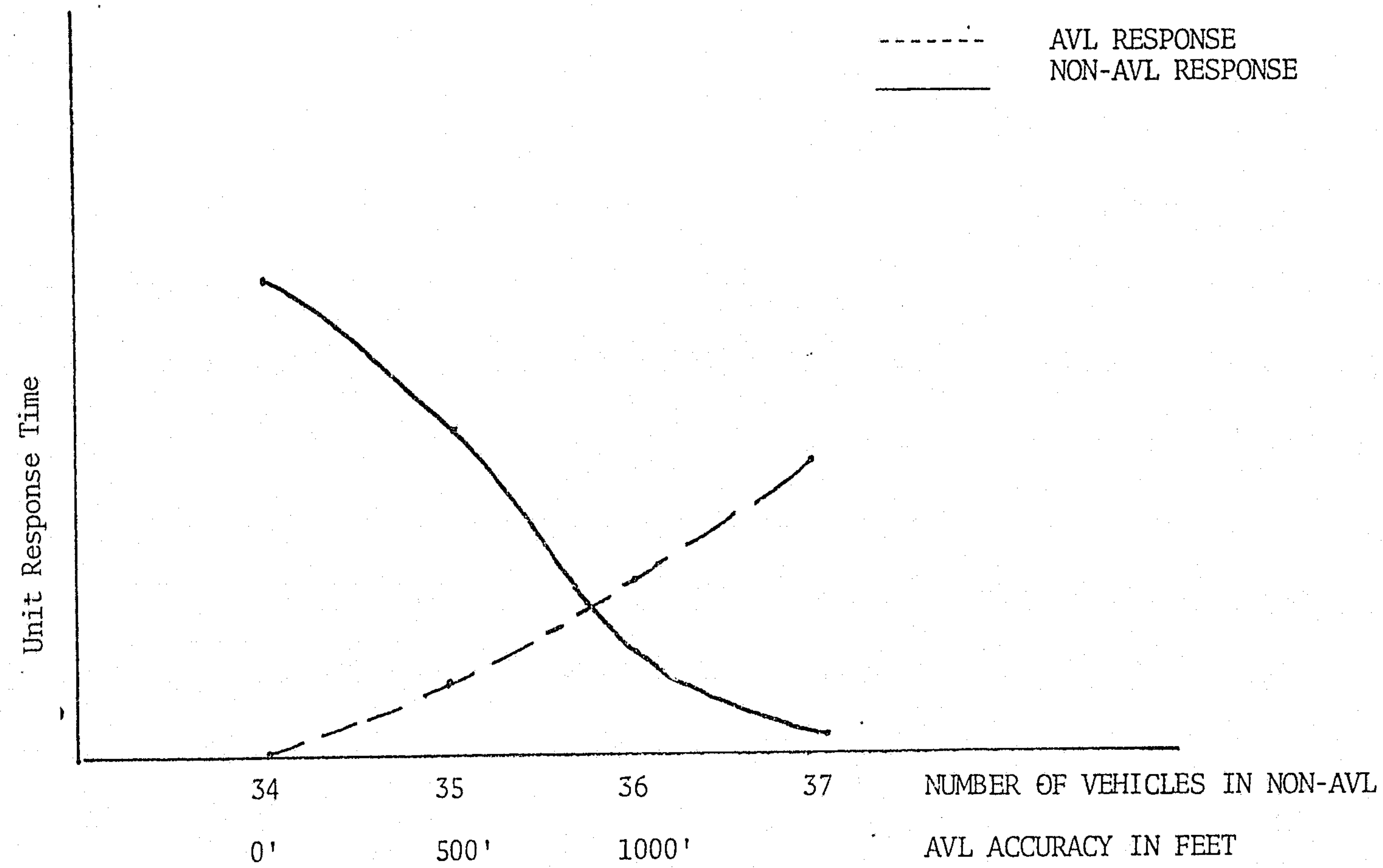


Figure 9: Comparison of Patrol Cars Required To Achieve Same Mean Response Time Assigned District And AVL Systems

and eliminating one field unit is the quantity ($115,000 - .10X). We then wish to solve the equation

X = ($115,000 - .10X) PWF - 5% - 10); (1)

where the quantity (PWF - 5% - 10) is the Present Worth Factor of an annual amount at 5% interest over five years. Five percent was assumed to be a reasonable return on investment for a municipality. Using a standard table of interest factors we have

X = ($115,000 - .10X) (7.722) (2)

which may be solved for X as

1.722X - $115,000 (7.722) (3)

or

X = $115,000 (4.357) = $501,000 (4)

Thus an elimination of one field car in Orlando justifies a capital investment of about $501,000. In a similar fashion, we can rapidly calculate capital investment justified for 2, 3, 4, etc. units eliminated from the field. This data is displayed in Figure 11. This show that a straight line relationship exists where for each car eliminated an additional $501,000 in capital investment is justified.

Conclusions

The variation in performance characteristics together with the local environmental interface made it impractical to compare the different AVL Systems on a cost basis at this time. In addition, the suppliers were generally reluctant to furnish supply cost information without considerable additional engineering effort. It appears, however, based on discussion with the two suppliers who are under contract, that a system with accuracy of less than 1000 feet and capability of monitoring 30-35 vehicles with the city limits of Orlando could be installed for approximately $600,000.

On this basis it was recommended that OPD install an Automatic Vehicle Locator System. It appears to be a good economic investment for the City and offers increased safety and security to both officer and citizen. In addition the fuel saved by two cars would be a significant contribution in this era of energy shortage. As a first step toward implementation of this recommendation this study should be extended to develop a performance specification for the system so that bids can be obtained for reputable suppliers.

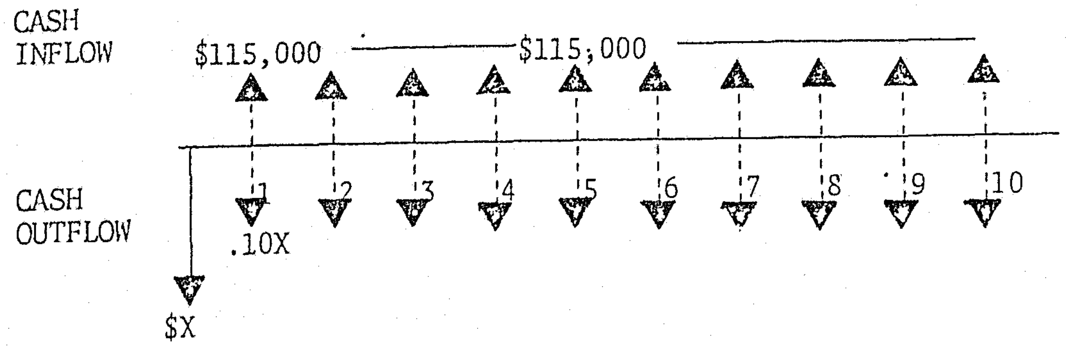


Figure 10: Cash Flow Diagram

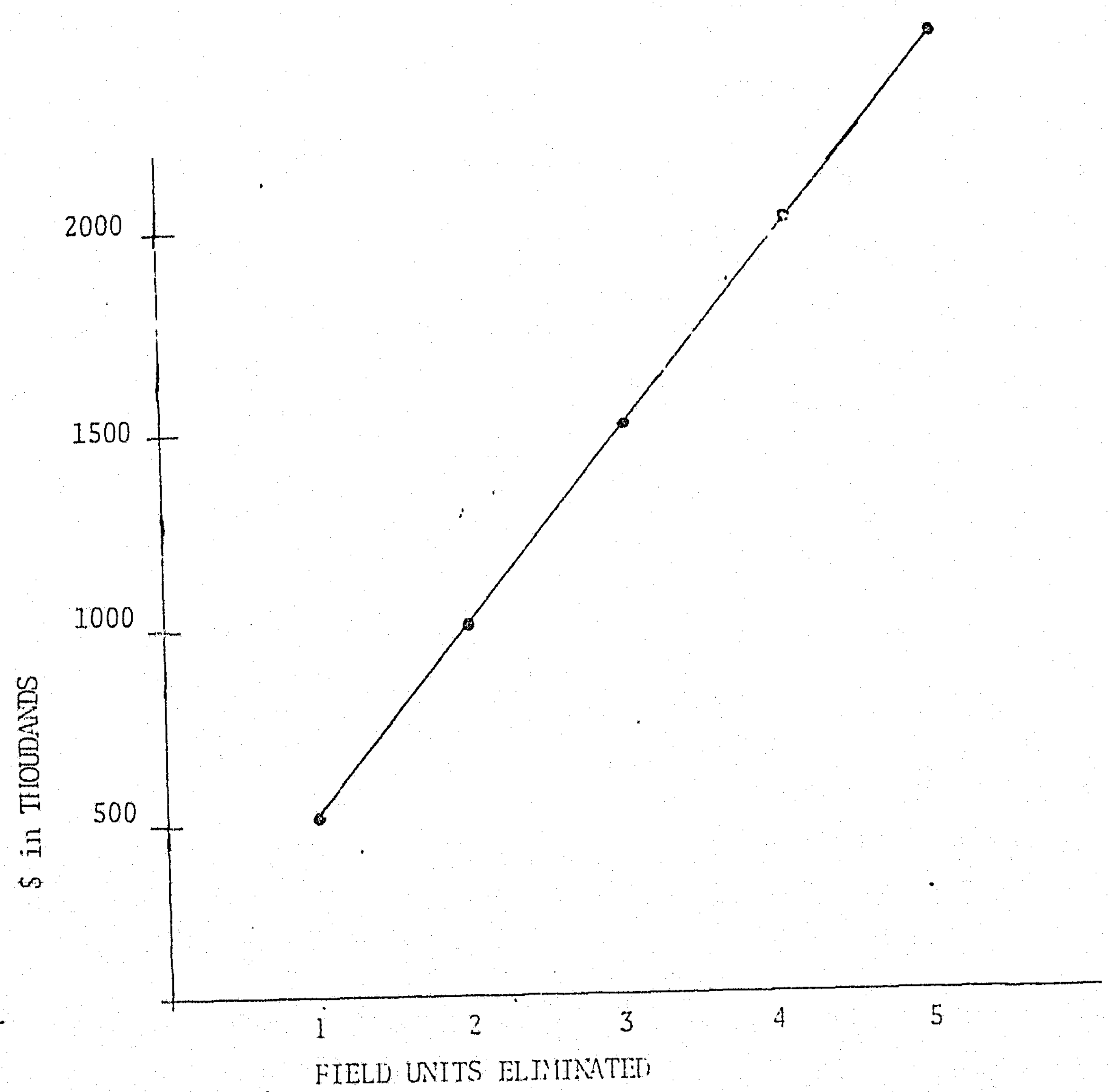


Figure 11: Capital Investment Justified By Elimination of Field Units

Bibliography

Automatic Vehicle Monitoring Technology Review, MITRE Corporation MTR 6059, Project 158E Contract No. DOT-UT-K0028, August, 1971.

Bussard, D. L., Los Angeles Police Department Operations Simulation, TP. 69-16-29, Hughes Aircraft Company, Ground Systems Group, Fullerton, California, August, 1969.

Doering, R. D., Computer Simulation of the Command/Control Operations, Project (70-04-05), Final Report to Governor's Council on Criminal Justice, City of Orlando Police Department, Orlando, Florida, September, 1972.

Larson, Richard C., "On the Modeling of Police Patrol Operation," IEEE Transactions on Systems Science and Cybernetics, Volume SSC-6, No. 4, October 1970, pp. 276-281.

Larson, Richard C., Urban Police Patrol Analysis, MIT Press, Cambridge, Massachusetts, 1972.

Vehicle Location and Status Reporting System, (LOCATES), Project No. 182, Final Report Phase I, City of Montclair Police Department, March, 1972.

A MODULAR APPROACH TO THE AUTOMATIC LOCATION OF VEHICLES

by

Basil E. Potter
MetrOscan, Inc.
Buffalo, New York 14240

Summary. This paper discusses a modular automatic vehicle monitoring system which we at MetrOscan, Inc. believe can evolve into a most valuable tool to those in the field of law enforcement. The paper was written with communications and administrative officers in mind as its principal readers. A low cost, spectrally conservative system is offered as the basic modular building block; it employs a technology, that is hopefully reasonably well described, which is commonly referred to as "one-way phase multilateration". Trade-offs are discussed concerning the use of modular additions to the basic system which, though more accurate, are also more expensive and spectrally less efficient. A simulation of an actual dense urban police district is employed to demonstrate the sufficiency of systems which are relatively inaccurate.

Introduction

MetrOscan, Inc. is in the business of providing automatic dispatching equipments. For several categories of application automatic dispatch involves the use of automatic location and reception of status data from all participant vehicles, the ability to accept input data (such as street addresses) for computer conversion, the real-time* display of vehicle location, destination and status, and an automatic or manual method of communicating with drivers. The ability to automatically locate and to receive digital status messages from a vehicle is called automatic vehicle monitoring (AVM).

*If the results of a computation are used to influence a physical process (i.e.: to inform an observer as to the present location of a vehicle) and if this computation is performed during the actual time the physical process is taking place (i.e.: within the observer's ability to judge distance the movement of the vehicle is imperceptible) then the computation is said to have been performed in "real-time".

This paper has been written for the purpose of demonstrating to police administrators how a specific approach to performing the AVM function can fulfill requirements which arise in police applications. The paper treats police procedures to the extent that is necessary to portray the advantages of this specific approach. While it was a temptation to discuss the numerous advantages that police departments would derive from the use of automatic dispatch techniques, only those benefits which we believe shall specifically be attained from the use of the described AVM system are discussed.

A modular concept of vehicular location is described in this paper. The basic building block, functionally represented as figure 1, utilizes the radio frequency emission from a modified communications transmitter in a vehicle that has been measured at several different sites, and that has then been retransmitted to a base station and processed at this station to obtain the position of the vehicle. This basic system has been designed with spectral conservation and low cost being considered to be of prime importance. Modular additions to the vehicular and base station equipments allow for the operational system requirements to be viewed in the light of cost-effective design and spectrum utilization. A real-time functioning forerunner of the equipment discussed in this paper was built by the Sierra Research Corporation of Buffalo, New York. This equipment was extensively tested in the city of Philadelphia, Pennsylvania by the MITRE Corporation under the auspices of the Urban Mass Transportation Administration (UMTA) of the United States Department of Transportation.

This paper is addressed to operationally orientated readers. It is divided into discussions on: the fundamentals of the "one-way phase multilateration" principle which is the basic building block upon which the modular AVM system is built; the accuracies in vehicular location that can be attained using the various categories of modular equipment; and the accuracy that is actually required for police operations.

The Basic Building Block: One-way Phase Multilateration

"One-way". The first general class of vehicular location systems to be defined are those which use either two-way ranging or one-way ranging techniques. If a vehicle transmits a signal which is received and retransmitted back to the vehicle by a fixed station (the signal having made a round trip) then in a "clean environment" (devoid of signal blocking structures) the round trip time that this "two-way" signal traveled is proportional to the distance between the vehicle and the fixed station. We shall refer to such fixed stations as sensors. It is readily shown that the intersection of three such distances, each measured between the vehicle and a sensor, determines the position of the vehicle. This technique of

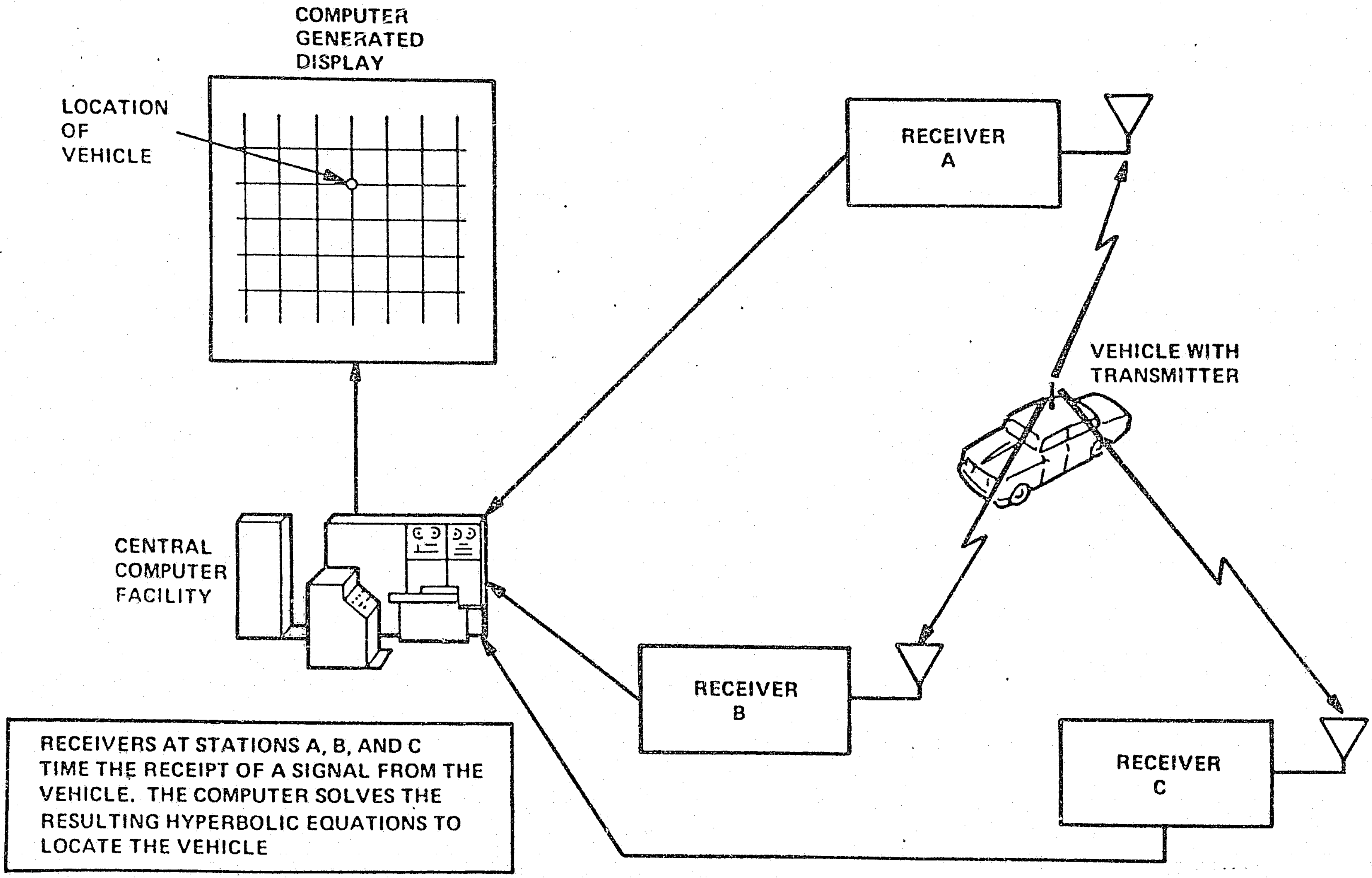


Figure 1. Vehicle Location System

position determination is known as two-way ranging. If a vehicle transmits a signal which is received by a sensor but not retransmitted back to the vehicle (the signal travels "one-way") the difference in time the signal is received at two different sensors describes a unique curve in space upon which the vehicles must lie.* The intersection of three such curves gives the location of the vehicle; this technique of position determination is referred to as "one-way"ranging. One-way ranging (synonymously used with the term "time-difference-of-arrival") is not inherently as accurate as two-way ranging (synonymously used with the term "time-of-arrival"), but since a system using the one-way concept does not require knowledge of the exact time that the vehicle transmitted a signal it is considerably less complex to instrument.

"Multilateration". The name commonly used to describe the use of sufficient intersections of time of signal travel to find an unknown position is trilateration (three intersections). Because of blocking structures (especially in an urban environment) signals do not travel in direct lines, but rather they bounce off the many surfaces between transmitters and receivers. As a result, trilateration often yields significantly wrong data as to where the location of a vehicle is. One technique used in overcoming this problem is called multilateration. Multilateration uses the intersections of many curves and deploys statistical voting techniques as to how to weight the value of each curve. It should be pointed out that trilaterative systems may use many sensors but only three intersections are used in the determination of location.

"Phase". Another important classification of systems which employ time measurement to determine location are the categorizations of pulse and phase ranging. Pulse ranging employs the use of a burst of electromagnetic energy that is turned on almost instantaneously. On the other hand, phase ranging techniques use a pulse of longer duration and essentially average data throughout the length of the pulse. Because a pulse system uses the first signal to get to the receiver, a phase ranging system uses the average of the many signals that are received to determine transit time, pulse ranging is not nearly as sensitive as is phase ranging to the harsh urban environment where a signal bounces off many surfaces between the

*Actually since from a "two-way" signal we obtain a known constant distance between the vehicle and a sensor, a "two-way" signal similarly describes a unique curve in space; this curve is a sphere. The name for the "one-way" curve is a hyperboloid.

transmitter and sensor (this bouncing effect is referred to as multipath). Thus, in the presence of multipath, pulse ranging is inherently more accurate. However, a major shortcoming of pulse ranging is that when energy is rapidly switched, a great amount of a valuable commodity – radio frequency spectrum – is used up; pulse systems require a larger amount of the spectrum than it currently appears can be allocated. Further, because phase ranging techniques can work within the spectrum legally assigned for mobile communications, phase ranging systems can make use of modified commercial two-way radio equipments, while pulse systems must deploy additional equipment to the standard two-way sets that shall be carried by virtually all potential system users. Thus, based upon cost and spectrum utilization considerations, it appears to us that the approach of refining phase ranging technology is a more practical method of determining the location of vehicles than is the use of pulse ranging.

Under contract DOT-UT-10024 the Sierra Research Corporation built and tested in Buffalo, New York and Philadelphia, Pennsylvania, one-way phase multilateration equipment. A simplified block diagram of this equipment is presented as figure 2. While for the purposes of testing in Philadelphia nine sensor stations (out of the nine utilized) were employed to solve for vehicular location, in a real system about twelve (approximately twenty-five sensors would be deployed in a large, congested city) time-difference-of-arrivals would be used to find the position of a vehicle. This "raw" technique yielded a 95 percent accuracy of about 2500 feet* in the downtown Philadelphia area.

The Modular Approach

History. The accuracy attained from the "raw" Philadelphia data was readily improved by utilizing coarse odometer data and more sophisticated computer processing. By using telemetered odometer data, which informed the system computer of the distance the vehicle traveled, the Sierra engineers were able to refine this raw data to a 95 percent accuracy of 1300 feet in the high rise area. The process of refining this raw data, with the aid of a vehicle odometer and the memory of the computer of several past locations it has determined, is called "filtering". It should be pointed out that these accuracies were attained over a torturous route that was intentionally picked to assure that narrow streets,

*The term 95 percent error of 2500 feet means that 95 out of 100 times the error will be less than 2500 feet.

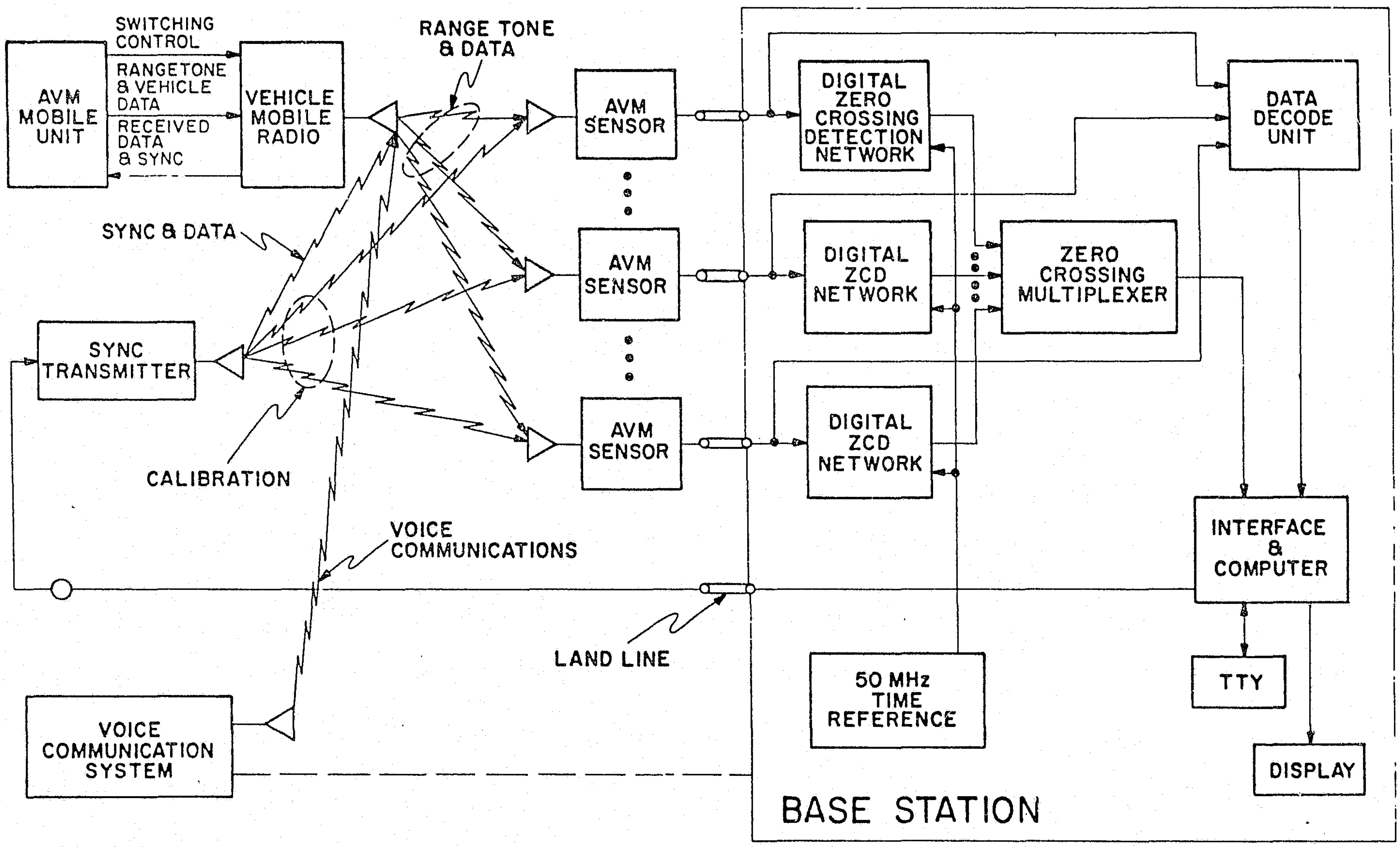


Figure 2. Simplified AVM System Block Diagram

high-rise buildings, and heavy traffic were the norm. It is important to note that a system which was designed only to prove the concept was built for the Philadelphia test (such a system is commonly called a "breadboard"). The test system deployed but one car; however, the test proved to the satisfaction of the evaluators that a thousand similar cars could have been located with the same accuracy.

To obtain an improvement due to filtering requires that independent samples of data be used. If a vehicle has not moved for some time, the many locations solved for while it stood still are said to be "dependent". In Philadelphia, a movement of about 200 to 300 feet caused single sample location information to become independent; movements of less distance yielded "partially independent" data. In a simplified sense it can be stated that filtering was optimized by using as many independent samples as was practical rather than a constant number of samples. Since, in essence, the odometer served only to count independent zones, its accuracy and thus the complexity of the device itself and the transmission time required for data derived from it were minimal.

The Sierra team later returned to Philadelphia with a "dead-reckoning" system which included a relatively inexpensive on-board compass with electrical pick-offs in the vehicle. Theoretically, without additional information, tracking of vehicular position can take place with use of only distance and heading (odometer and compass) data. However, in downtown Philadelphia for the most part a compass and a random number generator seem to be one in the same device (due mainly to d-c fields created by subways and trolley lines). Thus the solution technique employed weighed multilateration derived data far more heavily than may be necessary in other locations. The accuracy attained was about 850 feet. Though no scientically derived quantitative data is available, tests in Buffalo displayed that considerably better accuracy could be attained. But even in Buffalo nature has provided anomalous regions where the existence of the multilaterative equipment would have proved to be of critical importance.

<u>Configuration Limitations.</u> Sufficient data exists to claim that "raw", coarse odometer filtered, and "dead-reckoning" augmented one-way phase multilateration systems can be provided in dense urban areas with respective 95 percent accuracies of 2500, 1200, and 600 feet. The system could accommodate up to 1000 vehicles

on a single dedicated additional channel without degrading the normal voice transmissions of the vehicular radio. This is accomplished by the automatic switching to the AVM channel at the appropriate time, the emitting of a short tone burst for location determination, and the automatic switching back into the normal voice mode channel in little more than one-thirtieth of a second later. The vehicle switching time informs the system as to which vehicle is reporting, every vehicle having its own assigned time slot. Figure 3 is presented to illustrate this principle. "Filtering" does not come as inexpensively as it might appear. The addition of odometer pick-off and coding equipment is not costly nor is the small increase in time that is added to the single time slot length very significant. However the system now utilizes the history of a vehicle to help predict the future; that history cannot be too stale if it is to be of any use. In one proposed configuration of the "raw" system 800 vehicles could report on a once-per-minute basis and 200 on a once-per-fifteen-seconds basis (the time slot format for this configuration is figure 4). Since history plays no role in the "raw" configuration the reporting time and the sampling time (the time between slots which have been assigned to a given vehicle) are identical. For the odometer "filtered" system, experimental evidence indicates that about eight samples per minute shall be required on each vehicle – approximately two hundred vehicles per AVM channel. The improvement in accuracy is paid for in terms of channel capacity; no matter how infrequently the vehicle is required to report because of operational requirements it must be sampled with sufficient frequency.

"Dead-reckoning" requires the use of a fairly extensive vehicular equipment modification. While the compass mounting has to be appropriately designed to consider the local magnetic field profile, while it is preferable that a front wheel distance travel measurement device be employed, and while other similar vehicular constraints have to be dealt with, these conditions are not the cause of the basic system limitation. Dead-reckoning requires the employment of longer time slots which must be used on a higher rate of repetition basis – typically affording less than a one-hundred vehicle per channel capacity. The use of the standard communications radio with dead-reckoning equipment is questionable.

Modularity. If a mix of vehicular equipments is employed, it is our contention that a cost-effective automatic dispatch capability can be afforded to police departments throughout the country. As

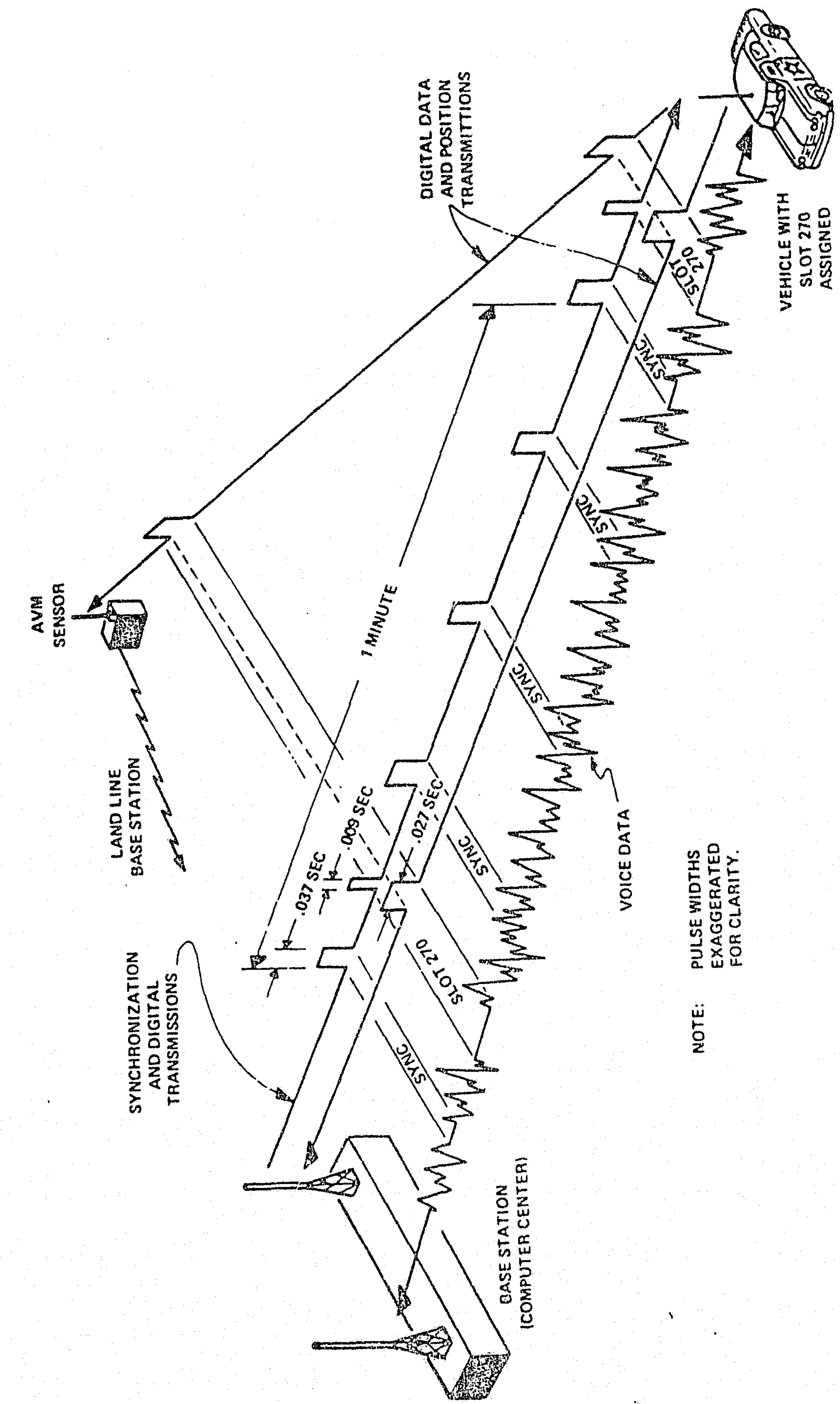


Figure 3. Basic Time Slot Structure

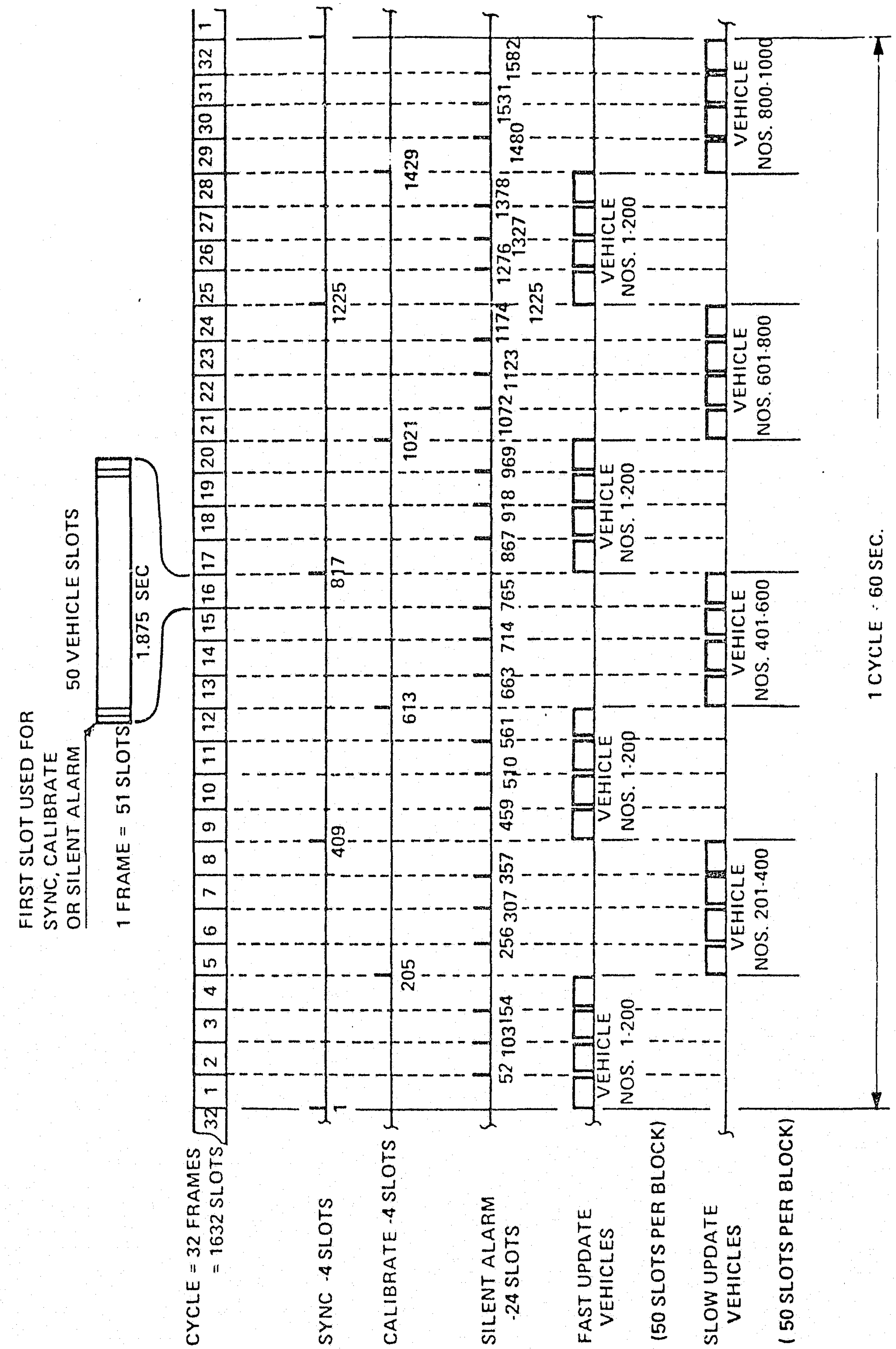


Figure 4. Basic AVM Multiplex Format

illustrated in the next section of this paper, most police requirements can be met with vehicular location inaccuracies of 1000 or even 2000 feet. However, it may be advantageous for a department to possess special vehicles, the tracking accuracy on which it would be desirable to be as low as 100 to 200 feet. When accuracies further and further below 500 feet are required, the systems discussed in this paper begin to fall more and more into the class of multilaterative-aided or backed-up systems as opposed to the augmented multilaterative systems which have been treated herein. While we have conducted extensive and successful simulations of multilaterative-aided and backed-up systems using vehicular gyros, on-board computational gear, and other equipment configurations to allow for the reliable attainment of specifically desired accuracies under the duress conditions of the "real-world", the outcome of any such efforts is not a subject of this paper. Only equipments that have undergone actual field tests which have been guided and scrutinized by a government-sponsored independent authority are described.

The following table is presented based upon the assumption that a modified police radio is utilized for all voice, data, and position location information transmissions and that reliable field-tested (as opposed to instrumentation or laboratory type) equipment that requires little servicing is employed. "Additional Equipment" refers to that which is required in addition to that needed for vehicular location using one-way phase multilateration.

Modular Configurations:

Configuration	95% Accuracy (Feet)	Additional Equipment
Trilateration	4000	-
Multilateration	2500	-
Filtered multi-lateration	1200	Rear-wheel odometer
Dead-reckon filtered multilateration	600	Rear-wheel odometer; compass with electrical pick-off

Required Vehicular Location Accuracy

Since accuracy has significant impact on cost, the obvious question as to what is actually required for automatic dispatch to be effective arises. Several simulations for police operations have been written. The first utilizing perfectly square beats was written by the Institute for Defense Analysis (IDA) and was presented in the 1967 President's Commission on Law Enforcement and Administration of Justice Task Force Report. The conclusion that was reached by IDA after they completed testing with their simulation was that an error of 40 percent of the length of the side of a beat effectively provided adequate vehicular location accuracy to afford the advantages of using vehicular location. The MITRE Corporation and the Raytheon Corporation are among those organizations who have since authored more complex and thus somewhat more realistic simulations.

A simulation of an actual high crime police district of a heavily populated city is presented in this paper. Figure 5 is a list of the ground rules used for the simulation. Figure 6 is the simulated map of the district; note that less than six square miles of territory are patrolled by eighteen cars. Figure 7 shows data selected to enable a comparison of the distances traveled utilizing a perfect automatic vehicle monitoring system (a system whose location error is zero feet) and of no automatic vehicle monitoring system using the current dispatch methods. For this district, typically six vehicles are out of service (typically this implies "on-call" as opposed to inoperative) at any given time. It is noteworthy that for the six vehicles out of service condition, while 14.3 percent of the trips are of distances greater than 8000 feet with no vehicle location, only 3.2 percent of the trips exceed 8000 feet with vehicular location.

Figure 8 depicts the distance traveled versus the number of vehicles out of service for no vehicle location system, a vehicle location system which demonstrates a 95 percent 5000-foot error, a vehicle location system which demonstrates a 95 percent 1000-foot error, and a perfect vehicle location system. It is readily seen that for this district attaining any better accuracy than about 1500 feet is not cost effective. Little is gained in the lessening of that all-important response time. A 2500-foot system is marginally acceptable in this locale and probably, for this district, represents about the maximum inaccuracy that could be tolerated. The assumptions made in deriving the simulation are such that it is not possible to predict that a 95 percent 2500-foot error would actually render vehicular location effective in impacting upon response time in the simulated district. Provided that appropriate status information is available, the possibility of such a coarse location system performing the functions that are required appears quite feasible. However, only after considerable usage of so coarse a system in the field would we suggest this level of inaccuracy as the norm for police applications. We do suggest that a system which demonstrates a 95 percent 1200-foot accuracy would readily perform the required location tasks.

A SIMPLIFIED SIMULATION OF DISPATCH DISTRICTS

1. THE AREA OF PATROL FOR EACH SINGLE VEHICLE IS A GIVEN SECTOR (A SECTOR REPRESENTS AN AREA WHICH DEMONSTRATES AN EQUAL PROBABILITY OF INCIDENT OCCURRENCE AS EACH OF ALL OF THE OTHER SECTORS).

2. THERE IS AN EQUAL CHANCE OF EITHER AN INCIDENT OR VEHICLE BEING LOCATED ANYWHERE WITHIN A SECTOR.

3. FOR THE UNIT OF TIME BEING CONSIDERED, WHEN A VEHICLE IS ASSIGNED TO AN INCIDENT THAT VEHICLE IS CONSIDERED TO BE OUT-OF-SERVICE.

4. THE POSITION DETERMINATION ERROR DISTRIBUTION OF THE VEHICLE LOCATION SYSTEM IS A SYSTEM INPUT; THE CAR THAT THE VEHICLE LOCATION SYSTEM DETERMINES IS THE CLOSEST TO AN INCIDENT IS THE CAR SELECTED TO COVER THAT INCIDENT.

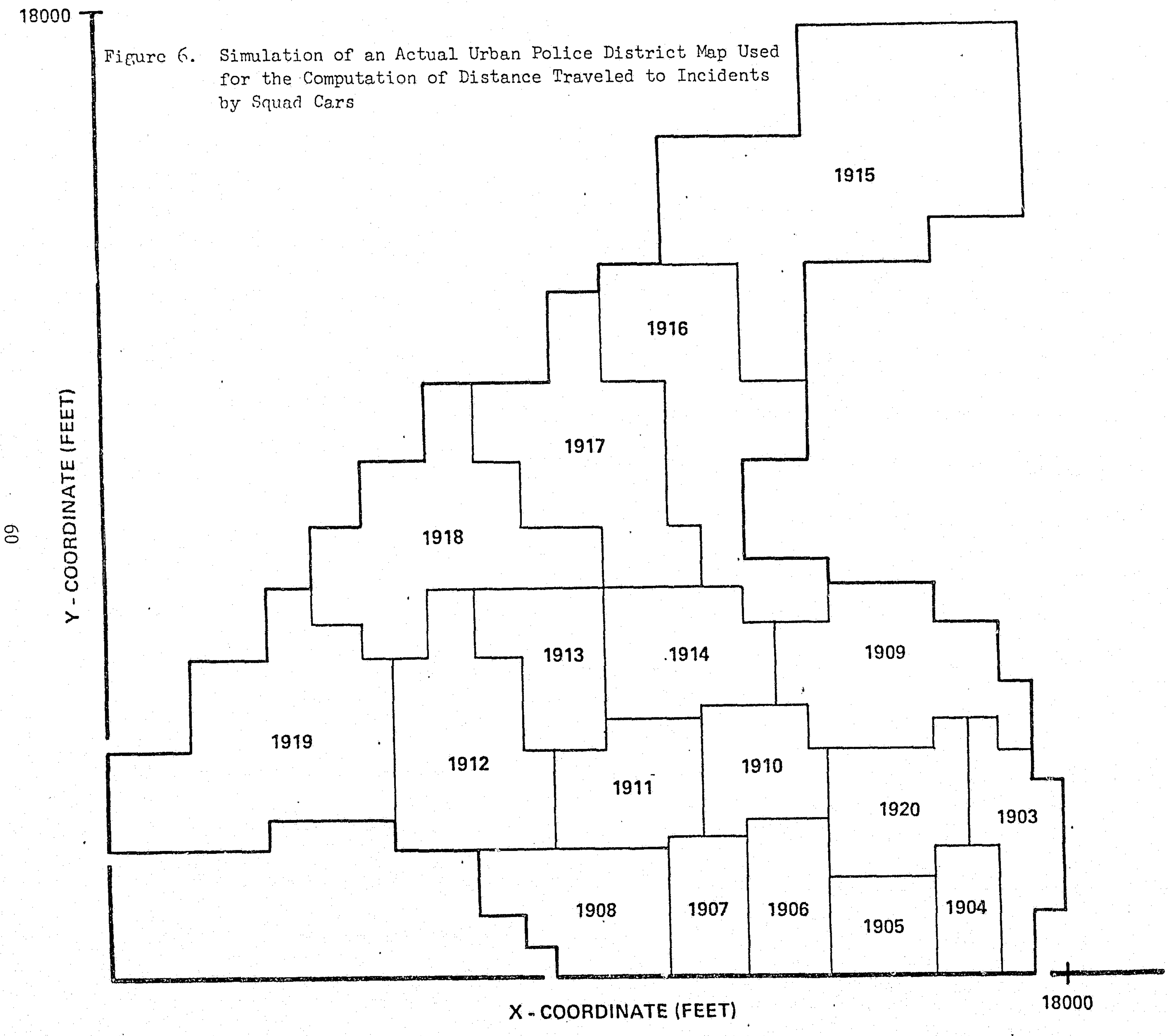
5. THE SIMULATED BOUNDS OF ANY SECTOR ARE GENERATED WITH USE OF RECTANGULAR ZONES WHICH LIE PARALLEL TO THE SELECTED X-Y BORDERS; THE DISTANCE A VEHICLE TRAVELS TO AN INCIDENT IS THE ABSOLUTE SUM OF THE DIFFERENCES IN THE X AND Y COORDINATE POSITIONS OF THE VEHICLE WITH RESPECT TO THE INCIDENT.

6. FOUR TYPES OF INPUTS CAN BE TESTED TO YIELD EITHER THE AVERAGE DISTANCE TRAVELLED BY ALL N CARS OR BY THE N^{TH} CAR WHEN N ASSIGNMENTS TO INCIDENTS HAVE BEEN MADE DURING THE ASSUMED UNIT OF TIME; USE OF: NO AVL, PERFECTLY ACCURATE AVL, AVL WITH A SPECIFIED ERROR DISTRIBUTION, AVL WITH A SPECIFIED ERROR DISTRIBUTION AND WITH THE ASSUMPTION THAT A VEHICLE ALWAYS SHALL LIE WITHIN ITS SECTOR WHEN IT IS UNASSIGNED.

7. THE SIMULATED MAP USED TO GENERATE TEST DATA IS TAKEN FROM AN ACTUAL DENSELY POPULATED POLICE DISTRICT OF A LARGE AMERICAN CITY.

Figure 5. Ground Rules Used for Simulation

Figure 6. Simulation of an Actual Urban Police District Map Used for the Computation of Distance Traveled to Incidents by Squad Cars



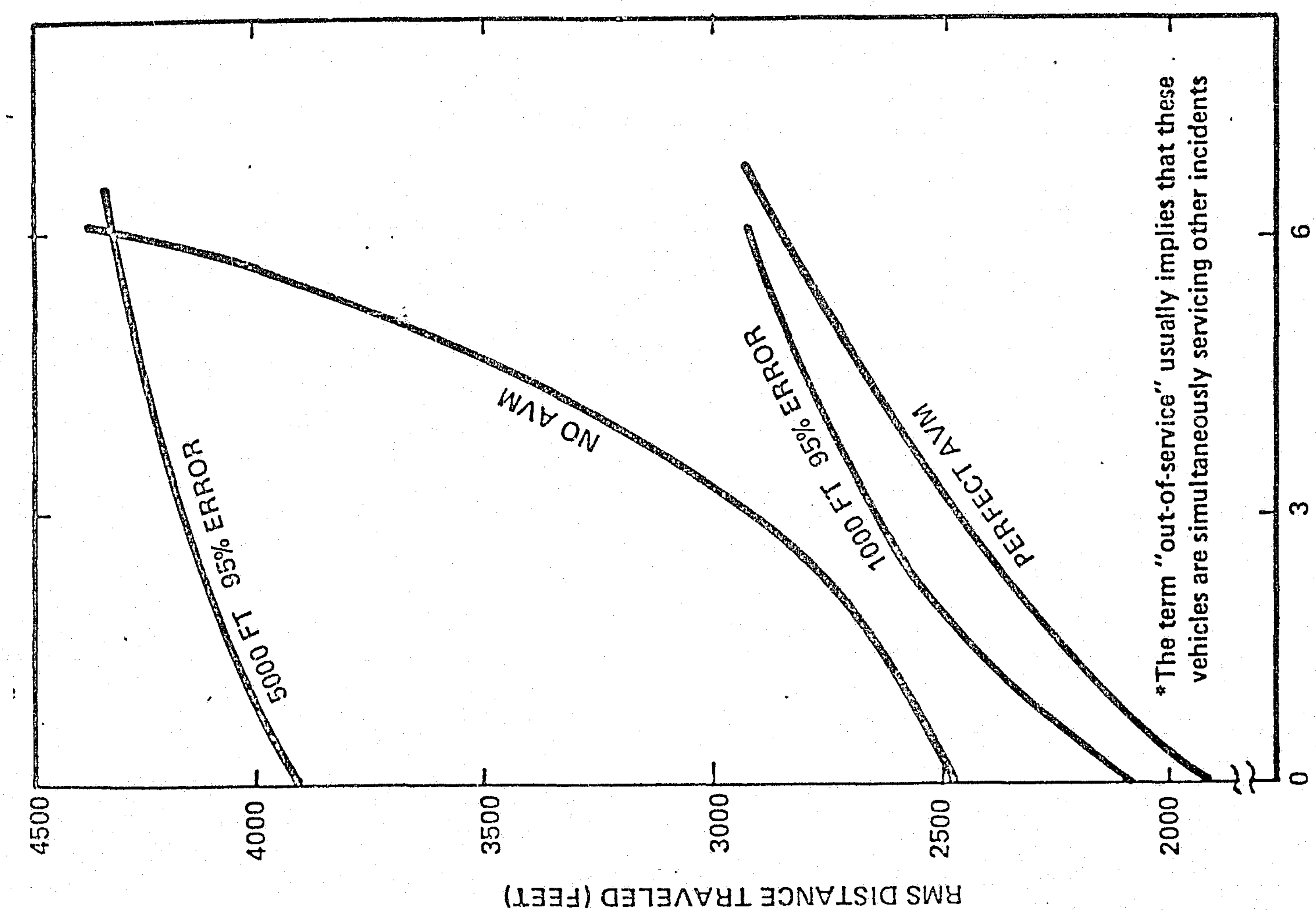
TRAVEL DISTANCE SAVED BY USE OF PERFECT (ZERO FT. ERROR) AVL FOR THE CITED POLICE DISTRICT

	NUMBER OF OUT-OF-SERVICE VEHICLES		
NO AVL	0	3	6
MEAN DISTANCE TRAVELED (FT.)	2100	2500	3300
RMS DISTANCE TRAVELED (FT.)	2500	2950	4300
PERCENT TRIPS ABOVE 8000 FT.	2.0	4.3	14.3
PERCENT TRIPS ABOVE 12,000 FT.	0	0.1	3.6
PERFECT AVL			
MEAN DISTANCE TRAVELED (FT.)	1650	2000	2300
RMS DISTANCE TRAVELED (FT.)	1950	2400	2850
PERCENT TRIPS ABOVE 8000 FT.	0.5	1.8	3.2
PERCENT TRIPS ABOVE 12,000 FT.	0	0	0.9

WITH SIX VEHICLES BEING OUT OF SERVICE:

- THE ODDS OF HAVING TO TRAVEL TO AN INCIDENT MORE THAN 8000 FT. ARE ONE-IN-SEVEN WITH NO AVL AND ONE-IN-THIRTY-ONE WITH A PERFECT AVL
- THE ODDS OF HAVING TO TRAVEL TO AN INCIDENT MORE THAN 12,000 FT. ARE ONE-IN-TWENTY-EIGHT WITH NO AVL AND ONE-IN-ONE HUNDRED AND ELEVEN WITH A PERFECT AVL
- THE AVERAGE TRIP IS 1000 FT. LONGER (44%) WITH NO AVL THAN WITH A PERFECT AVL

Figure 7. A Comparison of the Distances Traveled Utilizing a Perfect Automatic Vehicle Monitoring System and of No Automatic Vehicle Monitoring System



*The term "out-of-service" usually implies that these vehicles are simultaneously servicing other incidents

Figure 8. The Effect of AVL System Error on Distance Traveled for the Cited Police District

Conclusion: Advantages of the System

There are many very real selling points for the providing to police organizations of an automatic dispatch service that includes an AVM capability. There is no doubt that improved service at a reduced operational cost shall result from installation of this type of system. However, the conclusions of this paper shall be based upon the specific advantages of the system discussed above. They are:

- Because the system uses a "time-slot" structure and "phase" tracking equipment the standard communications equipment in the vehicle can be modified to accommodate position location and digital data transmissions.
- Because of the "multilateration" concept the basic system shall attain sufficient accuracy to meet most requirements.
- Because of the "one-way" nature of the system distortions of the signal do not greatly affect location accuracy.
- Because of the many sites employed there is an inherent guarantee of digital data communications.
- Because of the modular concept the system can be purchased on an actual vehicular equipment provided and number of time slots required basis.

Acknowledgment:

The equipment discussed in this paper was built by the Sierra Research Corporation of Buffalo, New York. In the performance of Urban Mass Transportation Administration contract DOT-UT-10024, this company did its usual outstanding and thorough job, thus making this presentation possible.

LOCATES PROXIMITY AVL SYSTEM

by

Robert B. Fleming
Vice President
Products of Information Systems
Costa Mesa, California 92626

Summary

This paper presents information on the subject of Automatic Vehicle Location and Status Reporting (AVL) Systems, and their application to the Command Control requirements of police agencies. Data contained in the paper documents results of the LOCATES - Phase II Project accomplished for the City of Montclair, California. Conclusions and recommendations developed during the course of this activity are provided to assist law enforcement officials in analyzing their Command Control operations for the use of AVL Systems. Although AVL Systems have been much publicized as a vital new tool for utilization by the police, a full scale system for everyday operational use had not previously been developed and implemented for the law enforcement community. Even though it is a "first", LOCATES has proven to be a reliable, useful System for the Montclair, California Police Department.

I. Introduction And Project Summary

A. Introduction

This paper has been prepared to provide law enforcement agencies with information concerning the results of the LOCATES - Phase II Project accomplished with the Montclair, California Police Department. The paper summarizes work performed and presents data assimilated on the use of an Automatic Vehicle Location and Status Reporting System (AVL) for a typical police application.

For purposes of reference, the moderate size cities discussed in this paper are considered to be those with populations of 100,000 or less. Montclair, with a population of approximately 27,000, and a geographic area of approximately 5.2 square miles, has proven to be an ideal location for the testing, implementation, and demonstration of an AVL System for potential application in other police agencies. The city's grid layout of streets enhances the testing and simulation of various police operations and situation conditions; there are few geographic or man-made barriers which adversely affect or confuse system testing; Montclair Police Department personnel are objective in their use and evaluation of new techniques and approaches for improving law enforcement operations; and Department management sincerely wishes to make improvements that will enhance the operations for any size law enforcement agency.

The definition of an Automatic Vehicle Location and Status Reporting System (AVL), as used in this paper, encompasses all of the system equipment elements necessary to provide for automatically locating Mobile Units in a geographic area, and providing for digital status messages to be transmitted between these Mobile Units and the Command Center.

As depicted in Figure 1, the LOCATES System consists of the necessary equipment elements which provide for automatic vehicle location by the sensing of Mobile Units as they move about patrol areas; transmitting this vehicle location information to a Command Center; computing and formatting the data; and displaying the location information to dispatching and police management personnel without the need for human intervention. The System further provides for sending and receiving status messages at the Command Center and in the Mobile Units without the need for voice communications. An additional feature of LOCATES is an emergency signalling device that can be worn by an Officer, away from the Mobile Unit, to alert the Command Center of assistance needed conditions.

The entire LOCATES System has been designed and constructed for compactness and ruggedness required for the around-the-clock operations of police departments. System equipment elements have been thoroughly tested under the actual conditions of typical use required by law enforcement agencies. The System has been tested and evaluated over a period of twenty-four months. During this time, the equipment elements have performed satisfactorily for Montclair's requirements without the need for major modifications or repair. Tests have been conducted during all times of the day, all days of the week, and all months of the year. This complete testing of System application in an operational setting has demonstrated the reliability and usefulness of LOCATES.

The LOCATES System as described in this paper, has been specifically configured to the needs of police agencies serving communities of less than 100,000 population. The System elements however, have been designed in a modular fashion to allow for expansion and sophistication of System capabilities. Therefore, although LOCATES at Montclair fulfills specific police department operating requirements, it can readily be configured to meet the vehicle location requirements for other law enforcement agencies and related applications.

This capability for expansion provides the law enforcement community and municipal governments with a System that "will grow with the city". Because of LOCATES modular construction approach, agencies can implement an AVL System at very low cost, and add to the System as requirements and budgets dictate.

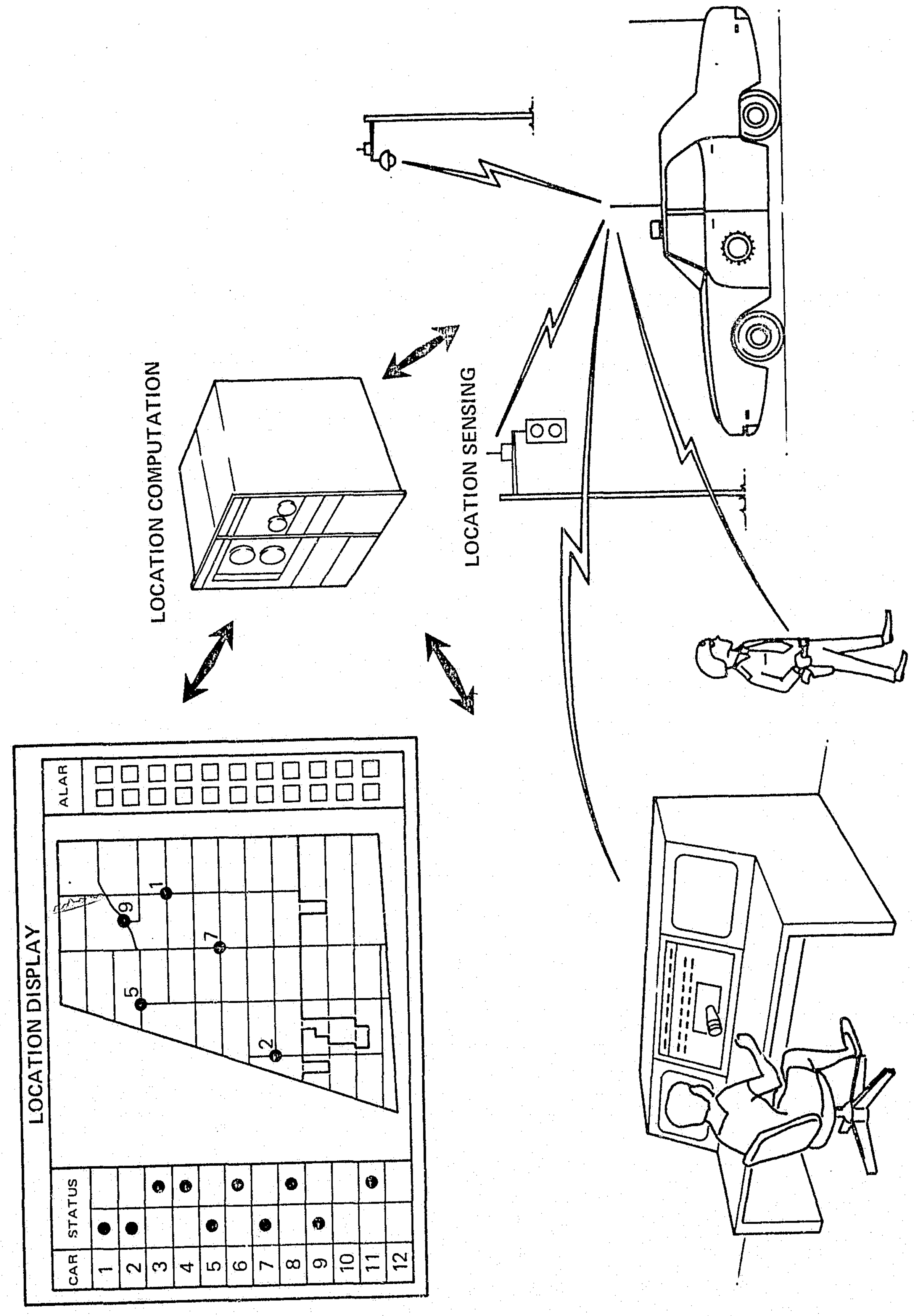


Figure 1. LOCATES System Diagram

B. Project Summary

The approach used for achieving the planned objectives on the total LOCATES Project has been to conduct a multi-phase group of inter-related projects in an operating environment of a typical Police Department (Montclair, California). In general, the total LOCATES Project plan consists of three major phases:

Phase I - Conducting a complete feasibility study of Automatic Vehicle Location And Status Reporting (AVL) Systems, including identification of equipment involved, systems availability and costs.

Phase II - Development and implementation of a total LOCATES System for operational use by the Montclair Police Department.

Phase III - Development of the LOCATES System on a regional basis, and possible implementation of a cooperative regional communications system.

Phase I activities of LOCATES were previously completed with all project objectives attained and exceeded. A practical AVL System approach was identified and demonstrated in Phase I, which enabled Phase II activities to progress in an expeditious manner.

The LOCATES - Phase I Project encompassed the analysis of the geographic environment of a model city (Montclair, California) and region (Montclair, Ontario, Pomona, Upland and Chino, California); the analysis of police operations and mobile vehicle patrol in this model area; the review of technology applicable to location and status reporting system design concepts; and the documentation of study results for use by other law enforcement agencies.

Phase II efforts provide the law enforcement community with the first full scale, AVL System. The LOCATES System will enable police agencies in moderate size cities to evaluate the effectiveness of this type of system for improving police operations.

The LOCATES System, although being the first complete AVL System to be implemented for the police, has proven to be reliable and useful for operations. The practical benefits to be derived from LOCATES as well as the potential for expansion and improvement have been clearly demonstrated by this Project.

With LOCATES implemented, Montclair can now be used as a test area by police agencies for operational theories involving AVL Systems using digital communications. Hopefully, the basic approach and techniques implemented for LOCATES, will foster more sophisticated use of advanced technology for improvement of operations by the law enforcement community.

II. System Approach

A. Introduction

To determine the proper system approach to be employed for this LOCATES Phase II activity, a complete analysis of vehicle location systems and techniques was conducted during the previous Phase I Study Project. This analysis encompassed reviewing the potential of two hundred and twenty (220) industrial firms for producing vehicle location systems for use by police agencies. As a result of this comprehensive study, the Proximity Sensing technique as used with the LOCATES System was selected as the most viable approach available to meet the total requirements of police departments in moderate size cities.

The findings of LOCATES Phase I indicate that of the numerous system techniques that can be pursued, the Proximity Sensing approach as implemented in Montclair, is a most practical technique for police applications in cities of less than 100,000. It is a practical system because it offers the most advantages in cost, utility, and reliability when compared to other techniques. It can be added upon in a modular manner and appears to have the widest scope of application to varying geographic and environmental needs. This system approach can be used on an individual departmental basis rather than requiring multi-jurisdiction involvement because the accuracy factor is predicated upon the placement of the proximity indicators within a specific geographic area.

With the Proximity Sensing approach, location accuracy is greatest in the immediate area of the proximity indicator. When a vehicle is near a sensing device, very accurate location data is automatically displayed. This location information is updated whenever the vehicle moves and comes into proximity with another sensor. Accuracy information, therefore, lessens as a vehicle moves away from a sensing device, and improves as a vehicle comes closer to a sensor.

B. LOCATES System Description

The LOCATES System selected and implemented in Montclair performs three major functions for Police Department operations. These functions are:

1. Vehicle Location. Automatic detection and location display of police Mobile Units at their last detected location as these vehicles move about a geographic area.

2. Status Reporting. Transmission and display of coded messages between these Mobile Units and the police Command Center (Headquarters).

3. Emergency (Alert) Signalling. Transmission and display of emergency signals generated by an Officer, on-foot, away from the Mobile Unit, using the vehicle to relay an emergency (alert) message to the Command Center.

1. Vehicle Location

The LOCATES System makes use of "Proximity Sensing" techniques for the automatic location of police Mobile Units. The scenario shown in Figure 2, illustrates the application of this Proximity Sensing approach to police requirements for a practical and useful AVL System.

As shown in Figure 2, Mobile Units are automatically located by the use of Wayside Emitters which are strategically placed throughout a prescribed geographic area. These Wayside Emitters transmit, via a low power radio frequency, digitally coded location identification data to the Mobile Units as these vehicles pass within proximity of the Wayside Emitters. The Mobile Units, in turn, transmit this location data together with the Unit's identification to the Command Center. At the Command Center, the location of each vehicle in the LOCATES System is automatically displayed to police Dispatchers and Supervisors.

The Wayside Emitters can be mounted on any convenient physical landmark that is situated at or very near the desired location for these devices. Traffic light standards, telephone poles, street lights, and buildings provide effective mounting platforms for the Wayside Emitters. Placement of these devices is governed by the area to be covered or sensed, location accuracy required, traffic flow, and similar operational considerations. The accuracy factor for vehicle location using LOCATES is established by the number and geographic placement of the Wayside Emitters. To increase or decrease location accuracy in any specific jurisdictional area, Wayside Emitters are added or removed from the System.

Each vehicle is equipped with a mobile computer and associated electronics to receive the location message from the Wayside Emitters, store these messages, and at the appropriate time transmit latest location and Mobile Unit identification data to the Command Center via the police radio frequency. Techniques utilized for display of LOCATES System data include a large wall-type map display and console displays for use by police personnel.

2. Status Reporting

Status messages are digitally transmitted via a radio frequency communications link to and from the Mobile Units by

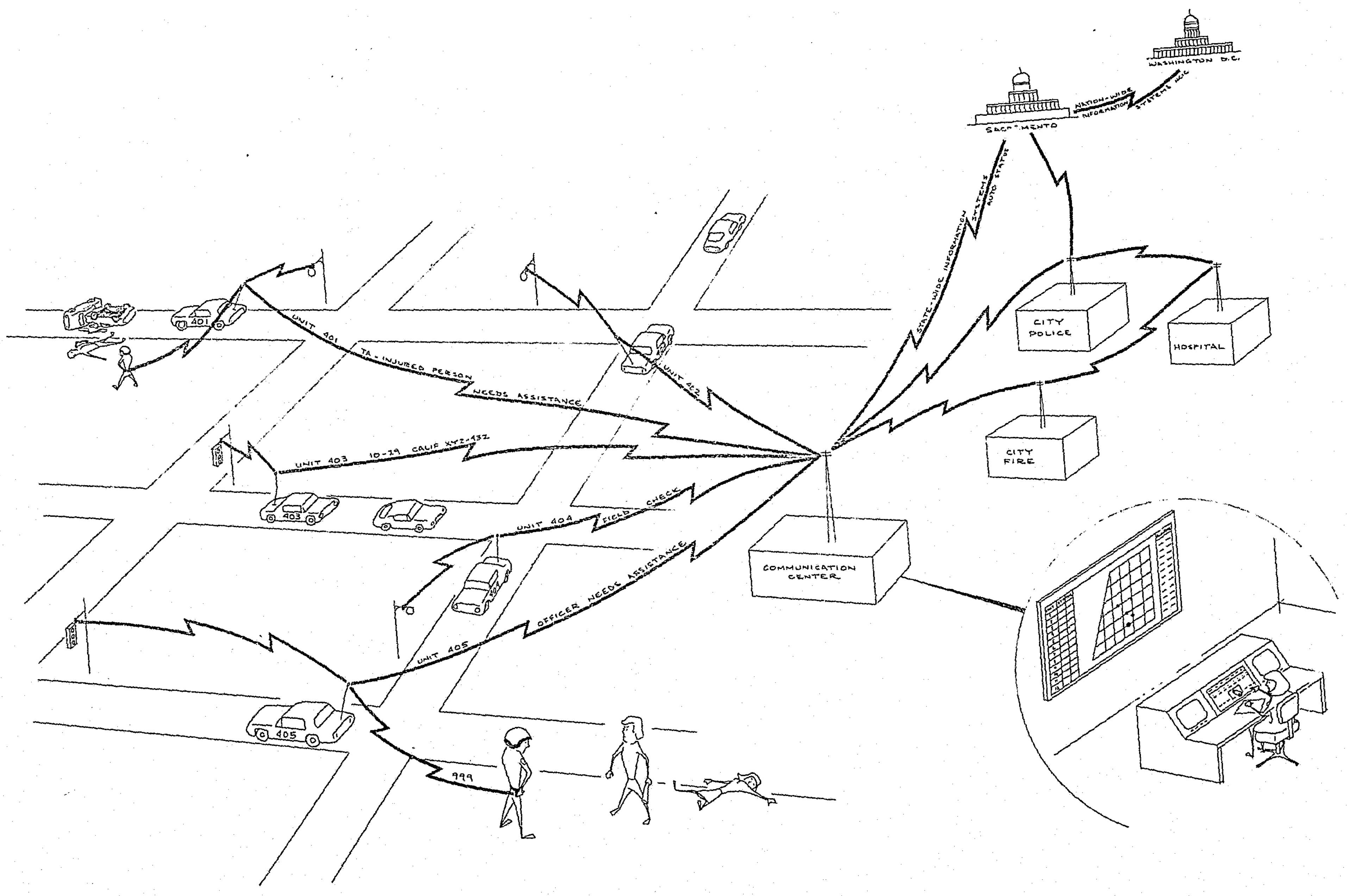


Figure 2. LOCATES System Scenario

means of convenient small size keyboards. These keyboards are located in the Mobile Units and at the Command Center for use by the police personnel. Incorporated with these keyboards are display panels to enumerate messages received by police Officers in the Units, and by the Dispatcher at the Command Center.

When status messages are keyed for transmission by the Officer in the Mobile Unit they are automatically transmitted and displayed at the Command Center. Thus, status of each Mobile Unit on patrol in the city is constantly updated and displayed for Dispatcher information. Status messages transmitted by the Dispatcher to the Mobile Units are similarly transmitted and displayed. Each Mobile Unit receives only the messages intended for the Officer in that specific vehicle.

3. Emergency (Alert) Signalling

In addition to automatic vehicle location and status reporting capabilities, the LOCATES System provides for emergency signalling, or requesting of assistance, by a Police Officer while away from his Mobile Unit. A miniature signalling unit located on the Officer's belt, enables him to transmit an emergency message to his Mobile Unit, which re-transmits the message to the Command Center. At the Command Center annunciators (lights and buzzers) alert the Dispatcher that a particular Officer needs assistance. This device enables the Officer to benefit from "hands free" operations, but still have communications link to the Command Center while away from the Mobile Unit.

III. System Operation

A. Introduction

The LOCATES System has been designed and configured for ease of operational use by police personnel. Because of the automatic updating features of LOCATES, personnel are required to perform only minimum activities for complete operation of the System. LOCATES has been configured to serve as a dispatching and communications tool, aiding the Dispatcher and Officer in their daily activities. Thus, the LOCATES operations are simple to perform, save valuable communications time, and enhance dispatching operations.

The LOCATES System provides for automatically locating each vehicle in operation using the System. No action or intervention is required for Mobile Unit location updating by any personnel using the System. The transmitting of status messages by an Officer or a Dispatcher requires only the pressing of the buttons located on their respective keyboards. This "button pressing" activity for transmitting status messages, replaces the need for using the typical

voice radio communications link. Display of both location and status messages occurs automatically, as does the sounding of alarms and flashing of alerting signal lights for the Dispatcher.

Because the LOCATES System requires only a minimum of action by the Dispatchers and Officers, it provides a useful tool for police operations. The automatic location and display of Mobile Units moving about a geographic area has proven to be an assistance to the Dispatcher, resulting in reduced response times in Montclair.

B. Dispatcher Operations

Presented in Figure 3, is a pictoral view of the LOCATES Command Center Display and Dispatcher's Keyboard in operational use at Montclair. The Command Center Display provides a panoramic view of the entire Mobile Unit fleet location and status. This wall-type display can be utilized by various personnel in the Command Center at the same time. Thus, the Watch Commander, Records Supervisor, and clerical personnel are also provided with Mobile Unit location and status data.

As can be seen in Figure 3, the Display contains a map of street layouts and related geographic data. This large map provides for graphically displaying the location of each Mobile Unit in operation for quick and easy reference by the Dispatcher. On the left side of the map each Mobile Unit number, status, location and beat assignment is also enumerated for use by the Dispatcher and other personnel in the Command Center.

When the Dispatcher receives a "call for service", she checks the LOCATES Command Center Wall Display to select the best Unit(s) to assign to the event. If the normal "Beat Unit" is not available for service, or if another Unit can handle the call more expeditiously, the Dispatcher can quickly make this determination from the Command Center Display. With this type of geographic "look up" display, automatical[illegible]ing and prsenting the location of each Mobile Unit, the Dispatcher's decision process for Unit selection is more rapidly accomplished.

When Unit location and status information is received at the Command Center, the Display is automatically updated. Each Wayside Emitter location has been numbered for ease in properly selecing a Mobile Unit for assignment. Light Emitting Diodes (LED's) are used to indicate Unit location and status information to the Dispatcher. These LED's readouts can be easily seen from across the Command Center by all personnel. The Display has been configured into a "picture frame" package that sits on the top of the Dispatcher's Communications Console. Size of the display was dictated by the present Montclair Command Center configuration.

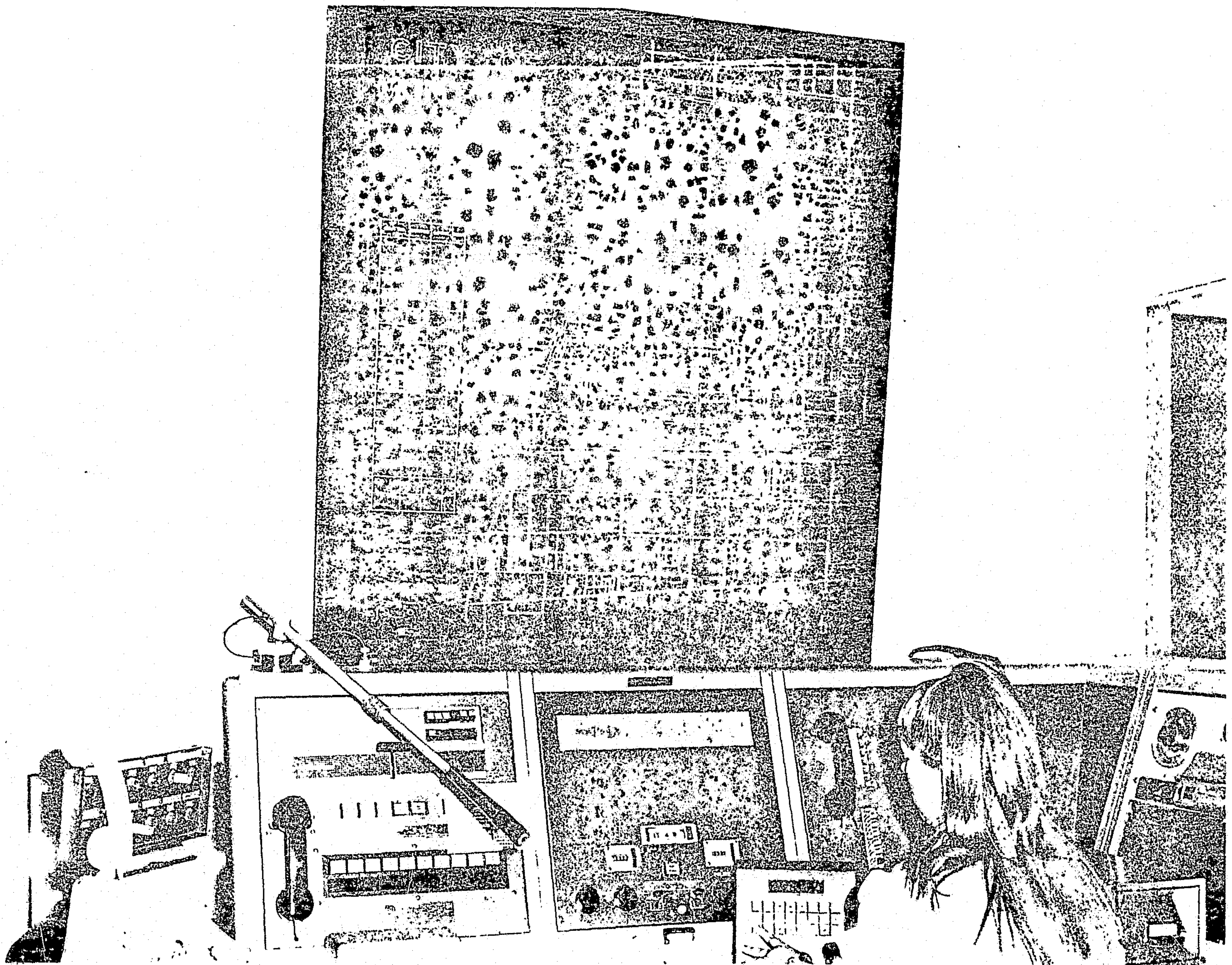


Figure 3. Operational Use Of Command Center Subsystem

With the use of a black background, and data illumination in red, the Display presents the characteristics of a very large Cathode Ray Tube (CRT). Eye strain, however, is considerably lessened with this Display as compared to a CRT. There is no flicker of the displayed data, and the size of data for readout is quite large. The Montclair Command Center Display thus combines the need for geographic display of location data with numeric display of status information using large screen display techniques.

Mobile Unit numbers which are presented at various locations on the map, continually change and update as each Unit moves about on patrol. Whenever a Unit does not move within fifteen minutes, that Unit Number begins to flash on the Display to alert the Dispatcher for necessary action.

Units are numbered 400 through 415 in Montclair, with Beat Assignments ranging from 1 to 6 under the present operational conditions. The small switches (knobs) in the lower left hand corner of the Display are used to set Beat Assignments for each Mobile Unit on duty. These knobs also provide for blanking out information on Units not in service. Immediately below these switches are two audible signalling devices for alerting the Dispatcher as required.

In the photograph of Figure 3, the Dispatcher is shown pressing one of the digital status messages keys on the Dispatcher's keyboard. By pressing the message key after selection of the proper Mobile Unit, the Dispatcher automatically transmits the required status message to the Officer in the Mobile Unit. This equipment is configured for ease of operation by the Dispatcher so as to enhance dispatching operations.

The Dispatcher's Keyboard/Display contains three rows of switches. The top two rows contain the Mobile Unit identification switches, numbered 400 through 415. The bottom row contains the status message switches and the assigned switch. When the Dispatcher wishes to transmit a status message to a specific Mobile Unit, she presses the Unit numbered switch (i.e. 403) and the status message (i.e. 10-4).

In the upper portion of the Dispatcher's/Keyboard Display is a display panel for enumerating the latest status message received from the Mobile Units. This display indicates the Mobile Unit identification and latest status message received. This same status message is displayed on the Command Center Display, as previously described.

The digital status messages selected by Montclair for transmission from the Dispatcher to the Mobile Units using the LOCATES System are as follows:

10 - 4	O.K., Acknowledgment
10 - 9	Repeat Last Message
10 - 19	Return To Station
10 - 30	Code 30, No Record
10 - 32	Code 32, Want Warrant
10 - 80	Contact Dispatcher Via Radio
10 - 82	Transmit On Channel 2

These messages were selected by Montclair before implementing LOCATES, after conducting an analysis of status message transmissions.

C. Mobile Unit Operations

The Officer in the Mobile Unit is required to perform only two operations in the use of LOCATES. The first of these operations involves message transmission and the second operation entails message reception.

The photograph of Figure 4, indicates the manner in which a Police Officer makes use of the Officer's Keyboard/Display located in the Mobile Unit. As shown in this picture, the Officer merely presses the status message switch for the specific message he wishes to transmit (e.i. 10-4 - O.K., Acknowledgment) to the Command Center. Transmission of status messages can be made at any time by the Officer without the need to wait for the radio channel to clear as is the case for voice transmissions. As can be seen from this picture, the Console equipment is non-complicated and provides for maximum efficiency in sending and receiving digital status messages in the Mobile Unit.

The Officer's Status Message Switches are located horizontally across the face of the Mobile Unit Keyboard/Display Console. These messages are arranged in ascending numeric order with 10-4 (O.K., Acknowledgment) located at the far left side, through 10-99 (Dispatcher Alert; or Emergency Conditions) at the far right side of the Console. The Mobile Unit Display of messages received from the Command Center is positioned in the upper left hand corner of the Console. In the top center of the Console is a Reset Switch for clearing the last message received and displayed, whenever the Patrol Officer wishes to do so.

At the upper right hand corner of the Console is a thumbwheel device used for dialing in the Mobile Unit Identification Number. Also, located with this equipment is a Light Intensity Control thumbwheel used for adjusting the level of lighting illumination for the Officer's Status Message Switches. This Light Intensity Control thumbwheel allows the Officer to adjust the illumination of the

Figure 4. Operational Use of Mobile Unit Keyboard/Display

message switches to suit his personal preference for various times of the day. Thus, if the Officer wishes to turn down the lighting illumination level during certain operational activities at night, he can readily accomplish this with the Light Intensity Control thumbwheel.

The Officer's Keyboard/Display Console has been configured for Montclair's Mobile Unit requirements. This Keyboard/Display Console is simplified, easy to use, and provides direct read-out of messages transmitted and received in the Mobile Units.

The status messages selected by Montclair for transmission from the Patrol Officers in the Mobile Units to the Command Center are as follows:

10-4	O.K.; Acknowledgment
10-9	Repeat Last Message
10-82	Transmit on Channel 2
10-84	Field Check
10-86	Send Back-up Unit
10-97	Arrived At Scene; Officer Leaving
10-98	Leaving Scene, In Service, Available for Assignment
10-99	Dispatcher Alert; Contact Officer Via Radio; or Emergency Conditions
Reset	(To Clear Display)

It has been found through extended use of LOCATES that messages such as 10-4 (O.K.; Acknowledgment), 10-97 (Arrived At Scene; Officer Leaving Mobile Unit), and similar messages are most advantageous for digital communications. These messages which require corresponding voice transmissions to qualify message content, such at 10-86 (Send Back-Up Unit) do not offer as much utility as messages which do not require corresponding voice transmissions. When selecting status messages for transmission via digital communications systems, police agencies should carefully select messages which can provide maximum utility using digital communications.

The second equipment unit comprising the Mobile Unit Electronics Subsystem is the equipment pictured in Figure 5. This box contains the entire electronics, computing, and transceiving equipment for LOCATES System operation, in the Mobile Units. This compact package, which fits conveniently into the trunk of the vehicle measures 7" x 13" x 9". The entire package has been configured for rapid and easy replacement, down to the electronics circuit card (board) level.

This equipment package contains a complete mobile computer system with full data management capabilities for receiving, storing, and processing location identification messages. In addition to these computing capabilities, this subsystem provides for receiving and transmitting status messages between the Mobile Units and the Command Center. This sub-system also accepts messages transmitted from the

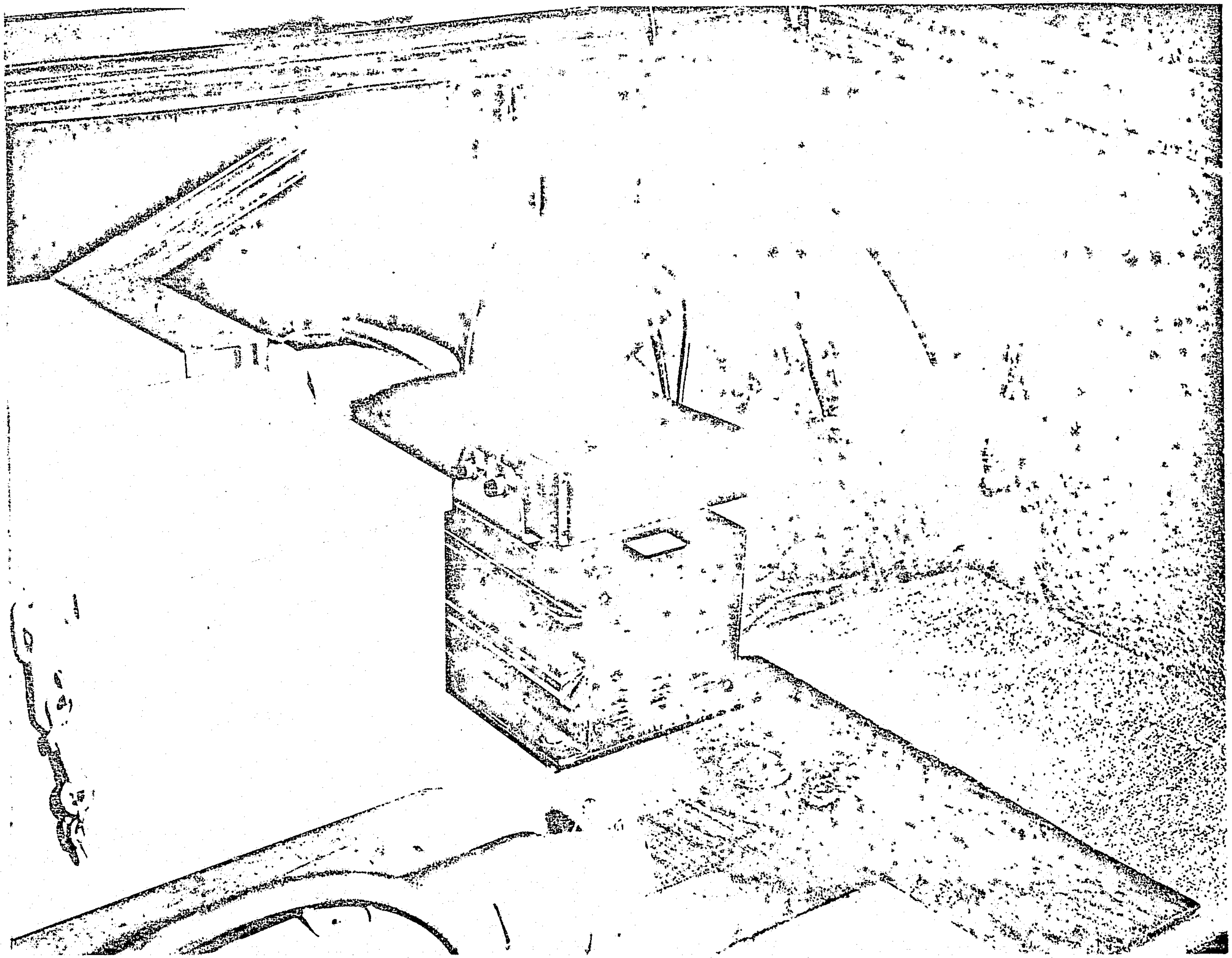


Figure 5. Mobile Unit Electronics - Trunk Mounted

Officers Emergency Signalling Units and re-transmits these assistance required messages to the Command Center.

D. Wayside Emitter Operations

There are no Wayside Emitter operating requirements for police personnel who use the LOCATES System. The Wayside Emitters operate automatically and require no human intervention or activation, except when maintenance is required. Each Wayside Emitter is mounted on an available pole or standard, and adjusted in range to cover the area or intersection selected.

Figure 6, illustrates a typical installation of a Wayside Emitter on a telephone pole in Montclair. As shown in Figure 6, the Wayside Emitter box is fastened to the pole, with a small antenna extending from the top of the box. In the background of this photograph, a police Mobile Unit is shown approximately one-half city block from the Wayside Emitter. As the Mobile Unit comes within transmitting range of the Wayside Emitter, the Unit automatically receives the location identification message, stores the message, and re-transmits this location information together with the Unit's identification and status to the Command Center.

The Wayside Emitter Electronics Subsystem utilized for LOCATES, is composed of solid state components housed in a weather-proof, tamper-resistant box measuring 7" x 9" x 4". The size and construction of the Wayside Emitter allow for easy mounting onto telephone poles, light standards, or traffic signal lights as required. These devices have proven to be extremely reliable and unobtrusive as implemented in Montclair. There has been no vandalism or tampering with these Wayside Emitters since implementation of the LOCATES System.

The placement of these Wayside Emitters was determined after careful analysis of patrol patterns and calls for service in Montclair. As a result of this operations analysis, fifty locations were selected for placement of the Wayside Emitters, as depicted in Figure 7. These Wayside Emitters have been numbered from one through fifty, starting at the Northwest corner of Montclair. There is an additional un-numbered Wayside Emitter located at the police Command Center, denoted as CC in Figure 7. With this placement of Wayside Emitters, all of the major street intersections, and a number of minor ones are used as location check points in Montclair.

As part of this LOCATES - Phase II Project, location accuracies, as required by a moderate size police agency, were established. These accuracies were based on the time of update for a Mobile Unit while on patrol. In Montclair, this update time averages slightly less than 25 seconds per Mobile Unit. The majority of Wayside Emitters provide for updates within 20 seconds, as indicated in Figure 7. Several are less than 15 seconds, while a few are nearly 30 seconds.

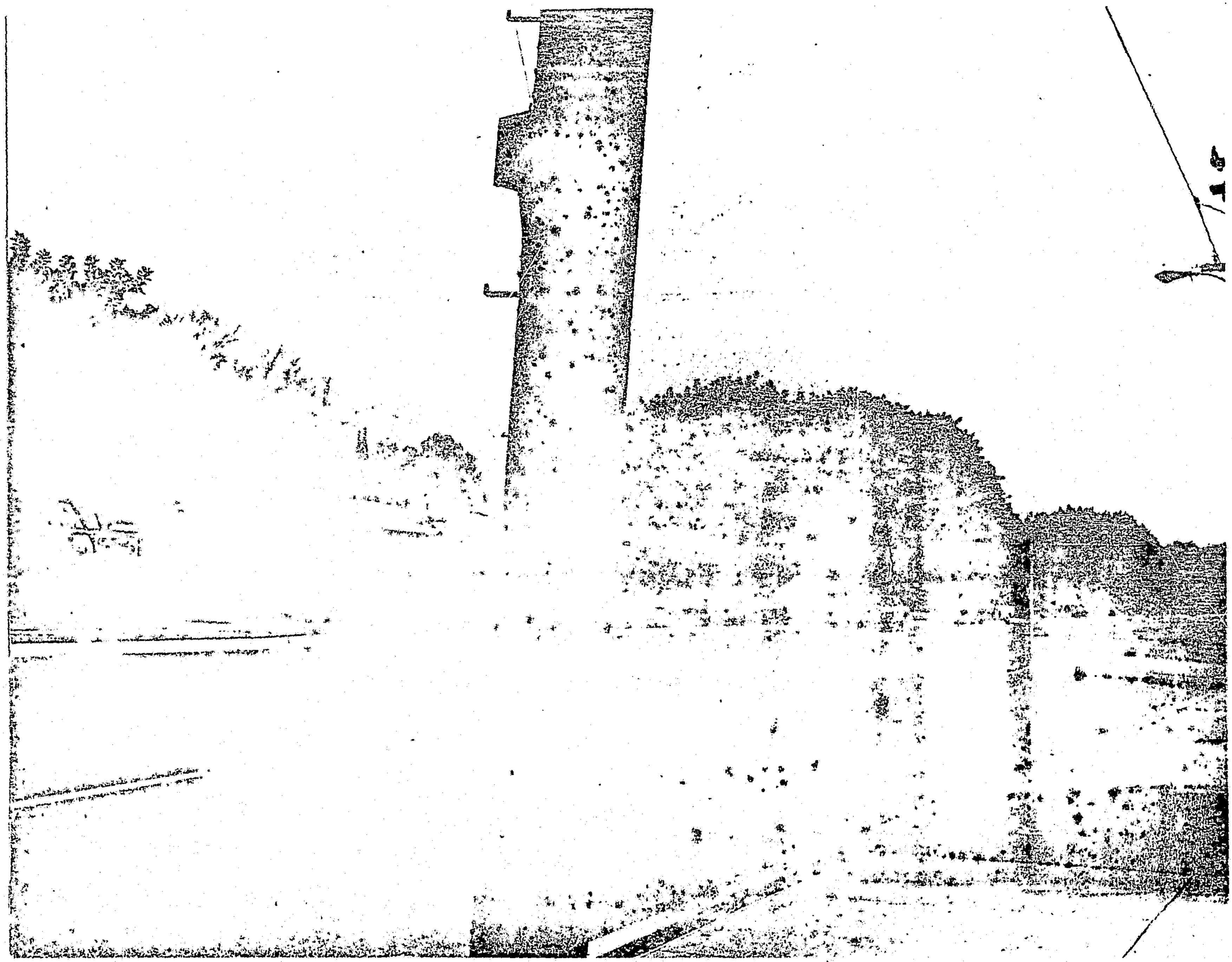


Figure 6. Wayside Emitter Electronics Subsystem

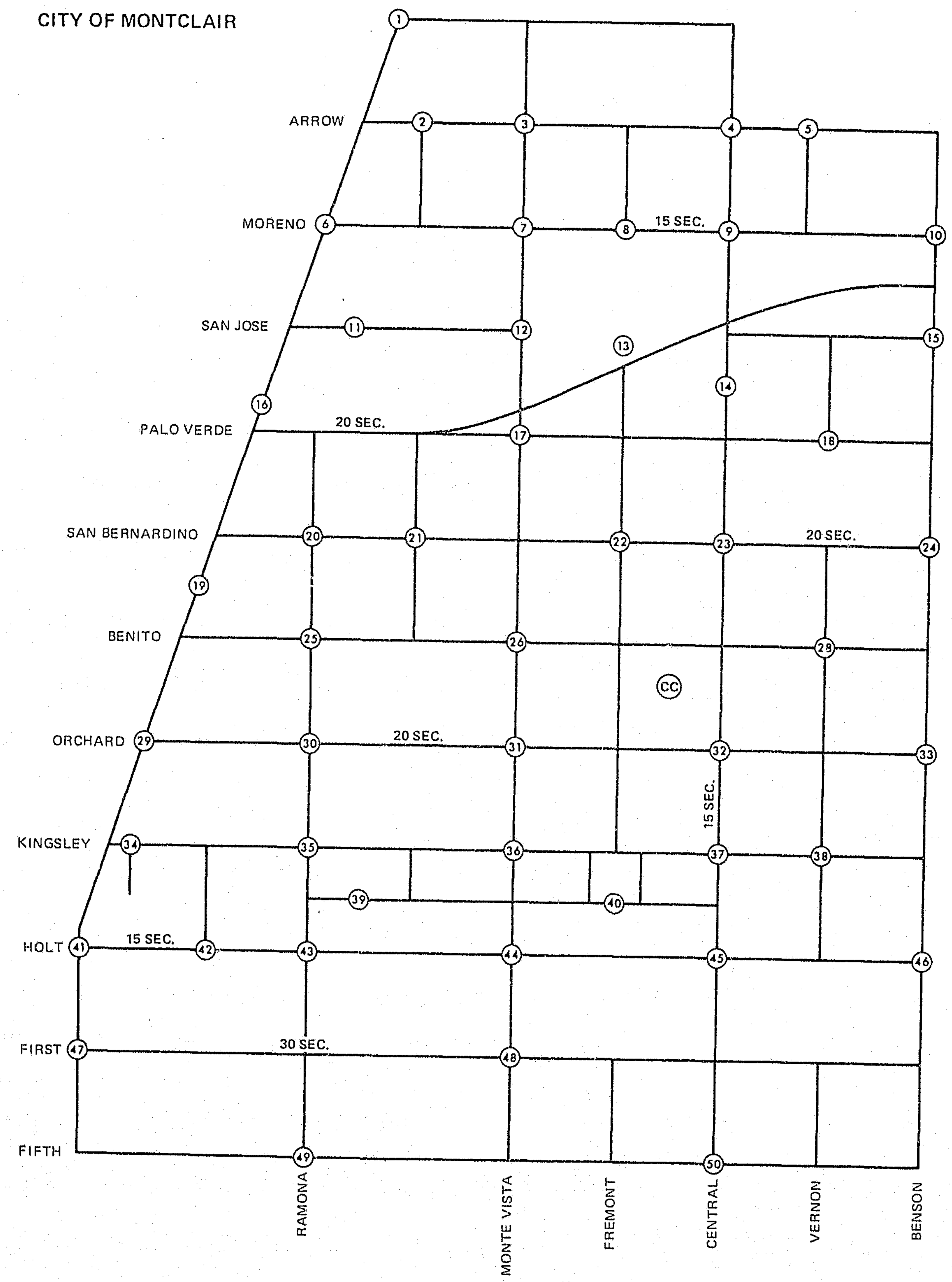


Figure 7. Placement Of Wayside Emitters In Montclair

Depending on the route of travel and traffic flow, a Mobile Unit in Montclair will normally be updated within 25 seconds. This update frequency has proven to be very effective from a Dispatching Response Time standpoint.

The daily use of LOCATES in Montclair clearly demonstrates that moderate size agencies do not generally require accuracies of less than one-fourth mile, or greater than twenty seconds update. The accuracy factor and update times, however, can be varied to meet each police agency requirement with the use of Proximity Sensing techniques.

E. Emergency Signalling Operations

Figure 8, presents a simulated operational use of the Emergency Signalling Unit worn by the Officer on his belt. In the "make believe" conditions of the photograph, an Officer is engaged in an altercation while on-foot away from his Mobile Unit, located in the background. While engaged in such an altercation, the Officer can press the button on his Emergency Signalling Unit to alert the Dispatcher at the Command Center of "assistance desired" conditions.

This device has been configured to be approximately the size of a package of cigarettes. The entire electronics and battery power pack is housed in a police tape case for convenience of wearing by the Officer. The signalling button for the Emergency Signalling Unit is located on the underside of the case to safeguard against accidental activation.

F. System Operation Evaluations

System Operation Evaluations of the LOCATES System in Montclair were conducted to review the utility of the System in a typical moderate size city police department. These evaluation activities resulted in determining that LOCATES does have utility for police operations and direct transferability to other departments the size of Montclair and larger.

1. Receipt Of Call-To-Dispatch Times Evaluation

Dispatch times were measured with the use of the LOCATES system, and without the use of LOCATES in Montclair. These dispatch times were recorded for a wide spectrum of events resulting from Calls For Service on all three shifts of operation. All evaluations were conducted during the same time period, with the same Dispatchers, under normal operating conditions. Figure 9, presents summaries of the data collected concerning times required for Receipt Of Call-To-Dispatch.

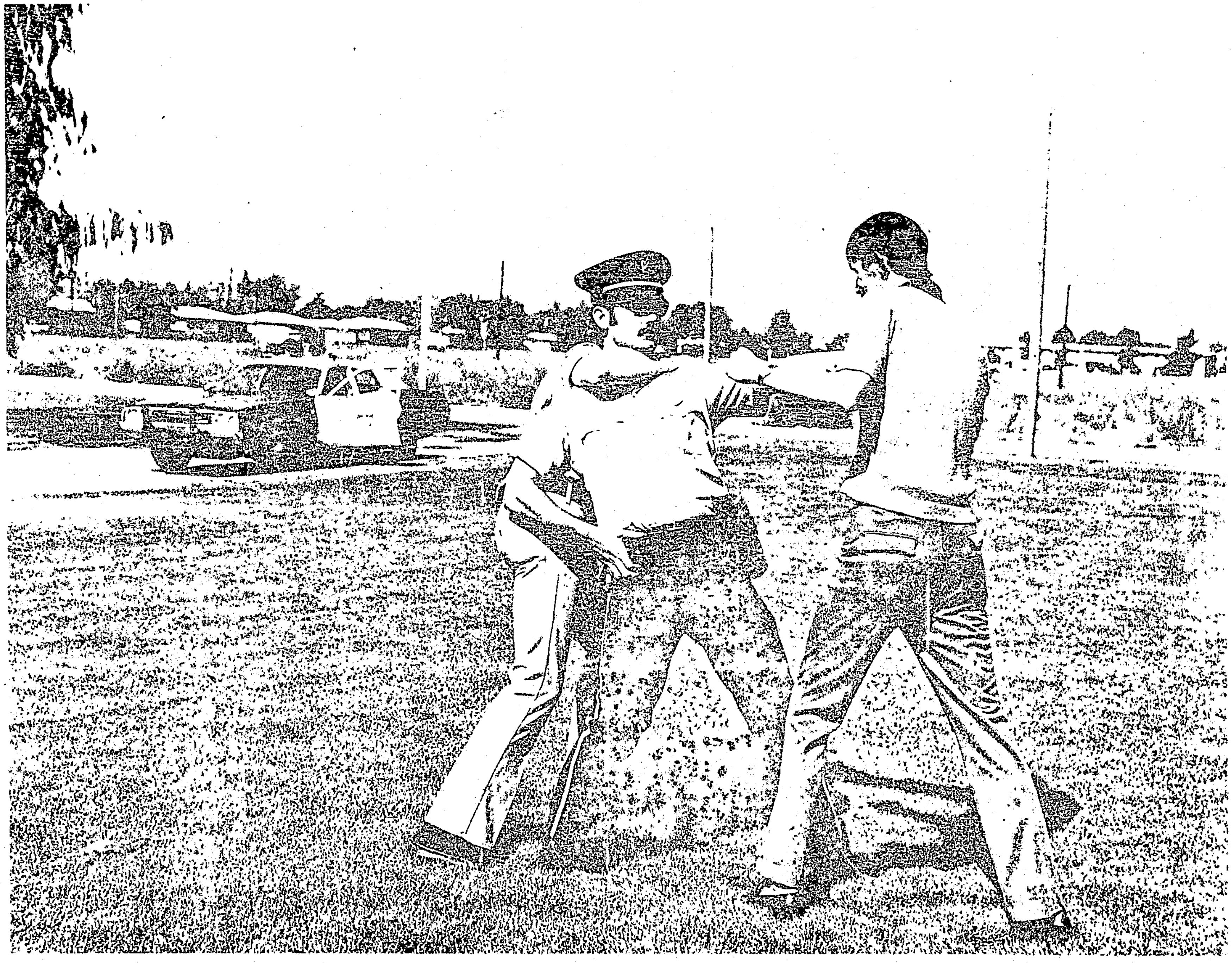


Figure 8. Operational Use Of Officer's Emergency Signalling Unit

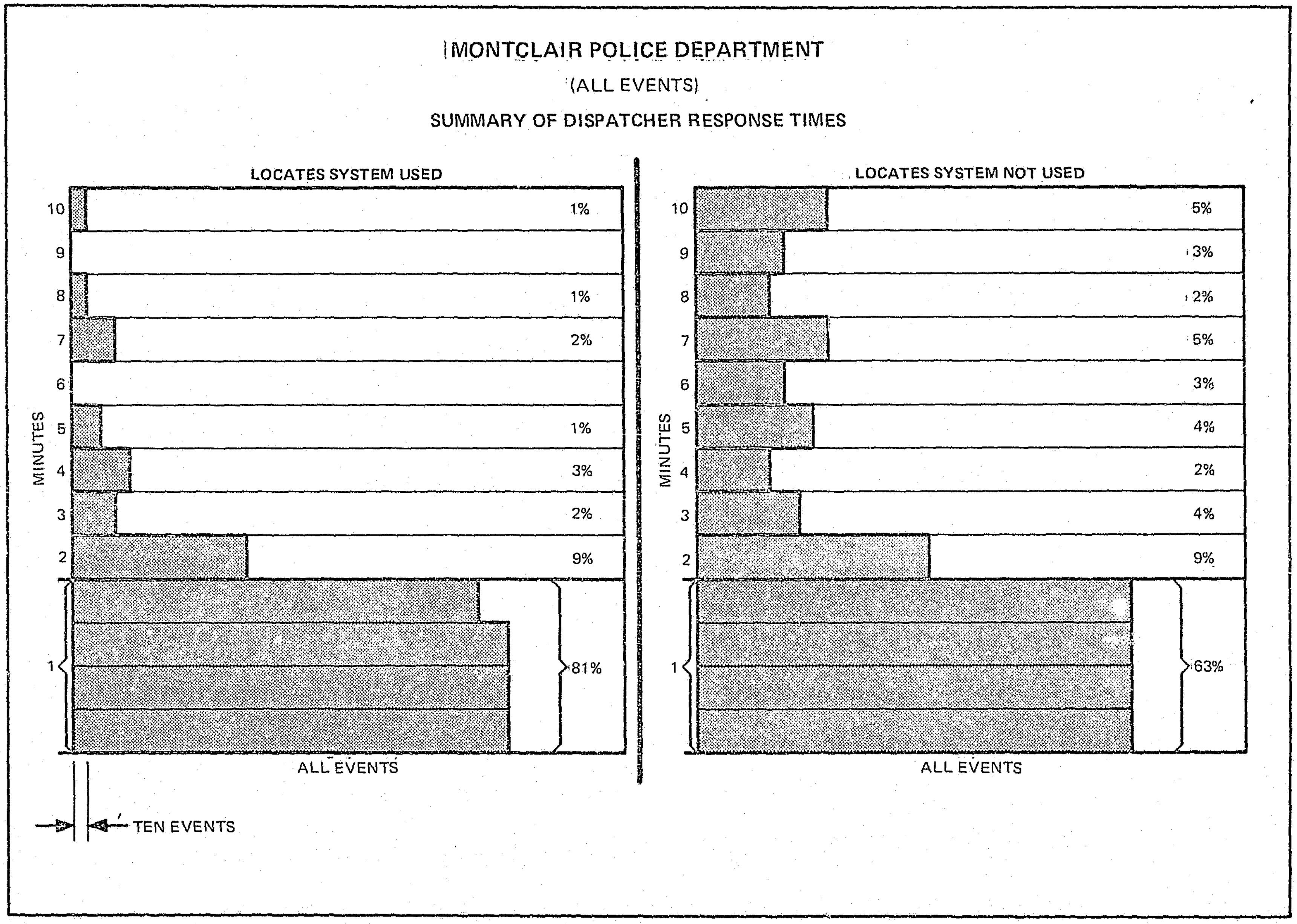


Figure 9. Receipt Of Call-To-Dispatch Times - All Events
LOCATES System Used Versus Not Used

As can be seen from this chart, with the LOCATES System, 81% of the dispatches took less than one minute to complete, while without using the System, only 63% of the dispatches were completed in less than one minute.

This significant change in dispatch time clearly indicates the usefulness of LOCATES for rapidly decreasing the time required to dispatch Mobile Units. Because of the automatic display of the location for Mobile Units on patrol in Montclair the Dispatcher is able to complete the dispatching activities much more expeditiously, than without the use of the System.

2. Dispatch-To-Arrival Times Evaluation

The times for Mobile Units to reach the scene of Calls For Service were also measured with use of the LOCATES System and without use of the System. This evaluation of Mobile Unit response times was conducted on every shift for all types of events. Figure 10, presents the results of this evaluation activity. As shown in Figure 10, when using the LOCATES System, the Montclair Mobile Units reached the scene of Calls For Service 80% of the time in less than 3 minutes. Without using LOCATES, this percentage dropped to 61% of the time. This dramatic improvement in Mobile Unit response times with the use of LOCATES demonstrates the real values of vehicle location as an effective tool for police operations. By choosing the closest available Unit to an event, Mobile Unit Response Time can be greatly reduced.

Figure 11, presents another comparison, for Total Response Times (i.e. Dispatcher Response Times + Mobile Unit Response Times), in the use of LOCATES versus not using the System. When using LOCATES, 83% of all events in Montclair had a Total Response Time of less than 4 minutes, while without LOCATES 60% of the events had this level of Total Response Time. Even in the small geographic area of Montclair, LOCATES has shown to provide a significant improvement in response times for both the Dispatching and Mobile Unit operations.

G. Emergency Signalling Unit Evaluations

The Emergency Signalling Unit was evaluated for operational capabilities in a number of locations throughout Montclair. Although these tests were conducted under simulated conditions, they closely approximated typical uses of the Emergency Signalling Unit for police operations. Figure 12, presents a summary chart of the results of these tests performed in varying locations under simulated operational conditions.

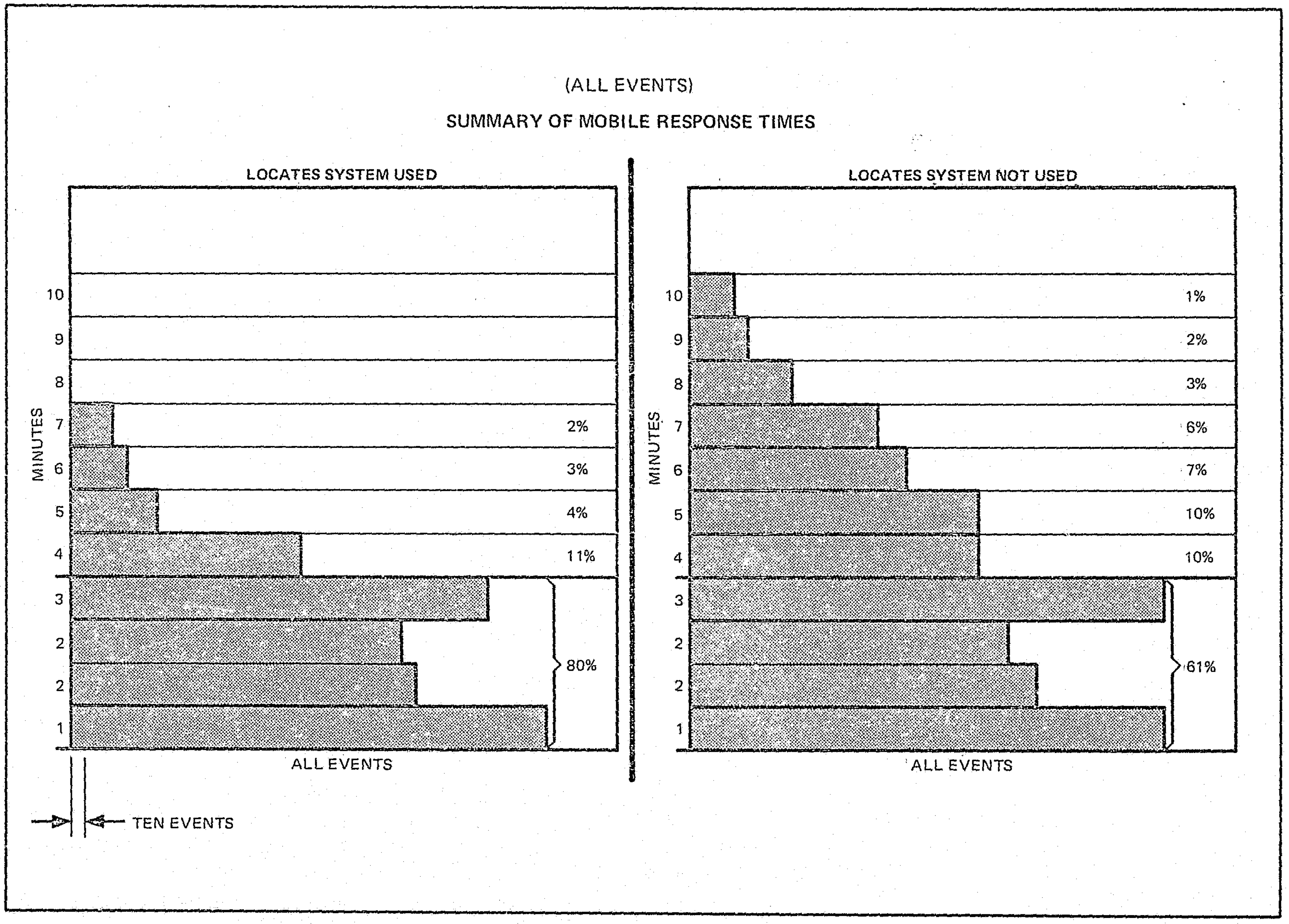


Figure 10. Dispatch-To-Arrival Times - All Events
LOCATES System Used Versus Not Used

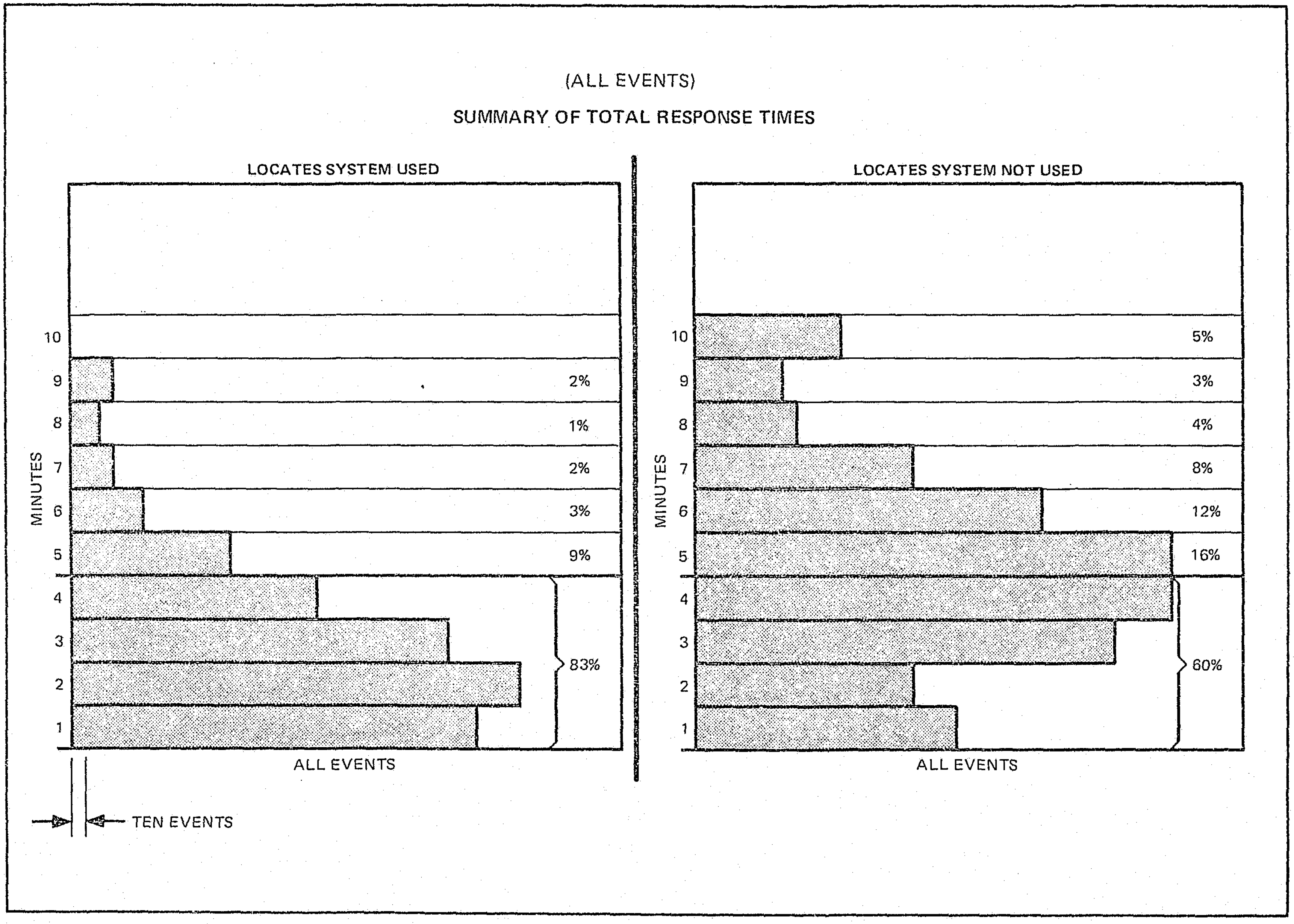


Figure 11. Total Response Times - All Events
LOCATES System Used Versus Not Used

TEST ACTIVITIES SUMMARIES	OFFICERS DISTANCES FROM MOBILE UNITS	RESULTS OF TESTS
1. Officer Inside Liquor Store (On Central Avenue between Freeway and Moreno)	80 Feet to 120 Feet	Working Properly
2. Officer In Lower Level Of Department Store (At Montclair Plaza)	150 Feet to 210 Feet	Working Properly
3. Officer Working Traffic Stop (Simulated)	50 Feet to 120 Feet	Working Properly
4. Officer Across Parking Lot (In Plaza)	500 Feet to 550 Feet	Working Properly
5. Officer Under Freeway Bridge (At Mills)	200 Feet to 230 Feet	Working Properly
6. Unit Under Freeway Bridge	240 Feet to 250 Feet	Working Properly
7. Officer Laying On Ground	150 Feet to 175 Feet	Working Properly
8. Shock Tested. Throwing Emergency Signalling Unit and Belt Onto Pavement	Not Applicable	Still Working Properly

NOTE: Tests on the Emergency Signalling Unit were by Montclair Police Officers selected to simulate actual conditions. The distances selected were not maximum capability of Emergency Signalling Unit for transmission range. All tests were verified by radio contact with Dispatcher.

Figure 12. Emergency Signalling Unit Evaluation

The tests were repeated on numerous occasions over a period of several months to establish the consistency of test results and equipment capabilities. As can be seen from the summaries in Figure 12, the Emergency Signalling Unit performed properly under various police operational conditions throughout Montclair. These tests indicate that this device can be utilized from both inside and outside of buildings with the Mobile Unit acting as a relay communications link to the Command Center.

Figure 12, shows the results of conducting tests over open ground area to determine transmission range capabilities of the Emergency Signalling Unit. For these tests, the Officers were able to send an "Assistance Needed" signal to the Command Center while being approximately 550 feet away from the Mobile Unit. The other tests were conducted with the Officer performing his normal activities, which generally were approximately 100 to 200 feet away from the Mobile Unit.

IV. Project Results And Findings

A. Introduction

The LOCATES System implemented in the City of Montclair, California has demonstrated that an AVL System provides for improved operations and enhances the efficiency of dispatching police Mobile Units. The results and findings of this Project have established the cornerstone for other law enforcement agencies to evaluate the applicability of system features to their operational requirements.

This Project has proven that "Proximity Sensing" provides a viable, cost effective technique for locating Mobile Units in an urban environment. Use of the "Proximity Sensing" system approach provides location accuracies which fulfill the dispatching requirements of police departments of moderate and smaller size cities (i.e. less than 100,000 population), and can fulfill the needs of even the largest size agencies. Because of the modular expansion capabilities of this system approach, major metropolitan areas can make use of this viable tool for improved operations.

Prior to initiation of the LOCATES Project, both the law enforcement community and industry technicians looked with some disdain on the use of "Proximity Sensing" for police applications. The reason for this attitude centered on a false premise of the need for extremely fine accuracies for the location of police Mobile Units. The Montclair Police Department, with the use of LOCATES, has proven that this vehicle locating technique does provide location accuracies that significantly reduce response times and enhance dispatching/patrol operations. The actual use of LOCATES, with somewhat coarse location accuracies, in a small geographic area has resulted in major improvements in Mobile Unit response times. This fact has occurred even with

Montclair maintaining excellent response times before LOCATES was implemented.

B. LOCATES System Cost Effectiveness

The Cost Effectiveness of the LOCATES System can be established in a number of ways. The costs for keeping a one man Mobile Unit in service twenty-four hours per day is approximately $110,000 per year, including depreciation, maintenance, salaries, and administrative costs. For LOCATES, which can cost $200,000 for a thirty (30) unit sized police department, the System can pay for itself in one year with a 6.0% improvement in Dispatching and Patrol Operations (i.e. $200,000 Total System Cost ÷ $3,300,000/Year for 30 Units = 6%). For complete Return On Investment in two years, only 3% improvement is needed; for a three year complete Return On Investment, 1.5% improvement; etc. Thus, Return On Investment of System costs can be readily calculated based on department size and improvement in operations resulting from the use of Automatic Vehicle Location and Status Reporting with LOCATES. As can be seen from this example for analyzing potential System Cost Effectiveness, a small percentage improvement in operations causes a rapid Return On Investment.

Naturally, this simplified cost analysis does not include all of the peripheral operating costs of each Department. For example, the salaries and benefits for Command Center personnel and management have not been included in the operating costs of maintaining a Mobile Unit field force, nor have the maintenance costs necessary to keep LOCATES in proper working order during the Return On Investment time period. This simple approach to determining System Cost Effectiveness, however, can be embellished for each specific Department to determine Rate of Return on LOCATES System investment.

C. Potential Use of LOCATES System

The potential for use of LOCATES by Public Safety Agencies is virtually unlimited. The Montclair Police Department has proven that a moderate size organization can successfully implement and receive benefits from advanced technology. The LOCATES System used by Montclair is an effective method for demonstrating that the needs for improved dispatching, enhanced communications, reduction of radio air times, and added safety for Officers can result from the use of digital communications. Using the Montclair LOCATES Project as the base, other Public Safety Agencies can now implement the System to fit their particular needs and operating conditions. LOCATES meets the needs for these organizations for more rapid dispatching and improved operations.

The effects of Automatic Vehicle Location System use for patrol strategies and response time have been studied using computer simulation techniques. These simulation studies quantitatively measure the effectiveness of a police patrol system, in terms of response times, with and without the use of an AVL System. In a recent operational simulation study presented at Texas A & M University, it has been determined that an AVL System can reduce the Mobile Unit patrol activities by seven percent (7%) without reducing the effectiveness of police protection. Conversely, an AVL System can increase protection equivalent to increasing the number of Mobile Units by seven percent. This potential increase in operating efficiency can be used to determine cost benefits to each law enforcement agency by system implementation.

Using annual costs for keeping a Mobile Unit in service of $110,000 (One Man/Unit) to $200,000 (Two Man/Unit), the potential savings per year can be determined. For example, for a police department with 30 Mobile Units in operation, the city would realize $231,000 of additional protection per year by implementing an Automatic Vehicle Location (AVL) System. It should be noted that an AVL System is a sophisticated tool to improve the quality of police operations and not necessarily to be used merely as a substitute for resources.

Law enforcement agencies must determine the potential use and value of an AVL System for specific applications. Similations and theoretical studies cannot take into account all of the operational conditions and uses of automatically determining vehicle locations for police operations. The Montclair LOCATES System proves in actual everyday use that even moderate size police departments can benefit from Automatic Vehicle Location and Status Reporting Systems. Improvements in communications, police personnel utilization and citizen services are additional advantages which can be realized with the use of this technology. Montclair has demonstrated that improvements in Response Times are realized with this System, now other agencies must determine how best to implement this new tool for their operations.

FLAIR

(FLEET LOCATION AND INFORMATION REPORTING)

by

A. J. Henson
FLAIR Program Manager
The Boeing Company
Wichita, Kansas 67210

Introduction

The Boeing Company began development of FLAIR* in February 1971, when requirements for a system with the accuracy of FLAIR became known through working with the Wichita Police Department. It was found very quickly that vehicle location was not just a requirement of the Wichita Police, but was a desire of police departments throughout the United States; in fact, throughout the world. During the first two years over a hundred patrolmen and dispatchers from Wichita helped in establishing the design requirements. They spent many hours at the Boeing facility in Wichita to insure that it evolved into a system considered by the officers, themselves, to be of the most value to a police department. Great reliance was placed on aerospace technology in the design of the FLAIR concept. Considerable assistance in the past eighteen months has come from working with various people in the St. Louis Metropolitan Police Department to develop the details of the information to be transmitted to the dispatcher from a vehicle, as well as how the information is to be displayed.

System Description

The general system requirements are to track a car with an accuracy of 50 feet; precisely display these city-wide locations to a dispatcher; provide vehicle status information; automatically identify each vehicle by number; indicate if the car is in or out of service; and using a small keyboard on the instrument panel of the car accessible to either operator, instantly send up to 99 coded messages, similar to the standard ten-code type information; an officer emergency silent alarm feature, activated by a single button in the car; a record/playback feature.

* FLAIR is a trademark of The Boeing Company.

There are four basic elements of the FLAIR system. The equipment in the police cars and located at headquarters, a display for each dispatcher, a minicomputer, and a base station two-way radio transmitter/receiver.

The mobile equipment consists of an odometer, compass, coded message unit and vehicle data processor. Installation in the vehicle requires approximately three hours. A tie-in to the front wheel with the odometer provides distance information. Boeing has developed a magnetic compass which senses the earth's magnetic field to provide heading or direction. These units, along with the coded message unit, are connected to a shoe-box size electronic package called the vehicle data processor, located in the trunk of the car. The information of distance, direction and officer status is sent as digital pulses through a standard, although modified, police mobile radio.

FLAIR equipped cars navigate by dead-reckoning. Each car's initial location is known and is inserted and stored in the memory of the computer at central headquarters. Changes in direction of travel and any distance covered since the previous report, are transmitted in digital form by radio every two seconds, to the base station. To avoid navigation error build-up due to inaccuracies in the odometer and heading sensor, a map matching technique is used by the computer to keep the cars located on drivable surfaces to an average accuracy of 50 feet.

The coded message unit is located on the dashboard of the police car. See Figure 1. Lights indicate the two-digit message that will be transmitted. After pressing the Transmit (T) button that information is transmitted to the dispatcher and displayed on his panel.

The Video Display and Control (Figure 2) receives the vehicle location information from the computer and presents it at the proper position, in the form of bright symbols on a video map - TV monitor immediately in front of the dispatcher in the center section of the console.

Data regarding city streets and other drivable surfaces is stored in the memory of the computer. Through computer software a video map of the entire city or a section thereof may be called up by the dispatcher. The dispatcher has the option of selecting a view of the entire city or any of five magnifications which provide views down to the scale of one mile by one mile. The system provides for simultaneous viewing of the same section of the city by all dispatchers.

The dynamics of the display are such that the dispatcher can estimate the speed of cars, note when they turn corners and observe when they stop. Due to the precision of FLAIR, cars can be tracked even in multilevel indoor parking garages. Each dispatcher can individually select a portion of the

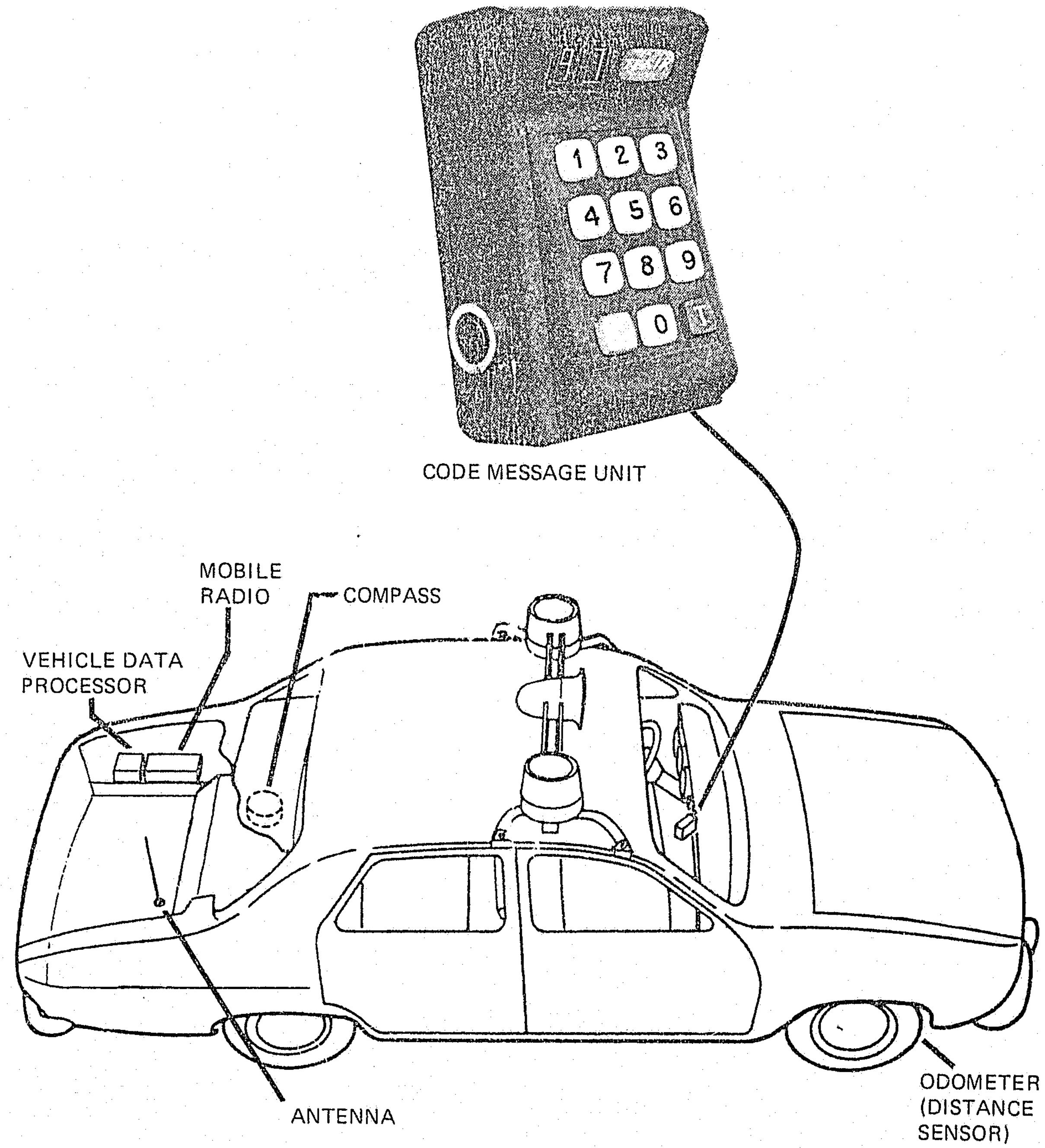


FIGURE 1 – VEHICLE EQUIPMENT

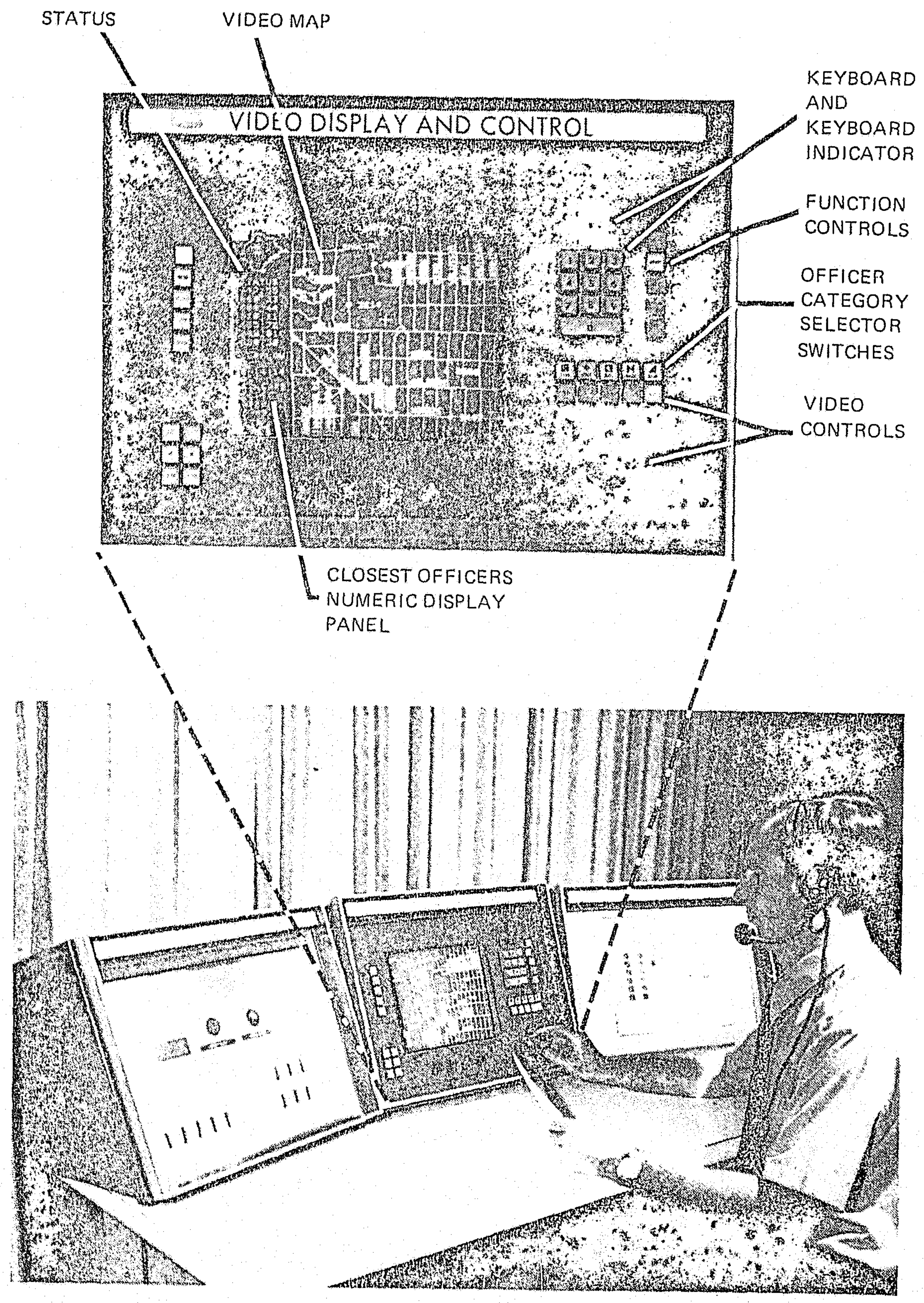


FIGURE 2 – VIDEO DISPLAY AND CONTROLS

city for detailed observation. Magnifications enable the dispatchers to read street names on the video map display. Also each dispatcher may choose to display selectively a single group of officers such as Patrol, Detective, Investigation, Lab or Vice, or any combination of officer groups.

The status of each officer appears on the display. "In-service" officer status is shown by the symbol on the video map. Other controls and status panels which are part of the Video Display Unit serve to assist the dispatcher in accomplishing his command and control function.

Two key elements of the FLAIR video display are the cross, "+" cursor and the box, "□" symbol. The +cursor is part of the normal display and can be maneuvered by the dispatcher. It's position on the display determines which map segment is brought forth and which cars are identified as "closest cars". The □ symbol appears on the screen surrounding a specific vehicle symbol when the dispatcher keys in that vehicle's number and depresses the "Locate" button. The + cursor disappears from the screen when the □ symbol appears. The □ then automatically tracks the vehicle it surrounds, brings forth appropriate map segments and becomes the focal point for calculating closest cars.

Test Results

Over 15,000 miles of testing has been accomplished since 1971 in Wichita and St. Louis in a number of different vehicles. In November 1973 a Pilot Program contract was received from the St. Louis Police Department with funding provided to St. Louis by a grant from the Law Enforcement Assistance Administration. This contract provides for twenty-five cars outfitted with FLAIR, one base station transmitter/receiver, one mini-computer and one dispatcher display. Installation and evaluation of the Pilot Program systems will be completed in October 1974.

In June 1974 Boeing completed a FLAIR evaluation contract with the London Metropolitan Police. The mobile equipment was installed in a Scotland Yard Rover police car and the Police drove areas of G-Division in London. The FLAIR mobile data was recorded on audio tape. The tapes were then transmitted over ITT Datel Lines to a computer in Wichita. The computer traced the routes driven on a map of G-Division. An x-y plot tracing of one run is shown in Figure 3. Average maximum error of all runs was 34 feet.

Projected Operational Benefits

The St. Louis Police Department expects that several operational benefits can result from a FLAIR installation. The FLAIR system provides a number of features which operate almost instantaneously to give the dispatcher detailed information on individual officers. One important example of an

X-Y PLOT TRACING OF LONDON RUN

Figure 3

application of these features is in locating an officer in trouble and dispatching the nearest officers to assist him. An officer can be located by inserting the officer number or car number into the computer by use of a small keyboard and depressing a single button which causes the box "□" symbol to be displayed on the video map at the location of the officer's car. This can be done regardless of the officer's status. In addition to that officer's number, the numbers of the three cars closest to him in order of proximity, are instantaneously shown on the dispatcher's "CL Cars" display. If the dispatcher desires that more than three cars be sent to assist an officer in trouble, the location and number of the eight cars closest to the officer can be displayed on the video map. This is done by the dispatcher depressing a second button. Officers from any combination of officer groups can be selected for display and if warranted they can be sent to service an incident regardless of their current assignment.

The symbol on the video display blinks very rapidly for an officer in an emergency situation, rapidly for an officer on a high priority call, slowly for officers on low priority calls and is steady for officers in service and not on call. The officer numbers are not displayed on the map in normal operation. The dispatcher may call for the officer number, however, by simply depressing a button.

In order to locate the officers closest to an incident, the dispatcher places the + cursor at the point of the incident. The four closest cars in order of proximity, will be instantaneously displayed under "CL Cars" on the Video Display. By depressing the NMBR button the dispatcher can display on the video map the location and number of the eight closest cars and continuously track them. Again, officers from any combination of officer groups can be selected for display.

Since the dispatcher can view the continuous movement of all his field forces, communication security can be provided by directing the officer to the incident by route to travel rather than by incident address. The dispatcher can also use this information to direct officers around barriers, such as street construction, and to assist the officer in finding an address.

Digital transmission of coded messages from the police cars to the Command and Control Center significantly reduces voice communication congestion. Coded message transmissions are initiated by use of a keyboard in the police car which also features an emergency button. When an officer depresses the emergency button an audible alarm sounds in the Command and Control Center and the officer's symbol flashes rapidly. This positive instantaneous communication plus the features of the FLAIR system discussed above gives the dispatcher the capability to send help immediately.

The FLAIR system improves many facets of police response to an incident because it gives the dispatcher full knowledge of the location and status of all the field forces thus improving command and control of these forces. Situations such as road blocks, civil disturbances, community disaster and burglar or robbery alarms require that a large number of officers be dispatched in a timely manner to precise locations if the operation is to be most effective. FLAIR provides the information to accomplish these operations effectively. For crimes such as armed robberies and burglaries in progress, the dispatcher has the information so that the appropriate officers can be selected for fast response. Real time information on location of the responding officers gives the dispatcher the strategic capability to direct patrols around the scene of the crime. Thus he can be sure that all areas are patrolled and the placement of the patrol can be adjusted as new information is received on the incident.

A playback capability may be provided in an additional console located remotely or in the Command and Control Center office. This permits a replay of previously recorded sequences of location and status from magnetic tapes allowing the evaluation of vehicle utilization during normal patrolling or periods of high police activity as well as providing material for training classes. Analysis of previous operations will provide a means of developing new law enforcement tactics. The newly developed tactics can be evaluated by analyzing recordings of situations which utilize these new tactics.

Remote monitors located in offices away from the Command and Control Center (several can be provided if desired) give command officers the capability to observe in real time the operation of the total force. This capability is vital for the most effective command of large police operations such as those associated with civil disturbances, natural disasters and VIP escort. The remote monitor also has community relations benefits by providing a means, at the discretion of the police department, for the press and the public to observe police operations on special occasions.

By utilizing long range radio communications equipment, FLAIR can be extended to cover state-wide police operations. Other applications of FLAIR include local, state and interstate commercial vehicles such as trucks and military ground vehicles where precise location, tracking and tactical status information is needed.

Operational Effectiveness Analysis

To establish the operational value of FLAIR to the St. Louis Police Department an operational effectiveness analysis is being conducted in St. Louis using data which will be generated from the FLAIR system operation. This analysis is the responsibility of the St. Louis Police Department with

Boeing providing assistance to them for this effort. To insure that a valid evaluation can be conducted, the St. Louis Police Department has established District 3 as the operating district and District 5 as a control or base line district. Both these police districts have similar five year crime trends. Data will be collected in both districts before as well as after FLAIR is installed in District 3. The personnel in both the control and operating districts have been stabilized during the evaluation to the maximum extent feasible in an operational organization. The operational philosophy in both districts are to remain the same during the evaluation. During this joint evaluation the following effectiveness measures will be made:

- Crime Rates
- Arrest Rates
- Dispatcher Hold Time
- Enroute Time
- Response Time
- Call Service Time
- Out For Service Call Time
- Available For Service Time
- Work Load Leveling
- Officer Safety
- Command and Control Effectiveness
- Complaints Against MPD Personnel
    - Internal
    - External
- Communication Congestion
- Police Car Accidents

It is expected that preliminary results will be available by October 31, 1974, with more complete data available from the analysis by the first quarter of 1975.

In addition to the evaluation conducted by the St. Louis Police Department, the Law Enforcement Assistance Administration has awarded a contract to Public Systems Evaluation, Inc., Winthrop, Massachusetts, to provide results of an independent study. This will include the development of a digital computer "patrol model" in which response time, work load and patrol coverage data can be extrapolated to other cities. In addition an attitudinal survey of equipment operators, patrolmen and dispatchers, will be conducted by Public Systems Evaluation Inc., and an independent analysis of the FLAIR accuracy, reliability and maintainability will be made.

These types of operational effectiveness analyses are important not only to the police user but also to industry. Results should be of benefit to industry in determining the potential value of future business investments to be made in further development of automatic vehicle location technology.

HENSON, A. J.
FLAIR Program Manager

EDUCATION: BSEE, Texas Technological College

Mr. Henson joined the Transport Division of Boeing in 1958, where he engaged in the development of aircraft instruments, displays, and control systems for 707 and KC-135 airplanes. In 1961 he was assigned the preliminary design and systems analysis responsibility for advanced navigation and control systems for special C/KC-135 command and control airplanes.

In 1963, Mr. Henson joined the Aero Florida Division of Honeywell, Inc. where he became Marketing Manager responsible for the development and sales of space and aircraft inertial navigation systems. In 1966 he rejoined Boeing, Wichita Division, as supervisor of the Communications Group, Avionics Staff. In 1969 he was assigned the position of Chief of the Reconnaissance, Communications and Microwave Staff. His assignments included responsibility for division contracted, research and development programs involving advanced avionics systems.

In February, 1971, Mr. Henson and an associate conceived a unique system for automatic tracking of ground vehicles. The system, called FLAIR (Fleet Location And Information Reporting), has since been under development as a product of the Wichita Division. In 1972 he was named FLAIR Program Manager with responsibility for Engineering, Manufacturing, Marketing and Sales, Finance and Contracts activities associated with the FLAIR product and for product line expansion.

Mr. Henson is a member of Tau Beta Pi, Eta Kappa Nu, and Kappa Mu Epsilon, Engineering Honorary Societies.

END