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GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station

PROJECT INITIATION

Date: February 14, 197

Project Title: City of Savannah Public Safety Communication System

Project No.: A-1505

Project Director: Mr. S. L. Robinette

Sponsor: City of Savannah, Georgia

Effective 2/1/73 Estimated to run until: 6/30/73

Type Agreement: Contract dated 9/Jan/73 Amount: $ 14,974.00

REPORTS REQUIRED: Monthly Progress Letters; Final Summary Report

SPONSOR CONTACT PERSONS: Contractual Matters
Mr. William M. Graham
Director, Finance & Admin. Services
City of Savannah
P.O. Box 1927
Savannah, Georgia 31402

Assigned to Communications Division

COPIES TO:

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Patent Coordinator	Project File
	Other

RA-62

no action req'd

GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station

PROJECT TERMINATION

Date ~~October 1, 1973~~

PROJECT TITLE: **City of Savannah Public Safety Communication System.**

PROJECT NO: **A-1505**

PROJECT DIRECTOR: **Mr. S. L. Robinette**

SPONSOR: **City of Savannah, Georgia**

TERMINATION EFFECTIVE: ~~9-24-73 (Final Report submitted)~~.

CHARGES SHOULD CLEAR ACCOUNTING BY: ~~9-30-73~~

CONTRACT CLOSEOUT ITEMS REMAINING: Final Invoice when all charges clear.

Communications Division

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Engineering Design Services	

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

13 April 1973

City of Savannah
City Hall
Savannah, Georgia

Attn: Mr. William Graham

Subj: Monthly Progress Reports No. 1 and 2, covering period 1 February to 1 April 1973, Project A-1505, contract File 5002.60, "City of Savannah Public Safety Communication System"

Gentlemen:

Two trips were made to Savannah, 6 February and 26 March, to examine the needs of Savannah for radio communications. Some immediate problems have been given priority attention. These have included (for the Police Department) a brief review of the items requested for LEAA funding in FY 71, an analysis of the radio interference from Chatham County's primary dispatch frequency, and the implementation of Mobile Radio District cross-banding. The first of these -- FY 71 LEAA items -- was handled by telephone and conference. The latter two problems are covered in an attached Interim Report.

Because of a prior teaching commitment, the rate of effort on the contract was low during February and March; for this reason, a two-month extension of the duration of the contract, at no cost to the City of Savannah, has been requested.

The unexpended funds are considered to be adequate for satisfactory completion of the contract.

Respectfully submitted:

S. L. Robinétte
Project Director

Approved:

D. W. Robertson, Chief
Communications Division

SLR:iln

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

13 April 1973

MEMORANDUM

To: Mr. William Graham
Director, Finance & Administrative Services
City of Savannah, Georgia

From: S. L. Robinette
Senior Research Engineer

Subject: City of Savannah Public Safety
Communication System, Georgia Tech Project A-1505

Two operational problems of the Savannah Police Department radio communication system are analyzed in this memorandum.

1. Radio Interference

The Savannah Police Department has for a number of years been equipped and licensed for radio frequencies, 460.400 MHz and 465.400 MHz, which have been unusable because of direct interference from the third harmonic of Chatham County Police Department's primary frequency, 155.130 MHz. Alternative solutions are available which should release the unused channels from the paralyzing effect of interference.

Alternative No. 1: Either the City frequency or the County frequency could be changed; it would cost less to modify the County equipment. Modification would require changing a pair of crystals and retuning each base and mobile unit. The cost for changing the City's frequency would be $7,224 (172 units @ $42). If the County and the local jurisdictions which share their frequency (155.130 MHz) modify their equipment, the cost should not exceed $4,400 for 80 units @ $55. To modify the County equipment would thus cost $2,824 less than modifying the City equipment.

Alternative No. 2: If the County would insert a low-pass, harmonic filter between the 155.130 MHz transmitter and the antenna, the on-channel power loss would be negligible (only 0.2 dB) and the third harmonic would be attenuated 60 dB -- enough to permit operation of Savannah's 465.400 MHz base station receiver. Cost of the filter would be only about $100. When the County moves its transmitter to the new location at Montgomery Cross Road, the added distance will reduce the severity of the problem but the third harmonic could still cause trouble, so the harmonic filter should continue to be used.

Recommendation: The low-pass filter between the County transmitter and the antenna is recommended. It is suggested that Savannah purchase the filter, if the County agrees to use it. If the filter fails to relieve the problem, the first alternative should be adopted.

Justification for either alternative is to release for use one-fifth of the capitalized investment of Savannah in its Police Department radio communication system. The dollar value of the paralyzed portion of the system is about $80,000; far more than the cost of either of the solutions described above.

A supplier for the filter is:

Decibel Products, Inc.
3184 Quebec St.,
Dallas, Texas 75247

Phone (214) 631-0311

The filter required would be similar to DB Products Model D4065 low-pass filter, 3 dB cutoff frequency about 200 MHz, 60 dB or greater attenuation at 465.400 MHz. Insertion loss at 155.130 MHz as specified by the manufacturer is about 0.2 dB, the voltage standing wave ratio is 1.25:1, and the power handling capability is 300 watts. System impedance of the County system and the connector types will have to be specified if a purchase order is written.

Alternate suppliers are:

Texscan Corporation
2446 Shadeland Ave.,
Indianapolis, Ind. 46219

Phone (317) 357-8781

CIR-Q-TEL, Inc.
10504 Wheatley St.,
Kensington, Md. 20795

Phone (301) 946-1800

2. Cross-Band Repeater

The County has offered the use of its UHF-to-Sheriff net, cross-band base station. It cannot be recommended that this be implemented at this time inasmuch as a study of the State mutual aid frequency plan is presently under way, which may affect the proper implementation. If, however, it is not feasible for the County to delay implementing the system, the following system characteristics are suggested.

The County base station should be a repeater with frequencies:

460.500 MHz Transmit

465.500 MHz Receive

This pair of frequencies will conform with the present assignment of frequencies in the State Radio Communications Plan. To complete an MRD crossbanding arrangement, Savannah would install a remote control with the frequencies:

465.500 MHz Transmit

460.500 MHz Receive

The remote control station transmitter should radiate only enough power to key the County's repeater. In addition to the remote, Savannah would equip a number of vehicles for

465.500 MHz Transmit

460.500 MHz Receive

Until the mutual aid and crossband frequency plan for the State is made final, only a small number of Savannah vehicles should be implemented.

Before the crossbanding system is implemented, the frequencies should be approved by FCC.

The County base station repeater should be capable of furnishing coverage of the entire MRD for the Savannah vehicles.

Transmitting at the recommended frequencies, the Savannah dispatcher and/or vehicles would key the County's 460.500 MHz repeater, and also the 154.905 MHz transmitter, to access the Sheriff's net, State Patrol, and other vehicles in the County. Incoming messages on 154.905 would also key the 460.500 MHz transmitter.

Richmond County and Augusta have licenses for base station frequencies of 460.500 MHz and 465.500 MHz, with authorized powers of 180 watts into 9.2 and 10 dB antennas. Mobile frequencies authorized for the County are 460.500 MHz (10 units) and 465.500 MHz (106 units). For Augusta mobile units, 465.500 MHz is authorized (100 units) with power at 220 watts. The aim is that communications be maintained from mobiles back to base station over a thirteen-county area.

Richmond County evidently operates the 460.500/465.500 MHz base station as a relay, with Augusta keying in by remote control. The base station signals radiated from Richmond County could be strong enough to be received by the Chatham County base station, and the Augusta remote control frequency, 465.500 MHz, could cause confusion in Chatham County if Augusta radiates at authorized power. However, there is no apparent reason for Augusta's remote control transmitter to radiate a strong signal; one watt or less into a dipole should suffice to key the Richmond County repeater.

If Savannah vehicles are driven to the Richmond County area, the vehicle frequency pair, 465.500/460.500 MHz would permit communication with Augusta and Richmond County vehicles. Full compatibility will require that the equipment include tone-coded squelch, equivalent to Motorola 6A code.

S. L. Robinette

SLR:iln

A-1505

ENGINEERING EXPERIMENT STATION

GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

14 May 1973

City of Savannah
City Hall
Savannah, Georgia

Attn: Mr. William Graham

Subj: Monthly Progress Report No. 3, covering period 1 April to 1 May 1973, Project A-1505, Contract File 5002.60, "City of Savannah Public Safety Communication System"

Gentlemen:

During May, a study was made of the operational advantages of digital radio dispatch systems. The advantages include security of information, decreased redundancy (requests to repeat messages), direct computer access to files such as vehicle registration, and compatibility with a computer aided dispatch system. A properly designed digital radio system would reduce the time of response to emergency calls by reducing the delay between incoming call and subsequent dispatch and by increasing the speed of response of the patrol car officer. The factors which reduce the total delay include:

1. Keyboard initiation of the complaint record, with direct entry into a computer and with cathode ray tube display, remotely if required.

2. Computer activated status display, which can be reviewed for accuracy by direct digital query from cars. A frequent voice message is "What is my status?" This would be replaced with a single push-button switch. The high error found in present status map displays would be greatly reduced through better automation.

3. High speed address verification, if required, by search of a computer-filed city street directory.

4. Push-buttons for often used code messages, and keyboard generated additional information.

5. Printed message terminals in patrol cars. Misunderstood voice messages would be avoided.

Other desirable features possible with digital radio and computer-aided dispatch are:

1. Better records system.
2. Easier extraction of statistical information about police operations.
3. If printers are in vehicles, messages can be transmitted even if the vehicle is unattended. (On the average, the unattended period is about 60 percent.)

Digital communication systems, even without computers, are more costly but also more effective than voice systems. Computer-aided dispatch would add still another increment of cost to the systems, and justification based on increased effectiveness would be more difficult. If, however, the PRC/PMS study should recommend a separate, dedicated computer for the Police Department (because of LEAA requirements for data bank security) the added cost for computer-aided dispatch would be more easily justifiable.

The unexpended funds are considered adequate for satisfactory completion of the contract.

Respectfully submitted:

S. L. Robinette
Project Director

Approved:

D. W. Robertson, Chief
Communications Division

SLR:iln

A-1505

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

19 June 1973

City of Savannah
City Hall
Savannah, Georgia

Attn: Mr. William Graham

Subj: Monthly Progress Report No. 4, Covering period 1 May to 1 June 1973, Project A-1505, Contract File 5002.60, "City of Savannah Public Safety Communication System"

Gentlemen:

During June a review was made of the Criminal Justice Information System Master Plan for Georgia. It is recognized that the responsibility for recommendations concerning implementation of Savannah's real-time computer interface lies with a separately funded study; however, the effectiveness and operational flexibility of Savannah's public safety communication system will be affected by the configuration of the computer system. It is therefore recommended that a separate and dedicated computer be located at SPD. The State requirement for security of offender records could be met if these records were resident on the SPD computer. Only sworn officers of SPD would operate the computer; access would be available, to authorized queries only, on a full-time basis.

The dedicated computer could be used also for computer-aided dispatch, and for generating records related to patrol activities; it could also serve as a Data Communications Processor, to interconnect SALES files to SPD, to the State computers, and to Savannah area law enforcement terminals.

A suggested configuration (adapted from Figure 6-8 of the State Master Plan) is enclosed.

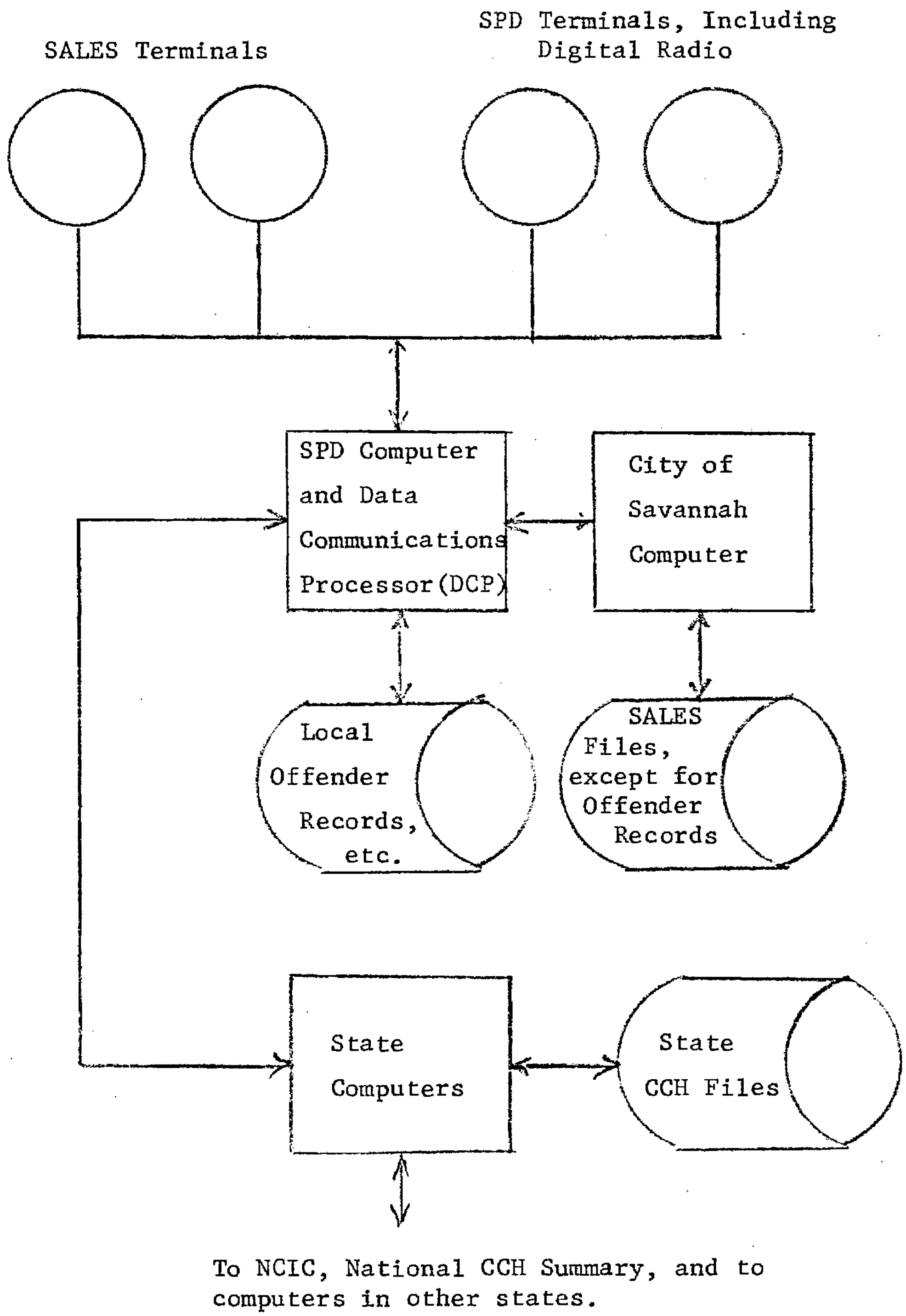
The unexpended funds are considered adequate for satisfactory completion of the project.

Respectfully submitted:

S. L. Robinette
Project Director

Approved:

D. W. Robertson, Chief
Communications Division


SALES Terminals
SPD Terminals, Including Digital Radio
SPD Computer and Data Communications Processor (DCP)
City of Savannah Computer
Local Offender Records, etc.
SALES Files, except for Offender Records
State Computers
State CCH Files
To NCIC, National CCH Summary, and to computers in other states.

A-1505

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

12 July 1973

City of Savannah
City Hall
Savannah, Georgia

Attn: Mr. William Graham

Subj: Monthly Progress Report No. 5, Covering period 1 June to 1 July 1973, Project A-1505, Contract File 5002.60, "City of Savannah Public Safety Communication System"

Gentlemen:

The most efficient configuration for command, control, and dispatch of mobile radio equipped vehicles of the City of Savannah would be a centralized facility similar to the attached sketch [1,2]. Emergency medical dispatch could be included in such a centralized facility. The concept would not be workable, however, unless the command officers of the police and fire departments, and the operations directors of public works departments were located close to the command center. The benefits of centralized command and control of emergency services can only be realized with a centralized public safety building, however. If and when Savannah constructs a public safety building, the San Diego concept is recommended.

The unexpended funds are considered adequate for satisfactory completion of the project.

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[1] S. L. Robinette, A Unified Emergency Communication System for DeKalb County, Vol. 2, pp 19-21, Project A-1362, EES, Georgia Institute of Technology, Atlanta, Georgia, 1 December 1971.

[2] H. G. Ryland, et al., Development of A Central Command and Control System for the City of San Diego, Phase III, System Design, ARINC Research Corp., Santa Ana, California, February 1969.

Respectfully submitted:

S. L. Robinette
Project Director

Approved:

D. W. Robertson, Chief
Communications Division

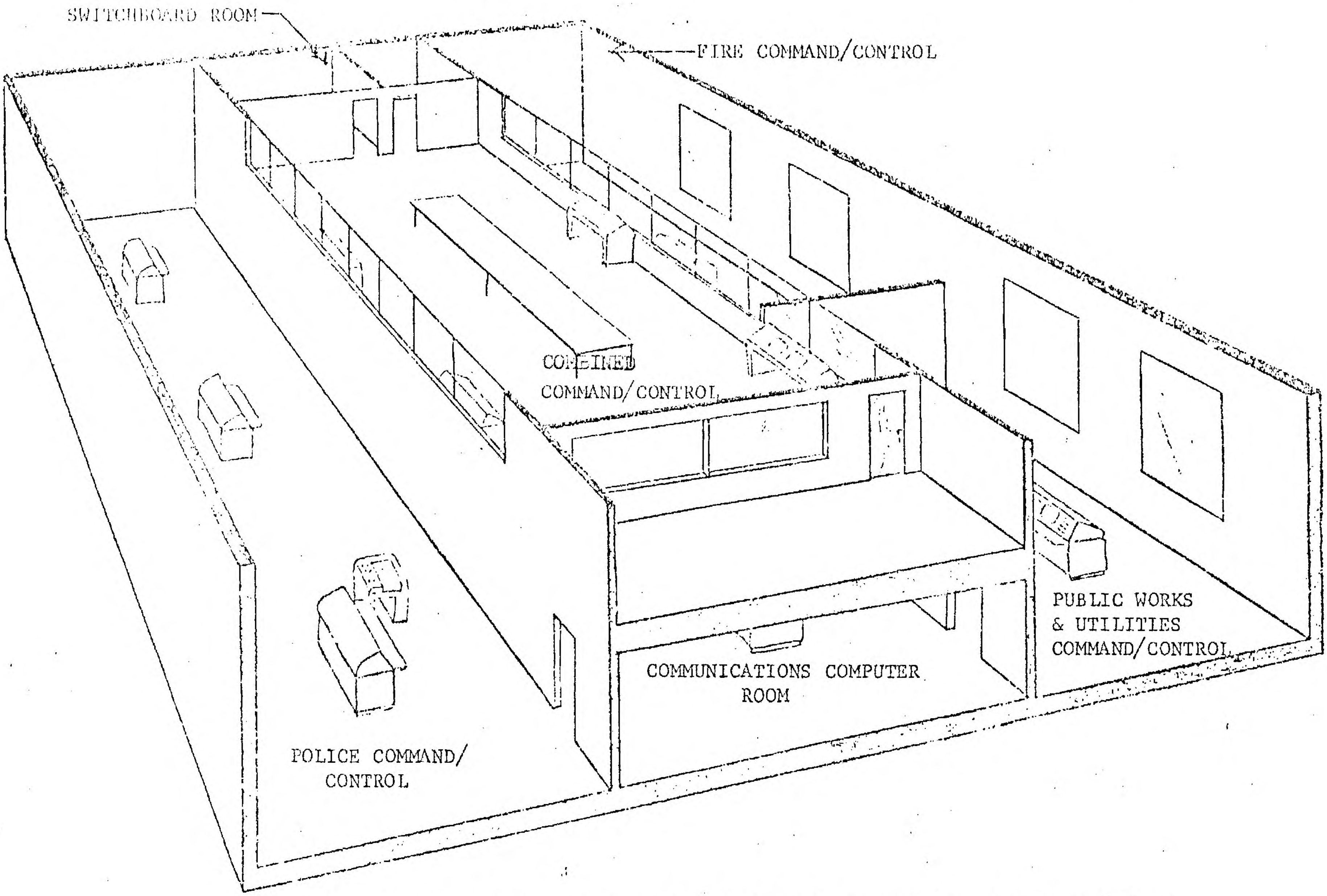

Figure 1. Sketch of Proposed Command and Control Central for San Diego [2].

A-1505

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

6 September 1973

City of Savannah
City Hall
Savannah, Georgia

Attn: Mr. William Graham

Subj: Monthly Progress Report No. 6, covering period 1 July to 1 August 1973, Project A-1505, Contract File 5002.60, "City of Savannah Public Safety Communication System"

Gentlemen:

A review was made in July and August of the literature background used for radio coverage calculations, to determine whether rule-of-thumb approaches in common use apply to Savannah. The following finding was made:

> In coastal plains areas UHF transmission over a given service distance requires 9 dB less power than in regions where the equivalent valley-to-hill height averages 500 feet.

The unexpended funds are considered adequate for satisfactory completion of the project.

Respectfully submitted:

S. L. Robinette
Project Director

Approved:

D. W. Robertson, Chief
Communications Division

Project A-1505

CITY OF SAVANNAH PUBLIC SAFETY COMMUNICATION SYSTEM

S. L. Robinette and J. L. Birchfield

10 September 1973

Prepared for
The City of Savannah
Savannah, Georgia

1973

Engineering Experiment Station
GEORGIA INSTITUTE OF TECHNOLOGY
Atlanta, Georgia

THE ENGINEERING EXPERIMENT STATION
Georgia Institute of Technology
Systems & Techniques Department
Atlanta, Georgia

CITY OF SAVANNAH PUBLIC SAFETY COMMUNICATION SYSTEM

Project A-1505

By

S. L. Robinette and J. L. Birchfield

10 September 1973

Prepared for
The City of Savannah
Savannah, Georgia

FOREWORD

This report was prepared at the Georgia Tech Engineering Experiment Station for the City of Savannah. The work was performed within the Systems & Techniques Department under the general supervision of Mr. D. W. Robertson, Chief of the Communications Division. The report includes the design definition of a recommended public safety communication system, and the basis and rationale for the recommendations.

The authors acknowledge the technical contributions of colleagues, Messrs. H. H. Jenkins, and R. W. Moss. Also to be acknowledged are the helpful contributions of Mr. William Graham, Major L. E. Mahany, Lieutenant M. C. Browne, Mr. S. H. Halter, Chief J. M. Schroeder, Mr. E. P. Moore, and other personnel within the City of Savannah government.

ABSTRACT

This report deals with a study of present and future requirements of the City of Savannah for public safety communications. Three categories of recommendations are presented based on (1) a need for enhanced coordination among Metro Savannah public safety agencies and organizations, (2) present and future plans for system improvements in the Police Department, and (3) the need to replace equipment and improve dispatch procedures in the Public Works Department. The recommendations include location, number, and other specifications for base station, vehicular, personal portable, and paging equipment.

The principal recommendations are that (1) a centralized public safety dispatch building should be seriously considered by the Metro Savannah governments as a means for achieving coordinated emergency responses; (2) computer aided dispatch, digital message capability, and county-wide radio coverage should be incorporated in the Savannah Police Department communication system; and (3) the Savannah Public Works Department radio system should be replaced with new equipment, new frequencies, and centralized dispatch using consoles that include status boards to display the position and status of the Department's vehicles.

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GLOSSARY

CM-3: Commercial voice grade quality of transmission, equivalent to standard telephone quality.

SINAD: The ratio of signal-plus-interference-plus-noise-plus-distortion power to interference-plus-noise-plus-distortion power, measured at the receiver output.

dB: Abbreviation for decibel, (one-tenth of a bel), the number of decibels denoting the ratio of the two amounts of power being ten times the logarithm to the base 10 of this ratio. With P_1 and P_2 denoting two amounts of power and n the number of decibels denoting their ratio,

$$n = 10 \log_{10} (P_1 / P_2) \text{ decibel.}$$

dBW: A unit for expression of power level in decibels with reference to a power of one watt.

EXECUTIVE SUMMARY

Background

This report to the City of Savannah deals with a study to design and recommend a public safety communication system. The purpose of this summary is to provide a concise overview of the study and the resulting findings and recommendations. The report is organized as a formal systems engineering study which proceeds from systems goals through function and equipment analyses to conceptual communication systems design. The appendices discuss details and methods used for the systems engineering analyses.

Approach

The approach was designed to utilize the best information available for the study. The radio dispatch function was emphasized but other system functions were included. Discussions were held with City of Savannah personnel, equipment vendor engineers, State employees in the Department of Communications, computer systems consultants working for Savannah, and Police communications officers in a number of cities. Where feasible, use was made of related data, documentation and open literature. No extensive data gathering activities were included in the study.

The study included the development of a propagation model for coastal plains areas. This model permits the determination of antenna heights, antenna gains, coupling losses, and transmitter powers required for specific mobile radio service distances.

The study also included an investigation of computer aided dispatch and/or digital message communication capabilities for the Savannah Police Department.

The information made available by the interviews and discussions, the literature surveys, and the systems analyses resulted in conclusions concerning the effectiveness of the current City communication systems and the improvements in performance that could result from alternative systems. Based on these conclusions, present and future conceptual communication system designs were developed.

Major Findings

Major findings of the study were as follows:

1. There is a need for improved coordination among public safety agencies in Metropolitan Savannah.
2. The Savannah Police Department plans to implement a computer interface with the Georgia law enforcement network, and this will require a minicomputer at Police Headquarters.
3. The present Police Department antenna is not high enough to provide acceptable signal quality throughout Chatham County.
4. The present Public Works Department radio equipment is old and in frequent need of repair.
5. The Public Works Department dispatch function is fragmented, with each section of the Department dispatching by remote station control of a single base station. This mode of operation does not permit close departmental command and control of vehicles, field forces, or the dispatch operation.
6. The Fire Department radio system was found to be adequate.

Major Recommendations

A centralized or coordinated emergency communication center is recommended for Metro Savannah. It would greatly enhance coordinated public safety responses throughout the city and county. The recommendations detailed in this summary are for present jurisdictional conditions and for present City buildings and sites. To overcome deficiencies in coordination in the present systems, extension of the present telephone network of automatic private lines, to interconnect all City, County, State and public utility company emergency dispatch centers in Metro Savannah, is recommended.

Recommendations for the Police Department and the Public Works Department communication systems are:

Police Department

1. Twelve dispatch channels, six transmit and six receive.
2. Six consoles.
3. A minicomputer for dispatch aid and interface with the State criminal justice information system.

4. CRT terminals at or in the consoles, for computer aided dispatch.

5. Digital communication coders, decoders, and other digital communication equipment in the consoles.

6. Digital communication capability installed in twenty-five vehicles, with extension to other vehicles as needed.

7. Erection of a new 400 foot tower within the city limits (but in the direction of the center of the county) to give 90 percent, CM-3 coverage (see Glossary for definitions) for vehicular radios throughout the county and for personal portable radios within the city limits.

8. A microwave or UHF relay link between the headquarters building and the new tower.

9. An automatic private telephone line to be backup for the microwave link.

10. A 40-track tape recorder to log messages on all communication lines in the dispatch center.

11. Adequate safeguarding of communication center facilities, including telephone equipment.

12. Additional telephone features, including Automatic Call Distributor, Called Party Hold, and Called Party Disconnect.

13. Totalizers for peg counts and other message traffic studies in the dispatch center.

14. Implementation of a cross-band repeater to permit radio communication between City, County and State Police.

15. A battery operated transmitter, located at the headquarters building, to provide emergency dispatch to back up the base station equipment.

16. Provision for operating the base stations at the base station site.

Public Works Department

1. Replace the present equipment with new equipment, operating on authorized local Government frequencies in the 155 MHz or the 450 MHz region.

2. A study by the Public Works Department to determine how many operational channels are needed, whether to centralize dispatch operations, where to locate base stations, and what vehicles need radio. (Four operational channels are tentatively recommended.)

3. One emergency/supervisory channel to be operated 24 hours a day, 7 days a week.

4. Status map type displays for dispatchers, showing the location and status of all vehicles of the Department.
5. Pocket pagers for supervisors and off-duty standby personnel.
6. Personal portables for nighttime crews, to back up vehicular radios, and for other special tasks.

1. INTRODUCTION

This report presents the results of a design study for an emergency communications system for the City of Savannah. The scope of the program was to study and investigate system designs and plans that may be used by Savannah to obtain an effective public safety communication system. The objectives of the program were: (1) to establish needs and operational goals for Savannah public safety communications; (2) to design a system that will best meet the operational goals; (3) to generate equipment specifications; (4) to derive acceptance tests; and (5) to establish a plan for implementing the needed communication system.

The presentation of the results of the study is structured as a formal systems engineering analysis [1]. The purpose of this mode of presentation is to include sufficient analytical background to enable City of Savannah personnel to make tradeoff estimates and decisions when the conceptual system is converted into an actual system.

A public safety communication system may be viewed as a sophisticated tool which enables the citizenry to obtain the services of their government and to enable the government to perform those services. In designing the conceptual system the primary goal has been to make it an economically effective tool. A basic requirement before undertaking the design was to establish a set of operational goals; these goals were developed from other studies published in various sources, and from interviews with department heads, departmental communications officers, departmental planning personnel, and staff members in the office of the City Manager.

A system engineering analysis [1], which is illustrated by the block diagram of Figure 1, incorporates operational goals as inputs, and shows how conceptual systems may be generated.

The system operational goals are used as a starting point for the process of analyzing the functions of an emergency communication system. The basic concept at this point is embodied as a structure of interrelated functions such as the function of receiving information concerning an

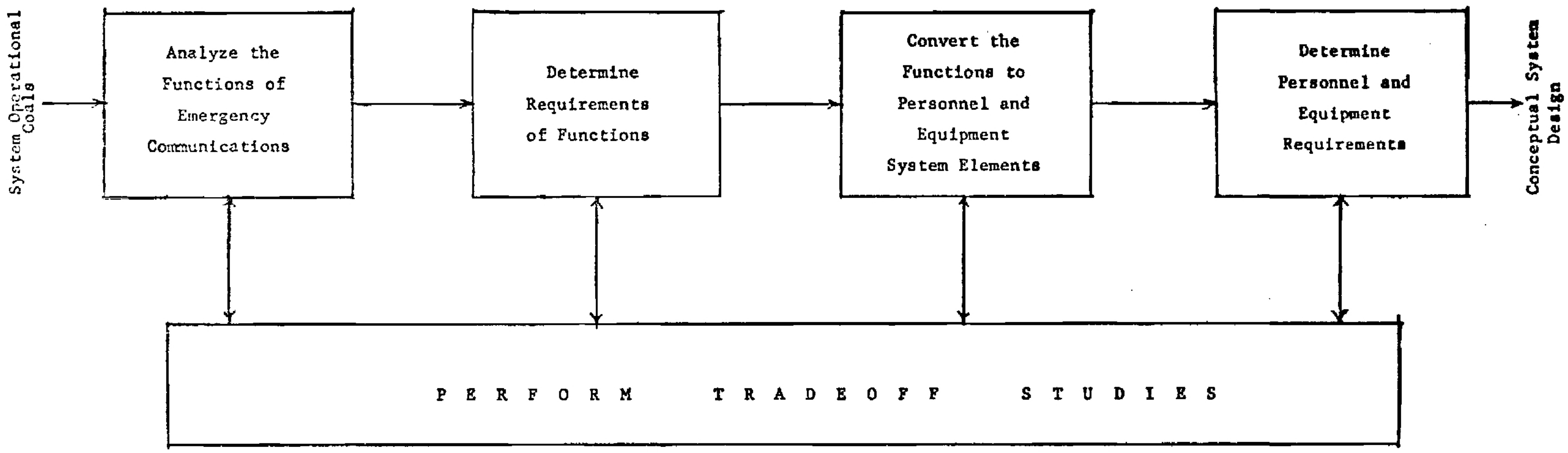

Figure 1. Steps in a Systems Engineering Analysis and Design of an Emergency Dispatch System [1].

emergency, the function of dispatching response to the emergency, and the function of responding to the emergency. The process of analyzing each function involves examining the substructure of the function.

After the functions have been analyzed and their requirements determined, the functions are characterized by a set of personnel and equipment elements which are needed to realize the functional requirements. An analysis of the personnel and equipment elements permits the specification of their requirements, and leads to a conceptual system design, as indicated by Figure 1.

The entire process of systems engineering analysis--analysis of functions, determination of function requirements, conversion from functions to system elements, determination of element requirements, and the development of a system--may be modified following study of the consequences of alternative approaches. These tradeoff analyses permit the selection of optimum system components along the way, as a final design is generated. A number of different systems will usually be generated with such a systems engineering process, because the tradeoff studies can seldom be definitive. For example, an optimum emergency communication system for Savannah might require construction of a new building, whereas a less than optimum but improved system can be adapted to buildings presently owned by the City. The choice between the two systems depends ultimately on tradeoff decisions that can only be made by government or the electorate of Savannah. The material in this report therefore includes, in addition to the specific study of Savannah's needs for emergency communications, discussions of methods that are useful for measuring performance, and for exercising command and control, and for modifying the emergency communication system.

2. OPERATIONAL GOALS

The first of the sequence of steps in a systems engineering analysis is, as was shown in Figure 1, a set of operational goals. Appropriate goals for public safety communication systems in general are that they shall:

1. Afford quick access for citizens seeking the services which the public safety agencies were created to deliver.
2. Facilitate rapid and/or cost-effective delivery of services to meet the legitimate needs of the community, which owns the agencies.
3. Accommodate requirements for management of the communication system.
4. Support coordination of multi-agency responses to disasters, major disturbances, war, etc.

The emergency response goals of each agency's public safety communication system stem from <u>operational objectives</u> that differ from agency to agency. Examples of agency objectives include:

1. Police Department: Reduce crime; maintain public order.
2. Fire Department: Suppress fires; minimize the loss of lives and property to fire and other disasters.
3. Public Works: Maintain delivery of services--water, street lighting, sewers and drainage, streets and bridges, waste control, traffic control.
4. Health Services: Deliver health services rapidly and effectively.
5. Civil Defense: Coordinate emergency responses of public safety agencies during war and/or widespread civil disaster.

The <u>emergency communication objectives</u> of a public service communication system reflect the variations of operational objectives of the various agencies. They include:

1. Police Department: Reduce response time; increase effectiveness of response; optimize command and control.
2. Fire Department: Minimize response time; optimize effectiveness of response; coordinate public utility company and other agency responses.

3. Public Works: Assemble work crews; optimize cost/effective response; coordinate with responses of public utility companies.

4. Health Services: Optimize response time depending on nature of emergency; assemble or alert emergency staffs; optimize cost/effective use of health resources.

5. Civil Defense: Coordinate activities of all emergency agencies in response to enemy attack or widespread disaster.

The most fundamental objectives of agency emergency systems will be related to minimizing the time required to respond to emergencies. These objectives should be stated as criteria which include the time required to dispatch vehicles. The criteria that are suggested for Savannah's public safety departments are:

1. Police Department: The patrol car which is available for duty and which is nearest the scene of a complaint will be dispatched within one minute after a citizen has completed dialing the police emergency number.

2. Fire Department: The appropriate fire station equipment will be dispatched within one minute after a citizen has dialed the fire emergency number, or an alarm is received.

3. Public Works Department: Dispatch of emergency standby crews will be completed within thirty minutes. Day shift dispatch and offshift alerting of operators of equipment used to help in rescue operations will be accomplished within five minutes.

These criteria should be adjusted to reflect reasonable and realizable response times, and should then be used as measures of emergency dispatch performance.

3. ANALYSIS OF FUNCTIONS

In Figure 1, the sequence of operations involved in the systems engineering process indicates that analyses of the functions which comprise the system are to be performed after operational goals are specified. The essence of the goals developed in Chapter II was high speed of response. The emergency systems can therefore be analyzed as real time systems of interconnected functions. The emergency communication systems in Savannah are shown in Figure 2. In the Police Department, the function of reception of requests for emergency response is distinct from the dispatch function; in the Fire Department and Public Works divisions the function of reception is combined with the function of dispatch. The Fire and Police Departments are single entry emergency systems; the Public Works is also single entry but is multiple response. Most emergencies require responses only by a single agency, but some require coordinated multi-agency response. Sometimes coordination with agencies external to Savannah departments is also required.

The block diagram of Figure 3 depicts the structure, or subdivision, of functions in a generalized emergency communication system. The function of reception shown in Figure 2, for the Police Department for example, is broken down into functions of analysis and record generation; the function of dispatch includes the effects of departmental goals and objectives, functional dispatch aids such as information retrieval and display, and the recording of information.

The outputs of each particular function initiate functions to which it is connected, and those functions will in turn, after a characteristic time delay, generate inputs to other functions. The total system of interconnected functions will respond, after a characteristic system delay, to system input stimuli. By analyzing the systems as real time interconnected functions, the sources of delay in the discrete functions can be separately analyzed, and methods of reducing time lags can be developed.

There is a tendency to be misled by a generalized view of emergency dispatch functions, because the generalization suggests that only the

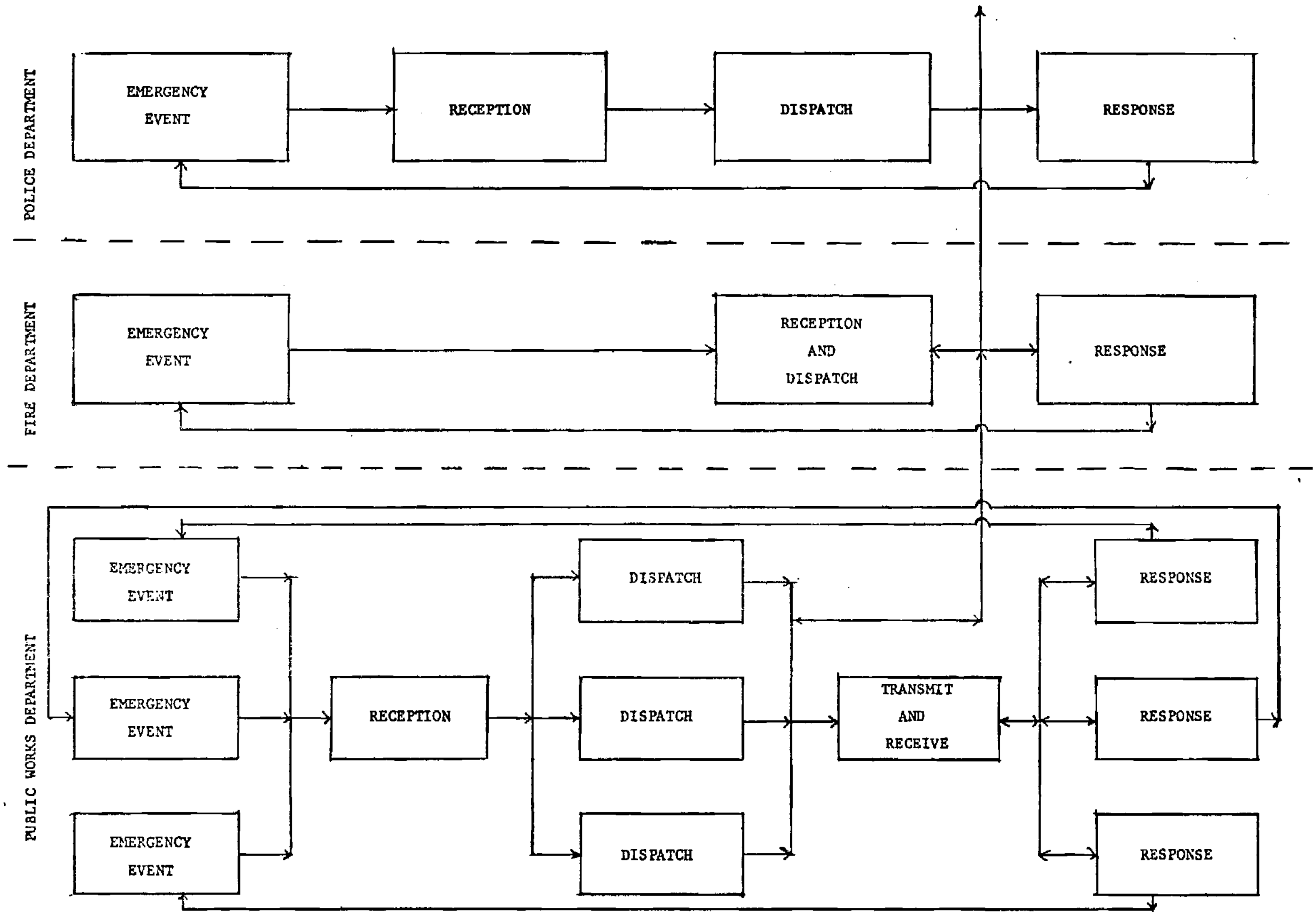

Figure 2. Savannah's Emergency Dispatch Systems.

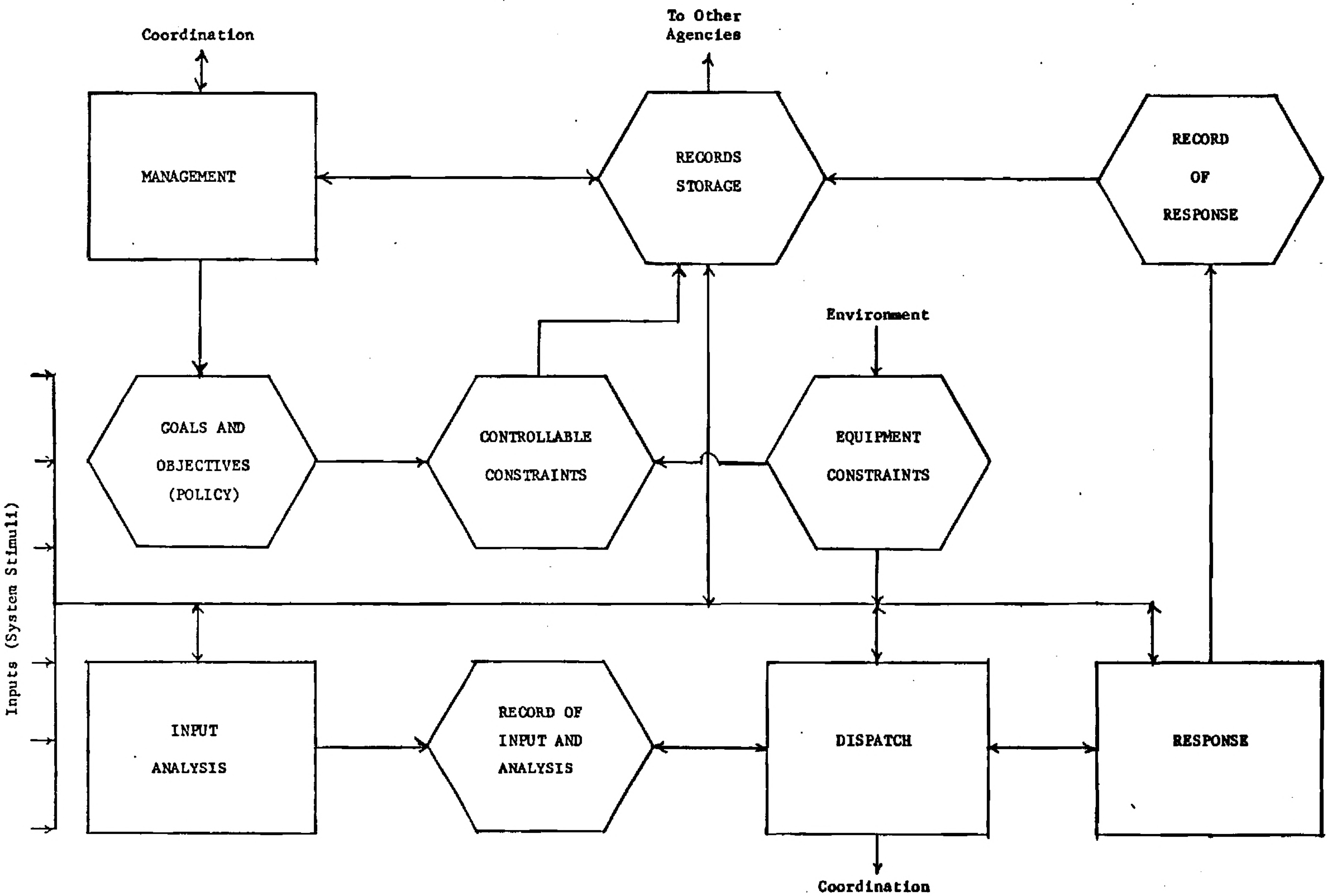

Figure 3. Interconnected Functions of an Emergency Dispatch System.

inputs (nature of emergencies) and outputs (nature of responses) are different for different agencies. This apparent similarity in functions has even led some local governments to adopt a single radio system for all agencies in an attempt to save money; but such a consolidation has been found to have the disadvantage that it reduces the effectiveness of individual agency responses.

The reason for the loss of effectiveness when agency systems are consolidated is that, in addition to the differences in inputs and outputs, there are internal differences in the structure of corresponding functions. These differences in structure of corresponding functions are caused by the dissimilar goals of different systems.

The purpose of this chapter is to discuss the internal structure and some of the functions of agency dispatch systems, and to point up major differences in corresponding functions.

3.1 Agency Goals and Objectives

The differences between the command and control functions (goals) of communication systems are recognized by agency managers. This can be illustrated by a hypothetical Fire Department Chief who, speaking against the concept of a single emergency telephone number, might say:

> "Incoming fire calls should go directly to the fire dispatcher, without the added delay of a telephone operator. It may be that speed of response to a reported crime is of less importance than speed of response to a fire. Because of the rapid rise of temperature and the rapid spread of conflagration during the first seconds, a fire is a rapidly developing emergency which will grow unchecked until the fire fighters go into action. On the other hand the usual police emergency is finished, the crime has been committed, and the criminal has left the scene before the police are even notified."

Such a view, of course, ignores the strong functional dependence of crime clearance rates on speed of police response, but it does point out a difference in the characteristics of the required responses of the two agencies. Different response requirements such as these would be embodied as different command and management functions (goals) that would in turn affect the controllable constraints, and even the internal structures of other functions.

In this example, incoming fire emergency lines would terminate at the fire dispatch console, but police emergency lines would terminate at a telephone switchboard in the police communication center.

Another difference between fire and police agencies is evident when their valuations of alarm signals are compared. A number of police departments have removed burglar alarm signal lines because of high false alarm rates; but most fire departments routinely continue to answer all alarms, including those which have a bad false alarm record. These different valuations (management goals) make the designs for fire and police communication systems different, not only in the controllable constraint functions, but also in other functions; namely, alarms would be an input stimulus to the fire control center but not necessarily to the police center.

The distinctive goals of other agencies will also produce differently structured functions for those agencies. For example, some local governments have recently assumed the responsibility for delivery of emergency medical service; namely, ambulance service. This emergency service, like fire and police services, demands a quick response capability; but ambulance responses will often be controlled to meet the requirements of a particular emergency. In cardiac arrest cases, speed of arrival and on-site treatment is essential for saving life, but rapid conveyance to an emergency room may be undesirable. However, in other types of medical emergency it may be imperative that the patient be rushed quickly to the hospital. The set of goals and objectives for the emergency medical radio system will therefore differ from the goals of police and fire systems, and the resultant communication functions will be different.

The goals and objectives are embodiments of management policy for the public safety agencies. The effects of management goals and objectives on emergency communication are shown in Figure 3 to couple into the system through controllable constraints. The structure of the goal and objective functions for an agency is usually very complex; it includes both formalized and informal elements. There are numerous input and output connections to other systems, both within and without the agency.

Departmental goals and objectives are affected by departmental budget constraints, by changes in court decisions, and by directives from City management. The embodiment of the function will be in memoranda, written and oral orders, assignments and promotions, and efficiency reports. Because of the internal and external complexity of the function, it is difficult for an agency manager to foresee the effects that changes in goals and objectives will have on the operating systems under his command. Probably his best measure of effectiveness is overall system emergency response time.

There is a strong requirement in all agencies for fast emergency response. The effectiveness of crime clearance rate, stabilization of cardiac patient condition, and suppression of fires are all inverse exponential functions of response times [2, 3] as indicated in Figure 4. The response time for radio dispatched response forces can be separated into two delays -- the dispatch center delay and the field response delay. Actions which contribute to the total response delay [2] are depicted in Figure 5.

3.2 Records

The record functions shown in Figure 3 are important to the effective operation of all other functions. In public safety communications systems, analyses using the record functions are valuable means for measuring the cost/benefit that a particular system configuration offers. The record functions encompass both the physical records such as forms, bar cards, ledgers, microfilms, audio tapes, magnetic tapes, etc., and the record keeping functions which include storage, retrieval, reporting procedures, distribution, periodic data updates, data purges, etc. In communications system configurations, the record functions employed can be modified by selection of particular types of data storage techniques as well as by changes in procedural and management organization. Since the functions can be used to provide data for a wide range of analyses and system performance measurements, they should be continually and critically reviewed to ensure that useful record functions are developed to go along with

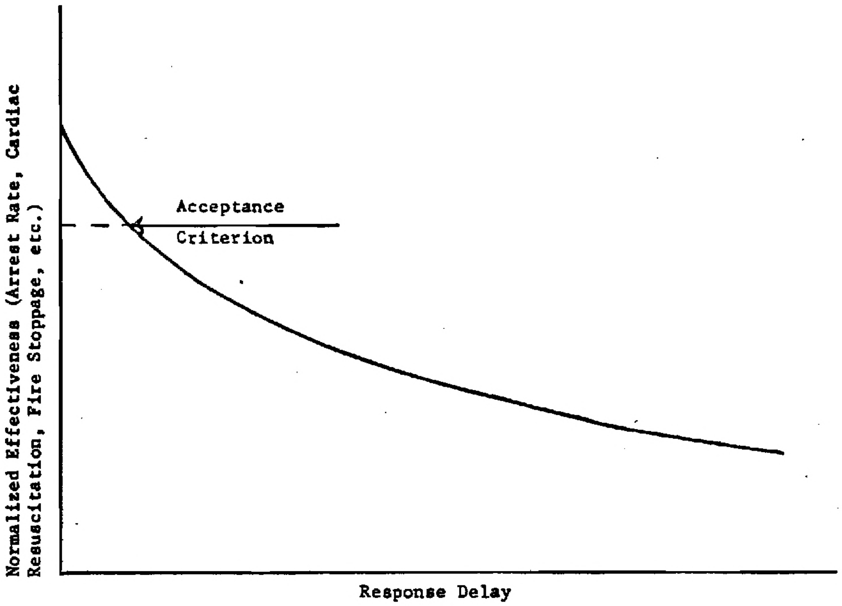

Figure 4. Effect of Response Delay on Response Effectiveness.

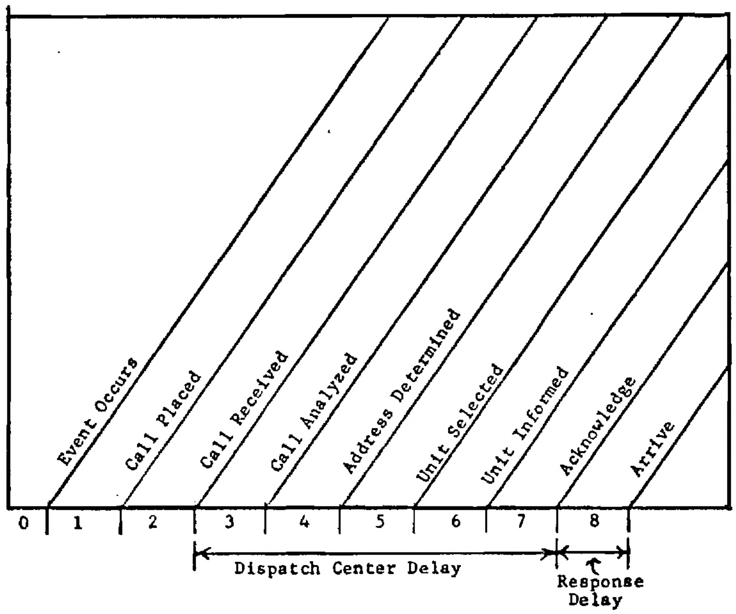

Figure 5. Event Map of Response of an Emergency Dispatch System [2].

changes in communication system goals and designs. The functional structure of records will be different in different agencies, reflecting the differences in goals and objectives.

3.3 Analysis of Inputs

The calls for emergency response have to be analyzed to determine the "what, where, who and when" of the emergency, so that the proper response can be dispatched. This function is separate from the dispatch function in some agencies; in others the two functions are combined. The output of the analysis function is a record of the analysis performed; it also includes the identification of the person who has received and analyzed the request for emergency response.

3.4 Dispatch

The record of analysis of incoming calls is the input to the dispatch function, which will include selection of the appropriate response force element, verification of its availability and transmittal of information about the emergency. The latter will include as a minimum the "what and where" from the record made of the incoming call, and other information necessary for the response function. The dispatch function will include the completion of the record, by the addition of times of dispatch, arrival of response force, and completion of the response. Other information added to the record, as part of the dispatch function, will be a record identifying code, the type of response dispatched, the unit dispatched, and the dispatcher identification.

3.5 Response

The function of response will be to answer the requests for emergency assistance, as conveyed by the dispatch function. The structure of the response function, as a part of the emergency communication system, will accommodate the exchange of information with the dispatch function, and the generation of records of response actions.

4. REQUIREMENTS OF FUNCTIONS

It has already been stated that the basic system requirements include speed of response, effective response, and ability to coordinate with other emergency agencies. It is clear that the system requirements for speed and effectiveness extend to all the functions which comprise each system. The ability to coordinate will require that the goals and objectives specify system actions for coordination, and in turn the actions will require equipment elements designed to accommodate coordination. (Chapter 5 will detail equipment elements of emergency communication systems.)

In addition to the system requirements, there will be requirements for each function of the system. The requirements of Savannah's emergency radio systems can be related to the interfaces between functions; they will have a dual nature because of the two-way nature of the interfaces.

4.1 Inputs

Figure 3 indicates that public requests for assistance constitute the major inputs (stimuli) to the emergency communication systems.

The requirements at the interface, from the viewpoint of the public, include:

1. Accessibility to the system.
2. Reliability of the channel.
3. Communicability with the agency person contacted.

4.2 Input Analysis

In some agencies the dispatcher is the contact person who analyzes the system inputs; in others, the functions of analysis and dispatch are handled by different persons. The division of the tasks will depend on the characteristics of the incoming message traffic, and also on the goals and objectives of the system as specified by departmental management. The contact personnel requirements include:

1. Articulate enunciation.

2. Calm, even temperament.
3. Analytical ability.
4. Training in procedures.
5. Motivation to serve the public in a courteous manner.
6. Ability to elicit information from the caller.

4.3 Dispatch

The personnel who perform the dispatch functions will require, in addition to the characteristics and abilities listed for contact personnel, knowledge of the functions, tasks, and dangers of the response force. Dispatcher training should aim at making every dispatcher able to effectively utilize an appropriate array of telecommunications equipment.

4.4 Response

The operational requirements for response, viewed in Figure 3 as a function of the communication system, are covered in broad terms by the listings for contact personnel and dispatcher. Training courses should aim at making each individual in the response force expert in the use of vehicular and personal portable communication equipment. Because every situation encountered may be different, the individual can be expected to seek information from the system to aid in analysis and decision. The training should therefore also include a thorough familiarization with the communication system as an information resource.

4.5 Records

Several record functions shown in Figure 3 can be differentiated. The record generated by the agency contact person is a source of information for the dispatcher. The history of actions performed by the dispatcher in response to the information conveyed from the contact person is added to the record. The actions of the response force, as reported to the dispatcher, are also entered; and the record ultimately goes to storage, to be joined by the record of the response as written by the response force. From storage the records are available for management and control of the agency, and for utilization by other systems.

The functional requirements of the records include:

1. High information capacity.
2. Fast information transfer.
3. Accuracy.
4. Durability.
5. Controllability.
6. Security.

4.6 Storage

The functional requirements for records and information storage files are the same as those listed for records.

4.7 Command and Management

The functions of command and management of the communication system are exercised by the control of goals and objectives which in turn modify the system controllable constraints shown in Figure 3. The requirements of the management function include knowledge about:

1. The communication system capabilities and limitations.
2. The adaptations possible to the system, and the incremental cost/effectiveness (positive or negative) inherent in the adaptations.
3. Tradeoff benefits.
4. The effects of changes in goals and objectives--how policy decisions affect the internal, controllable constraints of the system, and how the adjustments of constraints affect the structure and functions of the system.
5. Interagency coordination procedures.

4.8 System Constraints

The needs of the agencies vary with time; this means that the communication system should be adaptable to changes in goals and objectives. On the other hand, the overall response requirement for speed and precision demands a system that is stable, and abrupt or drastic changes in goals sometimes cause instabilities. The controllable internal constraints can be viewed as functions which allow the system to be adjusted. The equipment constraints include both those that are "built-in" by the design of the system, and environmental limitations which will be physical, legal, political, etc. The equipment constraints constitute hard limits on system performance. An aim of the designer is to minimize equipment constraints and maximize controllable constraints in order to have a flexible system. Both the controllable and the equipment constraints need to be understood by the system users and managers.

The equipment constraints that are built into the system when it is designed result from the interactions of a number of design factors which include:

1. FCC rules and regulations.
2. State, local, and Federal laws.
3. Cost factors (budgetary allowances).
4. Sizing factors (service population and area, response force size, volume and time distribution of message traffic, etc.).
5. Interference from other radio systems, and electromagnetic noise.
6. System reliability.

The system characteristics that result when the system is designed and built include equipment constraints that have one-to-one correspondence with the design factors listed above.

The equipment constraints include:

1. Licensed frequencies, powers, antenna heights, locations, and types of emission.
2. Enabling acts, intergovernment rulings, tower permits, judicial rulings, contracts, etc.
3. Amortized costs, operating costs, budgetary allowance, Federal funds available, incremental costs.
4. Response force size and disposition strategy, message traffic and loading, radio service distance.
5. Interference and noise.

6. Mean-time-to-failure, maintenance costs.

Once a system is designed the equipment constraints are relatively fixed. However, the controllable constraints can be more readily changed by management to control the system. The controllable constraints include:

1. Disposition of response forces.
2. Formulation of individual actions and reactions.
3. Structure of message and records flow.
4. Structure of management information channels.
5. Methodology of analysis of management information.
6. Formulation of policy -- changing the variable system contraints.

5. CONVERSION OF FUNCTIONS TO EQUIPMENT AND PERSONNEL ELEMENTS

The generalized emergency communication system of functions depicted in Figure 3 can be converted into a system of interconnected equipment and personnel elements, as shown in Figure 6. By comparing the two diagrams it can be seen that the function of stimuli input requires an array of telephone equipment: data terminals, teletype terminals, telephone terminal equipment, and alarm display equipment. The function of analysis of input calls is carried out in Figure 6 by telephone operators or other public contact personnel (in some cases, the dispatchers). The record functions of exchange, storage, and retrieval of information are performed by auxiliary radio sets, intercom lines, computers, information files, tape recorders, status maps, and other dispatch aids which are accessible at the dispatch console. Communication between the dispatcher and the response unit is performed through the console and in the base station equipment.

The equipment array in Figure 6 can be simplified for purposes of analysis into the following categories:

1. Telephone equipment.
2. Dispatch Console.
3. Dispatch aids.
4. Base station equipment.
5. Mobile radio equipment.

Before considering the equipment itself, attention must be directed to siting and architecture because the site of each dispatch control center will have strong effects on system effectiveness.

5.1 Sites of Control Centers

It is clear that the dispatch functions should be near departmental command personnel, so that the command and control of mobile field forces can be effective. It is also clear that the physical arrangement of equipment in the control center -- dispatcher's consoles, dispatch aids, and telephone terminal equipment -- should aid in fulfilling the requirements of speed for the functions of dispatch and analysis of reports of emergencies. The coordination between systems that is necessary for

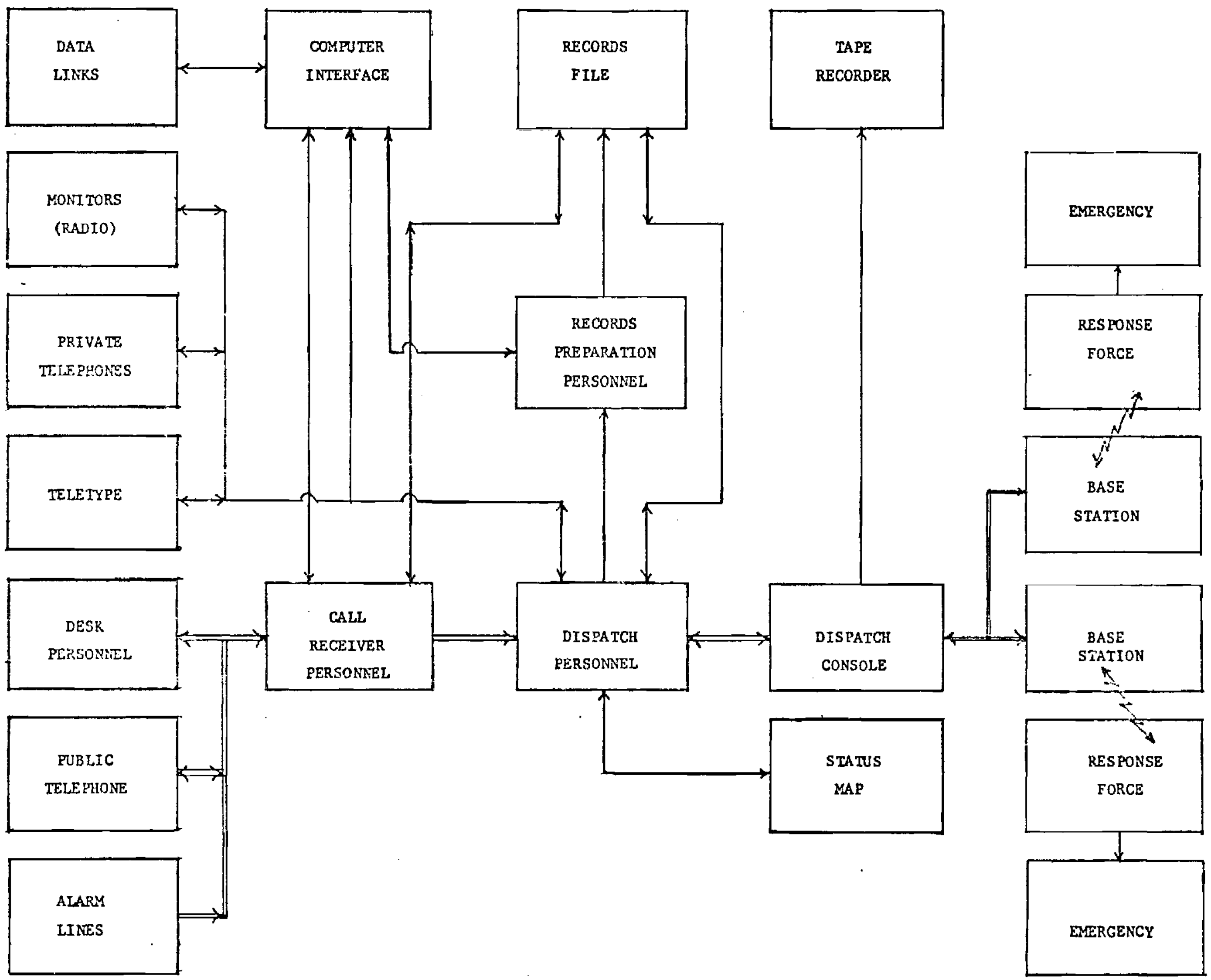

Figure 6. Equipment and Personnel Elements of an Emergency Dispatch Center.

effective response to some emergencies is strongly influenced by the siting of the dispatch functions.

5.2 Telephone Input Elements

Figure 6 indicates that a large number of communication channels may terminate at the dispatcher. The public contact person functions as a buffer between the dispatcher and the input channels (telephone, desk personnel, and alarm sensors) that couple the public into the system. The public access channels are shown as double line paths in Figure 6. The other paths indicate connections from the dispatcher to dispatch aids, records, and intersystem coordination links. The public contact person is a source of delay for incoming calls, and in some systems the time delay introduced by the contact person is deemed to be intolerable. In such instances the telephone and alarms connect directly to the dispatch control console. It should be noted, however, that the requirement for buffering the incoming messages depends upon the volume and time distribution of the incoming message traffic. Even if the incoming lines terminate at the dispatcher, extra personnel may sometimes be required to handle peak traffic telephone calls. It has been reported [4] that "in Minneapolis-Hennepin County, Minnesota -- in November, 1967, 82% of the calls received were for police service, 13% for fires, 2% for sheriff, and 3% for medical and other miscellaneous services." On this basis it can be inferred that the total police emergency message volume in Savannah will be approximately six times the fire messages, and about twenty-five times the Public Works Department emergency messages which originate with the public.

From a limited study of Savannah Police Department switchboard calls [5] (two operators, 7:00 a.m. to midnight) the hourly average varied from one call per hour (between 7:00 a. m. and 8:00 a. m. on a Sunday) to 372 calls per hour (between 3:00 p. m. and 4:00 p.m. on a Wednesday). The ratio of the peak hourly average rate divided by the daily hourly average rate ranged from 1.4 to 3.0. During the peak hour, the average service time was 20 seconds per call.

Telephone companies have for many years utilized such traffic studies to determine system design parameters when installing switchboards and other customer equipment. The equations which permit the telephone company to recommend a certain number of trunks to meet a customer's needs can also be used to predict the waiting time before a caller can obtain a clear channel. The same equations, Erlang's equations [2], can also utilize data from observations of radio dispatch traffic to determine how many radio channels an agency needs to render fast emergency response. Erlang's equations and a number of examples which illustrate their use are included in Appendix A.

The examples in Appendix A indicate that during the hour of peak telephone calls noted in the Savannah study the probability was 35 percent that a caller would have gotten a busy signal. The examples indicate the comparative values of adding more operators and trunk lines, and devices such as an Automatic Call Distributor (ACD), to emergency communication telephone systems.

Whether to add more trunks, ACD equipment, or other telephone system options will depend on what value the agency places on prompt and effective response to callers. If it is desired that the probability of a caller getting a busy signal is to be one percent, the examples clearly show that several trunks and contact persons must be provided.

The examples in Appendix A also indicate that the second delay interval in Figure 5 (the time that elapses between the instant a citizen places a call and the reception of the call by the contact person at the emergency center) depends on the telephone system at the agency. It also depends on the design of the system.

In some cities, the telephone operators who answer police calls initiate complaint records and forward them to the dispatch consoles. If there are more operators than dispatchers, and if the service time for the operator task is shorter than the service time for the dispatch task, it is clear that during periods of heavy demand the complaint cards will begin to accumulate at the dispatch console. This is how the buffering function of the telephone operators is realized. If the backlog at the dispatch console becomes too large, the overall response time will increase, and the agency effectiveness will drop. Examples in Appendix A show what improvement could be expected by adding radio dispatch channels, or by reducing the dispatcher's service time through the use of dispatch aids.

Equipment available for the telephone input includes key sets, call directors, manual boards, Centrex type switch gear, 911 equipment, etc. Some of the features available in key set equipment include:

1. Pick-up and holding.
2. Conference call.
3. Intercom.
4. Visual signals of line conditions.
5. Audible signals of line conditions.
6. Privacy.
7. Emergency override.

Large agencies should examine the benefits of key sets, Call Directors, and/or Centrex PBX telephone systems. Each offers a number of useful features.

The concept of the universal emergency telephone number, "911" is attractive, and it has already been implemented in over a hundred cities. There are a number of technical problems in implementing 911. Because the single number must connect the public to all the various emergency agencies and because telephone exchange service areas cross political boundaries, implementation will encounter jurisdictional conflicts. Another problem is in identifying the address of the emergency inasmuch as the towns, cities, and municipalities served by the single number often have repetition of street names and numbers. Emerging technology offers possible solutions for some of the technical problems encountered with 911. These include:

1. Automatic Number Identification (ANI), with automatic display of the number of the caller. A computer could be used to derive the address of the caller, and could then also automatically route the call and the address to the proper local government, where a single telephone contact person would determine the nature of the emergency.
2. Called Party Hold. The telephone of a caller can be held on-line, even if the caller hangs up, so that the call can be traced and ANI could be accomplished.
3. Forced Disconnect. Jamming could be prevented.

If 911 is implemented it should include all of the Savannah metropolitan area; and advantage should be taken of the most advanced technology, especially ANI.

The dispatch console should consolidate all of the emergency telephone equipment that is available directly to the dispatcher. The dispatcher earphone and microphone should be capable of being switched either to incoming telephone lines, or to radio channels. A set of telephone push-button keys built into the console (equivalent to a Call Director) will reduce the clutter and extend the dispatcher's flexibility.

5.3 Radio Dispatch Channels

The usefulness of Erlang's equations in structuring the telephone input and the radio channel output has been illustrated in Appendix A. The reduction of overall response time that can be expected if two dispatchers are used instead of one dispatcher is also calculated in Appendix A. It must be pointed out that the basis for Erlang's equation includes random distribution of the incoming calls. The random nature of telephone traffic is the basis of success of telephone systems. To take full advantage of the randomness of incoming messages, the radio dispatch system would have to be designed like a telephone system; i.e., the dispatcher should be able to contact any vehicle over any of the system's radio channels. (This might not be practical for police tactics, of course.) To illustrate the value of the ability to contact vehicles over any of the available channels, assume on the contrary that each of two radio channels is dedicated to half the mobile vehicles. Of three simultaneous incoming calls at least two but possibly three would be routed to one dispatcher. A total delay of as much as three dispatch service times could be required to dispatch all calls, and the maximum system delay would be experienced while one of the dispatchers was completely idle. With access to all channels by both dispatchers, no more than two of the three dispatches would ever be made by one dispatcher.

5.4 Dispatch Consoles

The dispatcher's equipment can be very simple if his function does not require elaborate equipment. The simplest radio dispatch terminal looks like a desk telephone. From the simple set, the available equipment proceeds through a table-top cabinet with separate microphone and headset, to equipment mounted in desks [6] such as that shown in the illustration in Figure 7.

5.5 Dispatch Aids

A number of the equipment elements in the system of Figure 6 (teletype, automatic private lines, monitors, status map, data link, and files) can be viewed collectively as dispatch aids. Each dispatch aid should be assessed in terms of its ability to decrease overall response time, and/or in terms of increasing the response effectiveness. Digital transmission equipment permits information to be exchanged between the dispatcher and vehicle operators by push button actuations; it also permits computer access from vehicles.

The data link and teletype terminal permit the extension of local information files. Monitors and intersystem radio and teletype terminals permit coordination of Savannah agencies with other agencies (State Patrol, Georgia Hospital network, Sheriff's net, etc.) The automatic private line telephones are point-to-point "hot lines," which interconnect dispatch consoles in various agencies, connect the central dispatcher to local control points (such as station houses), or connect management offices to the control center.

Status maps give quick visual reference of response, enabling the dispatcher to determine force disposition, the available vehicle nearest to the emergency, quickest route, etc.

The tape recorder is a multiple track instrument which logs all the control center messages. It is not normally used for quick recall, but is a source of information useful to augment the hard copy records. Sometimes another tape recorder is included in the console to be used by the dispatcher for quick recall to refresh his memory.

Some agencies will not require the same array of dispatcher aids shown in Figure 6. The degree of technological sophistication will vary with

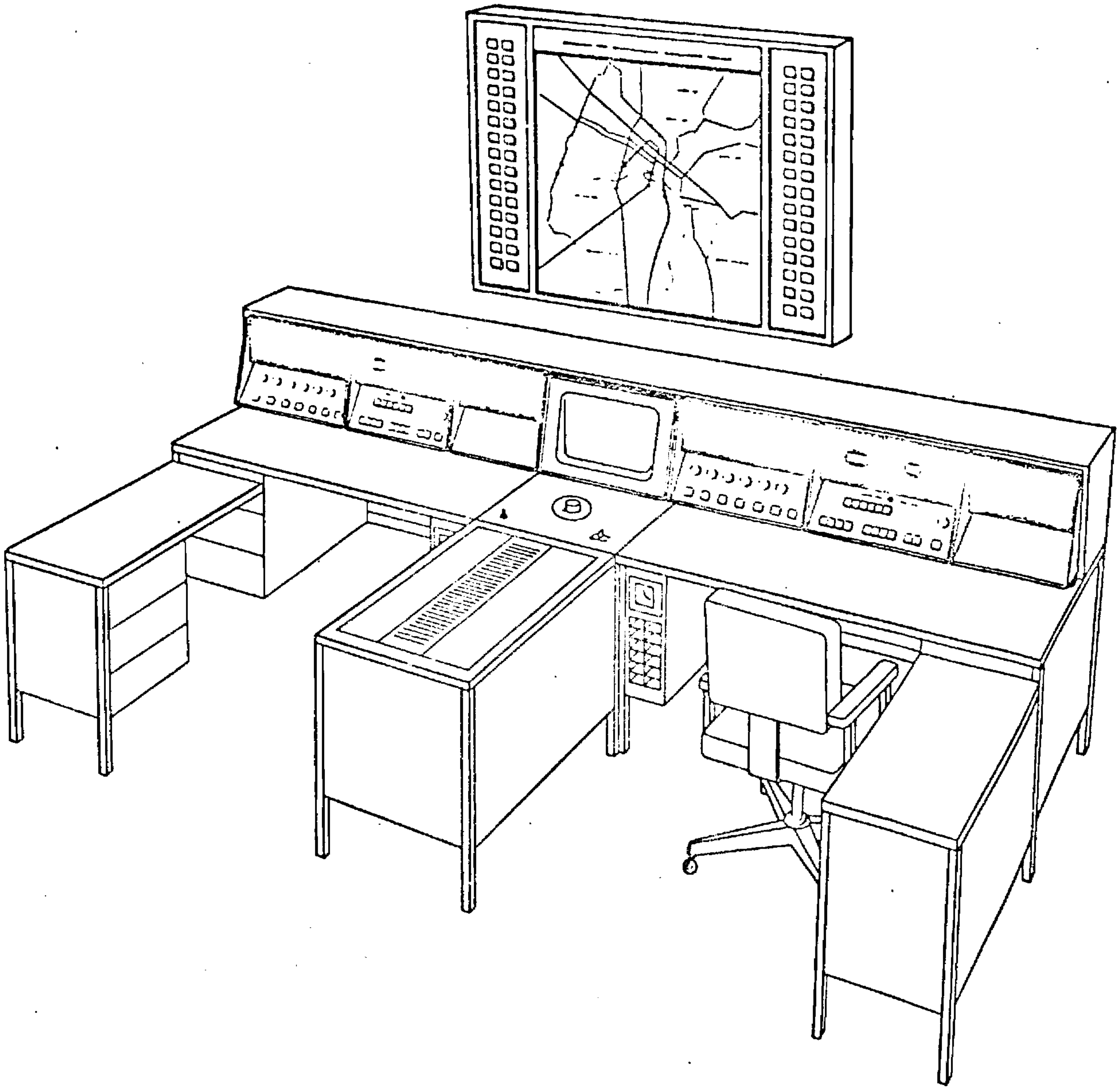

Figure 7. A Typical Dispatch Console [6].

different agencies. Computer aided dispatch is being employed in a number of police departments; this requires more devices than are shown in the figure.

5.6 Base Station Equipment

Base station equipment includes the base stations themselves and associated antennas, towers, antenna feed lines, power sources, and buildings.

Functionally, base stations are receiver/transmitter units through which communication is established between the dispatch control center and the response force. The communication mode may be voice or data with either analog or digital transmission. Terminals, either in mobile units or at the control center, may include voice transducers, printers, digital display, computer interface keyboards, status switches, vehicle location indicators, etc. The same base station can handle any of this information.

Base stations must be located near the transmitting antennas. The control signals and message signals can be connected from the dispatch console to the base station by telephone lines or by microwave or UHF radio link.

The ability to communicate must be secured against natural disaster, accident, and sabotage. This is accomplished by using telephone lines that are tagged to prevent inadvertent cutting by telephone maintenance crews; redundant, multiple telephone lines; microwave or UHF links; backup base stations (which can be mobile); and standby, gasoline-powered generators. Where possible, base station should be located in or adjacent to buildings that are continuously manned by City personnel -- police stations, fire stations, pumping stations, etc.

5.7 Mobile Radio Equipment

The mobile radio equipment includes vehicular two-way radio sets, personal portable two-way radio units, and pocket pagers which can receive one-way alerting signals and/or voice signals.

6. EQUIPMENT ELEMENT REQUIREMENTS

The preceding chapters have presented generalized emergency communication systems, first as a system of interconnected functions (Figure 3) and then as a system of equipment and personnel elements (Figure 6). It was stressed that the systems and their elements will respond with characteristic time delays to inputs. In Chapter 5 and Appendix A the methods of analysis used to design telephone systems were shown to be useful also to indicate how to design for reduced system delays and increased system effectiveness.

The equipment elements for emergency communication systems were categorized in Chapter 5 as:

1. Buildings and sites.
2. Telephone equipment.
3. Dispatch console.
4. Dispatch aids.
5. Base station equipment.
6. Mobile equipment.

6.1 Buildings and Sites

6.1.1 Centralized Emergency Communications

There are a number of factors, economic and operational, which argue for centralization or consolidation of metropolitan area public services. The potential economic advantages are obvious and real, although they are not always easily realized. The operational advantages include the use of a single or a universal emergency telephone number and the ability to coordinate emergency responses.

The universal emergency telephone number, 911, has been implemented for hundreds of communities in the U.S., and is widely recommended. It must be recognized that 911 would increase the delay after a call is received because the emergency message would first have to be routed to the proper emergency agency. This would increase the time interval in

Figure 5 labeled "call analyzed." To reduce overall response time, the additional time required for routing to the proper agency would have to be exceeded by a reduction in the time required for the citizen to place the call, plus the time required for the call to be received. This reduction can be estimated as about thirty seconds. For a trained operator, the extra time required to route the message to the correct agency can be estimated to be about ten seconds, for a net overall savings of perhaps twenty seconds.

There are other, more involved considerations in the adoption of 911, however. The implementing equipment is installed at telephone switching centers, some of which serve areas that cross jurisdictional boundaries. Adoption of 911 is thus feasible only for an entire metropolitan area or for a free dialing telephone area, and the consolidation of a number of emergency dispatch and control centers is implied. For Savannah, this would mean no less than the consolidation of all the present police dispatch operations in Chatham County into one command and control center, with similar consolidations of fire and ambulance dispatch operations.

It has also been suggested [7] that to help the telephone contact persons route the 911 calls to proper control centers, Automatic Number Identification (ANI) could conceivably be implemented. The telephone company automatic billing systems presently include ANI equipment to identify the telephone number of callers. The suggestion is that this capability be incorporated along with 911. With a digital computer, the telephone number of a caller could be rapidly correlated with his geographical location, and that information could be displayed for the dispatcher. The far reaching effects of implementing 911 place it beyond the scope of recommendations in this study; it is presented in concept only.

The building layout proposed for a dispatch command and control center for San Diego [8] would lend itself well to centralized emergency communication operations at Savannah. The isometric view in Figure 8 indicates how agency operations could be separated for optimum agency service and still permit coordinated responses when necessary.

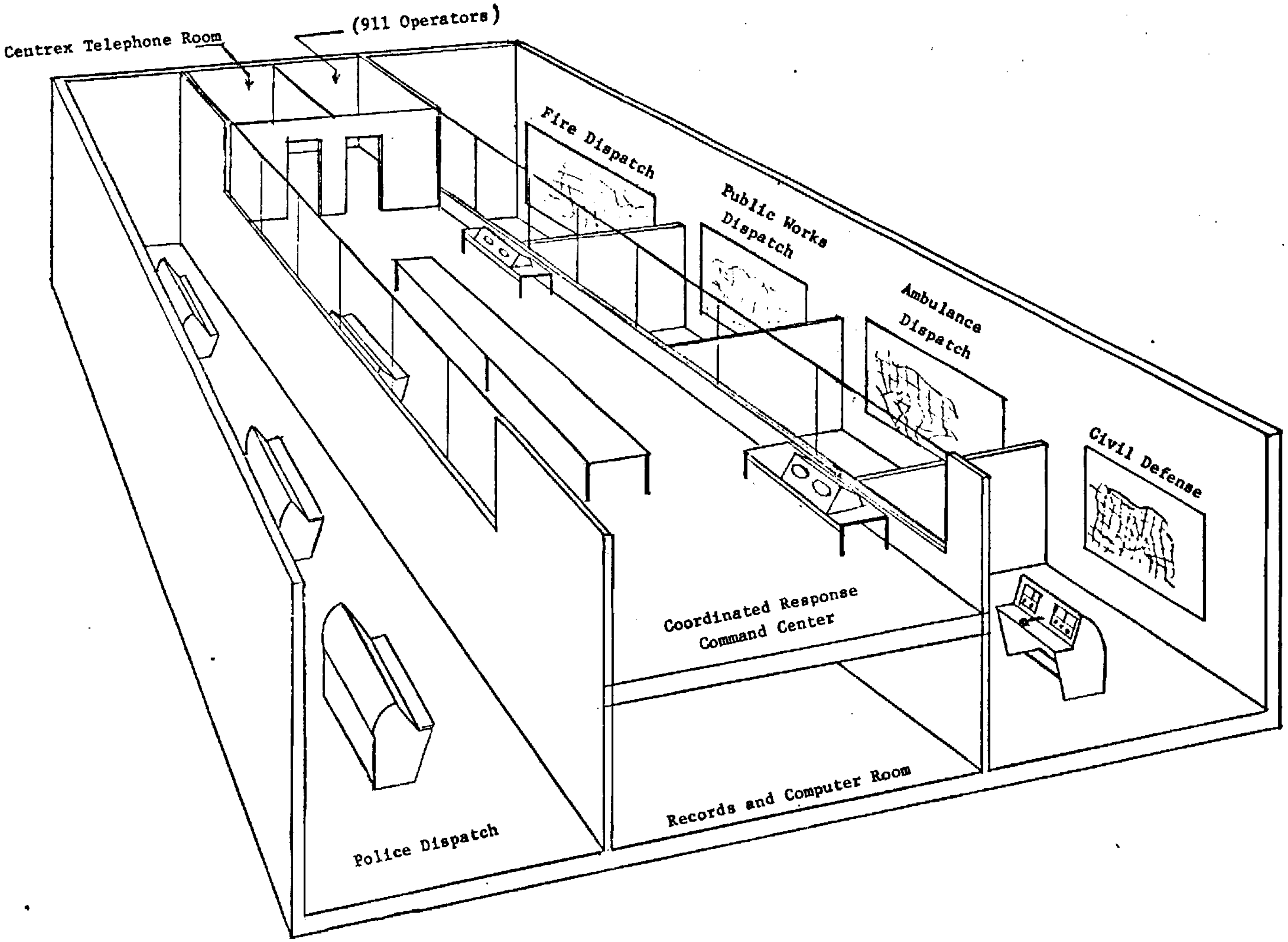

Figure 8. Sketch of a Centralized Command and Control Center, Adapted from a Plan for San Diego [8].

The building elements could be used either for a Metro Savannah consolidation; or for common occupancy by City, County, and State; or for a City of Savannah centralization. The 911 routing operator room is shown in parentheses because it would be feasible only in the case of a Metropolitan area consolidation. The command and control building for a metro area consolidated system would not need to be appreciably larger than one for a City of Savannah centralized system, if advantage is taken of system economies.

The equipment and room arrangement for a metro Savannah consolidated system could be similar to the first-floor plan in Figure 9. If Civil Defense and Emergency Medical dispatch are deleted from Figure 9, it could represent a conceptualization of a centralized site for a City of Savannah emergency dispatch system.

By separating City and County operations into separate dispatch rooms, and including quarters for a State Patrol radio room, Figure 10 indicates how area-wide emergency dispatch operations could be centralized without consolidating agencies. The addition of the second-floor gallery shown in Figure 8 would permit combined and coordinated responses as needed.

A newly constructed emergency communication center could be underground, hardened against air attacks, and equipped with auxiliary electric power. The offices of agency administrators should be in the same building as the communication centers.

6.1.2 Communication Centers in Present Sites

For the present it is necessary that the City of Savannah house its emergency communication centers at decentralized locations.

Police Department. The Savannah Police Department command center is being relocated into rooms set aside for that purpose in the Police headquarters building. Attention is being given to security of the center against sabotage. It is recommended that the emergency telephone equipment also be relocated within the command center so that it can be protected against sabotage. The incoming telephone lines should be relocated underground and/or in steel conduit to decrease their vulnerability.

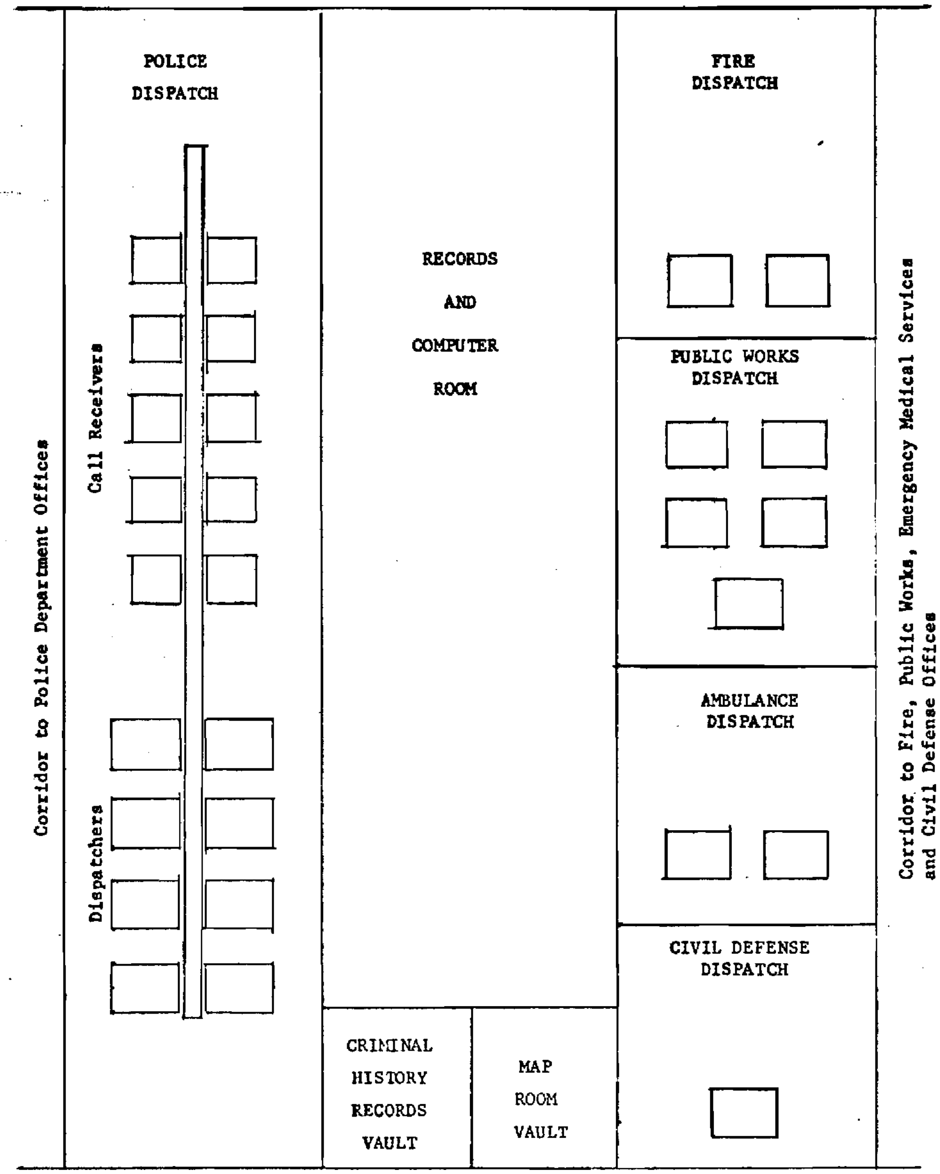

Figure 9. First Floor Conceptual Plan for a Metro Savannah Consolidated Command and Control Center.

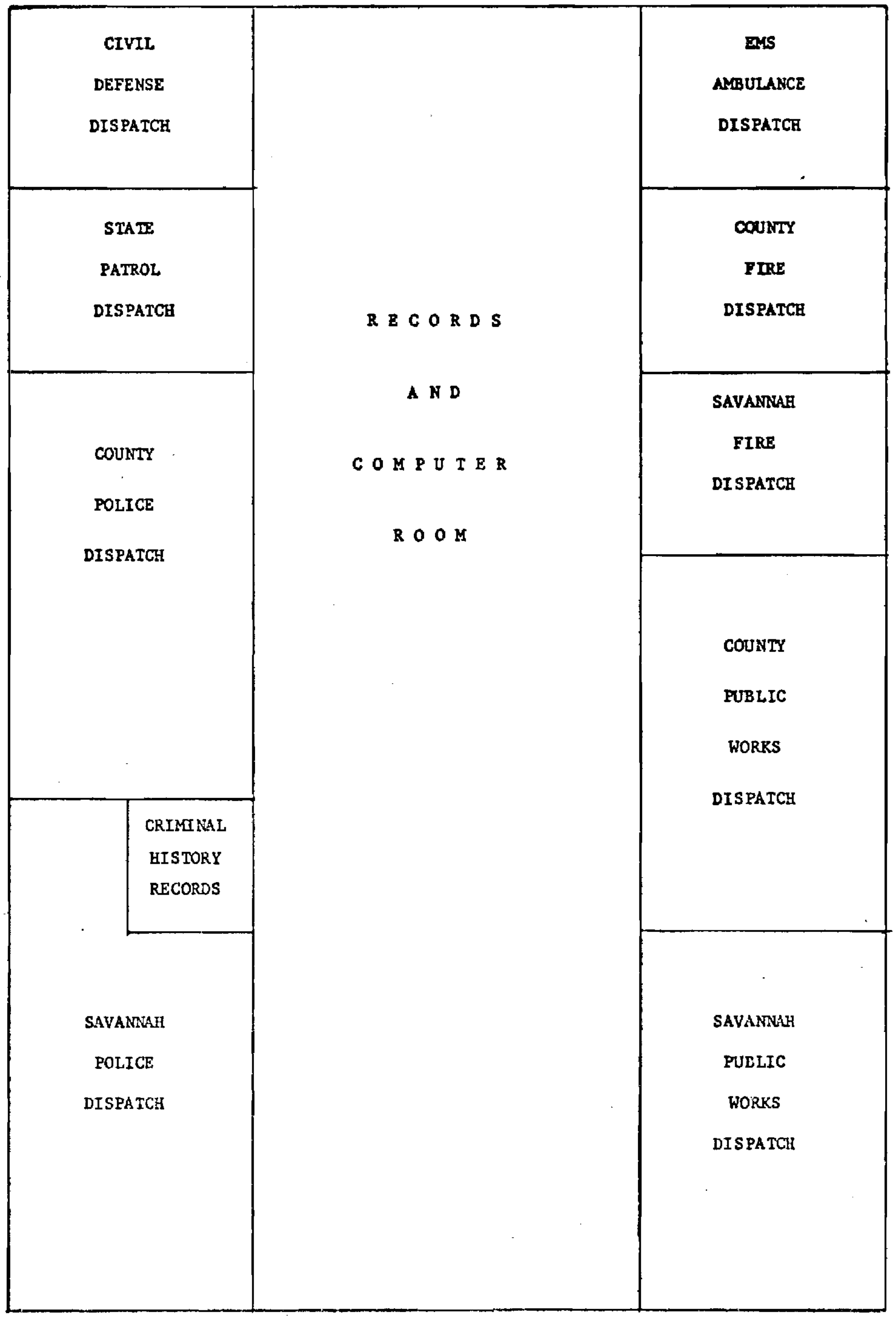

Figure 10. A Shared Quarters Plan -- Joint Occupancy by City, County, and State Emergency Dispatch Centers.

A new antenna tower is recommended. It should be located in the southwest part of Savannah, and for security reasons it should be adjacent to a Fire Department station house or other continuously-manned City facility. The base station equipment would have to be moved to the vicinity of the tower, and would have to be housed in a secure and protected location. Auxiliary power equipment would be required.

Pending the erection of a new tower and transfer of the base station equipment, the present location of the base station should be made secure against sabotage.

Fire Department. The present site for fire dispatch appears to be adequate.

Public Works Department. The radio dispatch operations of the Public Works Department need to be centralized in a location near the department manager's office, with the aim of increasing management effectiveness.

6.2 Telephone Equipment

The basic requirements for telephone equipment include:

1. Totalizers to perform traffic analyses, to determine the number of trunk lines and scheduling of telephone operators needed to assure an acceptable probability that callers will not get busy signals.

2. Automatic Call Distributors for multiple operator systems to help callers get service in periods of heavy demand.

3. Called Party Hold features for police and fire systems to permit call traces.

4. Forced Disconnect to prevent tie-up and jamming of trunks.

5. Security of lines against sabotage.

6. A sufficient number of automatic private lines to permit interagency coordination and backup operations of base stations.

6.3 Dispatch Consoles

The six consoles planned for the police dispatch center, and the one console in the fire control center are adequate. The Department of Public Works console and methods of dispatching need to be upgraded; at least two consoles and two VHF or UHF channels are required.

The requirements for consoles should be based on the functional requirements of minimum time delay and maximum dispatch effectiveness.

All consoles need automatic private line connections to all other city public service dispatch consoles, and also to wrecker companies and public utilities -- either to dispatch consoles or to emergency telephone operators. Private lines are also needed between city dispatch consoles and their county counterparts, and to the Emergency Medical Center and Civil Defense Center.

6.3.1 Police Consoles

The police dispatch consoles should include the following:

1. Earphone and microphone in a single unit, either a handset (like a cradle telephone) or a headset with lightweight, small microphone.

2. Volume control.

3. Channel selector switch and indicator.

4. Footswitch and bar switch to actuate microphone connection to radio.

5. Switch to connect microphone to telephone.

6. Call Director for telephone channel selection.

7. Selection of transmission options (selective address, all channel transmit, squelch disable, etc.).

8. Selection of intersystem radio channel.

9. Intercom switch.

10. Keyboard, display, and printer.

11. Dispatch aids, such as clock, time/date stamp, status map switches, VU meter, teletype terminal, computer terminal, card files, microfilm viewer, quick recall tape recorder, CCTV monitors, alarm sensor printout devices, call indicator, and switches for mute, 1000 Hz alert tone, repeater disable, and supervisory take-over.

The arrangement of consoles in the Police Department is planned as shown in Figure 11. There are six operational consoles and two desks. The console arrangement will be compatible with computer-aided dispatch, and will lend itself to effective operations. It will permit a variety of different tactical configurations of the Police Department response forces.

The six consoles recommended for the police control center are compatible with radio channel requirements to fit the functional needs of the Police Department. In Appendix B the requirement for three patrol channels is compared to published requirements, and a study is made of methods for determining police radio needs. The use of three patrol consoles is based on tactical decisions by the Savannah department to divide the city into three patrol sectors. The other three channels will serve other police functions: investigative, local area police net, and special detail. For Savannah, the six available channels might be assigned as follows:

Channel 1 - 460.025 MHz - Patrol, 3 shifts,
Channel 2 - 460.200 MHz - Patrol, 3 shifts,
Channel 3 - 460.325 MHz - Patrol, 2 shifts,
Channel 4 - 460.475 MHz - Investigative,
Channel 5 - 460.400 MHz - Special Detail,
Channel 6 - 460.500 MHz - Local Area Police Net.

The above channel allocation is only suggested as a starting point for equalizing channel loading. It is based partly on a SPD study made April 15, 1973, and on conversations with personnel in the Department.

The objective in radio channel management should be to equalize the channel loadings, and to provide enough channels to yield average loading factors lower than 35%. Radio traffic analysis should be performed, and adjustments made to equalize channel loading. Digital counters should be included on all radio consoles and telephones for radio and telephone traffic analyses and channel management.

Channel Six, used as suggested above, will give access to a cross-band repeater, which Chatham County presently owns. Savannah will need at its

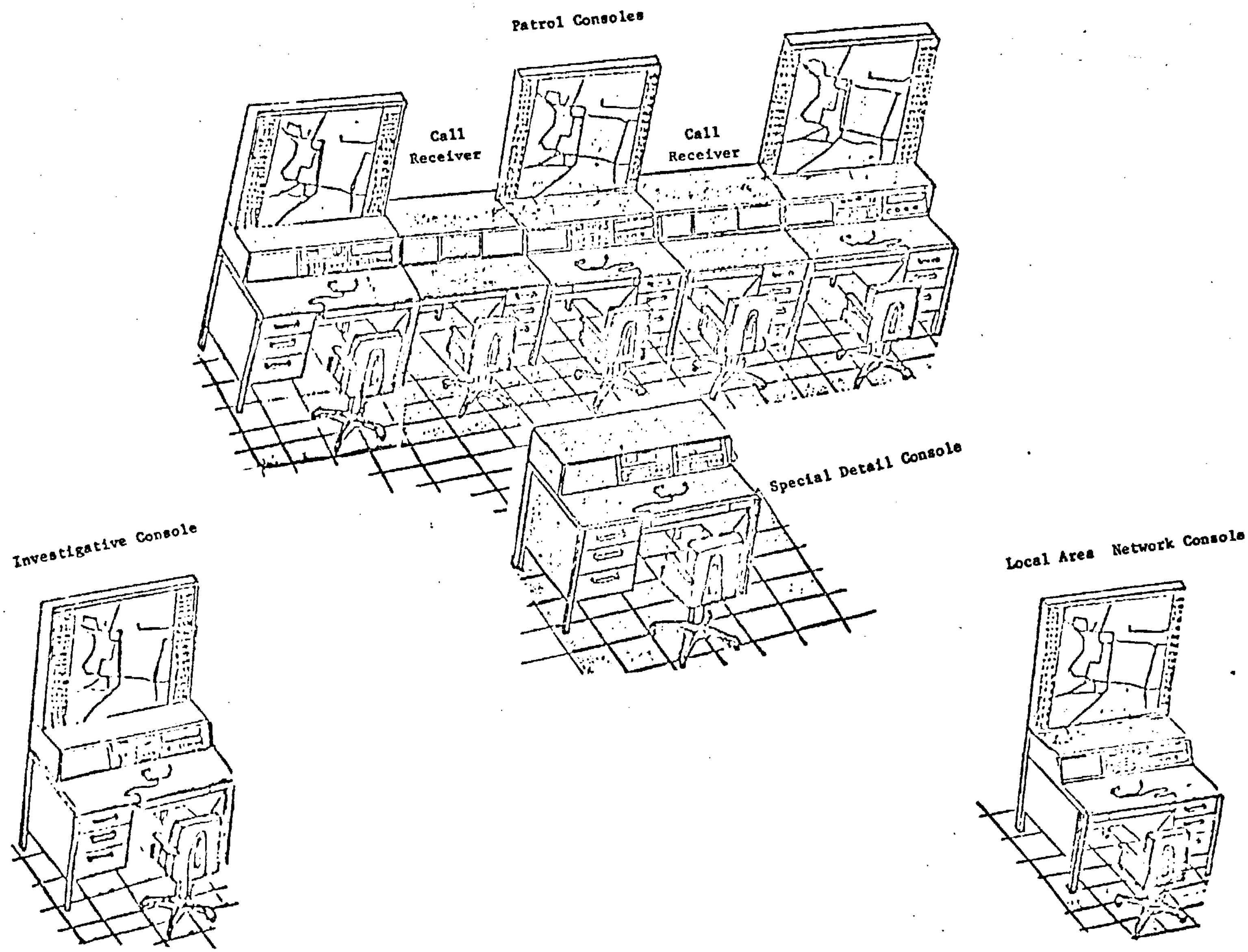

Figure 11. Console Arrangement in Savannah Police Department Dispatch Center.

command center a low-power (about 1 watt) 465.500 MHz transmitter with a roof mounted antenna to actuate the repeater, which can rebroadcast on both 460.500 MHz and 154.905 MHz. Channel Six will have a number of modes of operation:

1. SPD car-to-car county-wide. Transmission on 465.500 MHz from a car will be received at SPD and rebroadcast county-wide on 460.500 MHz for car-to-car relay.

2. Command and control of all SPD cars county-wide, using 460.500 MHz transmit and 465.500 MHz receive at the base station. This will be the SPD emergency mode.

3. Command center to GSP, FBI, or CCPD, via the 455.500 MHz low power transmitter to the cross-band repeater, which will rebroadcast on 460.500 MHz and 154.905 MHz. Reply messages from other agencies received on 154.905 MHz will be relayed on 460.500 MHz.

4. SPD cars transmitting on 465.500 could also inadvertently trigger the cross-band repeater. Repeater actuation from SPD cars to CCPD, FBI, and GSP must be controllable by the SPD dispatcher. This could be implemented by wire line from the SPD console to the County's cross-band repeater base station, for example, by actuating a relay to quiet the 465.500 MHz receiver in the cross-band unit. To prevent break-in on the SPD 460.500 MHz transmissions from the 154.905 MHz signals, the muting circuit could also inhibit the cross-band 460.500 MHz transmitter.

From the viewpoint of the VHF users -- GSP, CCPD, and FBI -- the VHF side of the cross-band equipment should likewise be under control of the County command and control dispatcher, to prevent SPD break-in on ongoing County transmissions. Indicator lights at the SPD and CCPD consoles would indicate when a radio request was being made for access to the cross-band facility by either user. An automatic private line will also be needed to interconnect the County and City consoles, in order to facilitate coordination.

6.3.2 Fire Department Console

A basic difference between fire and police department response force posture which has an effect on the radio system requirements is that police units are mobile and their targets may also be mobile, whereas available fire units are in stations, and their targets are fixed. One can add to this the higher possibility of a police unit being alerted locally. Fire personnel at the scene of a fire operate as self-sufficient units, only calling the dispatcher if specialized or additional equipment is needed.

Data that was cited previously [4] indicated that telephone calls for fire emergency response will be only one-sixth the number of police emergency calls. On this basis, the population that will generate one call per hour average will be 150,000 persons, and one dispatch channel and console is sufficient for the Fire Department.

The ratio of peak-to-average calls may be high because of false alarms, but the time required of the dispatcher should be less for the false alarms than for bona fide alarms.

After the initial dispatch message is sent, the urgency of the dispatch operation is reduced somewhat; but the necessity to coordinate requests for ambulances and traffic control assistance adds to the dimensions of the fire dispatcher operations. Although the present Fire Department console is sufficient, the telephone network may need expansion. A long-term study of telephone traffic is recommended.

The experience gained by the Police Department in computer aided dispatch should be used by the Fire Department to determine the value of the computer for address verification. If the technique is effective, the Fire Department should install a computer terminal.

The features listed for the police dispatch console, except for the keyboard, display, printer, teletype terminal, computer terminal, and CCTV monitor, should be incorporated in or be accessible to the fire control center console.

6.3.3 Public Works Department Consoles

The nature of dispatch operations for the Public Works Department differs greatly from police and fire dispatch. By far the major portion of dispatcher messages are non-emergency, being related to day-to-day operations; but Public Works dispatch is a 24-hour, 7 days a week operation, and responses must be made to emergencies. Examples of emergency calls include:

1. Broken water main. Response must be rapid to prevent damage to streets and property, and to restore normal water supply.

2. Bridge collapse. Adequate traffic barriers and warning lights must be put up quickly, to safeguard motorists, pedestrians, etc.; rescue of drowning persons may be required.

3. Obstructed drainage. Street and property damage can be prevented by prompt remedial response.

4. Construction accidents. Collapse of buildings, scaffolds, cranes, and ditches claim numbers of workers annually. Heavy lifting equipment, bulldozers, power shovels, ditchdiggers, etc., could, if brought quickly to the accident scene, save some of the lives that are now lost.

5. Fallen wires. Electrical hazards should be blocked off until power company employees arrive. Perhaps with proper training and proper tools, Public Works employees could with safety remove persons from contact with electric wires.

6. Inoperative traffic signals. Putting broken traffic lights back into proper operation can save lives, prevent property loss, and save time for motorists. An analysis of the cost of one broken traffic signal in terms of productivity lost when thousands of commuters are caused to be late to work, is convincing proof of the value of quick response to such an emergency.

7. Broken sanitary sewers. The hazard to health of raw sewage from a broken system is obvious.

8. Uncollected garbage. This is also a health hazard, but the degree of emergency may be low enough to delay the response until a scheduled collection can take care of it.

There are about 120 mobile radios in service in Public Works vehicles. Applying the FCC viewpoint that 30 mobiles is an acceptable average load for a radio channel, four channels would be required for day-to-day operations and a fifth channel would be needed for emergency dispatch. It is recommended that a study be made by Department management to determine the number and locations of consoles needed for best operational effectiveness. If four non-emergency radio channels are found to be required, they and the fifth channel might initially be assigned as follows:

Channel 1 - Sanitation.

Channel 2 - Water.

Channel 3 - Street, bridges, sewers and drainage.

Channel 4 - City engineer, street lighting, traffic signals, and others.

Channel 5 - Emergency and supervisors.

The dispatch consoles should include vehicle disposition maps which will indicate visually the location and type of radio equipped vehicles, and possibly other Public Works vehicles which do not have radios but might be useful for emergency response. Color coded lights and/or alpha numeric characters could be used to designate categories of vehicles, as indicated in the following list:

Red - On emergency duty.

Green - Available.

1. Truck with winch, large jack, rope, axes, oxygen, power saws, long handled wire cutters, life jackets, boat, other rescue equipment, and a trained rescue crew.

2. Ditchdigger.

3. Cherry picker.

4. Bulldozer.

The status map should include all of Chatham County, should measure about 40 inches wide by 30 inches high, with grids equivalent to 5 miles by 5 miles. On a scale of one-inch per mile, there would be a total of 48 grids, each with numbers, which could be illumined by red or green light (or turned off, of course, to indicate no rescue vehicle in that sector). Progress of a vehicle in response to an emergency could be tracked from grid to grid by actuation of appropriate lights. Available standby units could also be designated, perhaps by a blue light, to indicate unmanned equipment. The complement of features recommended for the fire control center console are also recommended for the Public Works control center consoles.

6.4 Dispatch Aids

Most of the dispatch aids have been catalogued under the console requirements. A recently developed dispatch aid which is proving extremely effective in police systems is computer-aided dispatch.

A digital computer reduces the communications center delay in a number of ways. The verification of address of the caller through a computer match of street files with information obtained from the caller is straightforward and extremely valuable. The selection of available units can also be done by a computer, with display of alternatives to the dispatcher. Given an analysis of the nature of the emergency, it is even feasible for the computer to send a code message to the unit, and to receive and record the "unit acknowledgement" and the "unit arrival" codes. All of the computer input/output information, together with time of day, could be displayed or printed for the dispatcher. Basic equipment requirements could be met with a small computer, mass storage units, and terminal devices.

Access to the computer from the field unit also increases the response force effectiveness. The computer would reduce the dispatch time and increase the effectiveness of the response force. Computer filed information is already available to the police response force, but indirectly through voice relay. The tradeoff benefit of aided dispatch is backed by experience in Nashville, Tennessee and in Kansas City, Missouri [9].

The radio equipment required for direct computer access includes digital message transmission capability.

Savannah Police Department has already initiated digital information and files, primarily with the Savannah Area Law Enforcement System (SALES). This constitutes one constraint on the design of a digital communication system. Fortunately, the SALES system in its present status can interface satisfactorily with feasible communications system designs. SALES is currently providing extensive law enforcement data to field units, via the dispatcher, on a demand basis. Thus, rather than representing a constraint in the negative sense, SALES represents a starting point from which a unified or comprehensive system can be developed.

The present embodiment of SALES, specifically the use of general purpose computer hardware, will, however, influence the direction of subsequent digital system design. Also, use of the centralized City computer represents a constraint that must be carefully examined since the computer is a major, if not the most important, component of a digital system. This situation influences the available choices of communication system configurations.

A study defining system configurations that will be useful to the Savannah Police dispatch operations is detailed in Appendix C where the benefits and costs of digital communication are examined. It is recommended that a mini-computer be installed at the Police communication center, that the control consoles be implemented for computer aided operations, and that a limited number of vehicular radios be equipped for digital communication.

6.5 Base Station Equipment

6.5.1 Police Department

The present tower is not high enough to give CM-3 quality, 90 percent talk-back coverage from the extreme reaches of Chatham County, according to calculations presented in Appendix D. For this reason it is recommended that the present tower be disassembled, and a new tower or towers be erected closer to the center of the county, but within the city limits.

Tower relocation will also require relocation of the base stations, and a secure building or buildings will be needed to house the base stations. The least costly configuration will most likely be a single tower and a single building.

It is recommended that the tower site be adjacent to a fire station or other City facility that is manned at all times.

A microwave link is recommended for two-way transmission of the six half-duplex channels between the roof of the Police Department building and the base station tower. Backup of the microwave link should be provided by at least one secure telephone line.

The base station antenna heights and gains should be designed to give two-way, 90 percent, CM-3 quality communication between dispatchers and City vehicles throughout Chatham County, and between dispatchers and personal portable radios throughout the city. Appendix D, and other sources [10] present approaches that can lead to alternative designs and antenna configurations to achieve the desired coverage. The approach recommended in this report will require a 400 foot antenna tower, as detailed in Appendix D.

6.5.2 Fire Department

The present Fire Department base station equipment is adequate for operations within the City of Savannah.

6.5.3 Public Works Department

The Public Works Department equipment, including base station and mobile equipment, is nearing the end of its useful life. It is recommended that the entire Public Works system be replaced with new equipment. Because the upper VHF and UHF spectra are not as crowded as the lower VHF spectrum in urban areas in the Southeast, it is recommended that either upper VHF or UHF assignments of local government channels be used, instead of the present lower VHF channels. It has also been recommended that the Public Works Department conduct a study to determine how many channels it needs.

6.6 Mobile Radio Equipment

Special requirements for vehicular and personal radio sets include needs for rugged construction and light weight. Both mobile and personal sets should therefore be solid state, with housings that are complete enclosures with no louvres or vents. The requirement for light weight means that the power of vehicular mobile transmitters will be limited to about 50 watts, and personal portable transmitters will be limited to about 2 watts. The limitations on transmitter power have to be compensated either by base station tower height, or by the use of a number of pole mounted relay receivers. Appendix D indicates that talk-back vehicular mobile coverage from the extremes of Chatham County can be achieved with the following system parameters:

1. Mobile transmitters, 50 watts.
2. Mobile antenna gain, 5 dB (see Glossary for definitions).
3. Line and coupling losses, 2 dB.
4. Base station antenna gain, 10 dB.
5. Minimum base station antenna height, 300 feet.
6. Tower height, 400 feet.

7. CONCEPTUAL SYSTEMS

The conceptual emergency radio dispatch systems for Savannah can be described, based on the analyses of the foregoing chapters. One deficiency in the City systems is in its facilities for coordinating emergency responses. An extension of the present network of automatic private telephone lines is recommended. The emergency telephone network should interconnect all City, County, State, and public utility company emergency dispatch centers.

7.1 Police Dispatch System

The conceptual emergency dispatch system for the Police Department can be described. The dispatch center will be located in the Headquarters building. There will be six consoles in the dispatch center, arranged as shown in Figure 11. Two telephone desks will be placed as shown, between the two outside patrol consoles and the center patrol console. Call Directors will be installed in all six consoles and in the two telephone desks, for a total of eight Call Directors. Incoming calls will first be screened by telephone operators to determine the agency involved, and if police response is required the caller will be connected to the first available Police center call director. (Optionally, any position can answer the call.)

At each of the eight positions will be a keyboard for entering a record of the call into the Police Department dispatch computer. As the complaint record is being entered by the "call receiver" officer, the dispatcher who will be responsible will be alerted.

There will be a cathode ray tube (CRT) display terminal at each of the eight positions. As the complaint is being received and entered into the computer, the call receiver officer alerts the responsible dispatcher; if the dispatcher's CRT is available, the complaint record will be displayed. If the dispatcher's CRT is busy, the complaint record will be stored in the computer until the dispatcher's CRT becomes available, then the complaint record will be displayed. Another dispatcher who is not busy can optionally call the complaint record to his CRT and perform the dispatch.

The police radio base stations, 400 foot antenna tower, and associated building and auxiliary power generation equipment will be located in the southwest of Savannah, in the direction of the center of the county. The transmitter and tower site will be adjacent to a Fire Department station house or other continuously manned City facility, for security purposes.

The base station antenna will have 10 dB gain; the mobile vehicles will have antennas with 5 dB gain. Base station antennas will be separated vertically by 20-foot spacings. The total coupling losses for a base station and a vehicular antenna will not exceed 2 dB.

A microwave link (or a UHF equivalent) will transmit the dispatch messages between the dispatch center and the base station location. For backup, should the microwave link be down for repairs, a single automatic private telephone line will permit operations over one channel at a time. The base station equipments will include provision for local emergency dispatch operations.

A battery operated transmitter will be provided at the Headquarters building to permit limited coverage (within Savannah city limits) single channel dispatch, for backup in the eventuality that all base stations become inoperative.

The radio system will include digital communication capability through any console. Initially, twenty-five vehicles will be equipped to communicate by digitally coded messages. Push button selection of commonly used 10-code messages will be implemented, and longer digital messages will be made possible by keyboard or thumbwheel switch. As the Department becomes familiar with digital communications operations, additional vehicles will be equipped with digital capability as needed.

From the dispatch center, telephone and radio communication links will be possible with all the emergency dispatch centers in the city and in the county.

Included in the dispatch center equipment will be totalizers and other devices to permit message traffic analyses so that the system operations can be well managed.

7.2 Public Works Dispatch System

The conceptual design of the emergency dispatch system for the Public Works Department will begin with replacement of all the present radio equipment with new equipment. Five dispatch channels, four for day-to-day operations and one for emergency responses, will be implemented. Channel frequencies will be in the FCC Local Government category, in the 155 MHz or the 450 MHz region.

The dispatch center will be located close to the offices of the Public Works director. Access from the offices of Water, Sanitation, Streets and Bridges, Sewers, City Engineer, Traffic and Street Lighting will be by automatic private telephone lines to the dispatch center, not by remote control of base station transmitters (the present mode of operation). Each console will have a status map which will indicate the disposition of all vehicles under control of the particular dispatcher. Incoming telephone calls will be screened by a telephone operator and directed to the proper dispatch console. Dispatch records will be written by the dispatchers.

Pocket pager equipment will be issued by the Department to supervisors and off-duty standby personnel. The emergency dispatch console will include the capability of selectively activating the pagers.

Nighttime crews will be issued personal portable units so that emergency radio contact can be made in cases of failure of vehicular radios. Personal portable units will also be issued in instances where it is found that their use results in more effective field operations.

The antenna tower for the Public Works base stations will be located at the City Lot. It will be 400 feet high if the vehicular mobile transmitters are 50 watt units. If the mobile transmitters are 100 watt units, the tower height can be 300 feet. The base station transmitters will be 100 watt units. A separate antenna and lead-in cable will be provided for each base station, with 25 feet of vertical separation between antennas. Base station antennas will have 10 dB gain; mobile antennas will have 5 dB gain. Coupling losses for one base and one mobile antenna will not total more than 2 dB.

7.3 System Installation

The use of a single tower as recommended in the conceptual system is one way to achieve mobile radio coverage. Another way would be to use a shorter tower and higher powered base station transmitter; but with short base towers, the limitation on mobile transmitter power to 50 watts or 100 watts would require that a number of satellite receivers be located over the county. The receivers would have to be connected, by telephone lines or microwave links, to the dispatch center where a "voting" mechanism would select the best of the incoming signals. This alternative approach is valid. When a system is put out for bids, the vendor should be free to bid alternatives, such as the satellite receiver approach. The decision on which system to buy should be based on the total costs, including telephone line rental, security, upkeep and maintenance, etc.

Appendix E is a set of specifications for an emergency communications system. It is included to suggest items that should be included in a bid invitation.

After the system is installed by the vendor, it should be thoroughly tested prior to acceptance. If the purchase contract is written in terms of system performance goals and specifications, the acceptance tests simply require that compliance with the contract be demonstrated. A plan for acceptance testing is included in Appendix F.

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APPENDICES

APPENDIX A. DETERMINING CHANNEL NEEDS -- MESSAGE TRAFFIC APPROACH

On the assumption that emergency telephone calls are random, Erlang's equations [2] are used to specify the number of channels needed. One of Erlang's equations expresses the probability P(w) that k channels are busy:

$$P(w) = \frac{\rho^k}{(k-1)!(k-\rho)} P_o \qquad \text{(A-1)}$$

where,

k = number of trunk lines.

$\rho = \frac{L}{\mu}$ = communication loading.

$\rho^* = \frac{\rho}{k}$ = normalized load factor

L = mean arrival rate of calls, calls/minute.

$1/\mu = \tau$ = service time for messages, minutes.

$P(w)$ = probability that all trunks are busy.

P_o = probability that all trunks are free.

$$= \frac{1}{\sum_{n=o}^{k-1} \frac{1}{n!}\rho^n + \frac{1}{k!}\rho^k \frac{k}{k-\rho}}$$

Curves for P(w) versus the normalized load factor, ρ^*, have been reproduced in Figure A-1 [2].

When all trunks are busy, a caller cannot get through to report an emergency. Figure A-2 plots the waiting time before a clear trunk is available to such a caller [2].

As an example to illustrate the use of Figure A-1, assume that incoming calls for police assistance are arriving at an average rate of one per minute, that the time required by the contact person to obtain the location of the emergency, and the name, address, and phone number of the person reporting the emergency requires 20 seconds. Then the load

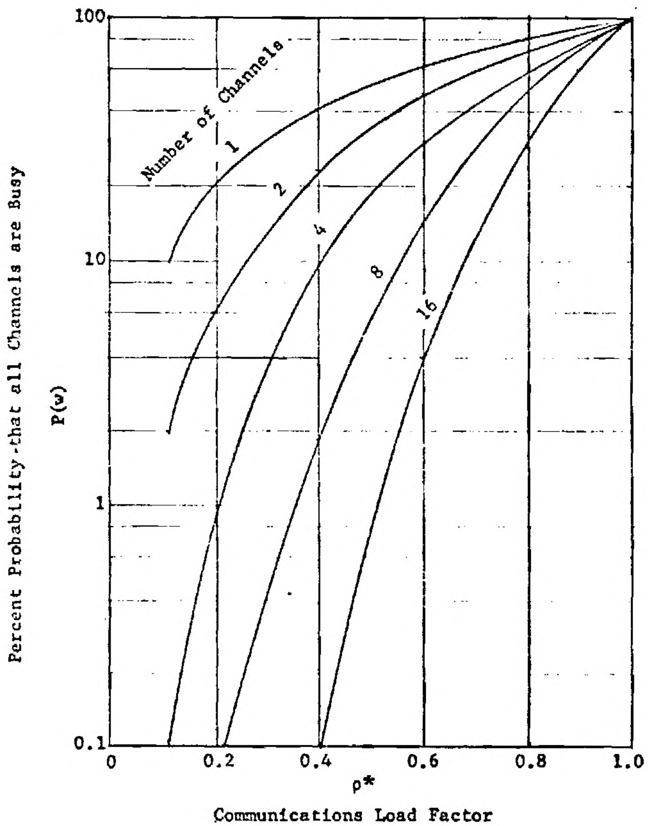

Figure A-1. Probability of Delay in Multichannel Systems [2].

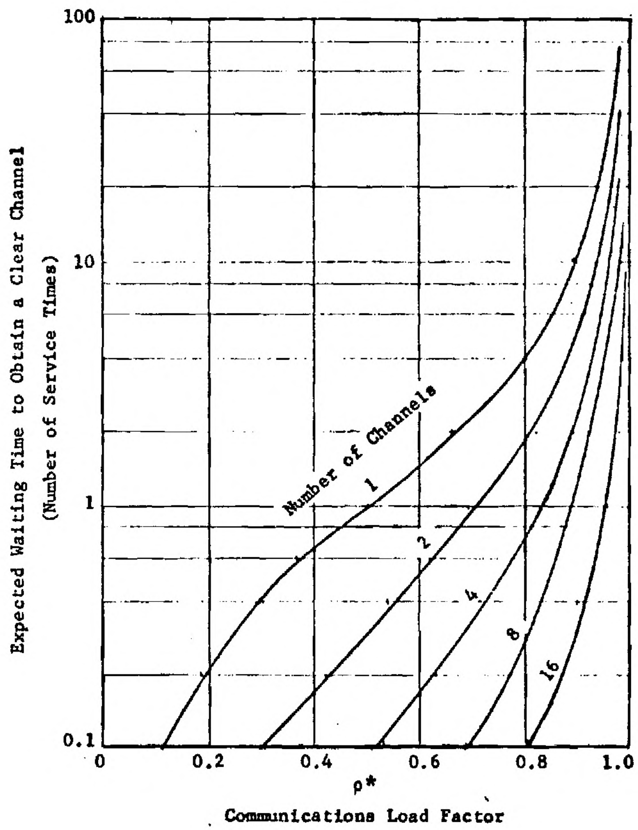

Figure A-2. Expected Waiting Times in Multichannel Systems [2].

factor, ρ^*, is:

$$\rho^* = \frac{L}{k\mu} = (L\tau)/k$$

$$= \left(1 \times \frac{20}{60}\right)/k \qquad \text{(A-2)}$$

$$= 0.33/k$$

If it is desired that the probability of a caller getting a busy signal is to be 1% (P(w) = 1.00 on the vertical axis of Figure 4) then three trunks and three contact persons ("channels" in Figure 4) must be provided. This answer is found by a trial process as follows:

Step 1: If k=1, ρ^* = 0.33, which corresponds to k=7.

Step 2: If k=2, ρ^* = 0.165, which corresponds to k>3.

Step 3: If k=3, ρ^* = 0.11, which corresponds to 2<k<3.

Therefore, k=3.

The curves are also useful for assessing the performance of a given system. Assume that the system has only two trunk lines, and that the incoming calls are arriving at the average rate of 6 calls per minute. (A "peg count" of telephone calls to the Savannah Police Department in late 1972 showed a peak count of 372 calls in one hour, for 2 switchboard operators. The average rate in that hour was 6.2 calls per minute.) The load factor that corresponds to the criteria of 1% busy signals is 0.08 (the curve for two channels crosses the value of P(w) = 1.00 at ρ^* = 0.08). The time for processing calls would have to be reduced, in order to match the 1% busy signal criterion:

$$\rho^* = \frac{L}{k\mu} = \left(\frac{L}{k}\right)(\tau)$$

$$0.08 = \left(\frac{6}{2}\right)(\tau)$$

$$\tau = 0.08/3 \text{ minutes}$$

$$= 1.6 \text{ second}$$

The processing time of 1.6 seconds would be impossible to achieve. It can be seen in Figure 4 that for processing times of 10 seconds (ρ*=0.5) the probability of busy signals when only two-trunk-lines are provided would be 35%. This illustrates the effect of overload demand on operators.

It would be entirely feasible to add an Automatic Call Distributor (ACD) to the telephone system so that a caller who would otherwise receive a busy signal could be advised (by a recorded message) to "hold on" until a trunk line becomes available, without his having to redial [4]. Figure 5 indicates that the delay experienced by a caller in the two-trunk-line example above, (when processing time is 10 seconds and the probability of a busy signal is 35%) would on the average be less than 4 seconds, compared to 10 or 20 seconds required to redial; and the ACD equipment would reduce the caller's delay by several seconds. The ACD equipment would also relieve the congestion caused by numerous redial operations.

The time required to analyze the incoming emergency call, verify the address, select an available field unit, and complete the dispatch (point 2 to point 7 in Figure 5 [2], Chapter 3) was found by observations at the Los Angeles Police Department to vary from 1.52 minutes for clearly emergency calls to 5.9 minutes for non-emergency calls [2]. The faster action of the dispatch control center for an emergency call indicates its potential capability; indeed for extreme emergency calls, the average delay at Los Angeles was only 0.67 minutes. (The field response to emergency calls was 3.8 minutes, and to non-emergency calls it was 6.8 minutes.)

The question clearly is: "Why should the average delay in the control center be as long as 6 minutes for any response category?" Again, Erlang's curves indicate the answer.

Assume that calls are arriving at a rate of 1 call per minute and that the message analysis and processing time is 20 seconds. Further assume that the time required to complete the rest of a dispatch ("select available unit," "send message to unit," and "unit acknowledge" time segments in Figure 5, Chapter 3) totals 40 seconds, so that the minimum communications center delay is 1 minute. Assume also that there are 3 trunk lines and 3 telephone operators. During periods of saturation of the 3 telephone trunks, 3 emergency telephone messages will be processed simultaneously by the 3 telephone operators.

If there is only 1 dispatcher, the 3 incoming message cards prepared by the operators will arrive at the dispatch console within seconds of one another, and the dispatcher will require 40 seconds to dispatch each response, or 120 seconds to complete all 3. Total delay for the third dispatch will thus be 140 seconds, or 2.3 times the minimum delay. Furthermore, the process will be cumulative. If the telephone saturation continues for 1 minute, 9 calls will have arrived by the time the dispatcher has completed the first dispatch, at the end of the first minute. The remaining 8 calls will require 320 seconds to dispatch, and the last delay will total 340 seconds, or 5.6 times the criterion.

Erlang's curve in Figure A-1 would also predict the 2.3 minute dispatch time for the third message in the above example, as follows:

$$\begin{aligned} \rho^* &= (L)\ (\tau)/k \\ &= 0.67/k \end{aligned} \qquad \text{(A-4)}$$

The dispatcher is a "one-channel system," so that k=1 and Figure A-2 indicates a waiting time of 2 service times, or 80 seconds, before a clear <u>radio</u> channel is available for the third dispatch operation. The third dispatch would require another 40 seconds, and to this would be added the 20 second telephone operator processing time, for a total of 140 seconds.

From Figure A-2, it can be seen that adding a second dispatcher and a second radio channel (k=2) would reduce the waiting time for a clear channel from 2 service times to 0.1 service times -- from 80 seconds to only 4 seconds. The third call would be dispatched in only 1.07 minutes instead of 2.3 minutes.

APPENDIX B. DETERMINING CHANNEL NEEDS -- TACTICAL FORCE DISPOSITION APPROACH

A published study [2] estimated that in 1967 one police radio channel was needed for patrol activities for every 120,000 citizens. This would have recommended only two radio patrol channels for all of Chatham County; Savannah alone will have three channels for patrol. A closer look at the basis for 1 channel per 120,000 shows that it was linked to findings that over a 24-hour period the average rate of radio contact per patrol vehicle was 1 per hour, and that a population of 25,000 would generate 1 call per hour [2]. If a radio message peak-to-average ratio of 5 to 1 was assumed, then 1 patrol vehicle would be required for each 5000 citizens during peak demand periods. On this set of assumptions, 38 vehicles per shift would be sufficient to patrol all of Chatham County, with 24 in Savannah and 14 in the rest of the county.

Another factor in the 1967 study [2] was an estimate of radio message length. It was found that a conversation averaged 25 to 60 seconds. Today's patrolman can be expected to seek more information from improved and expanded law enforcement data sources, so an average message length will be longer, with the result that fewer cars can be effectively served by each radio channel. If the average message length is as long as 120 seconds, and average channel loading is held to 33% or less, a dispatcher will be able to control only 10 vehicles. Three dispatchers (and three channels) will be required for the 24 mobile units in Savannah, and 2 for the mobile units in the county, if channel loading is 10 vehicles.

In the 1967 study there was still another method of estimating radio channel requirements, based on 1 patrol beat per 4000 population. That method would predict a need for 30 patrol vehicles in Savannah and 18 in the rest of the county, or an area wide total of 48 cars; and if the optimum load is 10 cars per radio channel, 5 total channels would be required -- 3 for Savannah and 2 for the rest of the county.

The 1967 study [2] stressed that individual police departments would have specialized requirements, and the estimates, which were based on statistically averaged data, would have to be modified. It is of interest at this point to compare the present Savannah and Chatham County (outside of Savannah) patrol car complement with the results of the above analyses.

Savannah presently fields 27 one-man patrol cars during peak demand hours. This is 1 vehicle per 4400 population. Savannah plans to assign 3 radio channels for patrol duty, and will require 3 patrol consoles, as shown in Figure 11.

Chatham County statistics, based on 17 field vehicles average per shift, is 1 car per 4100 population.

In addition to the 27 patrol vehicles in service in Savannah, there are 25 burglary and investigative vehicles, 8 traffic and accident vehicles, and 18 administrative vehicles. The radio traffic for some of these vehicles will be markedly different from the patrol car radio traffic. Only the traffic and accident investigation vehicles will be actuated by citizen complaints to the same extent and under similar emergency conditions as the patrolling police vehicles. (Some police departments have discontinued the use of accident squads, assigning such duty to patrol units). The burglary and special assignment vehicles will engage appreciably in predictive nighttime responses; the administrative vehicles will devote time to supervisory activities (primarily monitoring); and the investigative vehicles will be devoted mostly to case activities during the day shift. It will be possible to share some channels between categories of activities. For example, if burglary squads operate largely at night, they could share a channel with detectives, which is largely a daytime operation [2].

APPENDIX C. DIGITAL COMMUNICATIONS

The decision to incorporate digital communications equipment should be preceded by careful analysis of the costs involved (both in monetary and other less tangible terms) and the benefits to be derived from the equipments. In the Savannah Police Department, for example, the utilization of digital equipment will require both physical and personnel changes. Rather than allow the digital capability to evolve in piecemeal fashion, it would be more economical and more effective first to formulate a comprehensive communication system plan and then to provide digital subsystems for accomplishment of specific subsystem goals, within the broader framework of the complete system design.

1. Present Computer Usage

Savannah Police Department has already initiated digital information and files, primarily with the SALES information system: this constitutes one constraint on the design of a communication system. Fortunately, the SALES system in its present status can interface satisfactorily with feasible communications system designs. SALES is currently providing extensive law enforcement data to field units, via the dispatcher, on a demand basis. Thus, rather than representing a constraint in the negative sense SALES represents a starting point from which a unified or comprehensive system can be developed.

The present embodiment of SALES, specifically the use of general purpose computer hardware, will, however, influence the direction of subsequent digital system design. Also, use of the centralized City computer represents a constraint that must be carefully examined since the computer is a major, if not the most important, component of a digital system. This situation influences the available choices of communication system configurations, as will be described below. In order to define system configurations that would be useful in the Savannah Police Department the costs and the benefits arising from use of digital techniques will first be identified. These will then be analyzed critically to determine their impact on systems operation. Candidate systems designs that are capable of meeting the minimum communications requirements of the SPD will then be developed and presented in order of cost and complexity.

During the development of candidate systems it was recognized that the type of computer facility utilized strongly influenced system design. Consequently two basic types were assumed: one, a centralized computer facility, similar to that presently used in Savannah; and two, a computer dedicated to law enforcement/Police Department use. (A third type, a central facility administered and manned by police department personnel would be a functional derivative of the more general centralized system and is therefore not treated separately.) In each of the candidate systems described below the impact of each type of computer facility is described.

The first step in the analysis is to define the features of digital communications systems. Information concerned with benefits and costs has been obtained from discussions with equipment vendors and has been summarized in Table C-I. Each table entry is analyzed for relative importance and impact on digital systems design.

2. Records Assistance

In terms of records assistance, digital communications techniques can provide a simple means for capture of records from the communication system. For routine messages, coded identifiers can be transmitted. These can be recorded onto magnetic tape and subsequently processed by a computer. Time information, unit identifiers, and other data can be entered along with the message identifiers to form complaint/action histories, and can be printed in the form of case histories, daily reports, etc. This can be accomplished with minimum involvement of the dispatcher, the field unit, or records personnel.

Digital communications techniques and automated records capture will be useful to SPD administrative personnel, since management information can be easily obtained from stored records. Data on records flow and

TABLE C-I

SYSTEM PARAMETERS

Major Parameters of Digital Communications Systems

Increased Force Effectiveness

Records Assistance

- Automatic Capture of Field Unit Records
- Automatic Capture of Management Information

Work Load Reduction

- Computer Query
- Field Unit Memory Requirement (Hard Copy Mobiles Only)
- Dispatcher Routine Duty

Personnel Safety and Personnel Morale

Miscellaneous

- Channel Congestion
- Security
- Unattended Vehicle Message receipt

System Cost (Capital Expenditure)

- Initial Cost
- Recurring Cost
- System Use and acceptance
- Training
- Overuse

communications traffic density can be used to gauge the effectiveness of the systems. Data on numbers, types, and locations of crimes can provide a basis for determining the effectiveness of beat strategies and force deployment strategies, and could improve the operational effectiveness of the force. Presently, records and data to support such management studies are available, but the cost of capture of the data is prohibitive. Thus, decisions relating to such factors as force deployment, shift loading, and enforcement strategy must be based on incomplete data. Capability for obtaining the data is not without cost, in terms of both initial investment and continuing operational costs. These will be identified and described below.

3. Work Load Reduction

Utilization of digital communications techniques could also reduce the workload of communications and records systems personnel. If direct computer inquiry is available to field units then the relay function of the records dispatcher can be curtailed, and the miscellaneous data inquiries presently handled by the patrol dispatcher can also be reduced or possibly eliminated. In addition, use of digital techniques and mobile, hard-copy units will reduce the memory requirements and increase the effectiveness of field unit personnel. Currently, extensive lists and involved instructions received by a patrolman must either be recorded by hand or committed to memory. This results in requests for repeated instructions and increases the radio channel usage. Errors are also likely, especially with memorized data. Mobile hard-copy capability would reduce these errors and reduce channel usage and would increase the efficiency of field unit personnel.

Along with the elimination of the records relay function of the patrol and records dispatcher, the digital communications techniques would reduce the number of routine tasks performed by the patrol dispatcher, and would decrease the pressures on the patrol dispatcher which arise from multiple, simultaneous messages. Routine traffic could be handled via a digital dispatch console for all but urgent communications.

This would allow the dispatcher more freedom to act as a system monitor. Cathode ray tube display, interactive with the digital dispatch console, could provide visual display of the nature of communications (descriptor) and the units involved in simultaneous message situations.

Digital communications techniques could also be used to automate the vehicle status function. A status unit, updated by digital information received from the field and processed in the console or in a computer, could update the unit status information, without dispatcher assistance. This capability would also give the dispatcher more freedom to perform a systems monitoring function.

4. Personnel Safety and Morale

Digital communications techniques can be implemented so as to reduce field unit risk. Direct computer query from mobile units, made possible by digital equipment, would provide data on questionable vehicles, property, persons, etc., before the field unit would make a direct confrontation. Dangerous encounters could be anticipated, and risks could be minimized. In addition, simplified emergency calls from field units could be provided through the digital system. Single-button calls could be implemented so the the field unit could call for assistance without having to divert his attention from the situation at hand.

These safety features, resulting from use of digital communications, could be expected to improve field unit morale and effectiveness. The field unit personnel would be receiving increased information backup through the communications system, and direct assistance to personnel safety.

In addition to the above, several other benefits of a miscellaneous nature could also accrue from use of digital techniques. Included would be a reduction in radio channel congestion, improved security of communications, and provision for message recording at unattended vehicles. The use of precoded messages (required usage) for routine communications could reduce channel occupancy, since the time required to transmit and acknowledge receipt of digital messages is shorter than equivalent voice messages, and less repetition is needed. Radio traffic coded for transmission would be unintelligible without decoding equipment; this would deter eavesdropping. Mobile hardcopy equipment would record messages even when the patrolman is away from his vehicle. Routine data could thus be communicated at the dispatchers convenience, independent of the out-of-service status of field units.

The remainder of the features shown in Table C-1 are cost parameters in that they represent probable areas in which City of Savannah resources will have to be spent or dedicated in order to achieve any digital communication system.

5. System Cost (Capital Expenditures)

System capital cost is made up of two principal components. The most easily defined is the initial capital outlay required to purchase hardware for base and mobile installations. Initial cost will depend on the number of units purchased and the complexity of base and computer facility equipment. The second component of system capital cost is the continuing expenditure necessary to support and maintain digital communications capability. This component includes incremental costs for personnel and parts to maintain mobile and base station hardware, costs of facilities needed by digital communications system components, and incremental cost for personnel to operate more sophisticated digital equipment (training courses, etc.). As with the initial dollar outlay, the total magnitude of this cost component cannot be defined until a system is specified.

6. Initial Capital Outlay

Indication of some probable systems capital costs can be inferred from the digital systems in Atlantic City, N. J., and Atlanta, Georgia. The cost will approximate $10,000 per mobile unit for a ten mobile unit system. This figure includes the software development necessary to make the systems operational. The cost per mobile unit decreases if more than 10 mobile units are included. The approximate (1973) cost of each data head, which attaches to the mobile radio, is $2,500.

These are approximate figures, but they indicate useful "ball park" estimates of initial dollar costs of equipment needed for a basic digital system. The cost of equipment required for in-house maintenance will depend on the particular communication system purchased, but can be estimated to be about $10,000.

7. Recurring Expenses

Several recurring expenses will be encumbered with the purchase of digital communications equipment. Included are incremental costs for maintenance personnel, costs of replacement parts and equipment, and costs of increased-skill-level personnel to operate the digital facility and equipment.

If maintenance contracts are purchased from the equipment manufacturer or from a local service company, the costs can be estimated to be about the same for the digital mobile equipment as for mobile voice communications equipment. Since the digital equipment is needed in addition to the radio equipment, the contract maintenance costs for mobile equipment would be doubled by the addition of digital equipment. There should be no increase in maintenance costs for the base station equipment.

Costs for equipment to replace that lost to attrition through use or time will also be a recurrent factor. The useable lifetime of most modern solid-state radio and electronic equipment is advertised as being in excess of ten years, so the yearly replacement cost will be about ten percent of initial capitalization, plus another ten percent due to losses through damage. To keep this cost low, ruggedized equipment should be purchased initially. Ruggedization should be a key equipment specification and if necessary should be covered by a guarantee.

A third item of a recurring cost nature is the need for increased-skill-level personnel at base and mobile digital stations. The magnitude of this parameter is dependent on the type and complexity of base and mobile equipment which is purchased. The operation of this type equipment does require increased knowledge and competence and will therefore require an increment in personnel cost.

8. System Acceptance

A major consideration in the purchase of new equipment is the problem of acceptance. It must be apparent to user personnel that the equipment is potentially of benefit to them and that proper methods of operation will be to their advantage. Available information indicates that digital communications equipment is readily accepted by both base and field personnel. Similar acceptance can be obtained in the Savannah Police Department if the user personnel are properly trained and made familiar with the capabilities of digital communications aids. Formal training related to the communications system will provide the necessary orientation for new users and also serve as refresher material if provided on a periodic basis.

Excessive use of digital equipment at the expense of other duties may be a factor for consideration in system implementation. The novelty of the system may at first result in excessive, misdirected system use; however, this should diminish as system familiarity is gained.

9. Candidate System Configurations

The cost and benefit parameters discussed above are useful for making comparisons of various candidate system configurations and for illustrating system advantages and weak points. These, along with the restriction on assumed computer facility configuration of (1) a central computing facility operated by the city to service all city needs, and (2) a computing capability dedicated to police department needs form the bases for evaluating cadidate systems.

During the study of Savannah's digital communications needs, five basic system configurations were developed. These systems range from a very simple system with little digital communications capability to a fully automated, digitally oriented system. The major characteristics of these systems are outlined in Table C-II and are described below. The systems are also arranged in order of increasing benefits with system E representing a system with all the benefits listed in Table C-I available to the department.

TABLE C-II

ALTERNATIVE SYSTEMS

System	Characteristics	Estimated Cost*
A	·Present City Computer Support ·No Digital Mobile Equipment	None
B	·Increased City Computer Support ·No Digital Mobile Equipment	$ 25,000
C	·Increased City Computer Support ·Small Number (10) of Digital Mobile Units ·Digitally Instrumented Dispatch Consoles	$ 75,000
D	·SPD Computer Facility (Dedicated SPD Facility) ·Small Number (10) of Digital Mobile Units ·Digitally Instrumented Dispatch Consoles	$ 150,000
E	·SPD Computer Facility (Dedicated SPD Facility) ·All Mobile Units Digitally Equipped ·Computer-Aided Dispatch Consoles	$ 400,000

*These estimates are approximations, but they are representative of actual prices of similar system elements, with allowances for necessary software development.

The systems range from the basic systems presently operative in Savannah to a hypothetical, sophisticated system incorporating a dedicated SPD computer, computer aided dispatch, and all field units equipped with digital equipment. The systems are arranged in Table C-II in order of increasing complexity and costs. For example, System A, utilizing the present city computer and no digital equipment is the present situation and therefore introduces no cost increment. Alternatively, System E requires heavy costs, both in terms of initial capital outlay and in terms of recurring operating costs.

Of the systems listed in Table C-II, all can supply minimal digital communications needs. In terms of the parameters listed in Table C-I, systems A and B both offer the benefits of increased force efficiency and records assistance, provide <u>some</u> work load reduction and <u>some</u> increase in personnel safety. They offer little or no decrease in channel congestion and offer no channel security. System A has the advantage of requiring no new capital expenditure. Systems A and B represent a most basic form of digital communications capability, although they are digital only in the sense that information, through SALES, is available from computer memory. The systems are designed to provide demand access to SPD terminal operators, and thus can provide rapid response through a dispatcher to a requesting field officer. The current system priorities for processing access by non-PD sources, and the lack of multiprocessing capability limit the usefulness of the central computer for responding to terminal requests. Also, conversations with the Director of the City computer facility indicate that the city equipment is currently operating near full capacity. Increased storage and processing requirements for future growth of the SALES system will dictate purchase of additional computing equipment. Also, the presently operated city computer facility does not provide the necessary criminal history security that will be required for computer-to-computer access to the Georgia Criminal Justice Information System (GCJIS). These deficiencies make the continued use of the presently available city computer unattractive unless (1) the equipment capacity is increased, and (2) necessary security arrangements are provided.

System E represents the opposite extreme in system performance and system cost. It provides all of the benefit parameters listed in Table C-I It also has the highest initial capital outlay and has the highest recurring cost. It will require an extensive orientation and training period to familiarize SPD personnel with system operation. Placement of digital equipment in all mobile units would also introduce new equipment to a large number of officers and could cause extensive initial systems overuse with consequent service reductions in some areas.

Systems C and D both represent compromise configurations in that they allow for digital communications between a limited number of field units and an information bank. They provide, in a limited sense, the benefit parameters listed in Table C-I, and they do this at moderate cost. In addition, they each represent systems that allow controlled growth and they can be viewed as initial steps toward the development of a complete department digital communications capability. Of the two configurations, System C retains the centralized computer facility with additional equipment to give the SPD access, and to assure criminal history security. System D employs a police department operated computer facility, and could more easily meet GCJIS security requirements.

System D has three clear advantages over System C. The first advantage is an organizational factor, the second is a reduced software requirement, and the third is greater flexibility for law enforcement operations.

If Savannah chooses to implement System C, which is based on the City computer, the criminal history security requirements of GCJIS would require that only sworn SPD personnel could operate the city computer. This, in turn, would violate the organizational separation of city management functions from departmental functions. Management planning activities, such as budget allocations, for example, should not be prematurely accessible to SPD personnel. Operation of the centralized computer by the SPD could thus lead to awkward situations.

Sophisticated microprogramming, either through executive software or possibly through hardwire modifications to the central processing unit could conceivably separate the computer into two independent units -- one dedicated to SPD, the other to city administration. Strict adherence to the requirements for security of criminal history files would still necessitate that SPD personnel physically safeguard access to SPD terminals and files. The awkwardness of the conflict of authority might be reduced, but would not be eliminated.

Systems D and E, which are based on a separate, dedicated computer located at SPD headquarters, are thus reasoned to be the best choices among the Table C-II system configurations, for computer-aided law enforcement operations. In a cost comparison of a dedicated computer versus System C (city computer only) the costs of personnel and equipment modifications to the city system to achieve security of criminal histories, and the costs of operational awkwardness should be taken into account.

The System D (or System E) configuration would be adaptable to effective SPD law enforcement operations, analyses of tactics, assessments of effectiveness, modeling of criminal systems, detailed local MO files, documentation of reports, and interface with both the State CJIS and the regional law enforcement agencies that must use Savannah's computer (for input to the State network and to SALES files).

10. Recommendation

It is recommended that the System D configuration of computer-aided command and control be implemented in FY 74; this recommendation is made without knowledge of the computer system configuration that will be recommended in a concurrent study by PRC/Public Management, Inc. However, if Savannah wishes to adopt a system modeled on the State system in order to assure compliance with the State Master Plan, System D would conform to the requirement that "all offender records will be resident on the Data Communications Processors," which must be "housed separately from the general purpose computing equipment," and operated by sworn personnel 24 hours a day, enforcing the "right-to-know/need-to-know access" to the offender records.

Figure C-1 [11] depicts the recommended computer configuration.

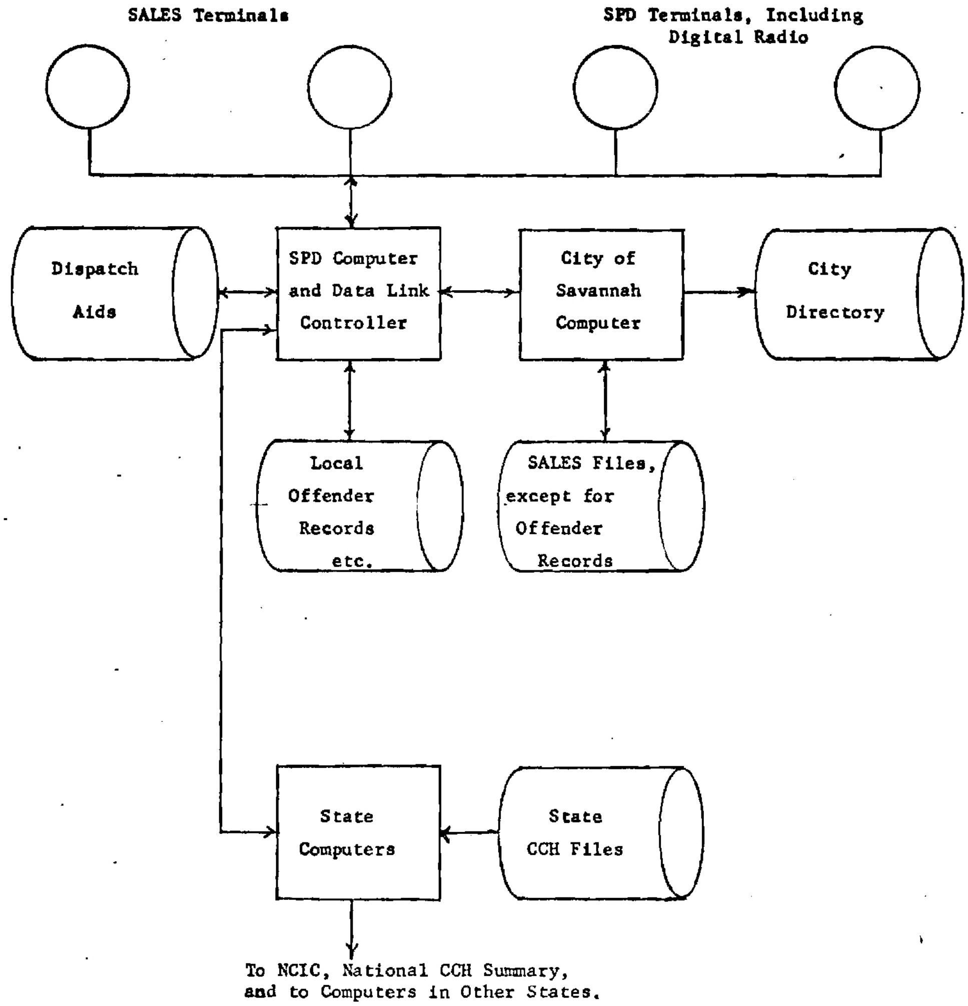

Figure C-1. Conceptual Police Department Computer Arrangement [11].

APPENDIX D. RADIO COVERAGE CALCULATIONS

In a previous report [10], the requirements for acceptable communication (90 percent coverage, 12 dB SINAD) were developed. The development was based on free space and plane earth propagation equations, modified by the addition of 36 dB for time* and terrain losses to fit the case of a UHF, mobile and fixed-base system.

A further examination of technical literature has revealed that an assumption on which the 36 dB correction is based is that the terrain is modeled as a random structure of hills and valleys which have effective 500 foot valley-to-hill differences in elevation--which is hardly the case in the Georgia coastal plains area. In Chatham County, variations of terrain elevations above sea level are about 30 feet.

In another report [12] curves and equations are presented for both VHF and UHF coverage in two types of terrain, "rough" and "average." The purpose here is to develop correction factors and propagation equations that will more closely approximate the coastal plains conditions.

The plane earth equation for rolling terrain [13] is:

$$P_{50} = \frac{3.45 \times 10^{-15} \, h_B^{\,2} \, h_R^{\,2} \, P_T}{d^4} \left(\frac{40}{f}\right)^2 \qquad \text{(D-1)}$$

where

P_{50} = power in watts, exceeded at 50 percent of locations that are d miles from the transmitter,

P_T = transmitted power in watts,

f = frequency of transmission in MHz,

h_B = base antenna height in feet,

h_R = randomly located receiver antenna height in feet, and

d = distance in miles from base to randomly located antenna.

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*Over a year's time, for example, propagation conditions vary with weather, vegetation, snow coverage, etc.

To be applicable to mobile communications, Equation (D-1) needs to be corrected to account for:

1. Particular terrain conditions.
2. Antenna gains.
3. Line losses, including duplexers, filters, etc.
4. Conversion from 50 percent to 90 percent reception reliability.
5. Vegetation losses.

For 50-foot valley-to-hill variations the 50 percent terrain correction factor is 6 dB and the correction factor for vegetation loss is 12 dB [14]. The correction factor for conversion from 50 percent to 90 percent reliability is 9 dB [13]. Total correction for time, terrain, vegetation, and reliability is therefore 27 dB. Only antenna gains and line loss corrections are left to be determined, and Equation (D-1) can be converted to

$$P_T + G_T + G_R - L_C - 176 + 20 \log h_B h_R - 40 \log d = P_R, \qquad \text{(D-2)}$$

where

G_T = transmitter antenna gain, dB,

G_R = receiver antenna gain, dB,

L_C = line and coupling network losses, dB,

P_R = power at receiver terminals, dBW, and

P_T = power at transmitter terminals, dBW

A corresponding expression for free space propagation is:

$$P_T + G_T + G_R - L_C - 117 - 20 \log d = P_R \qquad \text{(D-3)}$$

A reasonable estimate of the signal power required at a UHF, mobile receiver, for 12 dB SINAD, is -133 dBW [10]. This can be inserted in

Equations (D-2) and (D-3), to yield

$$P_T + G_T + G_R - L_C - 176 + 20 \log h_B h_R - 40 \log d = -133 \text{ dBW} \quad \text{(D-4)}$$

for plane earth, and

$$P_T + G_T + G_R - L_C - 117 - 20 \log d = -133 \text{ dBW} \quad \text{(D-5)}$$

for free space propagation.

Given the antenna heights, antenna gains, line and coupler losses, and service distance, the required transmitter power can be calculated from Equation (D-4), and free-space power can be calculated from Equation (D-5).

In Figure (D-1) the sum,

$$P_T + G_T + G_R - L_C = G_{system} \quad \text{(D-6)}$$

is represented as system gain (ordinate) and is plotted against the service distance, d (abscissa), for various values of antenna height product, $h_B h_R$. Both the plane earth Equation (D-4) and the free-space Equation (D-5) are plotted.

The key factor for mobile system coverage is the requirement for mobile-to-base transmission because the realizable power of a mobile transmitter is more limited than a base transmitter. If it is assumed that the mobile antenna has a gain of 5 dB, the base antenna a gain of 10 dB, duplexer and line losses are 5 dB, and the mobile transmitter power is 50 watts, the system gain is:

$$P_T + G_T + G_R - L_C = 17 + 10 + 5 - 5 = 27 \text{ dB.}$$

If the required service range is 20 miles, the product, $h_B h_R$, as obtained from Figure D-1 is 2400, and the height of the base antenna is (for a 6 foot mobile antenna) 400 feet. A critical element in this example is the coupling network. If its contribution to the assumed line and coupler losses can be reduced so that L_C is only 2 dB, the minimum base antenna

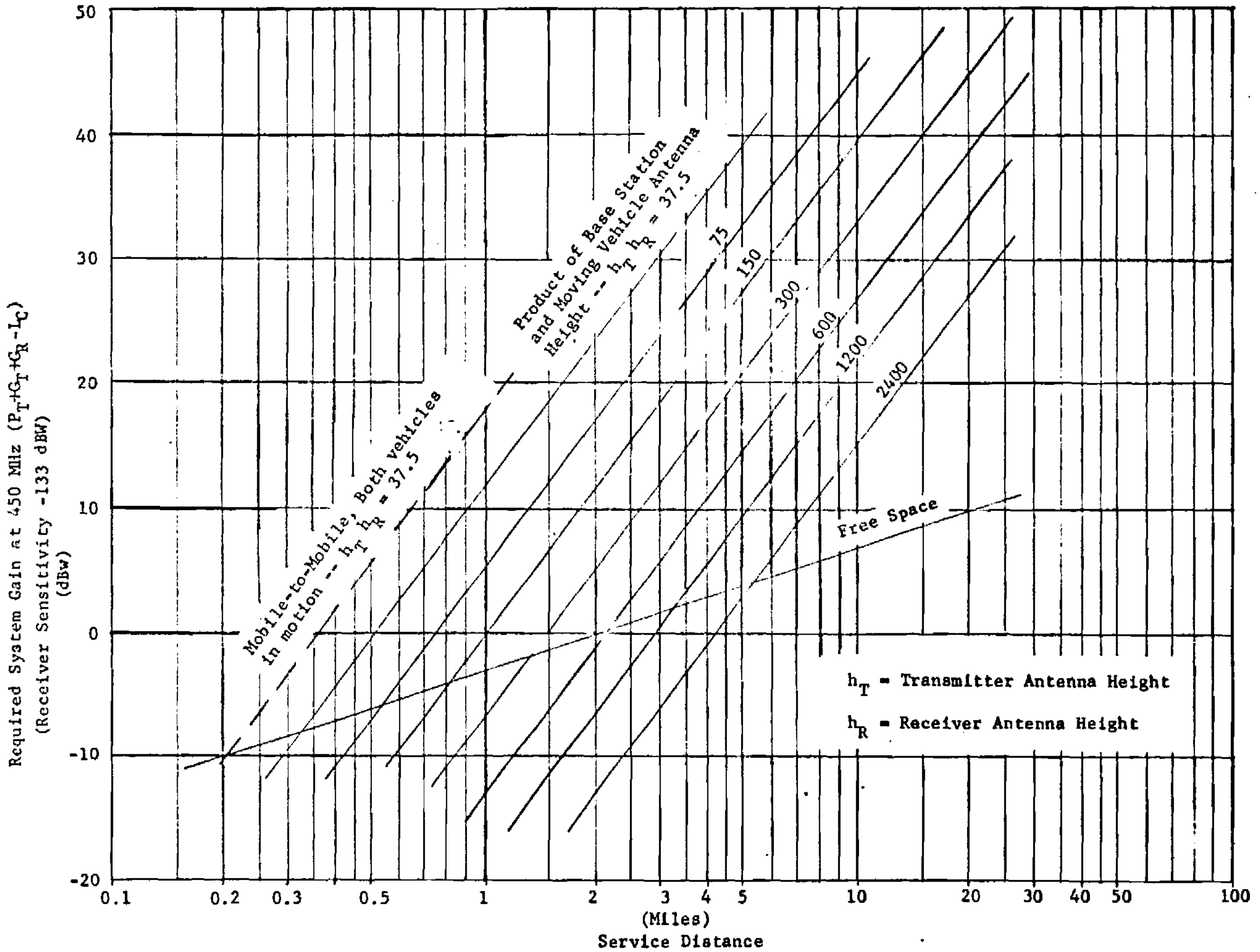

Figure D-1. Required System Gain versus Service Distance (12 dB SINAD, 90 percent Coverage) height can be reduced to 300 feet.

The assumed effective sensitivity of -133 dBW is based, not on receiver sensitivity, but on reported levels of UHF radio noise [15]. Noise of -150 dBW/kHz can be expected, so that in a 16 kHz channel, average noise would be -138 dBW. A 5 dB signal-to-noise ratio at the input of a good FM receiver will produce 12 dB SINAD, therefore -133 dBW signal strength is the criterion used in this analysis.

APPENDIX E. SYSTEM SPECIFICATIONS [10]

1. Introduction

This appendix is an adaptation of a set of equipment specifications with alternative, optional approaches aimed at giving competing vendors freedom to bid systems that may be different but equally workable. The specifications define equipment which is superior to that defined by EIA standards, in certain performance parameters. A request for bids could specify that these specifications shall be substituted, where applicable, for EIA standard specifications, but that the EIA standards shall apply where these specifications are silent.

1.1 Intent of Specifications

It is the intent of these specifications to describe a minimally acceptable public safety communications system. The vendors should take advantage of the latest advances in the field of mobile communications, particularly with regard to reliable and efficient operation. Since mobile communications frequently involve the protection of physical property, expedience of field operations, or concern for life itself, the continuity of communications is of prime importance. All equipment must meet or exceed the minimum requirements of EIA (Electronic Industries Association), and FCC (Federal Communications Commission) in addition to those specified herein. The absence of specifications regarding details implies that the best general practice should prevail and that first quality material and workmanship are to be used. Any reference to one manufacturer's equipment is meant as being descriptive only as to level of quality and type of equipment desired, but is not intended to be restrictive as to manufacturer. This is a guideline for prospective vendors, and is not intended to include all details.

This specification does not include any proprietary items, circuits, or devices which would preclude any communications equipment manufacturer from producing equipment to meet these specifications. All technical tolerances, ratings, and technically specified criteria contained within these specifications are considered to be within the current state of the electronics art and are currently being met by commercially available equipment.

1.2 Exceptions to Specifications

Items in this specification which materially contribute to equipment reliability will not be compromised. Where deviations from the specifications are necessary, the bidder must spell out said deviations stating why, in his opinion, the equipment he proposes will render equivalent reliability or performance. Failure to so detail all such deviations will provide grounds for rejection of the entire proposal as unworthy of further consideration.

1.3 Responsibility

It will be the responsibility of each bidder to bid a complete, installed, working system. If extra pieces or units are, in the judgment of the bidder, required to make this a working system, such materials shall be listed, and supplied, if that bidder is the successful bidder receiving the award.

1.4 Current Production Equipment

The equipment offered shall be of the latest design, in current production, and as free from obsolescence as possible.

1.5 Performance Bond

A contract surety (performance) bond in the amount of one hundred percent (100%) of the contract price, shall be furnished by the successful bidder, in order to guarantee a completed project in strict accordance with the specifications, and the payment for all labor and materials necessary to so complete the project.

1.6 Minimum Standards

The equipment offered will be certified to meet or exceed appropriate EIA standards, and current FCC regulations.

2. System Function

The function of this system is to provide improved public service efficiency, through the use of multichannel radio communications using voice transmission between vehicles and dispatchers (and data transmission, optionally).

The base stations will provide two-way, CM-3, 90 percent radio coverage between dispatchers and mobile units within the mobile service area and the personal portable service area.

To extend personal portable radio coverage to the limits of the mobile service area, mobile stations will have the capability of being enabled by the central dispatcher as portable relay stations, or satellite receiver/relay equipment will be provided (optional).

A data transmission system (optional) will provide improved efficiency through the use of radio communications by both voice and data between vehicle units and controlling dispatchers.

The system is intended to relieve problems caused by heavy traffic (large numbers of units, messages, and emergencies) and by organizations which have many different functional groups that must at times work cooperatively, and at other times independently.

It is necessary that the radio circuits provide clear and intelligible voice operation and that the coverage be adequate for the areas of operation. This is to be accomplished by obtaining radio performance to modern technical standards.

It is necessary that all controls and indicators used by cars and controlling dispatchers be easily understood and functionally reliable.

An optional feature (separate cost estimate required) would be the provision for transmission of data messages to and from the cars to report status, to transmit emergency calls, and to routinely identify all radio transmissions. The decrease in time required to transmit these messages as coded data will enable a large amount of information to be transmitted and received while using minimum radio channel time.

Another aspect of the optional capability data message is automatic status display and automatic printing of log entries at the control center. This reduces errors. Data transmission systems will also be compatible with (1) direct mobile-to-computer links, (2) printout of messages in mobile units, and (3) other technology as it becomes desirable.

Automatic emergency backup power, capable of operating a total of 10 mobile relay stations will be provided. Indication at the control center that the emergency supply has been activated will be included.

A two-frequency emergency mobile relay station will be installed to back up communication failures due to equipment failures at the primary base stations.

The dispatch center will be equipped with dispatch consoles each of which can switch 24 radio functions. Consoles will be identical, able to operate in parallel, and all features will be available on each console. Each console will be capable of controlling the entire system or any portion thereof so that dispatcher load can be shared to the best advantage.

A rear view projection panel located between the consoles will provide ready access for displaying detailed maps, operating procedures, telephone numbers, etc.

A status board at each console will indicate the immediate status of all vehicles. It will be designed to provide easy viewing by the dispatcher.

A visual readout and a printed readout of vehicle identification and data information will be provided for each console. Optionally, provisions for calling a desired vehicle by data transmission and the capability for sending a number of data transmission messages to the vehicle will be available to each dispatcher; and direct access to designated areas of information other than the main console will be available to the mobile operator via the data signaling method.

Facilities to monitor neighboring radio systems will be provided.

Small, local-controlled, control stations will be provided (optionally) in the offices of Department managers to allow monitoring of the system and also to serve as backup relay links.

3. Equipment Specifications

3.1 Control Center

The Control Center shall include the following equipment.

Control Consoles. Each control console will provide dispatcher position, and all features will appear at each position. The following features will be provided:

1. Switch selection control expandable to 24.
2. Monitor facilities expandable to 10.
3. 24-hour clock.
4. Foot switch.
5. vu meter.
6. Plantronic Headset, or equivalent.
7. Call Director recessed into operating surface.
8. 24 hours Date/Time stamp.
9. Alert tone generator.
10. Visual readout of data messages received, not fewer than 8 digit (optional).
11. Aural alarm for emergency calls.
12. Data generator and visual readout of data messages transmitted for signaling to mobile units, not fewer than 8 digits (optional).
13. Switch array for most common coded messages transmitted (optional).
14. Paper printout of eight digits, plus time. Black for normal, red for emergency (optional).
15. Multiple transmitter select.
16. Master Mute.
17. Provision to add remote consoles.
18. Acknowledgement data and keying information, for return transmission to mobile unit, if and when a true message has been received from a mobile unit (optional).
19. Data generating capability for dispatcher originated transmissions to the mobile units (optional).
20. Data generating capability for dispatcher control of status board (optional).

21. Output to digital line printer (optional).

22. Controls for status map lights.

23. Switches to transfer to backup base stations.

24. Switches to transfer to backup link.

25. Indicator status lights for transmit-receive functions.

26. Speakers, amplifiers, volume controls, and switches as required for monitoring selected audio, and other audio signals.

27. One "Take-Over" switch.

28. One Intercom switch.

29. One Multi-Select Switch.

30. One Multi-Select Release Switch.

31. One Headset-Microphone Switch.

32. Three Direct Remote Connect switches.

33. One Master Mute Release Switch.

34. Power amplifiers for the speakers and for the transmit audio shall be identical, and shall meet or exceed EIA standards.

35. Compression amplifiers used in conjunction with each power amplifier shall meet or exceed EIA standards.

36. One spare of each type amplifier and one spare Transmitter-Selector switch shall be furnished.

37. All pre-amplifiers, line amplifiers, compression amplifiers and power amplifiers must be separate, fully transistorized, self-contained, inter-changeable units. These amplifiers shall be quickly replaceable on an individual plug-in basis.

38. All of the above amplifiers must be mounted in standard rack-type mounting trays.
    (1) All transmit control functions shall be accomplished by use of plug-in telephone type relays and transformers.
    (2) All transmit and receive audio lines and all transmit control voltages shall be available at a terminal strip to permit strapping of transmit and receive control functions.
    (3) Control currents and/or voltages shall be adjustable on an individual channel basis.
    (4) All transmit and receive audio lines shall be nominally 600 ohms impedance.

39. All dc power units must be line and/or load regulated, solid-state units.

40. Design parameters must coincide with current MIL-SPEC human factors engineering practices.

Instant Recall Data Display System. The rear projection data display console will allow fast retrieval of information such as an enlarged view of an intersection, operating procedures, telephone number, etc. This console should be located conveniently to the operating consoles. This console will provide the following features:

1. Picture size, approximately 22 inches measured diagonally.
2. Provision to select and focus not less than eighty 35 mm slides.

Vehicle Status Display. The status display board will provide a visual status indication of all vehicles to dispatch personnel. The following features will be included:

1. The center approximately 4' x 4' portion shall be an enlarged photographic reproduction of a map of the service area. The front of the map will be protected by a sheet of transparent material, treated to reduce reflection, without substantial loss of light transmissions through the material.
2. Behind the front cover will be a means for positioning light groups (or projected spots of light). Each light group shall be made up of 3 colors, one each green, red, and yellow. Sixty light groups must be capable of being moved to any location of the 4' x 4' map area. (One watt per lamp, adjustable light intensity, 3/8-inch, sharply focused light spots.)
3. The above 60 light groups shall operate in parallel with a like number of lights groups, located in what is normally considered the "wild car" area.
4. Total "wild car" number shall be approximately 150. The "wild car" area shall be in two sections, one on each side of the map.
5. The lights of each "light group" shall be controlled from switches, or optionally from a console status decoder which in turn is controlled from vehicles via data transmission.
6. A data encoder will be installed in each dispatcher console to provide operator control of the status lights (option).

Control Station (option). This station will be controlled primarily from the office of the Department Head. The station will provide monitoring facilities, and it will have capabilities of being used as a backup relay link, in the event of telephone line and microwave link failure. The following features will be included:

1. The station will operate primarily as an extended local-controlled,

control station via a telephone-type desk set. It will include an internal speaker that is muted when the telephone is lifted from its cradle. Frequency selection will be available.

2. In order to utilize this station as a backup station in the event of telephone line failure, the station must supply audio to, and be capable of being keyed and modulated from, the main control consoles. Remote channel selection (at the dispatcher console) will not be required.

3. The station will be expandable to eight channels, by adding only two frequency determining elements per channel.

4. A directional antenna and the necessary coaxial transmission lines will be provided and installed on or near the dispatch center building. Lightning protection will be provided.

5. Other specifications:

   (1) The control station will operate on frequencies designated in the frequency plan.

   (2) Operating power will be 120 Vac $\pm$ 10%, 60 Hz, single phase.

   (3) Circuits will be solid-state.

   (4) Adequate protective devices will be included.

   (5) Field maintenance shall be convenient.

   (6) Minimum RF power output will be 100 watts.

   (7) Rated system deviation will be $\pm$ 5 kHz, as per EIA Standard RS-152-B.

   (8) Tone coded squelch encoder will be included.

   (9) EIA Standards RS-152-B, RS-204, and RS-220 will be met or exceeded.

<u>Monitoring Receivers (Optional)</u>. All monitoring receivers will be located in one cabinet. The following features will be provided:

1. Four High Band receivers and one Low Band will be supplied, these receivers to have 600 ohm outputs suitable for telephone line operation, and connection to the main console.

2. Space will be provided for an additional receiver. This additional receiver may be either Low Band or UHF Band.

3. All High Band receivers will operate from one antenna; therefore, a "splitter" must be provided.

4. A 6 dB High Band antenna and the necessary transmission line will be installed on or near the dispatch center building.

5. A Low Band antenna and lead-in transmission line will be installed on or near the dispatch center building.
6. Lightning protection will be provided.
7. Receivers will be transistorized, crystal controlled, double superheterodyne units.
8. Power will be 120 Vac, ± 10%, 60 Hz, single phase.
9. EIA Standards RS-204, RS-220, RS-374, and RS-237 (as appropriate) will be met or exceeded.

Message Handling (optional). Each console position will be provided with a conveyor belt for transporting information to and from the complaint telephone operators, or with other means for generating call records at the dispatcher console.

3.2 Base Stations

The main base-stations will be located near the antennas and tower. Space for installing the radio equipment will be provided in appropriate structures. The base station equipment will include:

UHF Mobile Relay Stations. Space must be allowed for the total planned base stations. Each station will operate as follows:

1. Each station will be provided with remote override from the main console.
2. The stations will have a dispatcher-controlled option of being operated as a mobile relay or as a base-station.
3. Each station will transmit on one frequency and receive on another 5 MHz removed.
4. In the relay mode, the base-stations will faithfully repeat audio signals from the mobiles, or from the backup control station. Automatic retransmission will require both a low frequency superimposed tone from the dispatcher, and a predetermined strength of the signal to be relayed.
5. Each base station will have an adjustable dropout time delay in the keying circuitry.
6. Each station will be equipped with a meter panel and local microphone for test purposes.
7. Each station will be capable of continuous duty.

8. Each station will have either a built-in duplexer for single antenna operation, or separate send and receive antennas if required for receiver isolation.

9. Transmitting antennas will have gain designed to provide a field strength pattern which, at a given distance, is constant with azimuth.

10. Lightning protection devices will be installed on all antennas.

    Transmitter and receiver frequencies will be as specified in the frequency plan.

11. Metering of all circuits essential for field maintenance and alignment shall be convenient.

12. Power supplies will be 120 Vac ± 10%, 60 Hz, single phase.

13. The base-station shall incorporate a control terminal panel to permit operation via a two-wire telephone line either from the remote control consoles, or from microwave equipment. The control panel shall have facilities for local test, including loud-speaker, volume control, and microphone input. The control terminal panel will provide additional functions such as:

    (1) Receive/transmit amplifier.
    (2) Three-minute time limiter.
    (3) 0-6 second adjustable delay release.
    (4) Carrier operated switch.
    (5) Tone operated switch.

14. Output power shall be such as to provide 90%, CM-3 coverage of the service area.

15. Rated system deviation will be ± 5 kHz, as per EIA Standard RS-152-B.

16. Antenna transmission lines will be low-loss. They will be matched for minimum VSWR.

17. Circuits will be solid-state, except for final.

18. EIA Standards RS-152-B, RS-204, RS-237, RS-220, and RS-374 will be met or exceeded.

Emergency Power Source. A 120 volt, single phase, 60 cycle standby generator will be installed at the base station to provide emergency power for mobile relay stations. This generator will have the following:

1. Capacity for 10 base stations.
2. 25-gallon gasoline tank.
3. Automatic start, with automatic load transfer panel. A time

delay will be made part of the automatic load transfer panel so as to preclude immediate transfer back onto the main line during times of repeated power-line failures.

4. An automatic exerciser to periodically check the operation of the emergency system.

5. Aural or visual indication at the main control console to indicate emergency-power operation.

3.3 Mobile Units

The mobile radio shall consist of a transmit/receive unit with controls, speaker, microphone, antenna, interconnecting cables and such other items as shall be required for a complete two-way FM mobile, trunk mount, radio installation.

Transistors and solid-state devices shall be used throughout the radio with no vacuum tubes or mechanical relays. Circuitry shall be incorporated that protects components against damage caused by excessive voltage, high ambient temperature or accidental mistuning or loading.

All units shall be designed to operate directly from a nominal 12 volt, specific* ground, vehicular electrical system without internal power supplies. All units must be interfaced to operate with the existing sirens. Primary power input shall be protected by a resettable circuit breaker of proper rating.

The equipment shall meet or surpass all applicable FCC regulations, EIA standards, and the technical requirements of these specifications.

The mobile radios shall operate on the frequencies designated in the frequency plan. All units shall be capable of expansion to eight transmit and eight receive channels, merely by adding two frequency-determining elements per channel.

The housings shall be completely enclosed, with no louvres or vent openings. A single, multi-contact, screw-thread-retained connector and a coaxial cable shall be the only external connections required. The front panel shall have a key lock that prevents unauthorized persons from opening the unit, or removing it from its mounting base. For trunk

*Whether the ground is specified positive or negative will depend on the present fleet vehicles.

mounting the control cable shall be at least 20 feet long. All hardware including grommets and cable clamps required for normal installations, and all cabling necessary for a complete installation, shall be included. All cables shall be insulated and of a weather-proof material, resistant to such contaminants as would be encountered in a mobile installation.

Data Transmission Control Head (optional). All mobile units, in addition to normal voice communications capabilities, will have a control head which will include data encoding, data decoding and processing circuitry. The following features will be included:

1. Normal controls for voice communication, including selection of 16 channel frequencies.
2. Data encoding capability which when operated in conjunction with complementary equipment at the control center, will provide to the dispatcher the following information:
    (1) Vehicle identification.
    (2) Pre-selected messages from the mobile.
    (3) Selectable, from the mobile, code signals, aid messages, acknowledgements, assignment clearing, status, etc.
    (4) Vehicle status information.
3. Decoding and processing circuitry which in conjunction with complementary equipment at the control consoles will provide to the vehicle operator the following information or features:
    (1) Audio and visual indication that the transmitted data information has been duly received, and processed, at the control center.
    (2) Enable, and/or disable the repeater function of the mobile unit, as controlled from the dispatch.
    (3) Indicate a dispatcher call, plus additional data messages.
    (4) Display code messages received by data transmission.
4. A continuous tone signal to provide access into the mobile relay.
5. A relay shall be provided so that data is transmitted 380 to 440 milliseconds after initiation of PRESS-TO-TALK, or push-button send, to provide time for switching operations in the audio path to central station.

6. FCC requirements for voice circuit sensing will be adhered to.

7. The entire data message shall be transmitted in less than 500 milliseconds.

8. The data modulation shall employ techniques that require no special treatment or modification of the audio pass band characteristics of mobile radio or interposed telephone lines. The modulation shall not require dc or unusual low frequency response. There shall be no requirement to alter, delete or bypass audio filters in the mobile radio transmitter.

9. A data message shall be transmitted once, whenever the send button or a message button is first depressed. A message shall be repeated if the button is released and depressed again.

10. The microphone audio circuit shall be muted while data transmission is in progress.

11. The coding of each character must contain redundancy to enable character error detection or correction.

12. Strapping of identification codes shall be possible in the field.

13. The acknowledgment lamp shall only illuminate from an address coded with vehicle identity. In the event of simultaneous transmission, where neither message is fully received, no acknowledgement signal will be transmitted.

14. Acknowledgement disable is provided when the incoming message is coded press-to-talk, by unique digits. This is to prevent acknowledgment from the base station interfering with identified vehicle voice transmissions.

15. The data function shall not be susceptible to malfunction from associated transmitter RF field, alternator whine, or locally generated ignition noise more than 20 dB down from fully modulated test tone.

16. External connections shall be provided for teleprinter operation, making use of common address and control circuitry in data equipment.

17. The data transmission must be rapid with low probability of error. While this specification does not call out details of modulation and method of character coding, the exact method is an evaluation factor with obvious preference for those which are most reliable at the required speed. The modulation must be suitable for both voice radio, and telephone wire transmission, and must meet current FCC regulations and appropriate EIA standards.

18. The number of units with operator changeable, and shop changeable, identity coding will be specified on order as in the following example:

    Identity will be determined by plug-in key, card, or connector device which is encodable by shop personnel with hand tools. It must preferably be impossible, but at least difficult, for identity to be set by unequipped and unschooled personnel. The key/card will plug into the control head to set identity. If the card has handles, it is operator changeable. If it is fastened by rivets, it is shop changeable only.

19. Control heads must be identical before strapping so that any head may be used in any vehicle.

20. Active circuit groups shall be constructed on modular plug-in assemblies, so that malfunctioning units may be repaired by module or card replacement.

21. Materials and workmanship shall be appropriate to heavy duty service. No materials which significantly deteriorate with age and humidity shall be used.

22. The enclosure shall be of such size as to be easily installed. Brackets and fasteners shall be provided which will allow quick removal and installation of control head assembly.

23. The front panel shall be so designed that it is not a safety hazard by reason of separable parts or sharp edges.

24. Connectors or separable connections shall be provided so that the entire unit can be installed and removed without the use of soldering iron or power tools. Connectors shall be small enough to pass through a round hole 1.25" diameter.

25. Battery power line shall be in-line fused and connectable to ignition switch.

<u>Mobile Receivers</u>. The mobile receivers will meet or exceed the specifications of EIA Standards RS-204 and RS-237. The following features will be included:

1. Separately housed speaker.

2. Palm-type microphone with built-in, transistorized preamplifier to reduce the effects of stray noise pickup. A push-to-talk switch shall be incorporated in the microphone. The microphone cable shall be the self-retracting type and shall terminate in a screw-thread retained type connector.

3. Audio output power of five watts or more, with 5% or less distortion.

Mobile Transmitters. The mobile transmitters will meet or exceed the specification of EIA Standards RS-152-B and RS-237. They will include the following features:

1. Power output of at least 50 watts (5 dB antennas).
2. A circuit in the keying circuitry to limit the duration of each transmission to 60 seconds. At the end of that time the transmitter shall automatically turn off and an audible alarm shall be sounded. The circuit shall be reset by releasing the push-to-talk switch.

3.4 Portables

The hand-held personal/portable unit shall consist of a compactly designed solid-state transmitter and receiver with associated battery power supply housed in an impact resistant case. The unit shall be furnished as a completely operational two-way FM radio set with battery, microphone and antenna. It shall meet or exceed EIA Standard RS-316.

The transmitter and receiver shall operate on frequencies as specified in the frequency plan.

The set shall be capable of being powered interchangeably by a replaceable mercury cell battery or a rechargeable nickel-cadmium battery. It shall be possible to charge the battery without removal from the set.

The antenna shall be a flexible coated spring type antenna.

The active circuitry shall provide the highest reliability and simplified maintenance.

A loudspeaker and microphone shall be supplied within the case.

A carrying case with shoulder strap shall be provided for each portable unit.

Battery charger equipment shall be provided.

External speaker/microphone units shall optionally be provided. The cord and plug of an external unit will disconnect the normal internal microphone and speaker unit; all units will also have plug-in earpieces.

Each personal portable radio unit shall contain a provision for emergency data transmissions.

Output power (into the antenna) shall be as high as feasible, consistent with other constraints.

Weight shall not be more than 42 ounces, including batteries.

3.5 Auxiliary Station

Backup facilities for the system will be provided, including a base station with interlock facilities to prevent simultaneous transmissions on the same frequency from both the primary and the backup units.

3.6 Installation

Complete installation will be the responsibility of the successful bidder. The installation of all equipment will be coordinated with the purchaser in a manner that will enable the transition to go as smoothly as possible.

Equipment will be shipped so that installation is made without the loss of communications at any time.

The installation will be made to the satisfaction of the purchaser and will be supervised by supplier personnel.

As the installation will cover a period of a few months it will be the responsibility of the successful bidder to provide all maintenance on the equipment, at no cost, until such time as the installation is completed and the system is accepted. In the event installation is delayed through no fault of the successful bidder, the purchaser shall immediately assume responsibility for maintenance of all equipment which has been installed and accepted.

The successful bidder will arrange for training and instruction of personnel in the use of this two-way radio system.

Technical assistance will be provided during the installation and as needed to train maintenance personnel.

3.7 Frequency Plan

The bidder should include a complete frequency plan.

4. Equipment List

4.1 Control Center

1. Control Console.
2. Instant Recall Data Display System (option).
3. Vehicle Status Display.
4. Control Station, antenna, and transmission line.
5. Monitor Receiver.
6. Remote.
7. Conveyor Belt (option).
8. Message Recorder.
9. Phone Patch.
10. Chair.

4.2 Mobile Relay Station

1. Mobile Relays, complete w/duplexers, antennas, and transmission lines.
2. Emergency power generator.

4.3 Mobile Units

1. Mobile units complete, with optional data control head, duplexer, continuous tone generator, time-out-timer, etc.

4.4 Auxiliary Stations

1. Two frequency, UHF Mobile Relay, Complete Antenna and Transmission Line.

4.5 Portable Units

Each unit will have continuous tone generator, NICAD battery, carrying case, external speaker/microphone, earpiece, and charger.

4.6 Data Equipment (option)

1. Control Head - included with each mobile unit.

2. Master Display Decoder.
3. Digital Line Printer.
4. Status Display Decoder.
5. Selective Calling Sender.

4.7 Installation, complete

4.8 Service

Per year, all parts and service.

APPENDIX F. ACCEPTANCE TESTS [10]

Compliance to and successful completion of the equipment specifications in Appendix E and the system tests set forth in this chapter should be made conditions for payment. The equipment specifications could be substituted for corresponding "Minimum Standards" of performance in EIA standards. Where the specifications are silent, EIA "Minimum Standards" would apply.

1. Radio Equipment

1.1 Certification of Equipment Tests (Minimum Standards)

The vendors should certify that the base transmitters and receivers (including satellite receivers, if used) have been type-tested as a system per EIA Standard RS-237. The manufacturer should certify that type-testing has been performed on base and mobile transmitters as described in EIA Standard RS-152-B, and on base and mobile receivers per EIA Standard RS-204. The term, "base receivers" includes satellite receivers, if used. The vendors should certify that portable/personal units have been type-tested per EIA Standard RS-316. If equipments embody a continuous tone control squelch system, it should be certified that type tests were conducted according to RS-220. If equipments embody selective signaling, type-testing per EIA Standard RS-374, and EIA TR-120, should be certified by the manufacturer. The manufacturer should furnish on demand copies of results of tests made on randomly selected samples of equipments, as described above.

The console, the status board, and equipment associated with the dispatch positions, should perform satisfactorily all functions specified by the vendor in his proposal. EIA Standards should be adhered to with regard to telephone interfaces (RS-210, RS-366); racks and panels (RS-130); rotary switches (RS-315); facsimile equipment (RS-328, RS-373); transmission lines (RS-259, RS-225, RS-258, RS-199), and microphones (SE-105). Certification of adherence to the standards listed should be furnished.

1.2 Equipment Field Tests

Base station antenna installations should be tested per RS-329 "Minimum Standards for Land-Mobile Communication Antennas, Part I -- Base or Fixed Station Antennas." The test results should be furnished to the purchaser. If erections of towers or passive reflectors are included in the vendor's system, test results and design data as per EIA Standard RS-195-A, "Electrical and Mechanical Characteristics for Microwave Relay System Antennas and Passive Reflectors," should be furnished to the purchaser. The emergency standby power equipment should be tested after installation, per EIA Standard RS-173, "Emergency Standby Power Generators and Accessories for Microwave Systems," and the results should be furnished to the purchaser.

Antenna pattern and gain tests should be performed on at least the first three mobile equipment installations. Tests should also be performed on these units for interference per EIA Standard RS-159, "Chassis Pickup of Vehicular Receivers," and if tests warrant, corrective measures should be specified for all installations.

When the base installations, the mobile installations, and the console installations have been installed, and all the above tests have been successfully completed, either the vendor or a third party organization (at the discretion of the purchaser) should perform functional acceptance tests on the entire system.

2. Radio System

2.1 Design Documentation

In order that the purchaser may be in a position to evaluate technical approaches, all approaches offered by a potential vendor must be fully justified technically. Guidelines for coverage computations are included in Appendix D. The following items are considered minimum requirements:

1. Projected coverage for all transmitter-receiver combinations must be provided. Where a repeater or relay is used, the coverage area must be broken down into transmitter-receiver combinations.

2. Net coverage must also be specified and the combinations of satellite receivers, satellite transmitters, repeaters, and relays used to obtain the coverage must be clearly evident.

3. For transmitter-receiver combinations and the projected coverage, the following parameters must be specified:

   Receiver:

   (1) Sensitivity.

   (2) Frequency of operation.

   (3) Receiving antenna gain.

   (4) Receiver noise level due to urban-surburban man-made noise.

   Transmitter:

   (1) Power output to optimum load.

   (2) Frequency of operation.

   (3) Transmitting antenna gain.

   (4) Losses in network between transmitter and antenna.

   Path Characteristics:

   (1) Type of path assumed, i.e., whether line-of-sight, surface wave, etc.

   (2) Total path loss versus distance.

4. For net coverage projections, the following parameters must be supplied:

   (1) Frequencies of operation.

   (2) Basic method of approach, i.e., whether satellite receivers and approximate location.

   (3) If included, the number of satellite receivers and approximate location.

   (4) If included, the total number of dedicated phone lines and type of lines required.

The calculations of mobile radio coverage in Appendix D are based on the desire for two-way, full duplex, voice communication between the dispatcher and field personnel using either mobile or personal/portable radios anywhere in the respective service areas. The criterion for acceptable performance is 12 dB SINAD, to or from 90 percent of all possible locations at service range, 90 percent of the time.

2.2 System Field Tests

Coverage tests, both talk-out and talk-back, should be made at mobile locations along roads which are nearest to randomly selected points at service range distances from the base station. As test vehicles are driven along roads nearest to the randomly selected points, signal quality of 12 dB SINAD or better should occur at least 90 percent of the test message time, for at least 90 percent of test locations. Tests should be conducted under typical weather conditions.

Digital transmission messages should be tested from the same sites and under the same conditions as the voice tests, but the acceptance criterion should be 1 message error in 100 messages transmitted.

Tests of reception of signals by mobile units should be made at predicted shadow locations, where shadow losses averaging 20 dB have been calculated. Shadow loss points where 12 dB or better SINAD voice reception is not established should be listed.

2.3 Functional Tests

The functions of equipment, as described by the specifications and the vendor's bid, should be verified after the system is installed.