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Technical Assistance for Law-Enforcement Communications

Case Study Report 2

Norman B. Reilly
James A. Mustain

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August 15, 1979

Prepared for

U.S. Department of Justice
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Jet Propulsion Laboratory
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ABSTRACT

Two case histories are offered as examples of the work done with 31 state and local law-enforcement agencies by the Jet Propulsion Laboratory under a grant from the federal Law Enforcement Assistance Administration to improve police communications systems. In one study the feasibility of consolidating dispatch center operations for small agencies is considered. System load measurements were taken and queueing analysis applied to determine numbers of personnel required for each separate agency and for a consolidated dispatch center. Functional requirements were developed and a cost model was designed to compare relative costs of various alternatives including continuation of the present system, consolidation of a manual system, and consolidated computer-aided dispatching. The second case history deals with the consideration of a multi-regional, intra-state radio frequency for improved inter-regional communications. Sample standards and specifications for radio equipment are provided.

FOREWORD

This report describes a part of the work done by the Jet Propulsion Laboratory to aid law-enforcement agencies in improving their communications. The work was done under a JPL-Caltech grant from the federal Law Enforcement Assistance Administration as part of LEAA's overall program of assistance to law-enforcement and criminal-justice jurisdictions.

For an introduction, definition of purpose and scope, background, and description of approach of the program, the reader is referred to Technical Assistance for Law-Enforcement Communications: Case Study Report 1 (JPL Publication 79-71) by Norman B. Reilly and James A. Mustain, prepared for the U.S. Department of Justice Law Enforcement Administration by the Jet Propulsion Laboratory, California Institute of Technology, Pasadena, Calif., and published June 15, 1979.

CONTENTS

I. A COOPERATIVE DISPATCHING PROJECT FOR SMALL CITIES

One of the goals of the LEAA program of technical assistance for law-enforcement communications is to support and encourage the development of joint projects that will enable cities that are individually too small to justify the investment in automated dispatching equipment to join together to improve their service to the public without losing their autonomy.

Such multi-jurisdictional systems are not new. As long ago as 1974 three small cities in Illinois set up a cooperative dispatching system (see LEAA/JPL publication, Application of Computer-Aided Dispatch in Law Enforcement, JPL 5040-16, December 1975), and a somewhat larger joint system is now in operation in Southern California (The South Bay Regional Communications Authority). Nevertheless, in many cases cities need some assistance and guidance in determining whether a cooperative system is feasible and the extent to which it can improve service or save money, or both. The LEAA grant to JPL covers the provision of such assistance and guidance.

The cities involved in this project are adjoining municipalities in the northern portion of Orange County, California. The cities, together with their populations and police department staffing levels, are shown in Table 1. These police departments have a long history of close cooperation, and it appeared reasonable to investigate the possibility of combining some of their operations as a means of controlling the rise in law enforcement costs while maintaining or improving service to the public. Controlling cost increases is of special concern in this period of growing public resistance to the rising cost of public services.

The entire project was facilitated by the Orange County Criminal Justice Council, a county agency that coordinates law-enforcement activities in the county's various jurisdictions. The JPL technical assistance team for law enforcement communications was enlisted early in the project, with LEAA approval.

Table 1. Cooperating Orange County Cities

		PERSONNEL		
CITY	POPULATION (1978)	SWORN	NON-SWORN	TOTAL
Brea	26,500	51	15	66
Yorba Linda	27,000	Police services provided by Brea under contract		
Fullerton	100,000	130	56	186
La Habra	44,400	56	24	80
Placentia	32,650	43	15	58

The staff of the Orange County Criminal Justice Council developed a concept paper for the cooperative system and presented it for consideration by the concerned cities' chiefs of police at a meeting in July, 1978. After they approved the concept the staff prepared a research plan and timetable. The Council staff also aranged for the participation of JPL team members in the project.

A meeting was held in November of 1978 to set the general guidelines for the project. It was agreed that the function most suitable for consolidation was communications, and an overall plan of action was adopted. Because of the expected implementation of the 911 emergency calling system, it was agreed that fire calls should be considered in any cooperative system to be established. Regular weekly meetings of the participants were scheduled to maintain coordination and to answer questions as they arose.

A. THE PROJECT PLAN

The first step was the measurement of call rates and service times at peak-load hours for all of the departments concerned. Since any consolidated system would require some investment in facilities and equipment, it was important to project a life-cycle cost for any new system. Life-cycle costing means that all costs (non-recurring and recurring) be identified for the expected service life of the system (in this case taken to be 10 years) to determine whether there would be a saving by consolidating the communications operations.

It would not be possible to make reasonable comparisons, however, unless the alternatives were compared against a common base. This common base is provided by defining the functional requirements for each department's dispatching operation.

Determining functional requirements is a step that is frequently omitted from many project plans. Functional requirements specify what a system is expected to do but not how the system will do it. Included in functional requirements are performance standards such as average wait times for incoming phone calls to be serviced, etc.

The next part of the analysis was to define a set of options that could be compared to determine which can meet the functional requirements at the lowest life-cycle cost. One of these options must be to continue with the present system (augmented if necessary to meet the functional requirements), since the value of any consolidated system can be determined only in relation to the cost of the present system.

Finally a cost model was constructed. The model itself is not complicated, since it merely adds up all the costs of operating any of the options over a 10-year period. Collecting all the input data for the model is more complex, however; each department has to identify all of its projected costs for each of the options (including the option of remaining with the present unconsolidated sytem). Once this information is entered into the cost model, the total 10-year costs for each option can be compared to the others to determine which shows the lowest total.

This brief outline of the process has been given to show the general framework of the study. The following sections will describe the process in greater detail. It should be pointed out here that policy questions were deliberately excluded from this part of the study. There are always policy questions to be answered in any joint project of this kind--how costs will be allocated, how local control is maintained, how authority will be delegated, and so on. It does not appear to be useful to address these questions, however, until it has been determined that consolidation of functions is in fact more economical (it may turn out that separate operations are more economical) and what specific system is to be selected if a new one is to be installed. The participants in the project thought that when a specific proposal could be made, it would be possible to work out the policy questions without serious difficulty.

B. MEASURING WORK LOAD

In February 1979 the JPL team held a one-day seminar for members of the police departments to specify what data was required and how it could be obtained in a uniform format. Forms were provided on which the information could be recorded. In most cases tape transcriptions were made, with the start and stop time and nature of each call listed for Complaint Board Operator (CBO) functions and start and stop times for radio transactions* for dispatcher functions. From this raw data it was possible to determine:

- Categories of calls (in, out, calls requiring dispatch, administrative calls, requests for information, etc.).
- Length of each call, from which average service time could be determined.
- Numbers of calls and hourly arrival rates.

*A radio transaction is defined here as all of the radio transmissions related to a given radio exchange. For example, a dispatch transaction might consist of four transmissions -- the initial call to the unit, the unit's acknowledgment, the details of the dispatch and the unit's acknowledgement of the details. Queueing theory assumes that each function is independent, yet clearly the last three functions above are dependent on the initial call. Therefore, this concept of a transaction is used, and the transaction is timed from beginning to end, including dead time between transmissions.

- Other functions performed by CBO (data-base queries, manual record checks, logging, clerical operations).
- Percent of time the CBO was busy (this is the utilization rate used in queueing analyses).
- Arrival rate and duration of dispatches.
- Rate and duration of radio transactions.
- Other functions performed by the dispatcher and their durations.
- Percentage of time dispatcher was busy (utilization rate).

In some of the departments the CBO and dispatcher functions were performed by the same person, but the forms allowed for separating the two types of functions.

At the same time, each department was asked to list its equipment (consoles, data-base inquiry terminals, phone lines, radio channels, etc.) and the major communications and dispatching functions performed (answer phone, fill out cards, dispatch units, make data-base inquiries, maintain logs, etc.). A block diagram of each layout was made and the number of personnel in each category was shown.

Call arrival rates and service times were measured by each department at a time expected to represent the peak load for the department. This is important for determining the maximum size of the physical facility, i.e., the number of consoles required, etc. The same analysis can be applied later to the other arrival rates during the day in order to determine staffing requirements.

Three types of forms were used for recording the data: a voice-function data sheet, with separate sheets used for telephone and radio voice functions; a manual-function data sheet, and a summary data sheet combining telephone, radio, and manual functions. The voice data was collected by listening to a tape recording made during the selected peak hour and the manual functions were measured by direct observation; in both cases a stop watch was used. Type of call or manual activity was listed along with the duration of each.

C. DEFINING THE OPTIONS

Five options were defined by the project team to be compared with respect to their relative total costs for 10 years of operation. The idea was to cover the full range of degrees of automation of the communications. In general, increasing the extent of automation reduces the manpower requirement because more functions are taken over by computer, and direct labor, which is the major component of most police department budgets, is reduced. This effect is most apparent in a police department in the area of management report generation.

The primary advantage of consolidation for small agencies is that overall manpower for the agencies combined can frequently be reduced. If an agency has enough work for, say, 1.2 people, then two people must be employed, even though the second person is substantially underutilized. If this were true for each of five agencies, 10 people would be employed, five of whom were underutilized. If the five agencies combined there would be five times as much work, which would require exactly six people--four less than if the agencies operated independently. If work expanded slightly, a seventh person could be added, still with only one person underutilized instead of five.

Five options were defined for the Orange County study:

Option 1 is to maintain the present decentralized, largely manual systems, but to add personnel as required to meet the defined functional requirements of each department. Since each department now has only one to three people for its dispatching function, there will necessarily be a large percentage increase in manpower costs as soon as the load exceeds the capacity of the present staff; the resulting larger staff is underutilized until the load increases considerably.

Option 2 is to retain the present largely manual systems, but combine them in a central location. In any combined operation there is a question of how local departments are to maintain control over their units when they are being dispatched from a remote location. The methods of local control generally considered are: 1) monitoring of the radio channel by the local department to maintain awareness of the status of its units; 2) a hot line from the local department to the dispatching center, permitting the local department to override a dispatch if appropriate; and/or 3) monitoring the status of units equipped with mobile digital terminals (MODATs) by means of a status board driven by the radio signals from the MODATs. This last method is of course available only if the patrol units are equipped with MODATs (as are some of those in the cities considered here). The cost of any new equipment or personnel required to maintain local control must be added to the costs of the centralized system. (The methods of maintaining local control described above are applicable to any centralized dispatch system.)

Option 3 is a centralized system using a computer-aided dispatch (CAD) system. Such a system generally requires a fairly large capital expense. With a minimum CAD system, local control would have to be maintained by the methods outlined above under Option 2. For the cities involved in this study, radio channel occupancy is not a problem and the principal advantage of a CAD system would be in manpower reductions. It must be pointed out that CAD in itself does not reduce manpower requirements for the dispatch function. Rather, centralization will permit a manpower reduction through the savings of fractions of operators as described above. CAD can reduce manpower requirements in the area of management reports generation.

Option 4 is to install a CAD system as in Option 3, but to add a supervisory console at each local department as a means of providing a greater degree of local control. This would eliminate the requirement for a hot line to the dispatching center, but the consoles represent a large investment and would have to be connected to the dispatching center by full-time telephone links.

Option 5 is to install a CAD system, but one in which only the computer is shared by the different departments. Dispatching would be done from a console in each department, using its own dispatchers. This system maintains full local control but realizes few economies in manpower because the staffs are not centralized.

D. FUNCTIONAL REQUIREMENTS

We mentioned earlier that a set of functional requirements were necessary to provide a standard basis of comparison of the different options. Each department was asked to list its functional requirements, which include what functions are to be performed as well as performance standards. Table 2 lists the kinds of information provided by each department. Note that reference materials used by CBOs and dispatchers are included, since they are frequently stored in the computer in a CAD system, resulting in faster access but requiring some additional cost to computerize.

One of the difficulties in comparing CAD systems with manual systems is reporting. In manual systems, reports are generally expensive and slow to generate; in CAD systems they can be generated quickly and cheaply. Most CAD systems will generate more timely and better reports than are usually produced in a manual system, but it is difficult to assign a dollar value to the improvement in quality, variety and timeliness of the reports. Nevertheless this factor should be taken into account in comparing CAD systems with manual systems, even if it must be a subjective consideration. There may even be a morale factor to be considered, since most police department personnel do not enjoy preparing reports and view them as peripheral to their main functions.

Table 2. Functional Requirements Furnished by Each Participating Police Department

1. CBO Functions:

Call Types	Peak Volume (per hour)
law-enforcement emergency	
fire emergency	
medical emergency	
non-emergency	
administrative	
animal control	
outgoing calls	

Reference materials used (beat books, maps, etc.)

Response time goals

- Acceptable probability of caller receiving busy signal (%)
- Average wait time of caller not more than _________ seconds before call is serviced
- Acceptable total transaction time from first ring to time dispatcher receives dispatch
- Other functions (typing, response at public window, etc.)

2. Dispatching Functions:

Call types (as above)
Peak call volumes by type (as above)

3. Radio Functions:

Dispatches
Status reports
Data base inquiries from field units and responses

Reference materials used

Response time goals

Average wait time for radio channel not more than _________ seconds at peak hour

Dispatch complete time (from receipt of dispatch from CBO to end of transaction) to average not more than _________ seconds at peak hour

Other dispatcher functions
Number of supervisor consoles or stations
Required administrative reports
Required availability (percentage of time system not down).

The information submitted by the four departments concerning their functional requirements varies with respect to call volumes, as would be expected, but is very similar with respect to performance requirements, reference materials, and required reports. Response-time requirements are listed in Table 3, which shows that there is very close agreement on the desired response times.

Table 3. Response-Time System Design Goals

	Brea	Fullerton	La Habra	Placentia
Probability of caller getting busy signal, %	0.1	0.1	0.1	0.01
Average wait time for phone to be answered, sec	8	6	8	6-8
Total CBO service time, sec (average at peak load)	60	60	60	60
Radio channel wait time, sec (average at peak load)	15	10	10	10
Total dispatch service time, sec (average at peak load)	20	15	15	15

Reports specified in the functional requirements documents are standard for most police departments and were essentially the same for the four departments in the study. A typical list of required reports is shown in Table 4. It can be seen that these reports, and others if desired, could readily be generated by a CAD system; the required information is stored in the computer memory (or a peripheral storage device) as part of system operation and can easily be retrieved in the desired formats.

As the above discussion indicates, there are virtually no incompatibilities in the functional requirements of the four different departments concerned in this study; a centralized system should be able to meet the requirements with no difficulty.

Table 4. Typical Reporting Requirements

Type of Report	Frequency
CFS (call for service) workload	daily, weekly, monthly
Beat workload and crime categories	on demand--by shift, and weekly summary
Incident log	weekly on demand by shift
Juvenile statistics	monthly
Uniform Crime Reports	monthly
Management reports	variable
Personnel work status	weekly

E. ANALYZING THE DATA

With work loads measured, options defined, and functional requirements specified, it was possible to project this information to the 1981-1990 period, when any new consolidated system would be in operation. First the incoming call rates and numbers of radio transactions per hour were extrapolated from the data provided, with the results shown in Table 5. Next the numbers of CBOs and dispatchers that would be required to handle these rates (while meeting the response time requirements) with the present decentralized manual system or a centralized manual system were determined from a queueing analysis. These results are shown in Table 6. Generally speaking, utilization of personnel must be kept below approximately 50% in order to keep average waiting times for service within reasonable limits. Note that two of the departments, Brea and Placentia, now have one-stage operations combining telephone answering and dispatching in one position. To determine the number of CBOs and dispatchers required in a combined manual operation, their requirements were prorated in accordance with the measurement data provided.

F. DEVELOPING THE COST MODEL

Once the numbers of CBOs and dispatchers required for a manual system (the current decentralized system or a centralized manual system) have been determined, the necessary information is available to start comparisons with automated systems. A great deal of additional cost data is required, but it is primarily in the form of known data that needs to be collected and factored into cost projections for the different options. That task is now under way.

Table 5. Projected Call Rates and Radio Transactions, 1981-1990

Year	Incoming Calls per Hour				Radio Transactions per Hour			
	Brea	Fullerton	La Habra	Placentia	Brea	Fullerton	La Habra	Placentia
1981	13	26	27	13	28	72	73	31
1982	13	26	28	13	28	72	76	31
1983	14	26	29	14	30	72	78	34
1984	14	27	29	14	30	75	78	34
1985	15	27	30	15	32	75	83	36
1986	15	28	30	15	32	77	83	36
1987	16	28	31	16	34	77	83	39
1988	16	28	31	16	34	77	83	39
1989	16	29	32	16	34	80	86	39
1990	17	29	32	17	36	80	86	41

Table 6. Projected CBO and Dispatcher Requirements

Year	Brea		Fullerton		La Habra		Placentia		Combined Manual		Reduction
	CBO	Dis.	CBO	Dis.	CBO	Dis.	CBO	Dis.	CBO	Dis.	
1981	0	1	2	1	2	1	0	1	4	3	1
1982	0	1	2	1	2	1	0	1	4	4	0
1983	0	2	2	1	3	1	0	2	5	4	1
1984	0	2	2	1	3	1	0	2	5	4	1
1985	0	2	2	1	3	1	0	2	5	4	1
1986	0	2	2	1	3	1	0	2	5	4	1
1987	0	2	2	1	3	1	0	2	5	4	2
1988	0	2	2	1	3	1	0	2	5	4	2
1989	0	2	2	1	3	1	0	2	5	4	2
1990	0	2	2	1	3	1	0	2	5	4	2

Each department is developing estimates for its non-recurring and recurring costs for operating each of the options over the 1981-1990 period. The general categories of cost estimates being provided are listed in Table 7. When these data have been furnished to the JPL team they will be entered into the model and a total life-cycle cost for each of the options will be computed.

Table 7. Elements of Cost Model

1. NON-RECURRING (CAPITAL) COSTS

   a. Facility: structure, modifications, lighting, regular and standby power, air conditioning, security.

   b. Consoles

   c. Computer, its peripherals and software

   d. Support equipment: conveyor, intercom, tape recorders, etc.

   e. Telephone equipment and lines (new installations)

   f. Installation of all above.

2. RECURRING (ANNUAL) COSTS

   a. Facility: utilities, maintenance, insurance, supplies

   b. Personnel (including associated overhead)

   c. Telephone line charges

   d. Telecommunications: National Crime Information Center and other services

   e. Management reports, including personnel and computer time

   f. Computer maintenance and programming personnel.

F. SELECTING A RECOMMENDED SYSTEM

The cost estimates for the options are intended for comparison only and are in no way intended for budgeting use. Therefore the process can be simplified by omitting such considerations as inflation, which would only exaggerate the cost differences between options. Presumably the option with the lowest cost estimate will be selected (assuming that all options meet the functional requirements).

The selection task will be simplest if there are clear-cut differences among the various options, with one showing a significant cost advantage. Preliminary indications are that Option 5 will be too expensive for this project; it involves large capital expenditures with little compensating reduction in manpower. Option 4, the CAD system with supervisory consoles at each agency, is also likely to be too expensive because of the cost of the extra consoles and their communication lines. We have already seen that Option 2, the centralized manual system, offers some small reduction in total manpower; the amount saved by the five cities, however, may be too small to justify the cost of making the change. These are only guesses, however; when the cost model has been completed the situation will be much clearer.

G. CONCLUSION

This report has been devoted to the process of analyzing one specific project for combining the communications and records functions of several small police departments. LEAA is interested in encouraging such joint efforts because they offer the promise, especially when combined with CAD systems, of raising the quality and lowering the cost of law-enforcement services in contiguous small jurisdictions.

We hope that the above description of one such project provides some insight into the process of defining and analyzing the requirements for combining dispatching operations. We have not discussed the many policy issues that are certain to arise in such a project, but these issues must be identified and resolved before a combined system can be implemented. First, however, a process like the one described above must be carried out to identify the costs and benefits of combining operations. If all parties are persuaded that there are real improvements to be made in costs and performance, they will have a sound foundation on which to base their policy discussions.

SECTION II

EASTERN CONNECTICUT POLICE EMERGENCY COMMUNICATIONS NETWORK

Another example of JPL projects relating to multi-jurisdictional programs is the preparation of equipment and system specifications for a new radio installation. In this case, traffic and queueing analyses were not required; rather, the task was to assist a group of communities in eastern Connecticut that had already decided that they needed to be directly interconnected by a special radio network. In cases where a chase crossed jurisdictional boundaries (where jurisdictions are relatively small), or where an area-wide emergency existed, normal communications by long-distance telephone were inadequate. What was needed was a dedicated radio frequency, to be used by all of the agencies for instant communication, that would also provide interconnection with the Connecticut State Police.

The decision to implement such a network had already been made, but before contractors could be asked to submit bids for the necessary equipment a detailed specification was needed as a basis for the bids. Under its grant from LEAA the JPL team prepared the equipment and system specifications for issuance to prospective bidders.

Ten police departments in eastern Connecticut participated in the project, which is called the Eastern Connecticut Police Emergency Communications Network. The project is being coordinated by the Eastern Connecticut Criminal Justice Planning Agency and is being supported by a grant awarded by the Connecticut Justice Commission. The 10 departments involved in addition to the Connecticut State Police are:

Clinton	Old Saybrook
Groton City	Stonington
Groton Town	University of Connecticut at Storrs
New London	Waterford
Norwich	Willimantic

The police department of Old Saybrook was designated as the procuring agency for the entire group except the University of Connecticut at Storrs, which acted as its own procuring agency.

Each of the departments is to be provided a low-band transceiver operating at 45.86 MHz and a local or remote-control unit for each, and an antenna with tower. Half of the departments already had remote-control consoles, which required only an appropriate control module.

Fortunately, the consultant used by JPL for this assignment had access to a set of standard specifications and quality standards for police communications equipment. In this way the existing quality standards and specifications could be used at a considerable saving in time and expense.

For each of the departments in the project, a specification was prepared that identified the requirements for:

- the base station transceiver
- the local or remote control unit (or control module, if a control unit was already in place)
- the antenna tower (different in each case)
- the antenna (different in each case, including electrical and mechanical specifications)
- the bandpass filter (required by five of the agencies)
- installation (including orientation of the antenna in each case).

General specification requirements were also given for common equipment items (primarily the transceivers).

With this 100-page detailed specification, the project can proceed with confidence in advertising for bids. All the requirements are spelled out in detail, and bidders will know exactly what is to be furnished and to what performance and quality specifications.

Appendixes A and B summarize quality and specification requirements for land mobile radio systems and low-band base station transceivers used in the Connecticut study in the hope they may provide useful guidelines to other agencies.

APPENDIX A

CAPITAL SCIENTIFIC CORPORATION
2607 Connecticut Avenue, N.W.
Washington, D.C. 20008

QUALITY STANDARD S-1001

STANDARDIZED QUALITY REQUIREMENTS
For
LAND MOBILE RADIO SYSTEMS

1. GENERAL

(1) Electronic equipment shall be transistorized and shall reflect the latest advances in the state-of-the-art to ensure against obsolescence.

(2) To ensure long life and reliability, the equipment shall be designed to maintain operation over a temperature range of -30°C to +60°C, and line voltage variations of plus or minus 20%, 117 volt reference. Certain equipment, because of its application or nature, may have other requirements and will be so noted.

(3) Design and construction shall be consistent with good engineering practice, and shall be executed in a neat and workmanlike manner. All connections shall be made with rosin-core solder or approved mechanical connectors.

(4) All equipment and systems that connect to telephone company lines shall conform to the requirements of the local telephone company with respect to audio levels and control voltages impressed upon the telephone lines.

(5) The electrical characteristics of all proposed equipment shall be included in the proposals submitted by prospective contractors. The electrical measurements performed to determine the equipment electrical characteristics shall either be referenced to a specific test procedure or shall be described in full by the manufacturer.

2. REFERENCE DOCUMENTS AND STANDARDS

(1) Equipment shall meet or exceed all applicable EIA, FCC, NILECJ, NEC and U.L. standards and requirements which are current at the time of bid submission.

(2) All equipment and systems shall be in conformance with FCC Rules and Regulations, Volume V, January 1970, and shall comply with applicable portions of the following EIA Standards:

RS-152-B	(1965)
RS-204	(1958)
RS-220	(1959)
RS-237	(1960)
RS-316	(1965)
RS-329	(1966)

(3) All pole installations shall conform to applicable portions of Electrical Transmission Specifications and Drawings, REA Form 805, Revision 2-73.

(4) All antennas shall conform to NILECJ-STD-0206.00 and EIA Standard RS-329.

(5) If the Specifications call for hardware or workmanship in excess of that called for in any of the above referenced documents, the Specifications shall take precedence.

3. GENERAL INSTALLATION REQUIREMENTS

(1) All work and material shall be in full conformance with the requirements of the Purchaser, the National Board of Fire Underwriters, the National Electrical Code, and any other applicable regulations or ordinances. Whereever the Specifications call for material, workmanship, arrangement or construction of a quality superior to that required in any of the above rules and regulations, the Specifications shall take precedence.

(2) All materials and equipment shall be new and as modern as the state of the art permits; be neat in appearance, and reflect good workmanship. There shall be no exposed wires or cable except handset or similar connecting cords.

4. PERMITS

(1) Procurement of bonds, licenses and/or permits necessary for authorization of the work shall be the responsibility of the Contractor.

5. WARRANTY

(1) The equipment furnished herein shall be warranted for both parts and labor for a period of one year after acceptance, except for incandescent indicator lamps, vacuum tubes, etc., which normally carry the manufacturer's Electronic Industry Associates ninety-day warranties.

6. SYSTEM DEMONSTRATION

(1) Manufacturer shall be prepared to demonstrate to the satisfaction of the customer or a duly appointed representative of the customer that the equipment meets the requirements of the Contract Documents.

7. FACTORY INSPECTION

(1) The Contractor shall employ a quality inspection system adequate to ensure that all equipments described in this Specification are manufactured in accordance with the details of this Specification and the applicable referenced specifications. The customer or his designated representatives will have the right to view any or all of the factory testing as well as sample procedures of factory manufacturing processes.

APPENDIX B

CAPITAL SCIENTIFIC CORPORATION
2607 Connecticut Avenue, N.W.
Washington, D.C. 20008

GENERAL SPECIFICATION REQUIREMENTS

FOR

LOW-BAND BASE STATION TRANSCEIVERS

1.0 GENERAL

(1) This specification covers VHF low-band (25-50 MHz) radio transceivers intended for operation as base stations at a fixed location.

(2) The radio operating frequencies, the numbe· of channels of operation, the operating frequency of each channel, channel search requirements where employed, tone frequency(s) for the continuous tone-controlled squelch system if employed, power output, etc. of the unit(s) are set forth in the Equipment and System Specifications. Antenna requirements are set forth in Equipment and System Specifications. Any exceptions to these General Specification Requirements are also set forth in the Equipment and System Specifications.

2.0 APPLICABLE STANDARDS AND PUBLICATIONS

(1) Applicable portions of the following publications of the issue in effect on date of Invitation to Bid shall be a part of this specification.

- Federal Communications Commission Rules and Regulations (FCC Rules)

  Code of Federal Regulations Title 47, Chapter 1, Part 89 - Public Safety Radio Services. (In the event of any conflict between this specification and the FCC Rules regarding performance requirements, the more stringent of the two shall apply).

- Electronics Industries Association (EIA) Standards

  RS-152-B Land-Mobile Communication FM or PM Transmitters 25 to 470 MHz.

  RS-204 Minimum Standards for Land-Mobile Communication FM or PM Receivers

RS-220 Continuous Tone-Controlled Squelch Systems (CTCSS)

RS-237 Minimum Standard for Land-Mobile Communication Systems using FM or PM in the 25-470 MC Frequency Spectrum

- National Electrical Manufacturers' Association (NEMA)

- Institute of Electrical & Electronic Engineers (IEEE)

(The requirements of this specification shall supercede any conflicting requirements of the EIA, NEMA or IEEE Standards).

- National Institute of Law Enforcement and Criminal Justice Standards

NILECJ - STD - 0201.00 Fixed and Base Station FM Transmitters

NILECJ - STD - 0206.00 Fixed and Base Station FM Receivers

(2) In the event of any conflict between the requirements of the above publications and this Specification, the requirements of this Specification shall take precedence.

3.0 REQUIREMENTS, BASIC UNIT

3.1 GENERAL TECHNICAL REQUIREMENTS

3.1.1 Physical Description

(1) Base station cabinets shall be formed of welded cold-rolled steel and shall be finished in baked enamel. A cabinet formed of equivalent strength plastic or other material will be considered acceptable only if it can be shown that it will provide the same, or a greater, degree of electromagnetic shielding than would be provided by a steel cabinet. Mounting facilities shall be provided inside the cabinets for standard 19" rack-type equipment chassis. Access, either front or rear or both as applicable, to components mounted within the cabinet shall be by means of a full-length door. Doors shall be fitted with key locks to prevent unauthorized personnel from entering and tampering with the radio-set chassis mounted within the cabinet. Floor-mounted cabinets shall not exceed 72" in overall height.

3.1.2 Power Supplies

(1) All rectifiers and regulating circuitry in the power supplies shall be solid-state.

(2) The power supplies shall operate from a nominal 110 volts, 50 to 60 Hz, AC primary power source and shall furnish all operating voltages. All power rectifiers employed shall be mounted on the chassis in such a way as to allow maximum air circulation for ventilation of power supply components.

(3) Transmitters, receivers, and control facilities shall operate within EIA Specifications at rated voltages ±10%, in accordance with Paragraph 3.2.3 of EIA Standard RS-237 and shall be capable of starting and operating for short periods of time without damage of the equipment at rated voltage ±20%.

3.1.3 Continuous Tone-Controlled Squelch System

(1) Unless stated otherwise in the Equipment and System Specifications, the radio sets shall have continuous tone-controlled squelch systems designed to minimize reception of co-channel nuisance noise and skip interference. The tone-controlled squelch system shall keep the receivers muted at all times except when an RF carrier continuously modulated by a particular tone signal is received. Narrow-band tone channels shall be available below 200 Hz with frequency spacing not to exceed 3.6%. The quantity and frequency of these tone channels shall be in accordance with EIA Standard RS-200. Tone frequency determining elements shall be hermetically sealed plug-in units, interchangeable regardless of frequency and without any type of adjustment. The tone frequency shall be stable within ±0.5% of its specified frequency over the radio equipment temperature range from -30° to +60°C.

(2) There shall be two modes of squelch operation available for selection. These are 1) carrier squelch operation in which the receiver squelch circuit opens for any sufficiently strong on-frequency RF carrier, and 2) tone-actuated squelch operation in which the receiver squelch circuit opens only when the incoming on-frequency RF carrier is modulated by a continuous subaudible tone of a particular frequency for the particular receiver.

3.1.4 Remote Control Interface Unit

(1) Remote control interface units, to be located within the equipment cabinets of remotely controlled units, shall operate into standard 2-wire and 4-wire telephone lines and shall, in every way, meet telephone company requirements and specifications with regard to output level, DC control voltages, line balancing, impedance matching, hum, and distortion. The interface units shall provide for unattended, remote control by control voltages or tones, and extended local control operation. Local control of the transceiver base station units shall also be possible.

(2) The remote control interface units located within transceiver equipments shall be capable of performing the following functions:

a. Maintain constant audio levels automatically.

b. Provide continuous protection against transmitter back-on in the event of control line outages.

3.1.5 Adjustments

(1) To facilitate servicing, tuneable circuit adjustments shall be readily accessible. Adjustments shall be possible without the necessity of special patch cords or intercabling.

3.1.6 Frequency Control

(1) Non-heated quartz crystals shall be employed to control both the transmitter and the receiver frequencies. Crystal oscillators shall be housed in a sealed, factory-adjusted, plug-in module to assure precise frequency control. To meet or exceed FCC Regulations, the oscillator modules shall maintain frequency stability within ±0.0005% of the assigned center frequency over an ambient temperature range of -30°C to +60°C (+25°C reference). An adjustment shall be included to permit setting oscillator units to the exact operating frequency.

3.1.7 Metering

(1) All metering and alignment shall be readily accomplished with a standard external single-scale 0 to 50 microampere, 20,000 ohms per volt volt-ohm-millimeter, and associated metering plugs. All

points essential to checking and tuning the radio set shall be properly shunted and connected to multi-pin connectors to facilitate routine maintenance.

3.1.8 Controls and Adjustments

(1) The following minimum number of control functions shall be accessible at the equipment cabinet:

a. Power on-off switch

b. Volume control

c. Channel selector (if applicable)

d. Squelch adjust

e. Line level (if applicable)

f. Microphone and speaker

3.2 TRANSMITTER TECHNICAL REQUIREMENTS

3.2.1 Type Acceptance

(1) The transmitter shall be rated for continuous-duty service and shall be "type accepted" by the Federal Communications Commission. Transmitter emission shall be designated 16F3 as defined in FCC Rules and Regulations Part 2, Subpart C.

3.2.2 Modulation

(1) In accordance with FCC Rules and Regulations, the transmitters shall include an instantaneously-acting deviation-limiter circuit. This circuit shall have a continuously variable control to permit setting transmitter deviation to any predetermined limit between 0 and ±5 KHz.

3.2.3 Signal Quality

(1) When measured according to EIA Standard RS-152B, transmitter specifications shall be:

a. Spurious and Harmonic Radiation - attenuated at least 85 dB below the RF carrier level.

b. Audio Distortion - Less than 3% at 1000 Hz test tone at 2/3 maximum deviation.

c. FM Noise and Residual Hum - At least 55 dB below 2/3 maximum deviation at 1000 Hz as measured through a standard de-emphasis circuit of 6-dB-per-octave.

d. Audio Response - At any input frequency from 3000 Hz to 3 KHz, the audio frequency response shall not vary more than +1 or -3 dB from a true 6 dB/octave pre-emphasis characteristic as referred to the 1.0 KHz level (with exception of a 6 dB per octave roll-off from 2.5 KHz to 3 KHz).

3.2.4 Tone Generators

(1) The radio sets with continuous tone controlled squelch systems shall include tone generators to modulate the transmitters in accordance with the requirements of EIA Standard RS-220. The tone-generating elements shall maintain frequency stability of within ±0.5% of its specified frequency over the radio equipment temperature range from -30° to +60°C. The tone generating elements shall be hermetically sealed and shall be a plug-in type unit so that tone frequency can be changed merely by plugging in a different tone-generating element without any type of adjustments.

3.2.5 Frequency Separation

(1) Multiple frequency operation with a frequency separation of up to 0.4% shall not degrade the transmitter output power level as compared to single frequency power output level.

3.2.6 Transmitter Duty Cycle

(1) The transmitter shall deliver full output power when operated on a 20% duty cycle per EIA RS-152-B, Paragraph 2.2.13.1.

3.2.7 Output Impedance

(1) The transmitter output shall match nominal RF impedance of 50 ohms.

3.3 RECEIVER TECHNICAL REQUIREMENTS

3.3.1 Types

(1) The receiver shall be of the superheterodyne type with crystal-controlled local oscillators. The circuit shall use high-quality, long-life transistors and diodes throughout; no tubes shall be used.

3.3.2 Selectivity

(1) Major selectivity elements shall precede the major gain determining elements to minimize effects from signals on other channels.

(2) A signal displaced to an adjacent channel center frequency from the receiver tuned center frequency shall require at least 85 dB greater power level than the "on-channel" power level to reduce a center frequency 12 dB SINAD to 6 dB SINAD.

3.3.3 Quieting Sensitivity

(1) An "on-channel" signal of 0.4 microvolt or less, when impressed across the antenna input, shall produce 20 dB of noise quieting in accordance with EIA Standard RS-204, Section 4.

3.3.4 Usable (EIA-SINAD) Sensitivity

(1) Usable sensitivity shall be at least 0.35 microvolt for a 12 dB ratio of signal plus noise plus distortion-to-noise plus distortion, in accordance with EIA Standard RS-204, Section 3.

3.3.5 Modulation Acceptance

(1) The modulation acceptance bandwidth of the receiver shall be at least ±6 KHz when measured in accordance with EIA Standard RS-204, Section 6.

3.3.6 Spurious and Image Rejection

(1) The spurious and image signal rejection at the usable sensitivity level shall be at least 100 dB when measured in accordance with EIA Standard RS-204, Section 8.

3.3.7 Audio Power Output

(1) The audio stages of the receiver shall deliver an output of at least five watts into a matching resistive load as measured at the receiver output terminals, as specified in EIA Standard RS-204, Section 10. Audio distortion using a 1000 Hz test tone shall be less than 5%. All noise and residual hum shall be at least 55 dB below the rated audio output level.

3.3.8 Audio Response

(1) Audio frequency response shall be within +1, -3 dB of the normal 6-dB-per-octave de-emphasis characteristic from 300 to 3000 Hz, measured in accordance with EIA Standard RS-204, Section 11.

3.3.9 Intermodulation Products

(1) At least 65 dB below the receiver center frequency response.

3.3.10 Impedance

(1) Receiver RF input impedance shall be 50 ohms.

3.3.11 RF Circuits

(1) Tunable circuitry shall be used ahead of the first RF amplifier for reduction of off-channel interference. This circuitry shall be highly selective and shall result in the reduction of interference on both the high and the low side of the incoming receiver RF carrier frequency.

3.3.12 Frequency Separation

(1) Multiple frequency operation with a frequency separation of up to 0.4% will not degrade the receiver sensitivity as compared to single frequency operation.

3.3.13 Limiters

(1) There shall be at least two low-frequency IF stages preceding the discriminator stage to reduce amplitude modulated interference.

3.3.14 Carrier Squelch Circuit

(1) The carrier-actuated squelch circuit shall be of the noise compensated, adjustable-sensitivity type. At the threshold setting a signal of 0.25 microvolt or less shall provide squelch opening. The squelch circuit shall be designed so as not to respond to noise bursts. With an on-frequency signal at the receiver input, the squelch control set at the threshold and the audio modulation adjusted and held constant at the maximum-rated system deviation, the sensitivity of the squelch circuit shall not exceed the rated threshold sensitivity at the modulation frequency is varied over the range 300 to 3000 Hz. The squelch sensitivity control shall provide a minimum of 20 dB adjustment range in direction of decreasing receiver sensitivity starting from maximum squelch point.

3.3.15 Tone-Actuated Squelch Circuit

(1) If the transceiver includes a continuous tone-controlled squelch system, the tone-actuated squelch circuit shall be controlled by electromechanical resonant reeds or active solid state filters and shall comply fully with EIA Standard RS-220. Squelch sensitivity shall be fixed at less than 6 dB of receiver quieting.

3.3.16 Accessibility

(1) All receiver components and circuitry shall be accessible from the front of the cabinet or rack by means of a fold-down shelf, swing-out panel, or similar device for fast and convenient trouble shooting and service. All tuning shall be from the front of the unit and shall not require special tuning devices.

3.3.17 Pulse-type Noise Suppressor

(1) The equipment shall include pulse-type noise suppression circuitry. With the noise suppressor switched in and the receiver subject to a pulse-type noise interference that would otherwise degrade the 20 dB noise quieting level of the receiver by 50 dB, the 20 dB noise quieting level shall be within 6 dB of what is normal for the receiver with the noise suppressor switched out and no pulse-type noise interference present.

3.3.18 Monitoring Facilities

(1) It shall be possible to monitor the receiver with a speaker which can be switched in or out as desired.

4.0 DOCUMENTATION

(1) Complete documentation shall be supplied with each item of equipment. This documentation shall include but not necessarily be limited to the following items:

a. One copy of a complete maintenance and operations manual for each item of equipment delivered.

b. Where basic components are interconnected to form a system, a system interconnection diagram showing functions of all switches and routing of all signals along with a clear explanation of system operation shall be supplied.

(2) Three complete sets of "as built" drawings shall be supplied by the Contractor upon completion of installation. These shall include both vertical and plain views of the actual installation, and it shall identify the location of each interface point, including power, audio and control circuits. The location of each terminal block or other point of interface shall be clearly indicated and the identity of each binding post or other type of interface connection be shown on the drawings.