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Guide to Computer-Aided Dispatch Systems

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FOREWORD

The application of advanced technology by law enforcement and criminal justice agencies continues to grow, driven by both the desire to enhance capabilities and the need to improve operational efficiency resulting from increasing demands upon limited resources. The Law Enforcement Standards Laboratory (LESL) was established at the National Bureau of Standards to conduct research that will assist criminal justice agencies in the cost effective procurement of quality equipment. To accomplish this objective, LESL conducts research and subjects commercial equipment to laboratory testing to develop voluntary national equipment standards, technical reports, and user guides.

This guide is directed primarily toward police departments that are contemplating the acquisition of a computer-aided dispatch (CAD) system or are in the planning phase in advance of procuring such a system. The information contained in this guide will provide a basic understanding of CAD systems and operations including equipment components, software, and information storage and display. The guide draws heavily upon the experience of many departments that have installed CAD systems to highlight those factors that are critical to system design, equipment selection, procurement, installation, and training.

Additional reports and guides as well as other documents are being issued under the LESL program in the areas of protective equipment, communication systems, security systems, weapons, emergency equipment, investigative aids, vehicles, and clothing. A list of all LESL publications is available upon request.

Technical comments and suggestions concerning this guide are invited from all interested parties. They may be addressed to the Law Enforcement Standards Laboratory, National Bureau of Standards, Gaithersburg, MD 20899.

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Guide to Computer-Aided Dispatch Systems

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This guide provides current information on computer-aided dispatch (CAD) systems as they are used by law enforcement and other public-safety agencies and is intended to serve as a procurement aid to those persons who are or will be involved with the planning and acquisition of a CAD system. Topics such as the improvements in operations that may result from installation of a CAD system, a description of the system components, various considerations that will require resolution when the decision is made to purchase a CAD system, and provision of sufficient background to enable a knowledgeable purchasing decision to be made are addressed. A general purchase implementation plan is included also.

Key words: command and control; communications: complaint operator; computer-aided dispatch; dispatcher; hardware; software.

INTRODUCTION

Prior to the 1970's the dispatching facility for police, fire, and other public-safety agencies almost always used manual methods. Where the population base being served was small-to-medium in size, say less than a population of 100,000, this worked and still may work well. But for larger populations, the ability of the dispatching personnel to be familiar with the increased number of street locations or to keep up with the increased amount of record-keeping had become progressively more difficult. Thus, when computer systems of sufficient capability and affordable price became available, they began to be employed to automate some parts of the dispatching operation.

Computer-aided dispatch (CAD) systems were first used in law enforcement operations in the early 1970's and their implementation, and use has increased steadily since. Whereas in 1975 only about 10 percent of the 135 police departments in jurisdictions of more than 100,000 population had a CAD system [1][1], by 1980 a little over 50 percent of these departments had operational CAD systems, and at least nine municipalities with populations under 100,000 had installed them [2]. A recent listing of 64 jurisdictions with operational CAD systems or systems under test included 13 serving populations of 100,000 or less [3]. This extraordinary growth seems to have occurred because a CAD system utilizes the special abilities of the computer to service calls from the public rapidly and efficiently and, in so doing, provides several significant dispatch operation improvements, e.g., improved information exchange within the dispatching system, automatic verification of certain information, and generation of case reports.

An excellent and wide-ranging document on CAD systems was prepared in 1975 by the Jet Propulsion Laboratory for the Law Enforcement Assistance Administration [1]. This publication is intended to summarize, supplement, and update the information given in that report as an aid to those persons who are or will be involved in the planning and acquisition of a CAD system. This planning involves such topics as the improvements in operations that may result from installation of a CAD system, a description of the system components, various considerations that will require resolution when the decision is made to purchase a CAD system, and sufficient background to enable a knowledgeable purchasing decision to be made. The reader should note that this report assumes that the major components of the overall system, such as a satisfactory communication's system, telephone system, and information system already exist. A general purchase implementation plan is given and a glossary of frequently used terms is attached as appendix A.

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[1]Numbers in brackets indicate the literature references at the end of this report.

BENEFITS PROVIDED BY A CAD SYSTEM

A CAD system that has been well planned and designed for the jurisdiction it is intended to serve can provide many improvements to the complaint-taking and dispatching operations of a police or fire department, and thereby to the public it serves. However, it should be clearly understood that a CAD system cannot and is not intended to take the place of the human aspect of the command and control operations· rather, it is intended to supplement it by performing certain routine and repetitive tasks quickly and without error, storing the information for future reference, and retrieving it essentially instantaneously.

Specifically, one benefit which should accrue from use of a CAD system is improvement of the accuracy of the information handled between the complaint taker and the dispatcher, and between the dispatcher and the officer on patrol. The computer is capable of analyzing information as it is put into or transferred within the system, and the computer will automatically signal for errors such as an incorrect case number or an improper patrol unit designation. Some systems, if equipped with the appropriate software, can compare an address with an address file to check for its validity and correctness.

Use of a CAD system, over the long run, should improve operator performance by providing relief from many tedious tasks. For example, when an address is entered into the system, the computer can automatically determine which police precinct it is in and display this information on the complaint operator's screen. Or when a complaint is telephoned in, the computer can automatically determine whether a case file has already been set up for this particular complaint. Thus, the complaint operator and dispatcher are better able to concentrate on the more critical decision-making aspects of their jobs.

Another advantage of a CAD system is that the properly-designed system is capable of responding quickly and accurately· thus, certain tasks can be added to the complaint operator's and dispatcher's routines with little or no loss in response time [4]. For instance, the computer in a CAD system can be used to quickly check its file to ascertain whether any previous incidents have occurred at the address where the current report is coming from. If a number of incidents have occurred at this location, it would be beneficial to a police officer's safety to have this information prior to arrival on the scene. Such a check would probably not be carried out using a manual system, because it would clearly increase the response time required to handle a complaint as well as decrease the number of calls a dispatcher could handle. Note that a CAD system cannot substantially reduce the time it takes an operator or dispatcher to process a complaint from an individual. There is a minimum amount of time needed to simply exchange information between two persons, and no computer is capable of reducing the time needed to accomplish this task. However, a well-designed CAD system can assist the operator by organizing questions to limit the time spent querying each caller.

Use of a CAD system is an efficient way to keep track of incidents and their status and the number of patrol cars available and their current status (i.e., those responding to an incident, on the scene, on patrol, etc.). Such information gives a dispatcher almost instantaneous knowledge of the events taking place within a jurisdiction and of available resources. Thus, as new complaints come in, the dispatcher is capable of accommodating them more efficiently and effectively.

Finally, a CAD system can generate certain reports thereby resulting in a decrease in paperwork for almost all groups in a police department [5]. Because it stores records of all cases, it is capable of either generating case reports on routine cases or generating the routine portions of a case report which require additional details from the patrol unit officer(s). The dispatch unit supervisor can use the CAD system to generate activity reports for each shift, and management can use it to generate statistical reports, sorting incidents by type, area, patrol unit, time of day, date, or any other useful classification. These accumulated data can then be used to balance workloads, redesign beats, and better manage manpower and financial resources [4].

In fairness, CAD systems are not without disadvantages. Complaint board operators and dispatchers require extra training to learn the skills necessary to operate the CAD system [6]. Additionally, significant initial funding and careful planning is needed to procure and initiate operations. Additional physical facilities and maintenance

agreements may be required before a CAD system can be installed and become operable. The computer may need a special uninterruptible power supply or a back-up power source in case of a power failure. Also, any problems which may arise with the computer and/or the software systems often can be resolved only with professional help. This complication was highlighted in reference 7. But it would appear from the growth in use of CAD systems since their inception that their benefits far outweigh their disadvantages. In fact, many jurisdictions are already in the process of purchasing a second-generation system, primarily because of increased demand for service.

HOW A CAD SYSTEM OPERATES

The operation of a CAD system can best be understood by following a hypothetical call for assistance through the complaint and dispatch phase of the police operation. The telephone call is forwarded to the police communications center and is routed to an available complaint board operator, whose responsibility it is to obtain from the caller all of the information needed to enable the police to respond to the complaint. This information will include items such as names, addresses, and a description of the problem. It is here, at the complaint board operator's position, that the CAD system begins its functions.

When a telephone call for assistance comes in to the complaint operator's work station (see fig. 1a), the complaint operator will press a special-function key on the keyboard. This action will cause the computer to display a questionnaire on the screen of the cathode-ray tube (CRT) display terminal. A typical screen display is shown in figure 1b and, as can be seen, the operator simply needs to fill out the "form" in the top third of the screen by asking the caller for the information needed. The CAD system provides assistance here and automatically supplies some of the information based on other information provided by the caller; for example, when the caller gives a street address, the computer will automatically search its geographic file to see if such an address actually exists. If not found, it will signal the operator to ask for a correct address. Once a valid street address is typed into the system, the computer will determine what police precinct, beat, or other appropriate designation covers that address and display this information on the complaint board operator's screen.

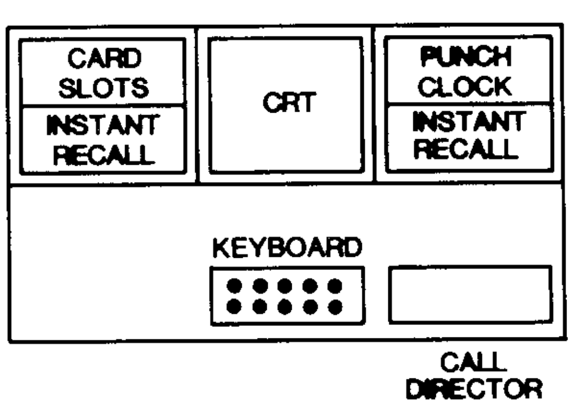


Figure 1a. Complaint board operator work station [1].

```
**********************************************************************
**********************************************************************
***                                                                ***
**          ***A13 INVALID STREET TYPE/DIRECTION - MAKE SELECTION   **
**  1.NO:49     2.STREET:NOKOMIS                       3.CITY:...   **
**  4.AP:...  5.FL:...  INT:..........      6.ROUTE:...  7.PZN:.... **
**  8.NTR:..... 9.PRI:. 10.AC:....   11.FZN:...12.EZN:...  13.OZN:.... **
**  14.SRC:... 15.CLR:.............. 16.PH:....... 17.AD:............... **
**  18.REM:................................................          **
**  19.REM:................................................          **
**                                                                   **
**                                                                   **
**                                                                   **
**  VALID TYPE/DIRECTION - CHOOSE ONE                                **
**  A - AV S                                                         **
**  B - CIR                                                          **
**  C - CT                                                           **
**  D - LA                                                           **
**  E - PKWY E                                                       **
**  F - PKWY W                                                       **
**                                                                   **
**  P-1-1322-ROBBRY-2613-GARFIELD-SO---A-2-1317-DOMEST-1575-JAMES-ST-NO----  **
**  D 1 1321 ALARM  1316 CEDAR ST       Q 3 1316 VANDAL 5200 31ST AV        **
**  P 3 1320 THEFT 3550 QUEEN AV SO     P 3 1315 PARTY  59 7TH AV           **
**  A 2 1319 BRGLRY 6115 FRANCE SO      D 1 1314 FIRE   15TH AV/HIAWATHA ST **
**  P 2 1318 PRWLER 425 5TH AV SO       D 1 1313 CRDIAC 257 ADAMS ST NE     **
**                                          **MP**     QUERY                **
***                                                                        ***
******************************************************************************
******************************************************************************
```

Figure 1b. Typical format of complaint board operator's CRT screen. (Note the fill-in-the-blanks information-gathering form shown on the top third of the screen (in italic type) and the list of recently entered incidents on the bottom third.)

If a street address acceptable to the CAD system cannot be provided, then the complaint board operator is able to override the computer's response and proceed. (This override feature is very desirable in a CAD system, since it enables the operator to correct for errors and omissions in the CAD system programs and data base, and to supply updated information.) After having obtained all (or most) of the information needed from the telephone caller, the complaint board operator pushes another special-function key on the keyboard which commands the computer to create an event file complete with the operator's data, with the current date and time automatically added. Since the CAD system now "knows" the street address, it will also automatically transfer the event data to the dispatcher handling the area where the event occurred.

The dispatcher's work station, shown in figure 2a, generally has two CRT screens, as he/she needs more information available at one time than does the complaint board operator. The dispatcher's primary screen is the one on the left (fig. 2b) and is used for the actual dispatching process. The screen on the right (fig. 2c) shows the status (available, enroute to the scene, at the scene, or out of service) of all of the field units for which the dispatcher is responsible. The CAD system also keeps track of how long each responding unit remains in the active status, and can alert the dispatcher if the time is unreasonably long, a possible indication of trouble.

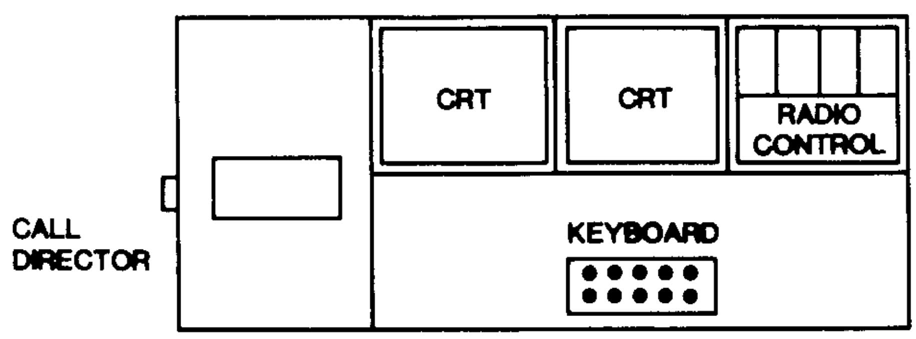


Figure 2a. Dispatcher work station [1].

```
 ***************************************************************************
****************************************************************************
***                                                                      ***
**  540,550
**  AD:1575  JAMES AV S  APT:3A  FLR:3     AT:16:52  FROM:C04  NO:327      **
**  NTR:ROBBRY PRI:1     INT:50TH ST W   ZONE:504   ROUTE:    MAP:1234 ESN:123**
**  SRC:CIV CALLER:      PH:             AD:                               **
**  REM:STRANGER SEEN ENTERING ADJACENT APARTMENT   EE/16:53/327           **
**      VICTIM BLEEDING--BURNING ODOR               MORE UE/16:55/579      **
**  HAZ: KNOWN DRUG USER HANGOUT IN APT 6 3RD FLR      05/09/79     MORE   **
**  DSPTCH STATUS: POLICE/   /  :  FIRE/DPCH/16:54 EMS/ARRV/16:56          **
**  RECOMMENDED DISPATCH:  540*   530*   571   504                         **
**                                                                         **
**                                                                         **
**                                                                         **
**                                                                         **
**                                                                         **
**                                                                         **
**                                                                         **
**                                                                         **
**                                                                         **
**  1-08:31-1318-ALARM--P-29-CEDAR-ST-----3-06:45-1254-VANDAL-P-425 5TH-AV-S  **
**  1 08:37 1322 ROBBRY P 1575 JAMES AV   3 07:00 1302 THEFT  Q 355 7TH ST    **
**  2 07:18 1240 DOMEST P  575 GRAND AV                                      **
**  2 07:33 1255 BRGLRY P 6115 FRANCE S                                      **
**  3 06:41 1238 PARTY  Q 5200 31ST AV **440                                 **
**  PEND TOT: P0=0  P1=2  P2=2  P3=3  P9=0  MORE **MP** *MDT* QUERY OVERDUE   **
***                                                                        ***
 ***************************************************************************
  *************************************************************************
```

Figure 2b. Dispatch screen of the dispatcher. (Note that the upper third of the screen displays the information for the incident currently being dispatched [in italic type], and that the bottom third of the screen displays a list of incidents waiting to be dispatched.

```
*****************************************************************************
******************************************************************************
***                                                                        ***
**  UNIT  NATURE STAT  LOCATION          UNIT   NATURE STAT  LOCATION       **
**  302                                  560*                               **
**  304                                  570*   ACC-PI A10   2931 W 58TH ST **
**  305                                  571                                **
**  307*                                 592                                **
**  310*  ASSALT A02 LAKE ST/40TH AV     602                                **
**  311                                  604                                **
**  320A*                                605                                **
**  330                                  607*                               **
**  340F                                 610A*  INFOR  A02   3636 FRANKLIN E **
**  350                                  611                                **
**  360                                  620*                               **
**  370*  HDQTS  D12                     630*                               **
**  371A*                                640*                               **
**  382                                  641                                **
**  392                                  650*                               **
**  504                                  660*                               **
**  505                                  670*                               **
**  510*                                 671                                **
**  520*  DOMES  E02  XERXES AV S        672                                **
**  530                                  935                                **
**  540*                                 1280                               **
**  550*                                 1902                               **
**  551                                    000 ADDITIONAL UNITS FOR THIS AREA **
***                                                                        ***
******************************************************************************
*****************************************************************************
```

Figure 2c. Status screen of dispatcher.

The dispatcher's primary screen shows all known information about the incident now waiting for the dispatcher's attention. This includes the information that was obtained by the complaint board operator, plus additional information that the computer added from various data files that are part of the system. Also, the incident record now includes a computer-selected recommendation of several field units that are suitable for responding to the incident. The dispatcher either may select one of these or may act on his own judgment and send a different unit (another example of human judgment being allowed to override the computer system). The actual dispatching is done either by voice over police radio or by a computer-controlled digital message that is sent over a radio channel allocated specifically for digital transmissions.

When a field unit has been assigned to respond to an incident, the primary job of the CAD system is almost done. All that remains is for it to update the status of the responding field unit as events progress from "enroute" to "at the scene" to "incident closed" and back to "available." It also will add to the incident's record any additional information and may perform any follow-up activities required by the particular jurisdiction. This might include requests for warrants, vehicle information, and travel details.

A possible physical layout of a CAD dispatch center is shown in figure 3. The number of personnel and equipment shown is only illustrative and is not meant to imply this is the typical number required. These needs are determined by the requirements of the individual department procuring the system. The main determining factors seem to be average waiting time before a caller is connected to an operator, average processing time per call, peak number of calls per hour, and actual time spent by the operator processing calls during the peak hour. A more detailed discussion of the considerations of sizing a CAD system is given in appendix B to this report. Due to the noise levels produced by processors, disk drives, and printers, several departments have decided to physically separate the hardware components from the room where communications operations are being performed.

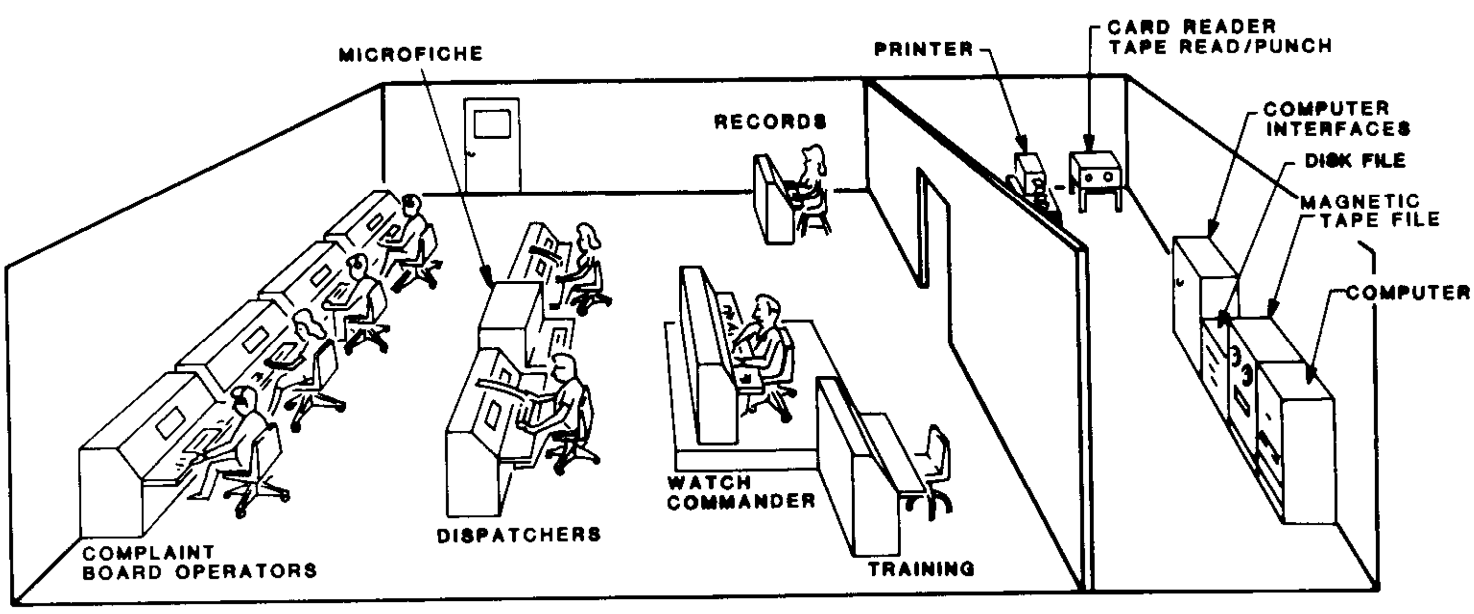


Figure 3. Typical computer-aided dispatch center [1].

COMPONENTS OF A COMPUTER-AIDED DISPATCH SYSTEM

Hardware

The major hardware components of a CAD system are:

1) Cathode-ray tube (CRT) terminal
   a) keyboard
   b) CRT display
2) terminal-to-computer data channel
3) computer
   a) central processor unit (CPU)
   b) memory
4) mass storage (external memory)
5) printers
6) power source

The following discussion will focus on each of these elements. A simple block diagram of the hardware elements of a CAD system is given in figure 4.

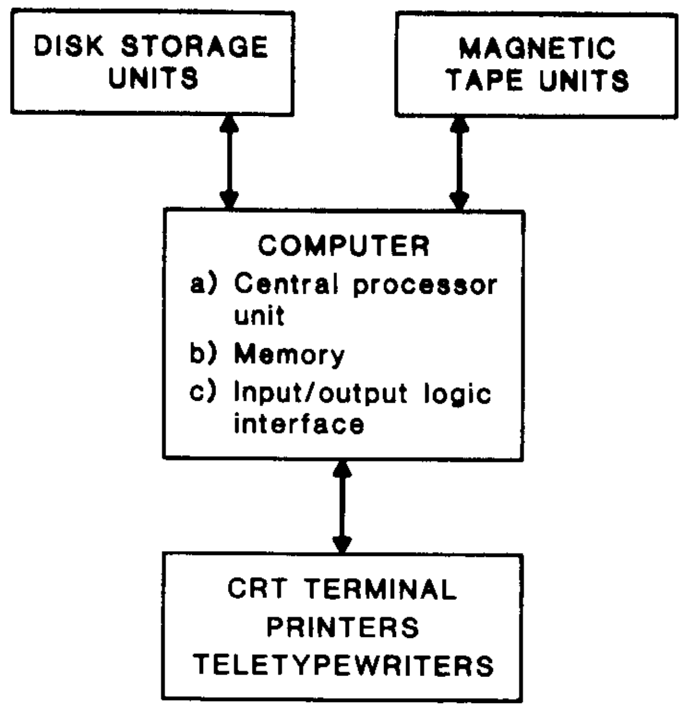


Figure 4. Simple block diagram of the hardware components of a CAD system.

CRT Terminal

Basically, a CRT terminal consists of a typewriter-like keyboard for entering information and a television-like screen which displays the information being entered into the CAD system by the complaint board operator and also transmitted by the dispatcher to the field unit. The only major consideration for the buyer is that the CRT terminal must be compatible with the particular hardware and software being used.

Keyboard

The purpose of the keyboard of a CRT terminal is to enter commands and information into the CAD system. The keyboard consists of a standard typewriter keyboard plus a number of additional keys, called function keys, which make it easier to give commands to the computer. Thus, while an ordinary typewriter has approximately 50 keys, the keyboard of the CRT terminal will have, in addition to these 50 keys, anywhere from less than a dozen to three dozen function keys. The alternative to using a function key is for the user to type an appropriate command code into the system via the standard typewriter keyboard. For example, if the desired command were NEXT PAGE, the correct code might be the character-string NP. After typing these two characters, the user would then press the RETURN key, and the computer would perform the task requested. If the function key were not used, the user would have to memorize (or look up) the command code as well as use three key strokes instead of just one. Obviously, dependence on an operator's memory can introduce a source of error and result in lost time.

There is no standard rule or practice governing the number of function keys that should be employed. At a minimum, each of the more important and/or frequently used commands should be assigned a special key in order to save time and reduce errors. The decision as to which commands will merit a function key will depend upon the specific CAD system, the system designers, and user preference. It should also be noted that an excessively large number of function keys may be self-defeating, because it then becomes difficult and time-consuming to locate the desired key.

Another important consideration concerning the keyboard is the presence or lack of tactile or audible feedback when a key is pressed. Tactile feedback means that the fingers can sense a distinct change in the key force as they "break through" the transition region during the keystroke. Audible feedback, which might annoy some people, is usually a short beep that is used to indicate that a keystroke has been accepted by the terminal. The benefit of some form of feedback is that it provides a positive indication to the user that the terminal has "recognized" the keystroke. Tactile feedback is generally recommended; audible feedback is an option that is a matter of personal preference.

Most keyboards on a CRT terminal have a long life if not abused. The most common hazards seem to be striking the keys too forceably and spilling liquid or ashes on and into the keyboard and its mechanisms.

CRT Display

Just as the keyboard is the means by which instructions and information are entered into the computer system, the CRT display is the quickest means to get information from the system. A monochrome (single color) CRT display is generally used in a CAD system. Full-color displays are seldom used in a CAD system or in any other situation where it is necessary to display a large amount of text. The reasons for this appear to be twofold. First, the spatial resolution of a monochrome CRT display is much better than that of a full-color variety. Second, the cost of a full-color display has been more than double that of a monochrome display. However, it should be noted that at least one jurisdiction effectively uses color displays to indicate unit status and emergency situations. In this case, use of several colors saves valuable text space on the screen and interpretation of the meanings of the colors becomes automatic for well-trained operators.

The typical CAD system terminal has a 30 or 37.5 cm (12 or 15 in) screen (diagonal measurement). The display usually produces 24 lines of text of 80 characters each (24x80 = 1920 characters). This is the industry standard at present, and represents the accepted trade-off between price and performance. However, the use of 24-line displays is definitely a handicap because abbreviations and space-saving screen formats must be freely used in order to display the amount of information that the users need. In addition to this, the dispatcher's work station requires the use of two display screens in order to display the minimum amount of information needed to ensure optimum performance. Terminals are available where the screen can display more than twice this number of characters, but their cost is higher.

Monochrome CRT displays have been found to be relatively free of technical and safety problems. With respect to safety, there are almost no problems. X-ray radiation (from the high voltage electron beam striking the phosphor screen) has proved to be negligible, provided that the high-voltage supply does not exceed the voltage specified by the CRT manufacturer (for a 12-in screen, usually between 11,000 and 14,000 V). The high-voltage components are well insulated, and a person would have to make a positive effort to create an electrical shock hazard.

Nearly all health-related complaints about CRT displays have nothing to do with the display itself, but rather are problems that develop from the way that it is used. The problems, when they occur, are usually caused by the combined stresses of sitting for hours at a CRT terminal and having an unsatisfactory work environment or work habit. For example, complaints of eye strain or back pain might actually be caused by improper display contrast or poor posture, respectively. Most eyestrain problems would be minimized if satisfactory choices were made for the following:

1) Eye-to-screen distance such that the eyes can focus comfortably;
2) Contrast of the display set at a comfortable level--not too high or too low;
3) Reflections from the screen minimized; and
4) Work sessions set up such that adequate rest periods are provided for personnel.

With respect to eye-to-screen distance, it is only necessary that each user find out the distance at which his/her eyes can comfortably focus on the screen. It may be useful to be aware that the characters on the screen are larger than those on an ordinary typewritten page, so it is not desirable to sit too close to the screen.

The contrast of the CRT display (i.e., the relative brightness of the characters with respect to the brightness of the background) should be set to a visually comfortable value. It is common to find that users set the contrast and/or brightness controls to produce very bright characters. This not only shortens the life of the CRT display but also promotes user eyestrain. When the contrast is too low or too high, eye comfort is likely to be affected at some point. As a guide, the contrast provided by an ordinary printed page is about right for minimum eye strain.

Minimizing the amount of glare and other reflections from the face of the screen requires several steps. The first step is to make the room brightness fairly low (this is commonly done at CAD system installations). and check to see which lights or other bright or shiny objects produce too much interference with the CRT display. If reflections cannot be prevented by appropriate positioning of the trouble source or the CRT screen, then an optically diffusing CRT faceplate. an optical filter, or a shading hood can do much to reduce the problem. Anti-reflective coatings and polarizing films also are now available and are quite effective. Use of a diffusing faceplate is quite common, and is effective because it scatters the unwanted light in all directions, so that only a small amount reaches the viewer's eyes. A diffusing faceplate tends to reduce the sharpness of the CRT display slightly, but the loss is small and the CAD system user is unlikely to notice it. Manufacturers also can produce diffusing surfaces by lightly etching the front of the cathode-ray tube, by applying a diffusing coating, or by bonding a diffusing plate to the front of the CRT display.

Some users feel that green display characters are easier on the eyes than white ones, and in some European countries, orange characters are used for the same reason. Again, this is a matter of personal preference, but the user would be advised to observe and try CRT displays with different colors in order to choose the one which seems to be the most comfortable.

Number of CRT Terminals Required

The minimum number of terminals required will be determined by the number of complaint board operators and dispatchers employed in the command and control center. The procedures to make this determination, presented in appendix B, were extracted and summarized from a previous study conducted for the U.S. Department of Justice [1]. Some departments provide remote (nondispatch) terminals that can access the system from locations other than the command center. As more applications programs are provided (see table 1), access becomes more attractive and other groups within the department may want terminals.

Terminal-to-Computer Data Channel

The terminal-to-computer data channel is an important link because it, in part, determines how rapidly the computer can respond to the information and commands it is receiving from the complaint board operator. In a typical CAD system, the exchange rate between the terminal and the computer is usually 9600 or 4800 baud. Expressed in other terms, at a rate of 9600 baud, it would take 2 s to completely fill the screen of the usual CRT terminal display (24 lines with 80 characters/line). Or, expressed in terms of typing speed, this is about 10,000 words per minute.

The extent to which the CRT terminal and data channel meet the user's needs depend on how they are used and on how long the user is willing to wait for new data to appear on the screen. When typing into the terminal, there is no contest as the system is a hundred times faster than an operator. On the other hand, although a screen-full of information can be obtained from the computer in a couple of seconds, this might not be fast enough. Fortunately, the vast majority of computer-to-terminal transactions need

to transfer only a small amount of data to the CRT screen. Thus, the typical transmission time falls closer to a 1/2 s than 2 s.

This would be an acceptable situation if each terminal was served by its own data channel. However, in a typical CAD system, several terminals are usually served by a single data channel because it is a much less expensive way to connect multiple terminals to the computer. Channels serving multiple users are more complex because it is necessary to provide additional circuitry and communications protocol so that the desired terminal, and only that terminal, will be connected to the computer at any one moment. The drawback is that too many terminals on a channel will cause excessively long delays for its users, because only one terminal at a time can use the channel. As an extreme example, suppose that a dozen terminals are served by a data channel and that each terminal needs to be sent a screen-full of text. At 2 s per screen, it would be almost 30 s before the last terminal got its message. The usual solution is for a medium or large CAD system to have several channels, with each of them serving several terminals, but even here, it is possible for noticeable delays to occur.

An actual CAD system is likely to use several of the communications techniques just described. As an example, consider three dispatching positions, each provided with its own dedicated 9600-baud channel, while the six complaint board operator positions are served by a single 4300-baud channel. The dispatcher is provided with the faster channel because this job requires a relatively large amount of information from the computer and requires relatively little manual (i.e., slow) typing. The operators make fewer demands on their data channel because their activities require much more typing time as well as time to obtain information from the incoming caller.

This data channel arrangement has one drawback. The computer itself is being used to directly control the data channel, and this, in itself, consumes an unreasonably large amount of computer time. This arrangement can be used effectively only if there are very few CRT terminals. When there are many, a data-channel controller may have to be placed between the computer and the CRT terminals, as shown in figure 5. Computer time is saved because the computer now can transfer messages to or from the controller at a very fast rate, while the controller takes over the entire process of transferring data to and from the CRT terminals at a slower rate. The controller is equipped with a buffer memory that temporarily stores the message to be sent to the terminals, or stores the message received from the terminal until the computer has read it. Except for the short time that the computer uses for its high-speed data transfers to or from the controller, it is free to work on other tasks.

The Computer

There are two parts that make up a computer: the hardware (what most people think of as the computer) and the software. By hardware is meant the electronic circuits, the cables, and connectors that join the various parts. By software is meant the computer programs that provide a sequence of instructions that tell the hardware what to do. Without hardware, there would be no way to carry out the software's instructions. Without software, there would be no way to control the operation of the hardware so that useful results could be obtained. This section will discuss only the hardware aspect of a computer (the software will be taken up in a later section).

The essential hardware components of a simple computer are:

1) Central Processing Unit
2) Memory
3) Input/Output
4) Power Supply

Central Processing Unit

The central processing unit (CPU), the function of which is to read, decode, and execute machine-language instructions automatically, is the heart of the computer. There will be anywhere from a few hundred to over a thousand such instructions in the repertoire of the CPU. These instructions are designed and placed into the CPU memory by the manufacturer and cannot be changed by the user. Each manufacturer usually custom designs the machine-language instruction set in order to best meet the needs of the market for which the computer is aimed.

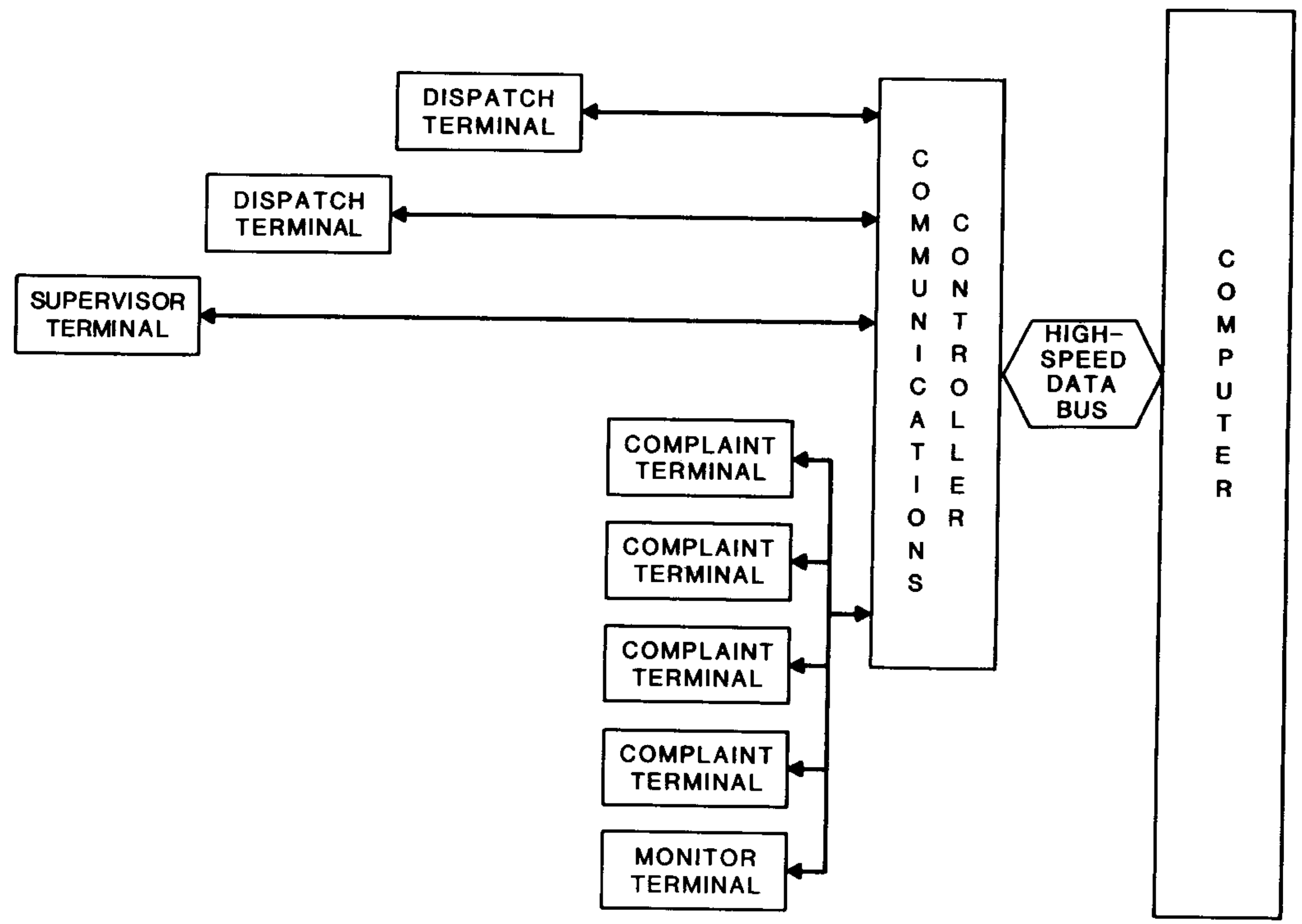
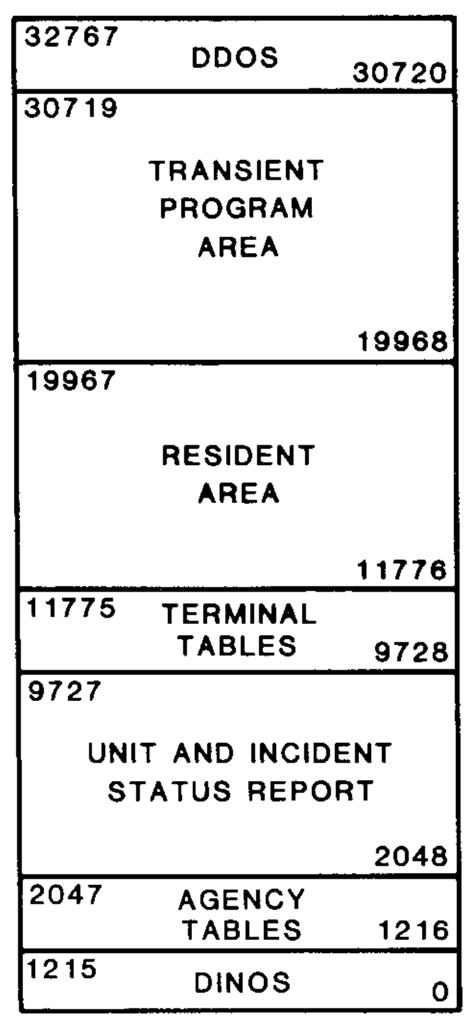


Figure 5. Using a communications controller to assist the computer.

Memory

The memory is used to store the program instructions and data which the CPU requires to perform its tasks. The storage capacity of a computer's memory is one of the factors that determine the speed at which a CAD system can respond to a user's request. The reason for this is that the capacity of the memory determines the amount of data which can be processed at one time. The greater the capacity of the memory, the faster the computer will be able to respond to requests from the users.

The memory will be used for a wide range of purposes, but in order to prevent conflict between the various tasks, it is necessary to reserve a separate block of memory for each. A memory map provides the best way to clearly document these assignments, and an example is given in figure 6. By giving each task its own block of memory, the designer is assured that one task will not destroy the memory contents needed by another task.



This memory map will support: **20 terminals**
240 status entries (in any mix of units and incidents)
26 agencies from one central dispatch point

Figure 6. Shown here is a memory map for an actual commercial CAD system. The numbers on the map give the highest and lowest address for each functional block of memory.

The partitioning and use of memory is an important task because it can have a large effect on the speed with which a computer system accomplishes its tasks. System speed is strongly influenced by the characteristics of the computer, the characteristics of the mass storage devices (see section on Mass Storage (External Memory)) used with it, and the type of work the system is to do. No single choice is best for all situations. This brings us to the most important limitation of memory; no matter how well the system is designed and implemented, there never seems to be enough memory to accomplish all the tasks. Note that the memory map of figure 6 shows that the entire memory is used. Actually, most of the useful information in a CAD system is not kept in memory, but is stored externally in a mass storage device. This means that the computer must send a great deal of data to the mass storage device, and must retrieve it again when needed. It typically takes more than a hundred times longer for the CPU to retrieve a few lines of text from mass storage than is needed to retrieve it from memory. This continual swapping between mass storage and memory is perhaps the major bottleneck of a CAD system. Therefore, the more fast memory, the better. The more information kept in memory, the fewer accesses of the mass storage device needed.

Other things being equal, the larger the word size, the faster the computer can process data. In general, a 16-bit word size is adequate for most CAD systems, although very large dispatch systems may prefer the increased speed and other performance enhancements that are provided by the 32-bit word size computers which are now available. The present memory capacity for a typical CAD system is roughly 100,000 bytes. Interestingly, a 64k byte memory that, in 1975, was fairly expensive and considered to be maximum capacity for a CAD system is now relatively low in cost and is considered to be minimal capacity. In some new or upgraded CAD systems, 128k and 256k byte memories are being used, and it can be expected that even larger capacity memories--say 1-2M bytes--will be utilized soon.

One point should be made about the construction of a memory. For many years, computers used magnetic-core memories. This kind of memory has the reassuring trait of not forgetting anything, even if its power supply failed, as the magnetic cores do not need electricity to maintain their magnetization. But, beginning about 1975, electronic memory became less expensive than core memory and the former is now used in almost all new equipment. These memories, however, forget everything the instant their supply voltage fails. This is not a major catastrophe since the CAD programs and data can be replaced from a backup mass storage device when power is available. However, to combat momentary power failures, some type of auxiliary or uninterruptible power supply is needed. Batteries are usually used to supply the necessary energy.

Mass Storage (External Memory)

Storing and retrieving information is one of the major functions of a CAD system. However, it is not possible to store in its own memory even a hundredth of the information needed by the system. Instead, the information is stored in a mass storage medium, two basic types of which are commonly used with a CAD system. These are the hard disk and magnetic tape. The information held by both types is stored in a thin coating of magnetic material. The data are reasonably permanent provided that the disk or tape remains clean, blemish free, and is kept away from extreme temperatures and magnetic fields. The data can be erased quickly, either intentionally or accidently, by external magnetic fields. Hard disks are always used; tape may or may not be used. Tape is less expensive to use than a hard disk, but is also slower and less convenient. This discussion is limited to the hard disk type of storage.

The capacity of mass storage devices is very large, and dwarfs that of the memory. It is not unusual for a CAD system to be able to hold roughly 1000 times more data in its mass storage devices than in its memory. As prices continue to drop, newer systems are being procured that have more of both kinds of memory than do the older systems. At the present, 100,000 bytes of memory and 100,000,000 bytes of mass storage are typical figures for a CAD system. The price structure for memories is interesting. From information published in November 1981, one manufacturer was offering 1M (1 million) bytes of memory for $16,000 or a 64M-byte hard-disk device for about the same price. In disk devices there are substantial economies of scale, causing the cost-per-byte to drop sharply as capacity goes up. The same manufacturer, for example, also offered a 16M-byte hard-disk system for approximately $10,000, and a 404M-byte system for about $28,000. In this last case, a 25-fold increase in capacity is obtained for less than a 3-fold increase in price.

Essentially all CAD systems use hard-disk storage systems as their real-time mass storage device. Thus, all information acquired by the system during its minute-to-minute operation must ultimately be stored on a hard disk. In comparison to the internal memory, disk-storage (external memory) has both benefits and drawbacks:

Benefits	Drawbacks
1) Almost unlimited storage capacity.	1) Much slower operation.
2) Nonvolatile data storage.	2) More sensitive to air pollutants, temperature changes, etc.
3) Much lower cost per byte.	3) More maintenance is required.
4) Portable (except for fixed disks).	

The four major components of a disk-storage system are:

1) Disk (the storage medium).
2) Disk drive (spins disk, moves read/write head).
3) Controller for disk drive (formats data for the disk).
4) Software for computer (tells the controller what to do).

The hard disk used in CAD systems is a flat, precision-machined aluminum disk 35 cm (14 in) in diameter and about .1 cm (.04 in) thick. Its top and bottom surfaces are coated with a uniform thin, mirror-smooth layer of magnetic material like that used on magnetic recording tape. This layer is approximately .025 cm (.01 in) thick and is the medium that actually stores the digital data. The disk drive is the device that performs the mechanical operations needed to store information on the disk and retrieve it. The drive rotates the disk at a constant speed, usually either 2400 or 3600 rpm. The disk drive contains one or more read/write heads that can move to any of several hundred positions located along a radial path from the disk's center. When the disk is rotating at operating speed, the read/write head is lowered to the disk surface, where it is supported by a thin layer of air created by the spinning disk. This air layer provides a low-friction, low-wear interface between the head and the disk. When the data are to be written or read, the head is placed at one of the positions, and the data transferred as the disk spins past the head. The data are written onto the narrow, circular path of the spinning disk that passes next to the stationary read/write head. This circular path is called a track, and a different track is accessed at each of the hundreds of possible positions of the read/write head.

Each disk surface holds approximately 400 to 800 tracks. Each track can store between 6000 and 40,000 bytes of data, with 20,000 bytes being typical for new disk-drive designs. These data are not written as a continuous unbroken string of data, however. Instead, each track is divided into sectors. Usually, the sectors have a storage capacity of either 256 or 512 bytes of data. This range of sizes usually produces the most efficient overall performance of the computer system. It is large enough to hold a sufficient amount of information, while also minimizing both the amount of wasted space on the disk and the time needed for data transfers. Data are written into or read out in one-sector groups.

Both the top and the bottom surfaces of the disk have a magnetic coating, and the disk drive provides a read/write head for each. However, only one of the surfaces is used to store data from the computer. The other surface is used to record information that tells the drive where the data tracks are located. The very close track-to-track spacing makes it very difficult to accurately position the read/write head over the desired track. Mechanical imperfections of the positioning mechanism and thermal expansion and contraction of the aluminum disk are just two of the difficulties encountered. But by putting the track-locating information onto the disk, these problems are reduced or eliminated. Although this means that only one of the two surfaces is used for storing data from the computer, the improved reliability makes this a reasonable choice. Also, the resulting improvement in head-positioning accuracy means that more tracks per inch can be placed on the surface that is used to store data.

It was mentioned earlier that a typical modern disk drive will store around 20,000 data bytes on each track, and that it must move the head to another track if more data are needed. Moving the head always uses up a significant amount of time, so some disk drives provide more than one read/write head for the disk surface. If, for example, there were five heads on the surface, then 100,000 bytes of data could be accessed

without moving the head. When more data storage is needed than a single disk can provide, the most economical way to obtain greater capacity is to employ a disk drive that uses a multidisk assembly. This consists of up to 12 hard disks, usually referred to as platters, mounted on a common shaft.

In order to obtain accurate data transfers, the magnetic coating on the disk must be kept blemish-free and clean. Thus, disks are always protected by one of three packaging arrangements. One of these is the disk cartridge, which consists of a single disk that is permanently mounted in a portable protective case. The manufacturer mounts the disk in the case and that is where it stays. Even when in use, the whole cartridge is placed in the user's disk drive. The major attribute of the disk cartridge is its portability. It can be easily removed from the disk drive and either stored on a shelf or installed in another compatible disk drive. This makes it suitable for archival storage and for transferring data from one computer to another, in addition to providing real time storage. Another benefit is that damaged disk cartridges can be easily replaced.

Another arrangement is a multiplatter assembly, also called a disk pack. This is somewhat similar to a disk cartridge, except that there may be up to 12 platters in the pack, all mounted on the same shaft. A disadvantage of this type of assembly is that the protective cover of the disk pack must be removed before the disks can be used in a disk drive, thus exposing them to damage from external sources. Disk packs store between 25M and 400M bytes of data. Like the disk cartridges, the disk packs are removable and have the benefits that this brings.

The third method of protecting disks is to permanently seal the disk inside a disk drive at the time of manufacture. This provides the best possible protection for the disk and results in more reliable performance. In this kind of design, the disk is in a compartment through which only highly-filtered air passes.

Printers

In a CAD system, one of the most important uses of printers is to produce a permanent record of each dispatching event. This is vitally important because, should the system fail, this becomes the only available record of the current status of in-progress dispatching incidents. This printed information also ensures that in-progress events will not be overlooked when reverting to manual dispatching techniques. Another customary use of printers is to provide printouts of reports or other useful information that the CAD system has collected, because, frequently, it is much more convenient to have the information on paper than to read it from the CRT display screen.

A CAD system is likely to use both medium- and high-speed printers. Medium-speed printers are appropriate for printing the record stream as the dispatching events unfold. They are also suitable for printing reports and general information if there is not an overwhelming amount. When the amount of information to be printed is very great, then a high-speed printer becomes desirable. Medium-speed printers print between 30 and 120 characters per second, which usually amounts to less than one line per second. High-speed printers print anywhere from 2 to 10 or more full lines per second, but the performance and price of the fastest printers are both probably higher than is needed in a typical CAD system. Conversely, the purchase of a printer even slightly inferior to the rest of the system can result in unnecessary slowdowns and the elimination of beneficial printed information.

Printers tend to be noisy, so it may be desirable to place them at a distance from communications center personnel, or even in a room not ordinarily used by people. On the average, the faster the printing speed, the noisier the printer. The print quality of printers used with a CAD system is usually inferior to that of an ordinary typewriter, but this is one of the tradeoffs made in order to obtain both high speed and lower cost. Although exceptions can readily be found, it is also customary for higher-speed printers to give poorer print quality than the medium speed ones. Printers require more repairs and routine maintenance than any other CAD system component. Paper and ribbons must be supplied periodically, and the mechanical wear on its mechanisms cause them to have a shorter life than other system components.

Power Sources

Normally a CAD system obtains its power from the local electric company. Although reasonably reliable, this external source is subject to three problems that can disrupt the system. These are electrical interference, high voltage transients, and power outages.

System Interrupts

Because the electric lines used by the power company are often long and may be connected to a wide range of users, there is ample opportunity for them to pick up additional electrical signals, some of which can interfere with a CAD system. As the length of a line increases, the likelihood of it acting as a receiving antenna for interference sources such as lightning and radio waves also increases. The more users served by any particular electric line, the more opportunity exists for this type of interference. Electric motors, radio transmitters, and high-power equipment being turned on or off are also sources of interference. If the interference is strong enough, it can cause the CAD system to become temporarily inoperative. This does no permanent damage, and merely requires that the CAD system be restarted. Restarting the system is usually done manually and takes roughly from 5 to 15 min, although in some systems, the restart is accomplished automatically and without human intervention. Several jurisdictions suggested that the ability to restart the system from the control center, rather than from the computer room, would be a nice feature.

When failure from electrical interference occurs, it is usually because a strong interfering signal is somehow coupled into the computer circuits and overrides the normal signals. Once inside the computer, a 1-V transient lasting less than a millionth of a second may be sufficient to cause failure. Because troublesome transients tend to occur infrequently, and because of their short duration, it can be very difficult to tell whether a computer problem is being caused by them. The best way to minimize the problem is to purchase computer equipment that has been tested and found to be reasonably immune to electrical interference.

A second problem is high-voltage transients, which are simply a more extreme case of electrical interference. In addition to being able to render a CAD system temporarily inoperative, they can sometimes be strong enough to permanently destroy computer equipment. Lightning is the most potent source of high-voltage transients, but transients can also be produced by other means, such as high-powered electrical equipment. As was the case for electrical interference, it is usually difficult to prove whether or not high-voltage transients are responsible for computer failure. Prevention is again the best way to deal with the problem. In addition to the steps taken to protect the system from ordinary electrical interference, it may be necessary to add components to limit the magnitude of the high-voltage transients before they reach the computer equipment.

The last problem, a power outage, is very easy to recognize. In a computer system the effect of a power loss is felt quickly, since complete loss of power from the public utility for even a fraction of a second is likely to render the computer system inoperative unless some kind of backup power source had been incorporated into the system. In urban areas, power failures are usually of short duration, probably rarely more than 2 s long. Battery powered backup supplies are available that can keep the entire CAD system (including the room lights) operating during short duration outages (roughly 15 min or less). The high cost and large size of batteries make it undesirable to use them as a long-term power source. When outages of long duration can be expected to occur, gas- and diesel-powered generators are the standard power source. As long as there is fuel, they can power the CAD system indefinitely.

The need to provide uninterrupted power to the computer system is vital. Uninterruptible power supplies are available from several companies, and there is more than one type of design approach that can be used. As an example, consider the method shown in the block diagram in figure 7. This is the design which provides the best possible protection to the CAD system, but it is also the most expensive to buy and the most costly to operate. In its favor is the fact that the transfer from public utility over to batteries is so smooth that the CAD system cannot even sense that there has been a change. Another benefit is that this kind of system inherently protects and shields the computer equipment from all three of the problems introduced by use of public electric power

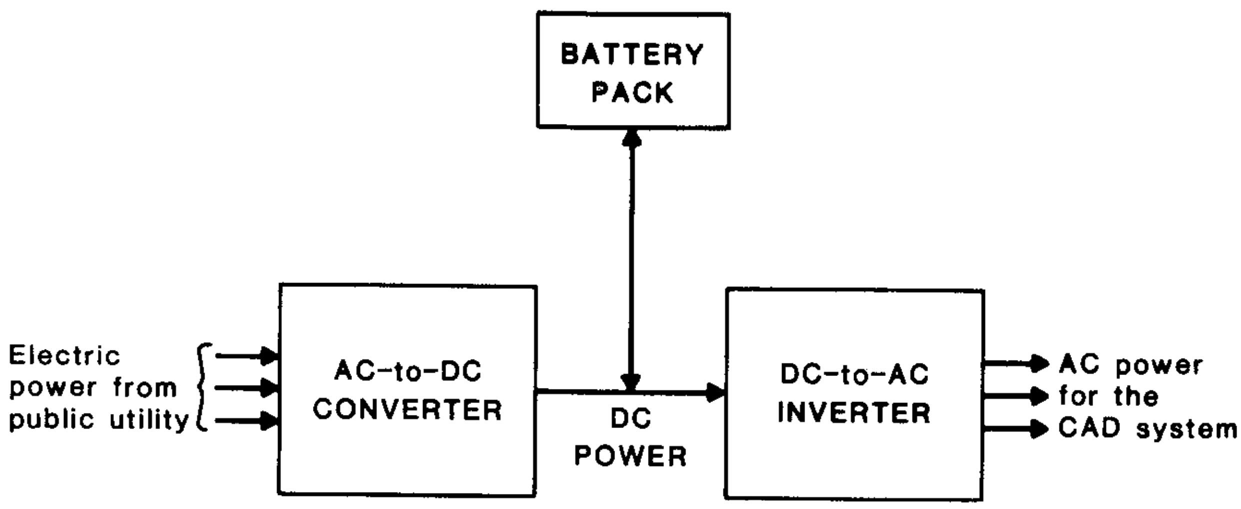


Figure 7. **Block diagram of an AC-DC-AC uninterruptible power supply.**

Other circuit arrangements can be used in an uninterrupted power supply, and they have their own sets of strengths and weaknesses. An uninterrupted power supply can be expected to give reliable service with the batteries being the component likely to have the shortest life expectancy. Batteries that have a long life may be expensive, so it is worthwhile to ask manufacturers about battery life expectancy and replacement cost.

Sizing the Hardware System

Determining the quantities of hardware components and their individual capacities is normally done when the system is designed in detail. It is important to note that a CAD system does not require very advanced or large-scale data processing equipment. A standard minicomputer is usually more than adequate and, if peripherals are added, the capability of the system to handle a larger load can be expanded. Many departments require a high system "on-line" time, resulting in the need for redundant hardware components. Dual recording of data is often done, especially in larger systems, to ensure against loss of data due to system interrupts (see previous section). A back-up computer may be required, with automatic switchover to maximize "up time."

The minimum equipment requirements for a medium-size department would be as follows:

Computer	Standard 16-byte minicomputer
Integrated-circuit memory	64k bytes minimum; 1/4 megabyte is better
Disk storage	One 25-megabyte unit
Peripherals	One line printer (600 lines per minute) One typewriter-typeprinter One microfiche file and viewer per console (optional)

Software

The term "software" is used to refer to a set of instructions executed by the computer to perform its tasks, plus the data in machine-readable form that is used by the computer in carrying out these tasks [1]. The software for a CAD system is usually supplied by the system vendor although, in larger law enforcement agencies, it may be possible (although it seldom seems to be done) to develop the necessary programs in-house if the agency has software support groups [8].

The overall package of software and files that would be needed in a CAD system is shown in table 1 and consists of the following three major parts:

1)	Operating system	General purpose utility programs
2)	Real-time dispatch system	Provides all dispatch capabilities
3)	Applications programs	Provide additional capabilities

Table 1. Software and file structure for a CAD system (adapted from reference 1)

Operating system	Real-time dispatch system	Applications programs
*System generation	*Access authorization	Data base query
*Job scheduler	*Sign-on/Sign-off	Management reports
*Communication control	*Incident log-in	Deployment schedule
*Executive services	*Incident file	Radio-telephone statistics
*System recovery	*Incident summary file	Operator activity file
	*Dispatch log-in	Patrol unit activity file
	*Patrol unit status	Address verification
	*Patrol unit file	Telephone directory
	*Deployment schedule	Address intelligence file
	*Data logging	
	*Geographic File	
	Unit Recommendation Algorithm	

*Basic elements· remaining elements are optional.

Operating System

The operating system software consists of a large collection of utility programs that provide a wide range of useful and commonly-used services. It is the core of the CAD system software, for the other two software components depend upon and use its capabilities. It handles such tasks as controlling the communications between the computer and the CRT terminals, providing a way to get data to or from a hard disk, and providing diagnostic messages when it detects problems. A CAD system requires a real-time multiuser (i.e., many CRT terminals) operating system: its response to a command typed into a CRT terminal must be quick. The operating system of at least one jurisdiction did not meet this latter criterion, and it became the fatal flaw that made the system almost useless.

Because the detailed structure of an operating system is greatly influenced by the design of its computer and the peripherals furnished with it, it is usually developed and supplied by the manufacturer of the computer. Although it is a complicated and expensive undertaking to write these programs, it is sometimes done by a CAD system vendor or user.

Real-Time Dispatch System Package

A real-time dispatch system package is a large collection of closely integrated and specialized programs that are the essence of a CAD system. These are the programs that perform such tasks as accepting information from the complaint board operator, sending that information to the dispatcher, automatically maintaining a file for each complaint event, querying remote data bases, responding to the commands of the dispatch personnel and, in general, controlling the entire dispatch operation. Each dispatch-related command and capability possessed by the CAD system is made possible by programs contained in this package. If it were necessary to add a new command, or modifiy an old one, the changes would be made in this package. Before a contract is signed, the vendor and users should develop a detailed list of every command and task that the proposed CAD system will be required to perform, as listed items will have to be implemented by the programs in the real-time dispatch system package. This package like the operating system package, is costly and is usually written by a vendor or a user.

Applications Programs

Applications programs are those that generate reports based on the information processed through the CAD system or provide the system with additional informational capability. These usually can be added to a CAD system at any time, and will provide the system with many additional features. Capabilities not provided when the system was originally purchased can be added by acquiring additional applications programs. Because these programs are not intricately interwoven with the internal complexities of the system software package, they are relatively easy to implement. They can be written in any convenient computer language, by either in-house or outside programmers, and are not very likely to have problems with speed of execution or other limiting factors. An example of an applications program would be one that generates crime statistics from the event records that the dispatch operation has already stored in the CAD system.

Modification of a CAD System Software Package

The cost of a CAD system software package is high because it is the result of several person-years of programming effort. Only by using the same software package for several CAD systems can the costs be recovered, which is a primary reason why the vendors of CAD systems prefer to sell a standard system.

Some vendors are willing to make major changes in their software package in order to meet the requirements of the purchaser, but this increases the cost of the system. Minor changes will sometimes be made by the vendor at no additional charge. It is important to realize that "major changes" means that it will take a programmer a significant amount of time to make the revisions. Some changes which appear to be trivial ones are actually very difficult to implement, whereas other changes may be much easier to implement than might be expected. Clearly, any changes contemplated should be reviewed by a relevant expert.

In the past, some vendors have been much more willing to modify their standard software package than others. If a new CAD system will require that the standard software be modified significantly, only those vendors who can demonstrate their ability to competently complete this task should be considered.

Software Maintenance

Software maintenance, rather than referring to the repair of software packages, actually refers to the ongoing development of new software and the correction of errors that have been discovered in old software. These errors may have been uncovered by the user, by users of other computer systems that employ the same software, or by the company that originally developed the software. After a software product has been used extensively, most of its errors will have been detected and corrected, but a new software product is quite likely to have some errors and shortcomings, and the users may initially have to devote a substantial amount of time to resolving these problems. To prevent programming problems from jeopardizing the functioning of the system, self-checks that detect when the program is in trouble can be incorporated that will enable the system to recover automatically. The CAD system may be inoperative during the recovery, a period lasting perhaps 20 s. One estimate is that this might occur about once in 24 h, making this a very minor problem.

Normally, software developers will keep their customers informed about corrections and enhancements to their product. Also, a knowledgeable user may be able to make his/her own corrections and write supplementary new programs. It is almost universal to find that software packages do not give the CAD system all of the features that its users would like. Quite often, this is because the user was not aware of the feature initially but, usually, this is due to a recent increase in the number of programs made available to the user by the software developer. Also contributing to this is the unwillingness of the user to pay the high price that a very thorough and complete software product would command, and partly because the user's needs also change. Occasionally, users must respond to changes not under their control, e.g., those prompted by change in a state or national data base. So, for one reason or another, there tends to be a continuous process of upgrading and expanding the software of CAD systems.

Maintenance and Repair of a CAD System

The owner of a CAD system can expect to encounter one problem with regard to the upkeep of the system. This is an unexpected hardware failure. Unless some provision has been made for this eventuality, the dispatch operation may be forced to revert to a manual mode for an extended period. The system should receive routine maintenance on a regular basis to reduce the possiblity of an unexpected failure.

During the planning for a CAD system, choices are made that have a direct and permanent effect on the maintenance and repair of the system. For example, will all of the major computer-related equipment, such as the computer and disk drives, be purchased from the same manufacturer? Some manufacturers will provide service only if the answer to this is YES. This policy is a reasonable one, because it protects the company from the expense of having to work with a wider range of equipment and from the expense of attempting repairs when the problem is not the fault of its own equipment. To explain the latter item more clearly, assume that a computer system is composed of equipment from two manufacturers and that each had agreed to provide repair service for their own equipment. A serious problem occurs if the computer system fails in such a way that it is not known whose equipment is at fault. Obviously, a company does not want to spend time on a problem for which they are not responsible, and the user does not want to lose time waiting for the CAD system to be returned to operation. If it should happen that different manufacturers supply the major computer-related equipment, then maintenance and repair can still be done by a third-party maintenance contractor or, in some agencies, by the agency's own personnel.

In return for the substantial sum a user pays for a CAD system maintenance contract (the annual cost of a maintenance contract will be roughly 10 to 15 percent of the purchase price of the system hardware), the contractor provides important services. The maintenance company can provide routine maintenance, guarantee to have a repair person arrive within a specified reasonable time after being notified that the system has failed, and maintain a stock of spare parts. Generally, the shorter the guaranteed response time, the higher the cost of the contract. Also, the contractor's stock of spare parts can be a tremendous timesaver. This is especially true for older equipment or for any scarce item. For example, the CAD system of the Police Department of Las Vegas, Nevada, needed a new motor for an old tape drive for which parts were becoming difficult to obtain. There was no service contract in effect at the time, and the manufacturer planned to construct a replacement tape drive with a delivery time of 6 weeks. It took much negotiation before the department was allowed to purchase one from existing, but reserved, stock.

There are several ways to obtain maintenance and repair services for the computer-related portion of a CAD system:

1) Maintenance and Repair Contract With an Outside Company: Depending upon circumstances, a maintenance contract might be held by either the equipment manufacturer, the company that supplied the CAD system package, or a third party company. Good results can be obtained from any of these, but to obtain the best satisfaction, the following information should be known before signing a contract. Does the company maintain an ample stock of spare parts and have capable service people available on short notice? A typical agreement will ask for help to arrive within 4 h if a breakdown occurs during normal working hours. A shorter response time can usually be agreed to, though at additional cost. The closer the CAD system is to the contractor's local service office and to the spare parts depot, the shorter can be the response time. When there is a large amount of equipment to be maintained, the contractor will usually station a service person at the user's site.

2) Repairs "On Demand" By An Outside Company: Agencies that have used this approach have generally not had good experiences. Without a contract, agencies are going to receive the lowest priority, generally. Help will be provided AFTER the company has satisfied its contract customers, and you might have no claim to reserved scarce parts. The other side of the story is that when the company is not busy and has an adequate supply of the replacement parts needed, good service is obtained at a low yearly cost.

3) Maintenance By The User's Own Personnel: When the maintenance work load is large enough this arrangement usually works well, except that obtaining scarce replacement parts quickly may be a problem. In some police departments the radio repairman may be able to provide the maintenance for the computer equipment. If hard-to-diagnose problems occur, it might be necessary to obtain outside help, because intimate knowledge of computer equipment is needed, as well as specialized and expensive diagnostic equipment. An example of this approach is given in reference 9.

4) Combinations of the above, i.e., in-house technician and backup contract with an outside company.

CAD SYSTEM PROCUREMENT PROCESS

Once a decision has been made to acquire a CAD system, typical steps which have to be followed include those listed below. Most jurisdictions suggest that you select a project leader early in the process, someone who will be able to guide the project through to completion. Give that person the authority, within some set of guidelines, to make the necessary day-to-day project decisions without having to consult a large decision-making group that takes valuable time to assemble.

Acquiring a Medium- or Large-Sized Commercial System

A) Obtain funding approval. The money to buy a CAD system is usually provided by the local government, although in the past some police departments have obtained grants from the Law Enforcement Assistance Administration (LEAA) of the U.S. Department of Justice. An example in which there was mixed funding was for the CAD system purchased by Prince George's County, Maryland. County funds paid for the hardware, and an LEAA grant paid for the software. However, LEAA grants are no longer available. For agencies which are unable to obtain the funds to purchase a system, there is the option of leasing one (perhaps with a bargain purchase option included). This has the advantage of spreading the costs over a more extended period (although the rentals will almost certainly exceed the purchase price in the end). Leasing is also the least hazardous way to acquire a CAD system, for the users need not renew the lease if they consider the system to be unsatisfactory. Normally the lessor also provides the maintenance and repair for the CAD system.

B) Outside consultants. The importance of the design of the CAD system cannot be overemphasized. If you have CAD experts on your staff, use them. If not, or if the new system is to be an expensive one, it may be desirable to hire an independent consultant to guide the planning. The vendors of CAD systems usually do not provide this service, because they would then not be allowed to compete for the system procurement. The vendors can, however, recommend independent consultants. Since the acquisition of a new system usually results in restructuring the entire dispatch operation, it would be a plus if the consultant had a background that extended beyond an expertise in computer systems. One agency warns that the hiring of consultants does not, by itself, ensure that your CAD objectives will be met. Be prepared to work with them, on a daily basis, to prepare a specification that will meet your needs.

C) Become familiar with the capabilities provided by a CAD system. This requires reading about them talking to both users and vendors, and visiting an operational facility. Different users and vendors tend to offer different viewpoints and capabilities, so it is desirable to obtain information from a variety of sources. If you have engaged a consultant, be sure that he/she attends all meetings and is able to obtain answers to all questions.

D) Identify and justify what the proposed CAD system will be required to do. There is much to consider here. Some CAD systems provide basic dispatching functions only, while some others also include report generators, mobile digital terminals, automatic querying of remote data bases, etc. It is important that the planned-for system have enough capability to make it satisfying to use. If funding cannot be obtained for such a system, then the wisest decision may be to postpone the acquisition until funds for an adequate system become available. Develop a functional specification that fully satisfies the needs of your department. Use appendix B to assist in the determination of the number of terminals needed. Be sure to tailor your specification to provide a CAD transaction response time fast enough to keep pace with other dispatch center requirements. The need for an accurate geographic file, produced in a timely fashion, should also be stressed. Include a requirement for maintenance and repairs to the system (see I below) if not maintained in-house, and any necessary training (see J below) and the services of a qualified programmer, who will probably be needed through the hardware warranty period and beyond.

E) Develop a Request for Proposal. Using the information gained from items B, C, and D, write a formal request for proposal (RFP) and distribute it to interested vendors. The RFP may specify a requirement for a turnkey system, i.e., one in which the vendor supplies a total hardware and software package to meet user design requirements, or it may specify any portion thereof.

F) Select a vendor and draw up a contract. Based upon the responses to the request for proposal, choose a vendor. Because the vendors may suggest capabilities that differ from those requested by the department, the selection process should have the flexibility to evaluate the merits of each offering, and to give competing vendors the opportunity to respond to any new requirements that differ significantly from the original request. Develop specific acceptance criteria and procedures at this time. The vendor must know what the user will consider to be acceptable performance and be able to verify compliance at a later date. It is imperative that the user and the CAD vendor agree on all aspects of the system before installation is begun. After a vendor is chosen, the contract must be drawn up.

G) Monitor the contract and all other related presystem installation activities. As stated earlier, one person should be given the authority, responsibility, and the time to handle the multitude of details and problems that occur during the installation and start up of the system [4]. This person would oversee the remaining items on this list, and deal with unforeseen problems.

H) Prepare the area where the system will be installed. Ensure that sufficient electric power, with backup, will be available at start-up time. If possible, physically separate the noise-making equipment, such as disk drives and printers, from the control center area to improve the working environment. Provide temperature control and correct area lighting. You might even want to select an architect who understands the need for sound proofing and a quiet environment [10].

I) Follow through on maintenance and repairs for the system. The vendor should be developing a maintenance plan and designating those spare parts that should be supplied with the system.

J) Train the personnel who will use the system. Work with the vendor on a training plan, than implement it. Personnnel must be trained prior to the operational use of the system. For complex systems, training is especially critical.

K) Contractor installs the system and it is tested in accordance with the acceptance criteria specified in F above.

L) Maintain the ability to operate the dispatch system manually. It has happened that this item was overlooked in the implementation of a new CAD system. It is almost inevitable that the computer system will experience temporary failure, but the dispatching operation must not be rendered helpless. In order to keep their personnel competent in manual dispatch techniques (i.e., with no computer), many agencies revert to manual techniques for a few hours each month.

A timetable showing the overall schedule of activities to acquire and place a CAD system into operation is shown in figure 8. Individual times will vary based on the type of system selected, amount of customization, number of peripherals, preparation of space, use of consultants and possible funding delays.

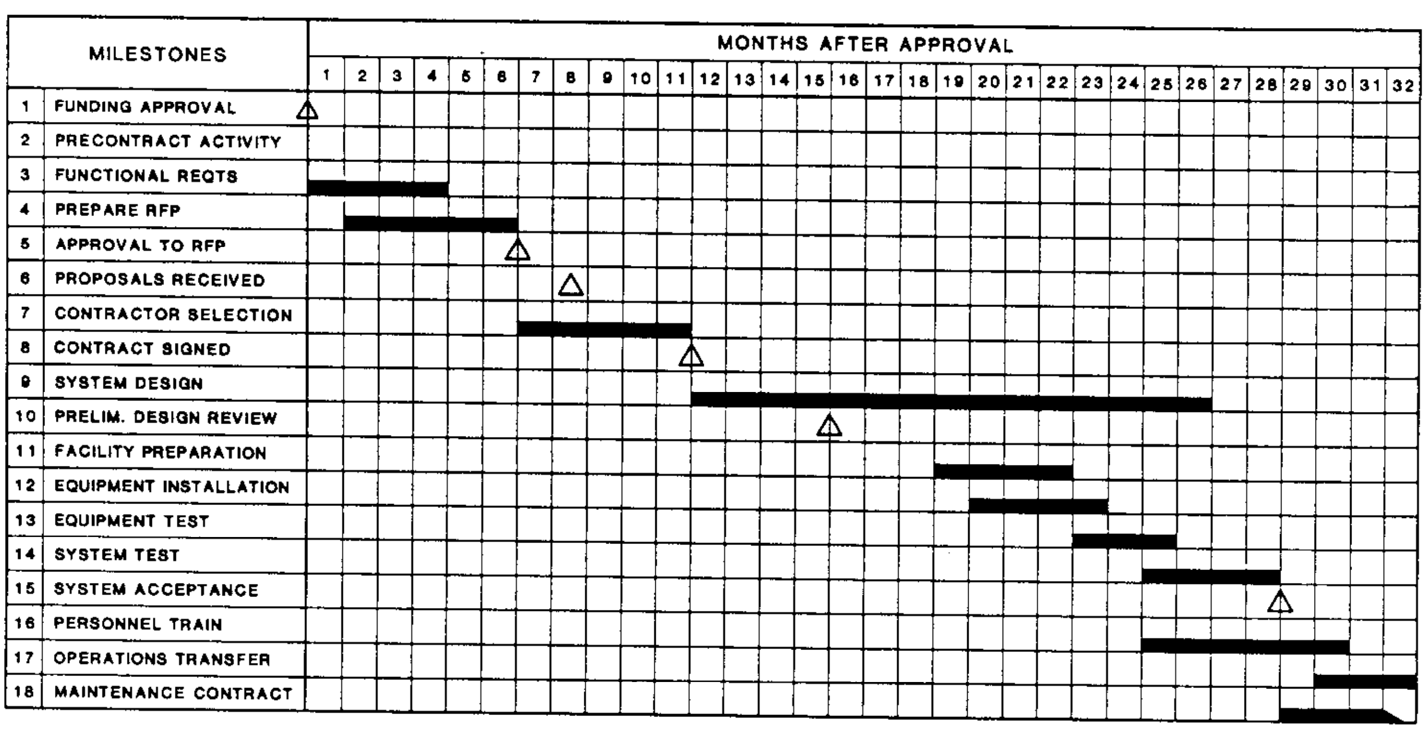


Figure 8. Overall schedule of activities to acquire a CAD system [1].

Acquiring a Small-Sized Commercial System

Each of the steps discussed above apply equally to the procurement of a smaller-sized system, albeit on a smaller scale. However, where the total amount to be paid to the vendor will be less than roughly $100,000, the cost of hiring a consultant and designing a functional specification may be an unreasonably large percentage of the total expenditure. Thus these steps are sometimes omitted and the system acquired directly from a vendor whose system meets the basic performance requirements. In other respects the steps listed above would apply to procurement of a small-sized system also. An example of how one very small department provided 24-h service to its citizens is given in reference 11.

Custom-Design of a CAD System Using In-House Capability

There are agencies large enough to have in-house expertise that can be used to design, implement, and install a CAD system of their own custom design. This is a very ambitious project, requiring many man-years of work, but it has been done by a few police departments. The main benefit is that the system can be tailored to the specific needs of its users, rather than having to accept a standard package from a system vendor. Two of the drawbacks to this approach are:

1) A one-of-a-kind system is much more expensive than a standard package, whose development costs can be spread over several systems.

2) Much more time will elapse before a custom in-house CAD system is installed and ready for routine operation.

The era of the in-house-built CAD system may have already passed. Several CAD system vendors now offer competently packaged systems that are relatively inexpensive and can be installed quickly. Different vendors produce different types of systems, so prospective users will probably find at least one that is well-suited to their requirements. Another major benefit of the packaged systems is that they have already been used by others, so most of their problems will have already been discovered and corrected. Most of the vendors are willing to add custom features to their standard packages, but will charge extra for this.

Still another variation of the custom-design approach used occasionally is for the user agency to plan its own system and then purchase the hardware, software, maintenance, etc., from various suppliers. This will work if the planners really understand the complexities of computer systems. Otherwise this can be a very risky approach. A good consultant may be a valuable asset when this approach is used.

Additional discussion of the ramifications of procuring a CAD system is given in reference 12.

GENERAL OBSERVATIONS

In the course of writing this report, the authors submitted preliminary drafts to a group of interested users and vendors of CAD systems for comment and constructive criticism. In return, many suggestions were received that were used to improve the topics covered in this document. The respondents who took time from their busy schedules to review the draft document and provide comments are listed in appendix C.

For the most part, those departments with operational CAD systems were enthusiastic about the benefits of CAD. For example, one reviewer stated, "Our system is only 9 months old and we wonder how we even got along without it. We are running about 35,000 events per month with 8 complaint operators and 6 dispatch positions. We feel it is a success." Nonetheless, virtually all of the reviewers encountered problems at various stages of planning, implementation and operational use. The comments and opinions summarized in the paragraphs that follow represent topics that those contemplating the acquisition of a CAD system should keep in mind.

Most of the reviewers stressed the importance of comprehensive planning, with at least two citing interface requirements as potential problems. Typical comments were:

A. One consistent area of deficiency is inadequate planning. Too many times contractors find themselves in the situation of being forced to automate a poor operational process.

B. In order to achieve a high level of success, the system must be designed by public-safety personnel with assistance from data processing professionals and/or consultants. If the system is designed without proper input from the public-safety sector, it is doomed to fail.

C. System design stages are very critical. Decisions made at these points will be with you for a long time.

D. It is imperative that system specifications dictate that the vendor is responsible to design the proper interfaces with other state or local information systems to prevent overlooking the requirement.

E. The subject of interfaces was almost swept under the rug by the vendor and overlooked by the purchaser.

F. Separate independent environmental control system is very critical.

G. The system, as designed, should be as idiot-proof as possible. System designers must anticipate that operators are creative and will spend their idle time looking for ways to beat the system.

H. There is a need to develop specific acceptance criteria and procedures. The vendor must know what the user will consider to be acceptance performance and be able to verify compliance.

I. Make the work area comfortable for dispatchers. Control the temperature and provide correct area lighting. Need accurate geographic file.

J. Serious problems with system acceptance will result if users must unreasonably change their procedures to satisfy the system design.

K. It is mandatory that the complaint board operator have the capability to override any system generated parameter. Do not be so rigid in your design as to not allow the operator freedom to correct design mistakes.

L. Costs are far less apparent when a system is being developed in-house. Advocates of developing systems in-house thus have a political advantage, even though the actual cost may be higher.

M. Having a real-time CAD system expert design the system cannot be overemphasized.

N. Early identification of a qualified project leader is essential.

O. The hiring of consultants by an agency does not, in and of itself, ensure that the objectives of CAD will be met.

P. The importance of the functional specification cannot be overemphasized. It is imperative that the CAD vendor and the user agree on all aspects of the final system before installation.

Q. CAD generates data for law enforcement models. Work load and performance can be measured and modeled. Dispatch data play a vital role in the Patrol Operations Budget.

As a part of the planning process, it is also important to recognize the critical need for training. Two reviewers commented as follows:

A. Depending on complexity of the system, there is a monumental training program needed to utilize system to full capacity.

B. Consideration for training on the new system must be made. Vendors who supply fantastic systems may not be fantastic trainers.

Finally, there were a number of cases in which the reviewers identified potential technical and operational problems. It should be noted that many of the following comments also support the need for proper planning.

A. One problem area is CAD transaction response time. Law enforcement communications is a very dynamic environment and the system must be fast enough to keep pace. The geographic file must be completed early in order to be folded in at the right time.

B. The multi-function nature of a CAD system is likely to lead to conflicts over its objectives, particularly between operations and management information points of view. The fact that reports and modeling often result in more or better utilized field resources gets lost in the scuffle. A shared backup or mainframe computer presents further contentions.

C. Inefficiently written programs, added on to a heavily-loaded system, can seriously degrade system response time.

D. The language issue needs to be addressed with reference to memory, compute power, system load and speed requirements. Not all departments can use BASIC on a microcomputer for a CAD system. The County's CAD system is so slow that they enter the barest minimum of information for calls for service and have very limited capabilities.

E. It is totally unrealistic to assume that no software maintenance or enhancements to the system will be needed or desired. It is also doubtful to expect that an agency will have in-house, a qualified programmer that can be assigned to learn the CAD system.

F. Operations personnel often do not understand the importance of record keeping and modeling. Management information personnel may not realize the need for real-time data and information.

G. CRT compatibility and obsolescence has been a problem.

H. One of our greatest problems has been printers slightly inferior to our system. This has resulted in unnecessary slow down periods and the necessity of eliminating beneficial printed information.

I. Do not forget that the operation, software maintenance and subsequent enhancement of a CAD system will require the services of a qualified programmer, usually beyond the hardware warranty period.

J. A major problem area was the coordination of systems development and implementation with dispatch personnel. Console manufacturer necessitated equipment changes.

SUMMARY

Computer-aided dispatch systems are having a major impact in the solution of some of the chronic problems of command and control of law enforcement agencies, both inside and outside of the United States [13,14]. Use of a CAD system has resulted in faster response time in emergency situations, greater accuracy of communication, and greatly improved utilization of existing manpower [4-5,13-18]. Use of CAD with mobile digital terminals in police cars has substantially improved response time and accuracy of communications as well as providing improved security of transmissions, according to two agencies [9,14]. Further, two departments cited a need for increasing officer safety as a reason for implementing a CAD system [4,19].

Additionally, the CAD system has proven to be cost beneficial in that it provides a more efficient return on the investment of tax dollars [4,5,13]. One department projected that their savings in the first year of operation would amount to more than $29,000, with the benefits accruing almost equally between hours saved by officers in the field and those manning the communication center [16]. Another locality estimated that even if it hired four additional people per shift, it was doubtful that they could perform the work of the computer, and further, it was unlikely that the work would be done as completely and as accurately [19].

Finally, a benefit which many departments viewed as significant was the generation, by the computer, of a wide variety of meaningful management reports [5,9,15-18,20]. The system's ability to provide department management with the kind of data they need to do their job efficiently and thoroughly would seem to be impressive. Included in this would be the ability to provide data crucial to criminal investigations [5 18].

It seems inevitable that the demand for computer-aided dispatch systems will continue to increase. They are becoming indispensable to communications control systems, and it is reasonable to expect that soon CAD systems will come within the reach of all but the very smallest localities and jurisdictions.

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APPENDIX A--GLOSSARY

American Standard Code for Information Interchange (ASCII) - A digital code widely employed with terminals, computers, and printers. It is a 7-bit (i.e., has 128 different characters) number that represents upper- and lower-case letters, the digits 0 through 9, punctuation marks, and control characters.

Baud - Measure of the speed of digital transmission, in units of bits per second. For example, a transmission rate of 9800 bits per second is the same as 9800 baud.

Bit, b - From b(inary + dig)it. A single, basic unit of information used in connection with computer and communication theory. A binary number system uses only two digits -- 0 and 1.

Byte, B - A unit of information for processing in certain computers, equal to one character of eight bits.

Cathode-Ray Tube (CRT) Terminal - Consists of at least a typewriter-like keyboard that is used to enter information into a computer system, and of a CRT screen that the system can use to display information.

Central Processor Unit (CPU) - The part of a computer incorporating its machine language instruction set and responsible for essential control and computational functions.

Disk Drive - The mechanical portion of a disk storage system. The drive contains the read/write head(s) and their positioning mechanism, a motor to spin the disk, and a protective case.

Geographic File - A computer file that contains the street names, street numbers, common place-names, and perhaps other geographic information about the area served by a CAD system. It can serve a variety of uses, from automatically verifying the existence of addresses given to complaint operators, to helping choose the squad cars that respond.

Hard Copy - Any permanent copy that can be directly read by people. Usually, this is simply the paper output from a printer.

Hard Disk - Mass storage medium commonly used to store data for a computer. The hard disks used in most CAD systems are made of aluminum **approximately** .1 cm (.04 in) thick and 35 cm (14 in) in diameter, with a thin magnetic coating on both sides. A single disk can hold several million alphanumeric characters.

Hardware - The actual electronic and mechanical equipment used in association with data processing; distinct from software. For example, a disk and its associated electronics are hardware; on the disk may be stored the programmed instructions--the software--for particular computer operations.

K - The number 1024 (2^{10}). For example, a 2k-byte segment of memory contains 2048 bytes.

Line Printer - A high speed printer used by a computer system. High speed, in this instance, means that a minimum of 150 lines of text per minute (each line having 100+ characters) is produced.

Mass Storage - Any means by which very large amounts of computer data can be economically stored. In a CAD system hard disks, and sometimes magnetic tape, are used for mass storage.

Microcomputer - A member of the smallest and least expensive family of computers. Microcomputers are presently available that have 1, 2, 4, 8, and 16-bit word sizes, and 32-bit word sizes will soon be available. Some of the more powerful 16-bit microcomputers have been successfully used in smaller CAD systems, instead of the usual minicomputer.

Minicomputer - A member of the family of middle-sized computers. These usually have a 16-bit word size, although 32-bit sizes also are available.

Real Time - By "real time" is meant that a computer system promptly performs the tasks given to it. For a CAD system this usually means that dispatching personnel need wait no longer than 2 s for the system to respond to a command.

Software - Anotner name for computer programs. It is the set of instructions put into the computer memory which enables it to perform the proper sequence of operations to accomplish a designated task.

Word - A sequence of bits that may be interpreted by the computer as an instruction or as data.

Word Size - The greatest number of bits that a computer's CPU can handle as a single group.

APPENDIX B--DETERMINATION OF THE NUMBER OF COMPLAINT OPERATOR AND DISPATCH TERMINALS REQUIRED FOR A CAD SYSTEM

In a study [1] conducted in 1975 by the Jet Propulsion Laboratory (JPL) for the Law Enforcement Assistance Administration, a model was developed for determining the number of complaint board operator and dispatcher terminals required for a CAD system. The model was developed from information obtained by direct observation of the CAD system operations of two police departments--Huntington Beach and San Diego. At Huntington Beach, the researchers obtained voice tapes of the dispatchers along with the corresponding case logs. The taped voice messages were timed with stop watches and elapsed time clocks and compared with the case logs to establish correlations between cases, cars on patrol, message rates, and operator utilization. In San Diego, the voice channel was recorded and videotapes were made of the dispatcher's incident display. These were analyzed for relationships between the keyboard and screen operations and the voice messages. The discussion below is a summary of the calculations which were developed from the observations of the JPL study.

Primary Complaint Board Operator Position

The key criteria for determining the number of primary complaint board operator positions are the number of calls which must be processed before a caller waiting in the queue is connected to a primary operator (delay unit) and the number of calls per hour during the peak hour(s). The delay unit is obtained from:

$$\text{delay unit} = \frac{\text{mean waiting time in seconds}}{\text{mean operator service time in seconds}}$$

The mean waiting time is the average time it takes for a caller to be connected with an operator and is an optimum value based both on the observations discussed earlier and the kind of service which the department would like to provide the public. Mean operator service time is the average time it takes to process a call and pass it along to the dispatcher, and is based on the observations.

The operator workload units, based on the peak call rate per hour, are then calculated:

$$\text{operator workload units} = \frac{\text{peak call rate [calls per hour during the peak hour(s)]} \times \text{mean service time, s}}{3600}$$

The intersection of these two parameters on figure B1 will indicate how many primary operators will be required. For example, consider the following information and performance requirements:

1) Average waiting time in the queue shall not exceed 2.5 s;
2) average service time per call is 100 s; and
3) peak call rate is 200 calls per hour.

The number of delay units is:

$$2.5 \text{ s}/100 \text{ s} = 0.025 \text{ unit.}$$

The operator workload units are:

$$(200 \times 100)/3600 = 5.56 \text{ workload units.}$$

It can be seen from figure B1 that where these two values intersect indicates that 10 operators would be required to handle the complaint board under the conditions described above.

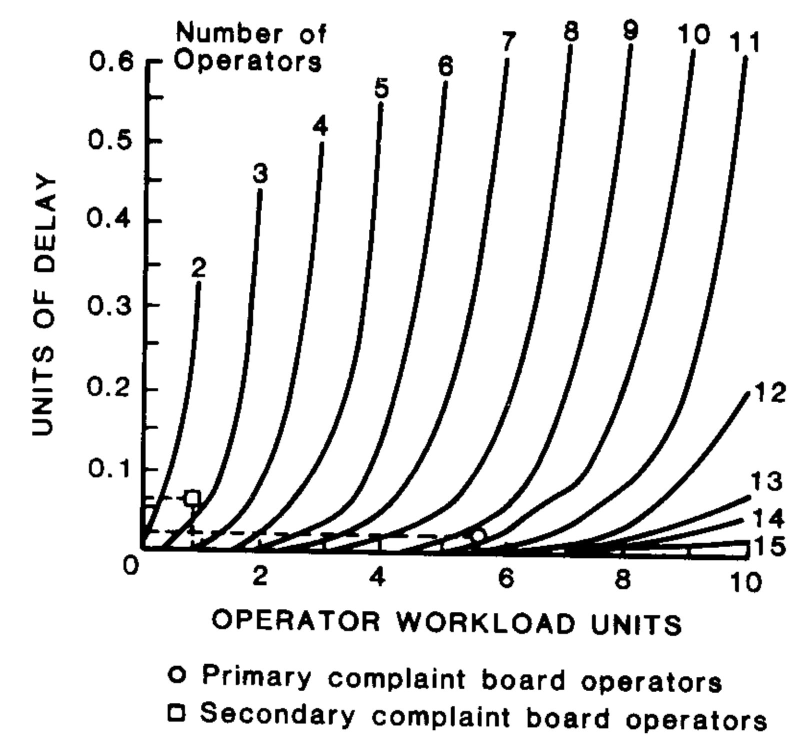

Figure B1. Complaint board operator position design (from Sohn, et al.).

Secondary Complaint Board Operator Position

The duty of a secondary complaint board operator is to handle longer incoming calls and calls which do not require dispatching. Although not all departments use them, it has been found to be an efficient way to improve service to the public and reduce the work load of the primary operators. The number of secondary operators needed is calculated in the same way as described in the Primary Complaint Board Operator Position section, except the data used would be different due to the different nature of the job. As an example, the following information applies:

1) Maximum average waiting in the queue is 20 s;
2) average service time per call is 300 s; and
3) number of "long" calls during the peak call rate time is 10.

The number of delay units is:

20 s/300 s = 0.066 unit.

The operator workload units are:

(10 x 300)/3600 = 0.83 workload units.

In figure B1, the intersection for these two values is between two and three operators. This would indicate that three secondary operators are needed if the average call waiting time is not to exceed 20 s.

Dispatcher Positions

The dispatcher is the heart of the command and control center operations as it is his responsibility to coordinate the patrol force to meet the many and varying demands for police service. Dispatcher duties fall into five main areas:

1) messages involving initial assignment of cases,
2) messages supporting cases in progress,
3) messages supporting units on patrol,
4) messages involving case dispositions, and
5) messages relaying queries to remote data banks (e.g., Department of Motor Vehicles, National Crime Information Center) and the answers to these queries.

In observations made of the dispatch activities of the San Diego Police Department, the following distribution of activities was found:

Type of activity	Percent of total
Initial assignment	26
In-progress case support	44
Patrol support	15
Case dispositions	15

In addition, queries to data bases were added in proportion to the number of patrol units deployed at a rate of one query per 2 h per on-duty patrol unit. From the observations, two things are especially worthy of mention. First, when dispatchers have to handle remote data base queries in addition to their other duties, it significantly reduces the number of cases each dispatcher can handle. Secondly, it was observed that when the dispatcher is busy 60 percent or more during the peak call time, the stress becomes severe and he/she begins (1) to defer action on calls perceived to be of low priority, (2) to shorten messages, (3) waiting times become excessive, and (4) patrol units cannot communicate with the dispatcher satisfactorily. The stress results because the dispatcher is faced with simultaneous and conflicting demands that cannot all be met at once and with which he/she must make critical decisions. The observers felt that when the dispatchers were busy 65 percent or more of the time, the peak limit of the system has been exceeded. They drew the conclusion that sufficient terminals and operators should be provided to keep the busy time to approximately 30-50 percent during peak periods.

Based on the observations, a computer simulation of a dispatcher work station under three different conditions was conducted. These conditions were:

1) separate complaint board operator and dispatcher; dispatcher does not handle queries to remote data bases (System A);
2) separate complaint board operator and dispatcher; dispatcher handles queries to remote data bases (System B); and
3) dispatcher takes calls from public, but does not handle queries to remote data bases (System C).

To determine the number of dispatchers needed under each system is a relatively simple matter. The system should be sized to handle the heaviest load--that is, the number of cases in progress during one or more of the busiest hours should be counted. Then the maximum allowable case load per dispatcher is determined. From these, the total number of dispatcher stations is determined as follows:

$$\text{Number of dispatchers needed} = \frac{\text{Total case load during peak hour(s)}}{\text{Case load per dispatcher}}$$

Based on the observations made at the San Diego Department, it was determined by computer simulation (in which the dispatcher's channel utilization rate during the peak hour(s) was 30 percent,* and the type of case handled was varied according to the percentages given above) the critical case loads for each system were:

System	Cases per hour
A	21
B	11
C	8

With this information, it is then an easy matter to determine the number of dispatchers needed. For example, under System A, assume the peak case load is 80 cases per hour. The number of dispatchers needed would be:

$$\text{Number of dispatchers needed (System A)} = \frac{80}{21} = 3.8,$$

which means four dispatcher stations will be required. Similar calculations can be done for System B and C.

Based on the results of the observations, the following general conclusions were confirmed:

1) Separating the complaint board operator position from the dispatcher position increased the capacity of the dispatcher position; and,
2) removing remote data base queries from the dispatcher position increases dispatcher capacity.

For a more detailed discussion of the calculations and simulations referred to and summarized above, the reader is referred to reference 1 of the basic report.

*If the channel utilization rate was above 30 percent, it was found that the waiting time to use a channel became too high.

APPENDIX C--LIST OF REVIEWERS

Mr. Robert J. Benson
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South Bay Regional Public Communications Authority
Hawthorne California

Captain Herman R. Campbell
Communications Bureau
Viriginia Beach Police Department
Virginia Beach, Virginia

Captain Dave Crow
San Diego Police Department
San Diego, California

Captain J. W. Hilliard
Greensboro Police Department
Greensboro North Carolina

Mr. B. V. Hughes
Management Information System
Memphis Police Department
Memphis Tennessee

Captain Larry Husemann
Computer Services
Phoenix Fire Department
Phoenix, Arizona

Major H. V. Johnson
Inspectional Services Division
Seattle Police Department
Seattle, Washington

Mr. Tom McKinney
PRC Public Management Services
McLean, Virginia

Mr. James A. Munson
Manager Special Projects
PRC Public Management Services
Huntington Beach, California

Mr. Jimmy D. Patty
Director of Communications & Information Services
Boone County/Columbia Disaster Preparedness
Columbia, Missouri

Mr. Thomas F. Sawyer
Assistant Chief
Phoenix Fire Department
Phoenix, Arizona

Mr. Steve Smith
Communications Supervisor
Public Works Department
Des Moines, Iowa