U.S. Department of Transportation

μtps Microcomputers in transportation

SELECTING A SINGLE USER SYSTEM

SELECTED READINGS VOLUME 2

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16. Abstract

The Urban Mass Transportation Administration (UMTA) and the Federal Highway Administration (FHWA) of the U.S. Department of Transportation provide training and technical assistance in the new and rapidly changing area of transportation application of microcomputers. These two agencies maintain up-to-date microcomputer references for transit and paratransit operators, transportation planners, and traffic engineers.

This document is one in a series of selected readings covering technical aspects of microcomputer equipment, software, data communications and other topics. Each volume of selected readings will focus on a single aspect. Thus far, these are:

Volume 1 "Getting Started in Microcomputers"

Volume 2 "Selecting a Single User System"

Volume 2 responds to the growing number of people in transportation-related industries who have decided to acquire a single-user microcomputer and are asking "What should I get?" It recommends a general selection procedure and describes hardware and software in detail.

Ordering instructions for the other volumes are contained herein.

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MICROCOMPUTERS IN TRANSPORTATION:

SELECTING A SINGLE-USER SYSTEM

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for

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U.S. Department of Transportation
Washington, DC

May 1983

ABSTRACT

This paper responds to the growing number of people in the transportation-related industries and professions who have decided to acquire a single-user microcomputer system and are asking "What should I get?" Rather than recommending specific products, it recommends a general selection process which, if followed, will increase the likelihood of selecting a microcomputer system which meets the specific needs of the organization within its resource constraints. Each step in the process is described in detail and issues to be addressed by potential buyers are identified.

Using a generic set of specifications which are designed to meet the basic microcomputing needs of a broad spectrum of small organizations, the costs of complete configurations based on five of the most popular single-user microcomputers (the Apple II, the Apple ///, the IBM Personal Computer, the Osborne 1 and the Radio Shack Model 12) are computed and compared.

PREFACE

It is difficult to know exactly where to look for information in the new and rapidly changing area of transportation applications of microcomputers. At UMTA and FHWA, we have tried to keep up with developments and to maintain up-to-date microcomputer references for transit operators, transportation planners and traffic engineers.

In our efforts to assess and keep abreast of developments in the microcomputer field, we develop technical reports on selected topics like hardware, communications, data base management, and others. We are also fortunate in occasionally discovering papers and articles by others that are particularly appropriate to transportation users of microcomputers.

This series of publications, "Selected Readings", is intended as a continuing source of readings selected for this audience. Each volume will focus on a limited subject area. Non-copyrighted material may be reproduced in full. Other material will be referenced with a source.

Another reference in this general series **is the "Software and Source Book"** (formerly titled "Information Source Book") which describes software available or under development for transportation planning, transit operation, para-transit and traffic engineering. If you don't have this software report, the latest update is available from either of the addresses below.

Finally, any donated (non-copyrighted) papers will be carefully reviewed for possible inclusion in future volumes. Papers should cover an area of very broad interest.

Urban Mass Transportation Administration
Methods Division (URT-41)
Washington, D.C. 20590
(202) 426-9271

Federal Highway Administration
Urban Planning and Transportation
Management Division (HHP-22)
Washington, D.C. 20590
(202) 426-0182

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INTRODUCTION

Microcomputers are state-of-the-art business tools with many applications to transportation-related industries and professions. They are rapidly being accepted into organizations of all types and are being put to work on an incredible variety of analytical, clerical and operational tasks. At the present rate of introduction, it appears certain that microcomputers will have a huge impact on both transportation organizations and the way people do their jobs within those organizations. Few aspects of few organizations will remain unaffected.

The U.S. Department of Transportation, principally through its Urban Mass Transportation Administration (UMTA), Federal Highway Administration (FHWA) and Transportation Systems Center (TSC), was quick to recognize the potential value of microcomputers to transportation industries and professions. Over the past five years, its computer-related research and development activities have become increasingly focused on the small computers. These activities have taken many forms and have been implemented under the banner of many different programs. No program, however, is more directly focused on the use of microcomputers than the Operations and Planning Support (OPS) Program.

Established in 1982 by UMTA, this program is aimed at providing direct technical assistance to operators and planners of transportation services. This technical assistance, now also supported by FHWA, has included the development of application software, demonstrations of the usefulness of commercial software in transportation applications, research into new ways to use microcomputers, review of commercial software and hardware products for potential utility in transportation-related settings, and a broad spectrum of

information dissemination activities: reports, periodical publications, seminars and direct user support. The direct support is provided primarily through two "technical support centers" -- one for users of microcomputers in the transit industry (supported by UMTA) and one for users in the transportation planning professions (supported jointly by UMTA and FHWA).

More information on the activities of these support centers and the OPS Program in general can be obtained from the UMTA sponsor, identified in the Foreword.

One function of these support centers is to respond to telephone inquiries regarding microcomputers. Many of these inquiries go like this:

> "I'm really interested in these new microcomputers. I've seen how they're being used over at the Planning Council and they're doing some really useful things! I've talked my Board into giving me $5,000 to buy one, but, just between you and me, I don't know the first thing about them. What should I get?"

Of course, there is no simple answer to this kind of question. Nevertheless, through our experience in using and studying these machines and their applications, we are in a position to offer some general guidance. This document is one way of responding to inquiries of this type.

In the pages that follow, we will describe the steps that we think you should follow if you are buying a single-user microcomputer system. Included with this advice is a description of the current microcomputer marketplace -- what products are being sold to meet your needs. Microcomputer system prices and capabilities can vary greatly from one configuration to the next, so to provide a common basis for comparison we will step through a hypothetical microcomputer selection cycle, using a hypothetical set of hardware and software specifications that we think meets the basic computing needs of many small organizations. We will assemble complete configurations based on five of the most popular microcomputers: the Apple II, the Apple ///, the IBM Personal Computer, the Osborne 1 and the Radio Shack Model 12.

In configuring these hypothetical systems, we will be following the same

steps that we recommend you follow in looking for your single-user system. At each step, we will point out some of the issues that you should address and resolve before proceeding to the next step. In discussing the various hardware and software components that comprise the system, we will point out some of the important distinctions that can be observed among competing products. In short, the emphasis throughout the paper is on the process rather than the product.

Now that we have stated what we intend to do, perhaps we should also state what we intend not to do.

First, we do not intend to educate you in the fundamental concepts underlying the operation of microcomputers. If you don't know hardware from software, then we recommend that you first consult one of the many introductory texts that can be found in virtually any bookstore (An Introduction to Microcomputers by A. Osborne and D. Busnell and The Howard W. Sams Crash Course in Microcomputers by L.E. Frenzel are two good ones). However, to be fair, we will attempt to briefly explain the technical terms that must necessarily appear in a document of this type.

Second, we will make no attempt to discuss any type of computer other than the entry-level single-user microcomputer system. Our primary intended audience is those small agencies which are contemplating the acquisition of their first computer system. While entry-level single-user computer systems have many applications in larger organizations and in organizations which already use computers, they are not the best solution to every organization's information processing needs. In particular, many larger organizations may be better served by a larger (minicomputer or mainframe) computer which can be simultaneously shared by many users. It is assumed here that you have decided that a single-user microcomputer may be right for you.

Third, we make no real attempt to advise you on how to anticipate and deal with the problems associated with the installation and use of a first computer system, other than to warn you here that computerization may not be as smooth and as painless a process as you would like. Computers can be very cost-effective tools that can enhance your organization's productivity in

many ways, but all of the benefits may not begin to accrue the moment you turn it on. You will have to convert your paper records into a form the computer can understand, you will have to develop plans for protecting your electronic information from accidental damage or destruction, you will have to establish procedures and policies for using and maintaining your new hardware and software resources, you will have to train people to use the new equipment, and you may have to deal with the feelings of employees who feel threatened by the machine. These are all difficult, complex and important issues which are not addressed in this document. We recommend that you seek out and talk to people who have already dealt with these problems.

A few disclaimers are also in order.

First, products are mentioned by name in this document, but the appearance of a brand name in these pages should not be construed as an endorsement by the United States Government, nor as a recommendation for use by your agency. For the most part, the products appearing here are among the most widely used products of their type, but many other products -- some as or more popular than the products appearing here -- exist and should be included in your product search.

Second, though the descriptions of products presented in this document are, to the best of our knowledge, accurate, our project resources did not permit us to verify each and every fact with the product's vendor. Also, there are many gaps in our knowledge and these gaps are evidenced by the presence of question marks in the factual tables. Despite our efforts to be 100% accurate, some errors probably sifted through our nets, so be sure to verify the capabilities of any product you are interested in before purchasing it.

Third, microcomputer hardware and software products are introduced and removed from the market daily and their prices are in constant flux. Many changes occurred in the products mentioned in this document in the short time required to write it. Although the information presented here was, to the best of our knowledge, accurate at press time, some of it will be obsolete by the time this reaches you. We advise you to check with your local dealers

for current prices and recent product releases.

Finally, the prices quoted here are the manufacturer's list prices as of the publication date. Prices vary substantially from dealer to dealer and large discounts can usually be negotiated on complete system purchases. So shop around.

Now that that's out of the way, let's begin by looking at the steps in the process that we recommend you follow when looking for a single-user microcomputer system.

THE MICROCOMPUTER SYSTEM SELECTION PROCESS

One approach to selecting a microcomputer system is to simply go out and buy whatever seems most appealing at the time. This approach has two advantages: very little analysis time is required and the system will be available for use very quickly. Unfortunately, the risk of choosing a system that is poorly matched to your needs is fairly high and you will be hard pressed to supply adequate justification if the purchase must be approved by a superior. If you are required to go through some kind of competitive procurement process, this approach is unavailable.

Usually a more structured approach is advisable and sometimes (as in the case of a competitive procurement) is required. We recommend the following course of action:

1. Do your homework. Hopefully, this paper will help you some, but there are many other sources of information. A little bit of self-education in advance will help you establish some reasonable expectations for what a microcomputer can do for you and how much you will have to budget to obtain a useful system. The goal is to come out of this step with a rough idea of what a microcomputer can do for your organization, how it would be used, the various hardware and software pieces that would be required to form a useful system and an estimate of the total cost.

2. Identify and prioritize your microcomputer needs. List all of the jobs you would like your microcomputer system to do for you. Try to estimate the benefits (in terms of time and/or dollar savings) of each application and its incremental cost (in terms of extra hardware, software, materials, maintenance and training). You should also establish some rough specifications for the performance characteristics the system will have to possess to be acceptable to you. You should leave this step with a specific list of intended applications and a very good idea of the specific hardware and software pieces that you will be searching for.

3. Establish a budget and allocate among the components. Get a commitment for a computer system budget that is consistent with the applications you picked for implementation and the performance standards you set in the preceding step. Allocate this budget to the major system components in a manner that is consistent with your intended applications. Set aside funds for training, furniture, supplies and all of the other incidental expenses.

4. Search for software. Look for application software that does the jobs that you've included in your list of intended applications and fits within your budget. Also look for system software that you are comfortable with and which gives you access to the computer's power. Try to configure several complete sets of application packages which operate under different operating systems. The goal of this step is to reduce the complex process of selecting software to a relatively simple process of selecting among complete packages of applications which operate in different environments on different machines.

5. Search for hardware. The goal of this step is to find hardware configurations -- the microcomputer and peripheral devices -- that are compatible with each of the packages of software identified in the preceding step. You will be looking for hardware which, using the selected application software, performs your jobs according to your performance specifications. In addition to performance, you will also want to consider the hardware's reputation for reliability, the availability of maintenance, the reputation of the dealer and a variety of other factors.

6. Evaluate candidate microcomputer systems and select. Evaluate the various hardware/software configurations that you found in your search, considering the cost, performance, ease of use, reliability, reputation, and upgradability of each, as well as a host of other factors. Select the system which, when all factors are considered, best meets your needs.

It is extremely unlikely that you will navigate all of these steps without encountering at least one conflict. Maybe you can't get the performance you want for the money you have available. Maybe your performance requirements are just plain unattainable. Or maybe the software you would like to use does not all run in the same environment. As each conflict is encountered, you will have to solve it by revising you requirements, your budget or the domain of your search. The entire selection process is thus iterative in nature, as shown in Figure 1.

The primary goal of this exercise is to find a feasible solution; that is, to find at least one microcomputer system which does what you want it to do, does it within your performance requirements and fits within your budget. Moreover, the value of what it will do for you must outweigh its cost. If only one such system exists, the choice is obvious, and if more than one such system exists, you must choose among the acceptable alternatives, presumably with an eye toward maximizing the benefit/cost ratio of the system.

If no such system exists, then either no computer will be useful or you are looking at the wrong kind of computer. If an entry-level single-user microcomputer does not provide the performance you need, then you should be looking at multiple-user microcomputers, minicomputers or mainframes.

If you are able to purchase the microcomputer of your choice, you can simply go out and acquire the system which came out on top in your analysis. If you must go through a competitive procurement, then your next step is to write your specifications. Your analysis can serve as a guide. The object in writing the specifications is to include enough detail that you are certain to acquire a system which meets your needs, but leaves sufficient freedom for competition among acceptable alternatives. This can be tricky, as you no doubt are aware, but you will find that you will be able to write better specifications if you go through the same analytical exercise you would go through if you were buying the system with your own money.

In the following pages, we will describe each step in greater detail and will give you a hypothetical example of how the process can be applied.

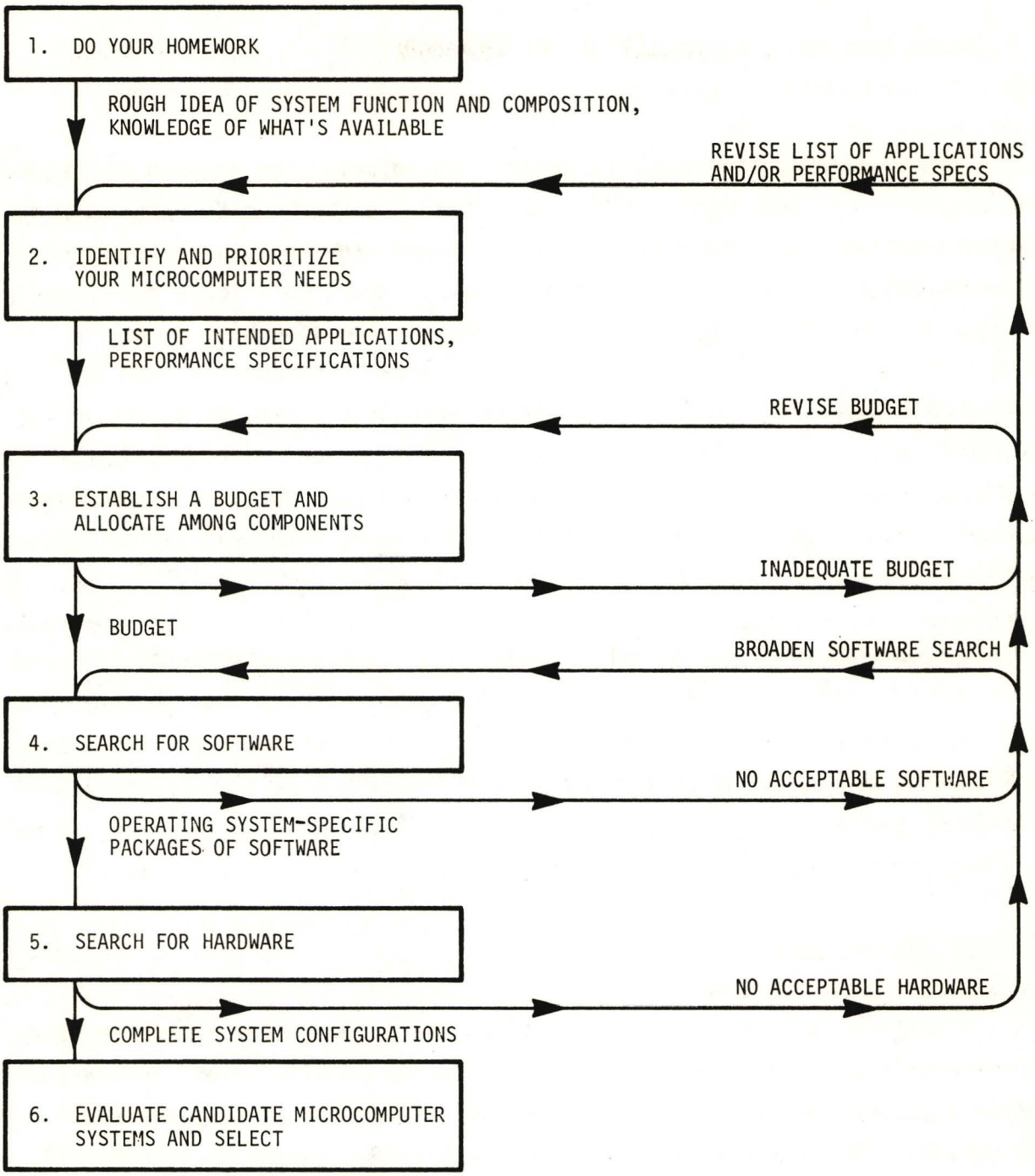


Figure 1

The Computer System Selection Process

STEP 1: DO YOUR HOMEWORK

The first step in the microcomputer system selection process is to learn enough about the technology and its potential applications to enable you to select applications, form realistic performance expectations and estimate the cost of the system you would like to install. You should leave this step with a good notion of the kinds of jobs that can be done well by a microcomputer and the various hardware and software components that are required by each application. You should also have a list of possible applications of the system in your organization, a good understanding of the various hardware and software components that would comprise a microcomputer system that can do these things and a rough idea of what that system will cost.

If you are confident in your knowledge of microcomputer technology and have already composed your list of possible applications, then you can skip this step entirely. If not, we will help you get started by directing you to some other sources of information and by giving you a brief introduction to the technology.

SOURCES OF INFORMATION

There are many sources of information on microcomputer technology and microcomputer applications. In fact, it is easy to get overwhelmed by the variety of sources and the sheer volume of information that is available. We do not recommend that you try to tap every possible source of information, and we certainly do not recommend that you attempt to become an overnight expert on microcomputer technology (it simply isn't possible). We do think it is a good idea for anyone who is going to be responsible for the selection of a microcomputer system to become aware of the major options and to try to understand the functions of the various hardware and software components needed to form a complete, functioning microcomputer system.

To this end, we recommend that you take the following steps:

1. Read the introduction to microcomputer technology that follows.

2. Talk to a few people who know more about microcomputers than you do.

3. Acquire the latest version of UMTA's Microcomputers in Transportation: Software and Source Book and Getting Started in Microcomputers: Selected Readings Volume 1. They can be obtained by writing UMTA's Office of Methods and Support at the address given in the Foreword.

4. Obtain some recent issues of some of the periodicals written for laypersons who are interested in microcomputers. Personal Computing, InfoWorld and Small Business Systems are three good periodicals of this type (see the appendix for the addresses of their publishers). Look for articles giving general overviews of application software and hardware that you think might be useful in your organizational environment.

There are also many books on microcomputers which you might want to take a look at, although it is our experience that these books tend to be outdated by the time they reach the bookstand. Books are a good source of general information on computer technology and terminology, however.

Another good source of basic information is the McGraw Hill Microcomputer Literacy Program which is a series of audio cassettes and workbooks comprising a self-study course on microcomputer fundamentals. It can be obtained from the McGraw Hill Continuing Education Center, 3939 Wisconsin Ave., N.W., Washington, DC 20016. Its cost was $95 at the time of publication.

In addition, you may find it useful to visit a few retail computer stores to hear the sales pitches for several different microcomputers, attend a computer show, tap the resources available through a local computer club or, possibly, hire a consultant for a short time to advise you on your next steps. You could, of course, hire a consultant to do the entire microcomputer selection for you, but you will eventually have to know enough about the technology to be able to operate it without the help of a

consultant, so why not start learning now?

You should also get in touch with one of the two UMTA/FHWA-sponsored support centers for users of microcomputers. They can assist you in numerous ways and can offer more specific advice than we can here. The transportation planning support center's address is:

MTP User Support Center
Transportation Systems Center, DTS-62
Kendall Square
Cambridge, MA 02142
(617) 494-2247

The transit support center can be reached at the following address:

TIME Support Center
Department of Civil Engineering
Rensselaer Polytechnic Institute
Troy, NY 12181
(518) 270-6227

These support centers are best suited to answering specific questions that you may have, but they also may be able to provide general advice on your selection process. Do not expect to obtain recommendations for specific products.

MICROCOMPUTER TECHNOLOGY

MICROPROCESSORS

All microcomputers (and now even most of the minicomputers) are based on microprocessors. These are miniaturized (no larger than your fingernail) electronic devices which contain the logic circuitry that enables the computer to "think." Each microcomputer has at least one of these things and some have several -- one main one and others to help out with specific tasks.

Each brand of microprocessor has its own peculiar language or "instruction set." Microprocessors differ from each other in the versatility of their languages, the speed at which they execute their instructions, the size of the pieces of information they can deal with and the amount of information they have access to.

All information (numbers, text characters, program instructions and data) in all microcomputers is represented as patterns of binary bits where each bit is equivalent to the setting of a two-way switch; that is, each bit is either "on" or "off" at any time. Virtually all modern microprocessors deal with groups of 8 bits called bytes. When text is processed by a computer, each character is represented by one byte of information: a 4-letter word such as "ball" would occupy 4 bytes of information. A decimal number (e.g. 3.14159) may occupy four or more bytes, depending on the number of significant digits that are stored (four bytes generally equates to about six significant digits; five bytes give roughly nine).

Each byte of information which the computer has access to is assigned a unique address or location at which it is stored in the computer's electronic memory. The computer can retrieve information stored at any memory address and can in turn store information at any address. Much of the microprocessor's time, in fact, is spent in sending information out to be stored and retrieving information from storage. To a great extent, the power of the microprocessor can be gauged by three information-related measures: (1) the number of addresses it has available, (2) the amount of information it can store or retrieve at one time and (3) the amount of information it can process simultaneously.

Most older microprocessors can access about 64,000 addresses and can get and process only 8 bits (i.e. one byte) of information at a time. They are called "8-bit" processors. The newer microprocessors can access many more addresses (usually between 1 and 16 million) and can usually get and process 16 bits at a time. They are called "16-bit" microprocessors. There are also some hybrid microprocessors which can process more information than they can get or store in one operation (e.g. some can add two 16-bit numbers in one

operation, but need to perform two separate operations to store the two halves of the 16-bit sum). Both "8/16-bit" microprocessors (which can get one byte and process 2 bytes) and "16/32-bit" microprocessors (get two, process four) are now on the market.

The volume of addresses available to a microprocessor is called its address space and is usually reported in units of "K" (for "kilobyte") or "M" (for "megabyte") where one K is equal to 1,024 addresses and one M is equal to 1,024K (i.e. roughly one million addresses). The size of a microprocessor's address space is not directly related to the amount of information that it can get or process at once, but address space sizes have grown with the development of the 16-bit microprocessors. There is no theoretical reason why the address space of an 8-bit processor should be smaller than that of a 16-bit processor, but it generally is.

A few 8-bit microcomputers use a technique called bank switching to effectively extend the address space of their microprocessors. This technique is based on the use of parallel banks of memory which are quickly switched in and out of use whenever the information stored there is needed. In a town, this technique would be equivalent to having several houses share one mailbox. It is roughly analogous to a platooned football team: only 11 players are active at any time, but the coach can switch between groups of 11 players at will, giving him access to the talents of a squad that is much larger than the active team. Using this bank switching technique, some 8-bit microcomputers are able to access 256K or more of memory.

The characteristics of the most popular microprocessors are summarized in Table 1.

MEMORY

Most of the addresses available to the microprocessor are random access memory or RAM which the microprocessor can both write information into and read information from. Most microcomputers, however, also have a small amount of read only memory or ROM which the microprocessor can read from but

MANUFACTURER	MICROPROCESSOR	ADDRESS SPACE*	TYPE
Intel	8080	64K	8-bit
	8085	64K	8-bit
	8088	1M	8/16-bit
	8086	1M	16-bit
MOSTEK	6502	64K	8-bit
Motorola	6809	64K	8-bit
	68000	16M	16/32-bit
Zilog	Z80	64K	8-bit
	Z8000	8M	16-bit

* Note: K = 1,024 bytes (i.e. approximately 1,000)
M = 1,024K bytes (i.e. approximately 1,000,000)

Table 1

Characteristics of Some Popular Microprocessors

not write to. The RAM is "dynamic" memory in the sense that all of its information is lost if the electricity is turned off; ROM, on the other hand, is "static" memory because the information stored in it is permanent. ROM is used to store information that the computer needs frequently and which doesn't change. RAM is used to store everything else, including all application software and data.

In single-user systems, the user has access to all of the RAM not reserved by the computer for its own needs. In a multi-user system, users must share the available RAM.

A computer system can have no more memory than its microprocessor can use, but it could have less because not all addresses need be occupied (think of those unused addresses as vacant lots). There is a minimum amount of memory required by the microcomputer if it is to function at all, but between that lower bound and the upper bound of what it can use, there is often a broad range of memory size options from which you can select. Your memory size choice will be influenced primarily by your applications' memory requirements and the cost of RAM: you don't want to scrimp on memory, but you don't want to pay for memory you will never use, either.

Memory prices are falling, but figure on paying $100 to $300 for 64K of dynamic RAM.

PORTS

From a microprocessor and memory, plus some miscellaneous components such as a power supply, a fully functioning microcomputer could be constructed. Such a computer would be absolutely useless to you, however, because you would have no way to communicate with it and it would have no way to communicate with you.

The electronic components that provide those necessary communication capabilities are called ports. There are many types of ports, some general purpose and some special purpose. We will describe only two generic types of

common general-purpose ports: serial ports and parallel ports.

Remember that all information can be represented as a series of bits and a bit can be represented by anything that has two states. A bit could be represented, for example, by a high/low voltage. In fact, a bit is commonly represented in this way because the use of voltage provides a convenient means for transmitting information over long distances. This is the principle on which the telephone is based.

Suppose we wanted to transmit a byte -- 8 bits -- over one or more wires. We could do this in two different but equivalent ways:

1. We could transmit the 8 bits in sequence (i.e. serially) over a single wire; or

2. We could transmit the 8 bits simultaneously (i.e. in parallel) over 8 wires.

Either way, the byte will get to the other end, but the two methods have different properties. The serial transmission is relatively slow, but uses a simple transmission medium (a single wire) that is easy to install and can be effectively shielded from electromagnetic interference. The parallel method, on the other hand, is potentially faster, but uses a more awkward medium (an 8-wire ribbon cable) that cannot be effectively shielded and, in fact, generates its own interference. Due to its superior medium, serial transmission can be used over greater distances than parallel transmission (a maximum of 250 feet for serial transmissions versus 50 feet for parallel transmissions under normal conditions).

Serial ports are often referred to as "RS-232C" ports in reference to the name of the Electronic Industries Association (EIA) standards for the protocols and connectors which are employed by virtually all general-purpose serial ports found on microcomputers today. Parallel ports have not achieved the same level of standardization. The most widely used protocols were originally developed by the Centronics Data Computer Corporation, so parallel ports using that protocol are said to be "Centronics-compatible."

Exceptions abound, but parallel ports are generally used to connect printers while serial ports are generally used to connect all other kinds of peripheral devices (except those using special-purpose ports).

Incidentally, the speed of data transmission is usually reported in units of baud. One baud is equal to one bit per second. Since each transmitted byte is generally accompanied by two other bits of information (for timing and error detection), the effective transmission rate in characters per second can be approximated quite well simply by dividing the baud rate by 10. A baud rate of 1200, for example, is equivalent to 120 characters per second.

PERIPHERAL DEVICES

Ports give the computer a way to communicate with other devices. Any device connected to the computer is a peripheral device. We will look at some of the most common types of peripheral devices.

Consoles/Terminals

The primary device for communicating between a computer and its user is the user console or data terminal. Both devices consist of a keyboard and a cathode ray tube (CRT) screen which is essentially a high-quality television without the tuner. Occasionally, a real television serves as the CRT (this is often the case with the less expensive "personal" computers). The keyboard is usually similar to a typewriter keyboard with some extra keys thrown in.

There are two common ways to attach the keyboard and the screen to the computer: they can be attached directly using special-purpose ports or can be integrated into a separate data terminal device which is linked to the computer via an RS-232C serial port. Most of the more popular single-user microcomputers have opted for the first method while virtually all of the

multi-user computers have opted for the second method. You can, however, find some single-user systems which rely on a data terminal.

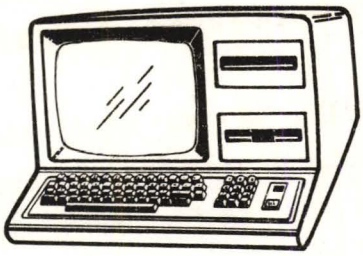
Data terminals are not highly standardized. Each manufacturer has included a peculiar set of features and options that can accessed only in some peculiar and non-standard way. A few of the more popular data terminals (e.g. the Digital Equipment Corporation VT-100 and VT-52 and the Lear-Siegler ADM-3A) have become de facto standards in the industry and have drawn some imitators. But for the most part, selecting a data terminal is a risky business because you must make sure that every software product you will be using will be compatible with it. You can avoid this selection dilemma by getting a microcomputer which uses an integrated console, but this arrangement offers less long-term flexibility since you cannot easily change you keyboard or (in some cases) your CRT as you can if you use a data terminal. Another drawback to data terminals is that few have the ability to display graphics; most are intended for displaying text only.

Those systems which use a special port to control the screen do so either by providing a screen that is integrated into the console or by producing a standard television signal that can be input to a separate monitor device. This latter arrangement affords more freedom in selecting a CRT while still avoiding the data terminal problems. Both arrangements are more likely to support graphics than data terminals.

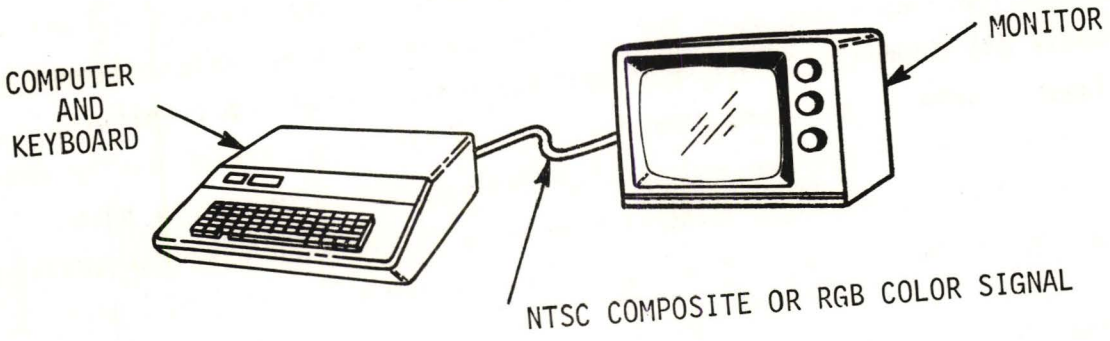
These various keyboard/screen arrangements are illustrated in Figure 2.

A few words about color CRTs are in order here. Most data terminals offer white-on-black or green-on-black ("green screen") displays. A few offer color displays (and color graphics), but these terminals are much more expensive than the plain data terminals ($5,000 to $30,000, as compared with the $400 to $1,500 data terminal cost). Practically speaking, color is not available on microcomputers which use data terminals.

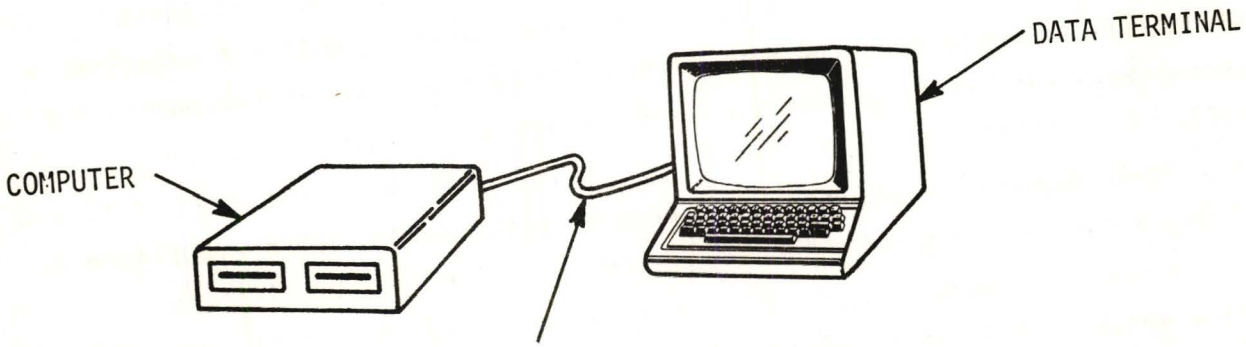
Similarly, few microcomputers which have integrated screens offer color. However, quite a few of the microcomputers which use separate monitors produce signals which produce color displays on color monitors. There are



(a) INTEGRATED KEYBOARD AND SCREEN



(b) INTEGRATED KEYBOARD, SEPARATE MONITOR



(c) DATA TERMINAL

Figure 2

Various Microcomputer Keyboard/Screen Arrangements

two types of color signal produced (and two types of monitors to receive them):

- o a National Television Standards Committee (NTSC) composite signal which incorporates all color picture information into one composite signal; and

- o a red-green-blue (RGB) signal which is really three separate red, green and blue picture control signals.

The RGB signal/monitor produces a superior color display, but is more expensive (by $200 to $400) than a composite monitor of otherwise equal quality.

Disk Drives

For long-term storage of programs and data, most microcomputers rely on floppy diskettes. These are flexible magnetic disks in cardboard covers that can be inserted into slotted boxes called disk drives. Floppy diskettes (and drives) are available in 5.25-inch and 8-inch diameters with some smaller sizes just entering the market. Information is stored on either one ("single-sided") or two ("double-sided") sides of the diskette and is recorded in either single or double density. If you are a mathematician, you can see that a double-sided, double-density diskette can store about four times as much information as a single-sided, single-density diskette.

The storage capacity of a diskette is a function of both the physical medium (e.g. whether it is single- or double-sided) and the magnetic format of the diskette. Before it can be used, the diskette must be "formatted" by the computer to prepare the magnetic surface for storing information. Different formats are used by different machines, so even machines which employ the same type of floppy diskettes may not use identical diskette formats. The only widely-used format is the IBM 3740 format for single-sided, single-density 8-inch diskettes. There is no widely-used 5.25-inch floppy diskette format at this time.

Floppy diskette storage capacities range from about 80K (the low end of the 5.25-inch range) to 1.2M (the high end of the 8-inch range). If you need more storage capacity, you have two choices: get multiple floppy disk drives or get a high-capacity hard disk. These hard disks (also called "Winchester" disks) use a rigid platter in a sealed enclosure in place of the floppy diskettes. Most hard disks are not removable from their drive, so your entire library of programs and data will be available to the computer ("on-line") at all times. This is convenient if you have room on your disk to store all of your programs and data, but this is not usually the case. Consequently, some library management and storage backup problems exist with hard disks that do not exist with floppy diskettes. On the other hand, a hard disk offers vastly larger on-line storage capacity (typically 5M to 20M per drive), much faster access to stored information (typically 2 to 10 times faster than a floppy drive) and improved storage reliability.

Hard disk prices typically run from around $2,000 for a 5M model to about $5,000 for a 20M model. Floppy disk drives run between $300 and $1,000 each and floppy diskettes cost from $2 to $10.

A third disk drive option which recently appeared on the scene is the cartridge disk. A cartridge drive uses a removable hard disk cartridge (usually 5M capacity) and therefore has many of the speed and capacity advantages of the hard disk and the backup convenience of the floppy drive. The reliability of the cartridges is unknown at this point, however. These drives are priced about the same as the 5M Winchester drives and the cartridges cost $50 to $100 each.

If you use a hard disk, your system should still include at least one floppy drive because commercial software is distributed on floppy diskettes. If you use only floppy drives, you should have at least two since many applications require two drives and because copying diskettes with a single drive is very tedious.

All disk drives are connected to the computer by way of a high-speed special-purpose port. These ports are very computer-specific, so most brands

of disk drive work with only one or at most a few microcomputers.

Printers

A printer is a device for creating a paper copy of information generated by the computer. There are three main types:

- o dot matrix printers which print one column of tiny dots at a time and form characters by printing several consecutive columns of dots;
- o character printers which print one complete character at a time; and
- o line printers which print one complete line of text at once (or almost at once).

Some line printers are called band printers due to their use of a metal band as the printing element.

Dot matrix printers cost from $200 to $2,000 while character printers range between $700 and $3,000. Line printers can cost from $2,000 to $10,000 or more. Due to their cost, line printers are rarely used with microcomputers.

Line printers are much faster than either character printers or dot matrix printers, generating text at the rate of 250 to 1,000 cps (characters per second) or more. Dot matrix printer speeds range from 80 to 200 cps while character printers generally operate at speeds in the 10 to 50 cps range. However, character printers produce the best quality print. Dot matrix printers are capable of creating hard copies of graphics (there are even a few models which can print color graphics) and are generally the most versatile. Some of the dot-matrix printers have a "correspondence mode" which produces text that is almost as good as the character printers.

Printers of all types generally are linked to the computer by means of a general-purpose serial or parallel port.

Pen Plotters

While dot matrix printers are capable of creating medium-resolution graphics, a pen plotter is needed to produce draftsman-quality graphics. Some pen plotters can also be used as input devices and can double as a digitizing tablet. If you want to work with computerized networks, you will need a pen plotter.

Pen plotter prices run from about $1,000 to $5,000 or more depending on features and size. They use general-purpose ports.

Digitizing Tablets

A digitizing tablet (or simply digitizer) is a graphical input device which supplies coordinate information to the computer each time the user touches an electronic wand to any spot on its flat input surface. It is used primarily for encoding graphical information (e.g. maps). They are extremely useful for creating a computerized representation of a highway network, for example.

Digitizers run from about $500 to several thousand dollars and use general-purpose ports.

Mice

A mouse is a hand-held input device that can be conveniently used to control the movement of a cursor on the CRT screen. Mice are not yet widely used, but are expected to become very popular in the coming years.

An add-on mouse would cost between $50 and $400.

Modems

A modem ("modulator/demodulator") is a device which enables your computer to communicate with other, distant computers over telephone lines. With few exceptions, they use general-purpose ports. They range in price from $100 to several thousand dollars with the price depending primarily on the speed of the communications provided by the modem. The inexpensive modems that are available for microcomputers offer two different speeds: 300 baud ($100 to $400) and 1200 baud ($500 to $900).

A modem can greatly increase the utility of a microcomputer by enabling it to double as a data terminal to a larger computer and by affording you access to the numerous national data banks containing technical bibliographies, computer product data and a wealth of other kinds of information. You can even make your own airline and hotel reservations and place messages on computer "bulletin boards." A modem can open up a whole new world of applications for your microcomputer.

Networks

Like modems, networks are electronic devices which serve to link computers. However, unlike modems, networks can link many computers simultaneously and can be used to share other devices (such as a disk drive) among several computers. Most networks use high-speed special-purpose ports, but a few use the general-purpose ports found on most microcomputers. The speed of the communications offered by even the slowest networks is many times faster than the speed of the fastest modems. Typical network baud rates are 50K to 10M.

Computers linked via a network can be much farther apart than when linked with simple serial or parallel ports. Separations of over a mile are allowed in some cases. Usually, though, if the computers are more than a mile apart, a modem is needed.

Network prices vary greatly, depending primarily on the speed of the

communications provided and on the number of different channels of communication that are supported. The least expensive varieties run about $2,000 to $5,000 in fixed costs, plus $200 to $1,000 per computer attached to the network. Generally speaking, networks are not cost-effective for use with fewer than five microcomputers.

Networks are an emerging and very complex technology which will be very important to the future uses of microcomputers. However, if you get one today, you will be a pioneer; expect to encounter the hardships of a pioneer.

Other Devices

A microcomputer can be connected to many other kinds of peripheral devices, including bar code readers (like those used in the checkout lanes of some supermarkets), robots and digital/analog converters which can be used to communicate with and control a variety of appliances, tools and instruments. Generally speaking, if a device exists which can be controlled by electronic means, then a device exists (or can be created) which will enable the computer to control it. It's all a question of what you want your computer to do for you.

SOFTWARE

Of course, without appropriate software, your microcomputer will do nothing for you; hardware without software is about as useful as a phonograph without records. Software is needed to make the hardware function in some meaningful way.

The software that carries the instructions to the computer to make it do the jobs you want it to do is known as application software. There are many kinds of application software -- as many kinds as there are jobs to do. Some simple applications (e.g. games) can be purchased for next to nothing, but you can expect to pay handsomely for transportation-specific application software. Generally, the price of the application software product is

inversely related to the size of its potential market, so products having broad appeal (e.g. word processors) are generally relatively inexpensive while narrow, industry-specific application packages are much more expensive.

As a general rule of thumb, if you use only commercial application software having broad appeal, you can expect the majority of your microcomputer hardware/software acquisition budget to go to the hardware (about two-thirds hardware, typically). However, if you include the acquisition of any industry-specific application software, the software costs can easily outpace the hardware costs.

We will look closer at a few types of popular application software later (see Step 4).

Application software can operate on a microcomputer only with the permission and assistance of system software; more specifically, it needs the permission and assistance of the system software known as the operating system. Every application needs an operating system to execute and it needs other types of system software -- editors, compilers, interpreters and linkage editors -- to be created. In short, system software is very important to the operation of a microcomputer and its role must be clearly understood by potential microcomputer buyers. We will look a little closer at system software in the following sections.

Operating Systems

Every computer's operation is controlled by an operating system. It can be thought of as application software which has been given the job of keeping the computer running other applications. It is responsible for handling all input and output, for managing disk files and disk space allocation, and, in multi-user systems, for allocating the computer's resources (i.e. the microprocessor, memory and ports) among the various user applications. By itself, the operating systems accomplishes nothing of direct use to a computer user, but by insulating application software from the hardware, it makes the application software more immune to changes in the system hardware.

Thanks to the operating system, you will be able to add a disk drive or change your brand of printer without affecting the operation of your applications.

The operating system greatly influences the character of a computer system. If you acquire a microcomputer system and later discover that you don't like to use it, it will probably be due to your dislike of the operating environment provided by the operating system. For this reason -- and because the choice of operating system, together with the choice of microcomputer brand, determines the size of the pool of application software that you will be able to choose from -- the selection of an operating system is one of the most important decisions you will make in assembling your system.

In most cases, an operating system is provided free with the purchase of the microcomputer, but there may be other kinds of system software you will want to purchase. If you decide to use an operating system other than the one provided with the machine (most microcomputers have multiple operating systems available), it will generally cost you an extra $100 to $1,000.

Some of the most widely-used single-user microcomputer operating systems are CP/M, the UCSD p-System, Apple DOS 3.3, SOS, TRSDOS and MS-DOS. We will take a closer look at these in Step 4.

Compilers and Interpreters

Every application is written in some computer language or combination of computer languages. Some are written in the language used by the microprocessor itself -- the computer's "native language" -- but most are written in languages that are easier for humans to work with. Computer programs written in these "high-level" languages must be translated into the microprocessor's native language before they can be executed. There are two major ways to do this:

- a compiler can be used once to translate the entire program which can then, as a second step, be executed; or

- the program can be executed directly through an interpreter which translates each statement of the high-level program as it is being executed.

The use of an interpreter slows the execution of the program significantly, but avoids the tedious compilation step. Interpreters can speed the development of simple programs. The best arrangement is to use an interpreter to develop an application program, then compile it when it is completed. However, few languages are served by both a compiler and an interpreter.

Of course, you need a compiler/interpreter only if you want to program your own applications since most commercial application software is sold in a compiled, ready-to-run form.

The most popular high-level languages used on microcomputer are the following:

- BASIC: a simple, easy-to-use, compact language that is by far the most popular microcomputer language. It is usually implemented with an interpreter, but some compiled versions exist. Several versions (dialects) have both interpreters and compilers. It is not highly standardized, but the dialect produced by Microsoft has become a de facto standard.

- Pascal: a highly structured language that is popular in universities and among professional programmers. It is more standardized than BASIC; both an ISO (International Standards Organization) standard and a UCSD (University of California at San Diego) de facto standard exist. It is strictly a compiled language.

- FORTRAN: the first high-level language, it is still very popular for scientific applications, but weak on file handling and text processing.

Two American National Standards Institute (ANSI) standards exist: ANSI FORTRAN 66 and ANSI FORTRAN 77. Compiled only.

- o COBOL: widely used for commercial applications, but verbose. An ANSI COBOL 74 standard exists. Compiled only. It is not widely used on the entry-level microcomputers due to its need for large amounts of memory.

Many other languages -- Forth, PL/I, C and LISP, to name a few, are available on microcomputers.

Compilers and interpreters usually cost between $100 and $500, but a BASIC interpreter is usually included with the purchase of the microcomputer.

Other System Software

Other kinds of system software exist and are available in many forms. Some of the major categories are:

- o Editors: these programs help you prepare and modify your application programs. Most operating systems include an editor, but superior editors are often available from other vendors.

- o Linkage editors: for operating systems which permit several separately-compiled programs to be merged into one, linkage editors are available to do the merging. A linkage editor is necessary to build complex programs.

- o Assemblers: these are essentially compilers for the machine's native language. "Assembly language" is only one step removed from the native language: symbolic names can be used in place of the numbers required by the microprocessor. Some operating systems include an assembler. You will need an assembler if you want to produce any native language software.

- Debuggers: programs which enable you to break the execution of an application at any point to inspect the values of the program's variables. Testing and correcting application software is accelerated by the use of a debugger. They are usually an added-cost option.

- Operating system "front ends": programs which intercede between you and the operating system for the purpose of improving man/machine communications. Front ends usually rephrase and reformat operating system messages and are useful with operating systems which are noted for their terse style (such as CP/M).

- Disk utilities: programs which provide additional disk management utilities to supplement the minimal set of utilities that are sometimes supplied with the operating system.

There are other types of system software as well, but these are some of the major categories. We will not consider them any further in this paper, but you should be aware that they exist.

STEP 2: IDENTIFY AND PRIORITIZE YOUR MICROCOMPUTER NEEDS

If you have done your homework, you should have developed by now a rough idea of what a microcomputer can do for you, the kinds of jobs you would like to use it on and a ballpark estimate of the total cost. Your goal in this step is to refine those ideas and come up with a specific list of intended applications and performance requirements for the system when applied to those tasks. If possible, the benefits and costs of each application should be estimated so that a prioritized ranking of applications can be developed. It is likely that your list of intended applications will have to be shortened later on in the selection process and these cost/benefit estimates will be helpful in deciding which applications to delete. For this reason, it is advisable to begin with a list of intended applications that is somewhat longer than you expect to actually install. Most people do this naturally and need no encouragement.

We recommend that you concentrate on those applications which will help you perform your daily chores. While there may be infrequent applications that have big payoffs, you are far more likely to find large cumulative benefits in an application which has a small payoff each time it is used, but is used frequently. Word processing is one prime example: there is no huge benefit associated with the ability to correct an error on a typewritten page without retyping the entire page, but when multiplied by the number of times that one feature can be employed over the course of a single day, the result is a large payoff in productivity gains.

What are some other applications of microcomputers that have been shown to have large potential benefits? Data storage and retrieval is one general area that has found a great many microcomputer applications. The computer is not always terrifically fast at finding a single record in a file (you might be able to beat it if you keep your paper records in a well-organized filing cabinet), but it is very good at sorting and manipulating those records. Simple aggregate facts (e.g. the mean time between failures of bus transmissions) which could take weeks to compute manually using paper files can be computed in a matter of minutes or hours by a microcomputer.

Here are some other possible applications for your microcomputer:

- o General calculations: budgets, cash flow projections, cost allocations, alternative comparisons and a host of other kinds of general calculations can be performed faster and easier with the help of a microcomputer. The kind of software that is most useful for these general calculations is known as "spreadsheet" software because it simulates, in electronic form, a paper spreadsheet of rows and columns. Many organizations have justified the purchase of their first microcomputer on the basis of the benefits to be derived from the use of this spreadsheet software alone.

- o Report generation: given data and instructions for formatting it, the microcomputer can quickly and efficiently produce complex tables, complete with computed columns, subtotals and totals. This capability is often included with the data management software and is sometimes included with word processing software, but can also be purchased as a separate product.

- o Data terminal emulation: this software enables your microcomputer to double as a data terminal which can be attached to another computer, either directly or remotely, connected via a modem and the telephone line. A microcomputer is even better than a data terminal in some ways; it can, for example, transmit and receive data files. If you have to deal with a remote computer, this application is very handy and is highly recommended.

- o Business graphics: some microcomputers have the ability to generate graphics on the CRT screen and they all have the ability to generate graphics on dot-matrix printers and pen plotters. Graphics are a very effective mode of presentation and the computer can produce very good quality pie charts, bar graphs and other types of displays much more cheaply and faster than a draftsman.

These are only a few of the thousands of possible applications for a microcomputer, but they are some of the most common and useful ones. Of

course, your organization may have some special need not mentioned here and it should be included in your list of intended applications.

A HYPOTHETICAL SITUATION

Let's suppose that we are in the market for an entry-level single-user business microcomputer system that we intend to use to help with a variety of chores around the office of our small bus transit company. We want to use it as a word processor and to keep track of a number of different types of records that we currently have on paper in filing cabinets. Of course, it will be a real labor-saver in computing budgets and helping out with some of the bookkeeping. We will probably use it as a terminal emulator, too, because we have to access the county's IBM computer from time to time.

For the record, our list of intended applications is:

- o word processing;
- o data management/report generation;
- o spreadsheet calculations; and
- o terminal emulation.

We do not intend to implement any graphical capabilities at this time, although we would like to be able to install those capabilities later as an "add on" application. We intend to use the data management software to manage our list of paratransit service subscribers initially, but would like to use the computer in the near future to maintain historical bus repair information. We are currently keeping that information on cards stored in a file cabinet in the maintenance garage.

We're not expecting to get any unusual hardware or software because we don't think we can talk our Board of Directors into approving the extra money and because the simple, daily applications we have in mind will probably keep

the computer pretty busy.

These intended applications have certain implications for our system's composition. We know, for example, that we will need a good quality printer to support our word processing application and will need a modem to support the terminal emulation function. Of course, we will need a disk drive (or several disk drives) with sufficient storage to support both the word processing and the data management activities. And we will need the application software to perform each function and whatever system software is needed by the application software.

We don't plan on doing much of our own programming, but there are some simple things we may want to do ourselves. To give us that capability, we will also want to acquire one programming language. BASIC, which is one of the simplest programming languages and is widely available on microcomputers, is probably the best choice for us, but much of the public domain transportation software available today is written in Pascal, so we may want to consider acquiring a Pascal compiler as well.

We're not too sure how much storage capacity is needed, but our best guess is 500K if we use floppies only or 10M if we use a hard disk (we need more on-line storage if we use the hard disk because its storage medium is not removable). These are moderate storage capacities; we may need more if we implement a storage-intensive application (such as vehicle histories). If we use only floppy drives, we will want to have two drives, so as to facilitate the copying of diskettes. If we use a hard disk, we will still have to have one floppy drive to handle the software (which is usually distributed on floppy diskettes).

We want the printer to operate at a minimum speed of 40 characters per second (that's about a minute and a half per page) and the modem to operate at 300 baud minimum (300 baud and 1200 baud are the two speed options for modems under $1,000).

As for the console, we don't care whether it's a data terminal or whether it has an integrated screen or not. We do want the CRT to be able to

display a standard 24 rows of 80 characters each, however, and we want the keyboard to have a standard "QWERTY" typewriter key layout, with a numeric keypad (i.e. a separate set of numeric keys, arranged as on a calculator, for fast numeric data input) included. We would like to have the option of displaying color graphics on the CRT, even if we don't exercise that option initially.

We would like to have the modem connected to the computer by means of a standard serial port. The printer can be connected by either a serial or a parallel port. If we use a data terminal, however, we will need a third general-purpose port -- a serial one -- to connect it to the computer.

The applications we have selected do not require huge amounts of RAM, so we can probably get by with 64K. That is becoming the smallest memory size available for single-user business microcomputer systems. However, we will have to adjust this requirement to meet the needs of our selected software.

This microcomputer system configuration is summarized in Figure 3. We figure the total hardware/software cost of this system is going to run between $5,000 and $15,000, depending primarily on the kind of peripheral devices we choose and the quality of the software. It also depends on other options we might choose that we haven't considered yet. Each microcomputer has numerous options available that can greatly influence the final cost.

Our hope is that we will be able to find a system that will be easy to learn to use, but we expect we will have to provide some formal training to our staff -- especially for the word processing. We are also figuring on buying a maintenance contract on all of the hardware.

We haven't estimated the benefits and costs of each application because that would require too much specific information about our hypothetical organization, but we recommend that you do it. Solid estimates of the costs and benefits of a proposed microcomputer acquisition are often needed to obtain purchase authority from your superiors.

HARDWARE

- o 64K bytes of RAM
- o two or more floppy disk drives (or one floppy and one hard disk)
- o at least 500K bytes of file storage space on-line (10M with hard disk)
- o two (or three if a data terminal is used) I/O ports (no more than one parallel, the rest serial)
- o QWERTY keyboard with numeric keypad
- o 24 x 80 CRT monitor (black-and-white or green screen)
- o one printer operating at 40 cps or faster
- o one 300 baud or 1200 baud modem

SOFTWARE

- o spreadsheet
- o data manager
- o terminal emulator
- o word processor
- o BASIC language interpreter
- o operating system and other system software

Figure 3

A Hypothetical Set of Microcomputer System Specifications

We have chosen to implement only applications which have been shown to be cost-effective many times in many places. If we had computed the cost/benefit ratios, we would have compelling evidence of the usefulness of this proposed system. Let's assume we have those figures and can now take them to our Board of Directors.

STEP 3: ESTABLISH A BUDGET AND ALLOCATE AMONG COMPONENTS

Before you begin to search for the specific hardware and software components that will comprise your microcomputer system, you will have to establish a total cost budget for the acquisition, installation and operation of the system for the first year and allocate the acquisition budget among the major system components. This means you will have to commit the funds (or obtain a commitment from the proper authorities in your organization), then partition the funds into several subfunds.

We recommend that you perform your budget allocation in two phases. First, split the total budget into three pieces:

1. first year operational costs;

2. installation and training costs;

3. acquisition costs.

Then take the acquisition budget and further divide it among the major system components in such a way as to reflect your intended applications.

These steps are discussed further below.

OPERATIONAL COSTS

A microcomputer system's operational costs generally consist of the following items:

- o supplies (paper, ribbons, print elements, diskettes, etc.);

- o utilities (electricity and perhaps some telephone);

- o maintenance.

You may also want to include the salary of any employee whose job exists primarily to serve the computer (e.g. maintaining it, handling supplies, etc.) or to serve users of the computer (e.g. data entry). Most microcomputer users also find they have a continuing need for new or improved software, so it is also a good idea to budget for continuing software acquisitions.

Operational costs can vary greatly depending on the volume of work (especially the volume of printing) performed by the microcomputer. Figure roughly 10% of the hardware acquisition costs for annual maintenance. Figure printing costs at between 2 and 6 cents per page (toward the low end if you use a dot matrix printer; toward the high end if you use a character printer and good quality ribbons). Figure at least 5000 pages per year if you are doing word processing; less if not. Diskette costs vary with the volume of data you will be storing, but plan on spending $7.00 to $30.00 per megabyte (i.e. per million characters) of storage (toward the low end for double-sided, double-density 8-inch; toward the high end for single-sided, single-density 5.25-inch). Figure on needing at least 5M of storage in the first year.

Utility costs are negligible unless you decide to air condition the computer room (it's a nice idea, but not required by the equipment unless you're in a hot, humid region) or dramatically increase your telephone usage.

INSTALLATION COSTS

The major installation costs are for facilities, furniture and training. Of the three, training is usually the largest because most microcomputers require no special facilities or furniture. Still, it is important to locate the equipment in a comfortable, convenient, well-lit location. It is also important to minimize the risk of static electricity (static electric shocks can damage the computer circuitry) or transient voltage surges in the electric supply (devices called "power conditioners" protect against surges and cost less than $100). A little money expended initially to provide a

good environment for both the computer and its users would be well invested.

Still, expenditures for facilities and furniture usually can be regarded as optional. Not so with training. If you have any intended applications which involve clerical people, you simply must plan on training them. This is an absolute must if you are planning on doing word processing and is also a good idea if you will be doing data entry or if the system will be used by managerial personnel. It is less necessary if the system will be used by only technically-inclined people who enjoy the challenge of learning how to operate a new device.

There are no strict guidelines for figuring training costs because much depends on the intended applications and the skills and personalities of the people involved.

ACQUISITION COSTS

Once you have established a total system acquisition budget, you should break it down into the following major components:

- o computer (microprocessor, memory, ports, keyboard, CRT);
- o disk drives;
- o printer;
- o other devices;
- o system software (operating system, languages, utilities);
- o application software.

In addition to these basic categories, you should identify as a separate line item any component that you estimate will cost more than $500. In allocating the budget to these categories, bear in mind the requirements imposed by your

list of intended applications; for example, if you plan on doing word processing, allocate enough money to the printer to buy one of adequate quality.

As an example of how a budget could be allocated among these categories, let's consider our hypothetical situation.

TWO HYPOTHETICAL BUDGETS

Let's suppose that we have taken the cost/benefit figures that we computed earlier to our Board of Directors and have issued a plea for $12,000 to purchase and install a microcomputer system that will allow us to perform all of the applications on our list. The Board, not entirely convinced by our arguments, has agreed to allocate only $7,000 in total. However, after further persuasion, we have convinced them that they should let us present to them alternate configurations at the $7,000 and $12,000 levels so that they will be able to see what we would be able to get for the extra $5,000. Consequently, we will budget out systems at both levels.

We figure that the installation and training costs will be identical at both levels. Based on our knowledge of our facilities and staff, we estimate these costs at $1,000 for training and nothing for facilities and furniture.

We also think that the supply and maintenance costs will be very similar at the two levels. Our best estimate of the first year supply cost is $600. The maintenance cost will probably be about $400 at the low level and $700 at the high level.

If we subtract these amounts from the total budgets, we are left with acquisition budgets of $5,000 and $9,700, respectively. Let's assume we will be able to obtain a 20% discount off the list prices on our acquisition. That gives us "list price" budgets of $6,250 and $12,125 to work with. By considering our list of intended applications and by looking at the component cost ranges given in the preceding chapter, we have come up with allocations of these budgets to the major components as shown in Table 2.

COMPONENT	LOW BUDGET	HIGH BUDGET
Computer	$2,700	$3,200
Disk drives	$900	$3,500
Printer	$1,300	$2,500
Other devices (i.e. modem)	$300	$700
System software	--	$700
Application software	$950	$1,425
Miscellaneous (cables, etc.)	$100	$100
TOTAL	$6,250	$12,125

Table 2

Two Hypothetical Microcomputer System Budgets

In these allocations, we have assumed that the additional money in the higher budget would be used to purchase a hard disk, some additional system software, improved application software and a better printer. In both cases we have set aside $100 to purchase cables, connectors and other miscellaneous items that will be required to fit the pieces together.

That done, let's begin our search for the components.

STEP 4: SEARCH FOR SOFTWARE

After you have determined how much money you have to spend on your microcomputer system's hardware and software components, you are ready to begin searching for the pieces you will need to form a complete system that does what you want it to do. We recommend that you begin this search by looking for the software you will need to get your jobs done. You cannot separate the search for application software from the search for system software, because each application must operate within the environment provided by the operating system. The search for system software and the search for application software must therefore proceed in parallel.

One good way to approach this search is to look for sets of application software, every member of which runs under the same operating system. If you can select the best software for each application available under each operating system, later on you will simply have to choose between sets. Choosing between a small number of sets is much easier than selecting from hundreds of application software products.

Of course, to do this you must first decide on which operating systems you are willing to consider. This implies, to some extent, a decision on which microcomputer brands you are willing to consider since no operating system works on all microcomputers. However, by this point you probably will have a good idea of the range of machines you are willing to consider, so this will not be very difficult. You do not have to be restrictive at this point; you can include in your search all operating systems that operate on all of the machines you are willing to consider.

You should also be aware that many microcomputers are now marketed with packages of application software "thrown in" with the purchase of the hardware. Since this arrangement can significantly reduce your final system cost, you should make an attempt to identify which software is offered in these deals and include any free packages that seem interesting among your sets of software to be evaluated.

In our hypothetical example, we are willing to consider the Apple II, the Apple ///, the IBM Personal Computer (PC), the Radio Shack Model 12 and any machine which uses the CP/M operating system. The Apple II, the IBM PC and the Radio Shack Model 12 (an upgrade of their Model II) are three of the fastest-selling brands, the Apple /// is a more powerful version of the Apple II and the many machines which use the CP/M operating system are, as a group, the most widely-used microcomputer system. These machines together represent over 80% of the entry-level single-user microcomputer system market and will give us a good cross-section from which to choose our system.

As a particularly interesting example of a CP/M machine, we will consider the Osborne 1 microcomputer.

Now let's look at what's currently available in the software marketplace. We will look at the system software first, then at the application software.

SYSTEM SOFTWARE

Operating Systems

Each of the five models covered in this report offer a choice of at least two operating systems:

- o the Apple II offers a choice of DOS 3.3, the UCSD p-System (versions II.1 and IV) or CP/M;
- o the Apple /// offers SOS, the UCSD p-System (a modified version II) or CP/M, plus the Apple II DOS 3.3 in emulation mode;
- o the Radio Shack Model 12 offers TRSDOS, CP/M and the UCSD p-System (version IV);
- o the Osborne 1 offers CP/M and the UCSD p-System (version IV); and

- the IBM PC offers MS-DOS (also called PC-DOS), CP/M-86, CP/M and the UCSD p-System (version IV).

Each operating system has certain characteristics, certain advantages and certain shortcomings.

CP/M and CP/M-86

Without a doubt, CP/M (Control Program for Microprocessors) is the most widely-used operating system in the world, operating on the majority of all installed microcomputers. This amazing popularity may be due less to its own characteristics than to the popularity of the Zilog Z80 processor (and its Intel 8080 predecessor) on which it operates, because it is not particularly easy or pleasant to use. In fact, many products exist on the software market today solely for the purpose of simplifying the use of CP/M. Nevertheless, CP/M is the dominant microcomputer operating system and supports a huge body of compatible application software.

CP/M is provided free of charge with the purchase of an Osborne 1; it is an added-cost option with the Radio Shack Model II ($195) and requires additional hardware with the Apple II (the Microsoft "Softcard" ($350) and others), the Apple /// (the Microsoft "Softcard ///" ($395)) and the IBM PC (the Xedex "Baby Blue" board ($600) and others).

CP/M-86 is a version of CP/M designed for use on the Intel 8088 and 8086 microprocessors. It is similar to CP/M in its appearance and performance, but application software which runs under CP/M must be modified to run under CP/M-86. Consequently, the body of software available under CP/M-86 is currently a mere fraction of what is available under CP/M.

CP/M-86 is available as a $240 option on the IBM PC. There is also a board available for the Apple II which enables it to run CP/M-86, but the price (nearly $1000) is not competitive.

Several versions of CP/M have been released by its creators, Digital

Research, Inc. The most widely used one is Version 2.2 which has been in use for about three years. A new Version 3.0 was recently announced, but is not yet widely used. The most important advantages of Version 3.0 are its ability to execute several applications programs simultaneously and its ability to use more than 64K bytes of memory. It will be an important operating system in the near future, but Version 2.2 is probably a safer choice in the near term.

Even among CP/M Version 2.2 operating systems on different machines, there are some minor but important differences. These differences arise from the fact that there is a portion of the CP/M operating system which must be customized to fit the machine. This portion of the software is called the BIOS (Basic Input/Output System) and it contains the operating system software which controls the operation of all peripheral devices. The BIOS resides in main memory, so the larger the BIOS the smaller the amount of memory available to the application software. Most CP/M applications programs expect to have 56K of memory to use, but on a few microcomputers 54K or less is available. In picking a microcomputer system using the CP/M operating system, pay attention to the size of the BIOS and any other idiosyncracies which may significantly reduce the size of the pool of application software you will be able to run.

The CP/M that runs on the Osborne 1 has more than its share of idiosyncracies. As a result, the pool of software available for the Osborne 1 is somewhat smaller than the pool of software available for other CP/M machines.

One other thing to watch for with CP/M systems is diskette compatibility. Most CP/M systems use 8-inch floppy diskettes. The 8-inch floppies, if formatted in single-sided, single-density IBM 3740 format, are readily transportable between different CP/M systems -- even between different versions of CP/M. However, double-density 8-inch floppies and all kinds of 5.25-inch floppies are not nearly so standardized and, as a result, cannot generally be used to carry software and/or data between different machines. The Apple II, the Apple ///, the Osborne 1 and the IBM PC all use different 5.25-inch CP/M diskette formats.

MS-DOS

MS-DOS (Microsoft Disk Operating System) was developed specifically for the IBM PC and is available as a $60 option. It will, however, operate on all IBM "look-alike" machines and most other 8088- and 8086-based systems. It is relatively new (first released in 1981), so it does not yet have a large body of application software running under it, but considering the rapid rate at which applications for the IBM PC are being developed, this body will expand quickly.

In its outward appearance, MS-DOS shows many CP/M characteristics, and since it competes directly with CP/M-86 on the IBM PC, comparisons are inevitable. Supporters of MS-DOS point to its ability to execute larger applications programs and its ability to handle larger disk files (1 billion bytes versus the 8 million byte limit under CP/M-86). As a general rule, applications programs will also run faster under MS-DOS than equivalent programs running under CP/M-86.

The UCSD p-System

The UCSD p-System got its start in 1974 at the University of California at San Diego (hence UCSD) when a programming instructor decided to implement the Pascal programming language on a microcomputer. The instructor, Kenneth Bowles, made two design decisions which are largely responsible for the p-System's commercial success: he embedded the language within a complete software development environment (an editor, a compiler and disk file handling utilities) and he decided to use an intermediate language to implement all of the components of the system. This intermediate language was called "p-code" because it represented the language used by an imaginary -- "pseudo" -- machine.

As a result of these design decisions, the UCSD p-System is a relatively easy to use operating system and is highly transportable between different computer systems. A program written in a high-level language -- say Pascal -- is compiled into p-code which is then passed through an interpreter at the

time it is executed. Languages used under the p-System are thus both compiled and interpreted. Because the compiler and all other parts of the p-System are written in p-code, all that is needed to install the p-System on a new microprocessor is an interpreter to translate the p-code into the machine's native language, plus a BIOS customization, as with CP/M. Developing a new interpreter is much simpler than rewriting an entire operating system.

As a result of this unique design, the p-System is now operational on the Apple II, the Apple ///, many machines based on the Zilog Z80 microprocessor, most 8086- and 8088-based computers, DEC 11's, Texas Instruments TI-99/4A's, and certain computers based on the Motorola 6809 and 68000 microprocessors. It also operates directly (i.e. without an interpreter) on systems using the Western Digital Pascal MicroEngine processor.

The most recent version of the p-System is SofTech Microsystems' Version IV which operates on the Apple II, the Radio Shack Model 12, the Osborne 1 and the IBM PC, among others. The only p-System operating on the Apple /// is a variation on an earlier version (II.1). Version IV is significant because it is the first version for which SofTech Microsystems will guarantee tranportability: any program written under Version IV is guaranteed to operate identically on any other machine running Version IV. This guarantee has certain strings attached (such as software using graphics is not included), but no other operating system can make a similar claim.

Earlier versions of the p-System, though offering a higher degree of tranportability than other operating systems, cannot claim 100% compatibility. Even the II.1 versions running on the Apple II and /// computers are not totally compatible; programs written in Pascal on the Apple II must be recompiled (and sometimes must be modified) to run on the Apple ///.

The pool of software currently available for the UCSD p-System is not nearly so large as the pool of CP/M software, but can be expected to grow rapidly now that Version IV is available. If you choose to use the p-System,

you will be choosing an operating system that offers a fair-sized body of application software and an unmatched ability to upgrade your hardware without disrupting your software.

It should be noted that a substantial body of public-domain tranpsortation-related microcomputer software exists under the UCSD p-System.

The greatest drawback to the p-System is its relatively slow execution speed. Due to its use of an interpreter, applications in p-code will generally execute more slowly than if they had been compiled directly into the processor's native language. The speed loss will range from almost none to nearly an order of magnitude, depending on the computer and the interpreter [see Gilbreath and Gilbreath, Byte, January 1983]. Also, the UCSD p-System is an added-cost option with most entry-level microcomputer systems, including the five microcomputers considered in our hypothetical example.

Prices for the full p-System (i.e. the text editor, the disk utilities, the p-code interpreter and the Pascal compiler) vary. The Version II.1 p-Systems for the Apple computers cost about $200 for the Apple II and $250 for the Apple /// and may be obtained from Apple Computer, Inc. Version IV costs roughly $700 on all machines. The only p-System for the Radio Shack Model 12 at the present time must be obtained from PCD Systems, Inc.; most other Version IV p-Systems may be obtained directly from SofTech Microsystems. The IBM PC version of the p-System may be obtained directly from IBM for $625.

However, if you are interested only in running software that operates under the p-System, a special, limited "run-time" version of the p-System is available on many microcomputers for a fraction of the full p-System price. The run-time p-System on the IBM PC, for example, costs $50. The run-time p-System is sometimes included with the application software, so you may not need to acquire it separately.

TRSDOS

Radio Shack's Model 12 TRSDOS (Tandy/Radio Shack Disk Operating System) operating system is similar to CP/M in some respects, including its use of 8-character file names. Still, users of TRSDOS seem to be relatively satisfied with its performance and ease of use.

TRSDOS is unique in that it comes with a built-in terminal emulator program which is adequate for most communications tasks. Users of TRSDOS therefore will probably not need to purchase a separate terminal emulator program.

No assembler, linkage editor or text editor is provided with TRSDOS, but separate products are available from Radio Shack and other vendors.

DOS 3.3

DOS 3.3 operates on the Apple II computer and on the Apple /// computer operating in Apple II emulation mode. It also operates on a small number of Apple II "look-alike" machines. It is thus more restricted in its domain than any other operating system discussed here except TRSDOS and SOS, but due to the Apple II's immense popularity, it has a huge body of application software.

DOS 3.3 is provided free with the purchase of an Apple II or Apple /// computer.

It is a relatively simple operating system of very limited power. It is easier to use than CP/M, but does not run on as many machines as CP/M, primarily because the MOSTEK 6502 microprocessor is not as popular as the Zilog Z80. It is apparent that Apple will use more sophisticated operating systems on its future products, so it is unlikely that any new machines will use DOS 3.3.

SOS

The SOS (Sophisticated Operating System) software which is provided free of charge with the purchase of an Apple /// computer has many attractive features, including use of a "tree-structured" file naming system. Under this system, a file directory is just another file and may contain references to other files which are directories. Consequently, it is possible to construct file names such as

/FY1983/CORRESPONDENCE/TO/ACME.CORP/MAY10

Under this scheme, names of arbitrary length may be constructed and any number of sub-directories may be maintained, both of which are very helpful in keeping track of disk files. Compared to the 8-character file names of CP/M, CP/M-86, TRSDOS and MS-DOS, the SOS file names are a joy.

SOS also treats its peripheral devices as files. Under SOS, a disk file is written to a printer in exactly the same way as it would be copied to another diskette; the physical device characteristics are hidden from the application software.

SOS is a relatively pleasant and powerful operating system which, unfortunately, operates only on the relatively unpopular Apple /// computer. Its pool of software is probably the smallest among the operating systems considered here.

Summary of Operating Systems

The seven single-user operating systems discussed above are summarized in Table 3.

The most widely-used operating system today is CP/M, but it is unlikely to remain dominant on the new computers; MS-DOS, CP/M-86 and the UCSD p-System Version IV can all be expected to be widely used in the future.

OPERATING SYSTEM	VERSION	# MACHINES OPERATES ON	PROB. OF USE ON NEW MACHINES	AMOUNT OF SOFT-WARE AVAILABLE	AVAILABLE ON	PRICE
CP/M	2.2				Apple II(*) Apple ///(*) IBM PC(*) Osborne 1 Radio Shack Model 12(a)	$350 $395 $600 free $195
CP/M-86					IBM PC	$240
DOS	3.3				Apple II Apple ///	free free
MS-DOS	2.0				IBM PC	$60
SOS	1.1				Apple ///	free
TRSDOS	2.0B				Radio Shack Model 12	free
UCSD p-System	II.1				Apple II Apple ///	$200 $250
	IV				Apple II IBM PC Osborne 1 Radio Shack Model 12	$375 $450 $375 $375

Notes:

a. available from Pickles and Trout

* requires additional hardware.

Key: 

few, little, low — many, much, high

Table 3

Operating System Summary

DOS 3.3 currently has a huge body of application software, but it will not be available on many new machines.

TRSDOS and SOS both are restricted to use on a single computer line. Neither has an extensive body of application software and neither can be expected to be widely used in the future.

For the purposes of our hypothetical example, we will try to put together application software sets for each of the operating systems mentioned above except for CP/M-86. It will be excluded because most software which operates under CP/M-86 also operates under MS-DOS. CP/M-86 and MS-DOS are very similar in appearance and capabilities, with MS-DOS having some operational advantages.

Languages

BASIC

The Apple II comes with two kinds of interpreted BASIC under DOS 3.3: Applesoft BASIC and Integer BASIC. However, the Integer BASIC is too limited in its capabilities to support any serious business software development. Compilers for Applesoft BASIC are available for $100 to $300.

The Apple /// Business BASIC is a relatively powerful dialect of BASIC, but no compiler exists for it. It is a $125 option, making the Apple /// the only microcomputer under consideration which does not provide a BASIC language free of charge.

The Radio Shack Model 12 BASIC is derived from the Microsoft BASIC (also call MBASIC) which is a de facto BASIC standard. It comes free with the machine. A compiler is available for $199.

The Osborne 1 provides both an interpreted BASIC (Microsoft's MBASIC) and a compiled BASIC (Digital Research's CBASIC) free of charge. However, these two BASICs are not identical, so using MBASIC for development and the

CBASIC for production may not be feasible. Both of these BASICs are available under CP/M on other machines.

An interpreted BASIC, developed by Microsoft but different than MBASIC, is provided free with MS-DOS. We call it IBM BASIC for lack of a better name. A compiler for this language is available for $300.

A compiled BASIC is marketed by Softech Microsystems for its UCSD p-System and sells for $225. It is not widely used, however.

Pascal

UCSD Pascal Version IV is available on the Apple II, the Radio Shack Model 12, the Osborne 1 and the IBM PC, among others. The pricing of the p-System usually includes one language and in that sense is "free" with the purchase of the p-System. Pascals based on the less standardized Version II.1 are available directly from Apple Computer for their Apple II and Apple /// machines. They are provided free with the purchase of the p-System as well.

Digital Research produces a Pascal compiler which runs under CP/M and CP/M-86 and is similar to the UCSD Pascal language. It is called Pascal/MT+ and sells for about $500. Microsoft markets a Pascal compiler under MS-DOS that has a $300 pricetag. For the ecoonomy-minded, JRT Systems markets a Pascal compiler that runs under CP/M and costs just $30.

FORTRAN

Radio Shack sells a FORTRAN 66 compiler for its Model 12 for $299.

Several FORTRAN 77 compilers are available under DOS 3.3. None are available under SOS or CP/M. Microsoft produces a FORTRAN 77 that runs under MS-DOS and sells for $350. There is also a FORTRAN 77 compiler that operates under the UCSD p-System for $175.

COBOL

COBOL is available on microcomputers in a variety of forms. Most are subsets of the ANSI COBOL 74 standard language, but there is at least one implementation of the full COBOL 74 language: the $1,600 MicroFocus Level II COBOL for the IBM PC under CP/M-86. Microsoft has a COBOL compiler under MS-DOS that it sells for under $400.

Other Languages

Many other languages -- PL/I, C, FORTH and LISP, to name a few -- are available in many forms on each of these machines. We will not mention any specific language products because most people interested in entry-level business systems are interested in BASIC, FORTRAN, COBOL or Pascal, or don't want any programming language at all.

Summary of Languages

Our hypothetical system specifications called only for a BASIC or Pascal language and did not specify interpreted or compiled. All five microcomputers we are considering provide, either free or as an option, a version of interpreted BASIC which will be adequate for our purposes. A compiled BASIC is also provided free with the Osborne 1. In the case of the UCSD p-System, which is not provided free with any of the machines, Pascal is the more logical choice of language. The price of the Pascal compiler is usually included in the price of the p-System.

Summary of System Software

Most of the machines we are considering here in our hypothetical example are delivered with free system software -- an operating system and a BASIC language interpreter -- that is adequate for our needs. The exceptions are the Apple /// and the IBM PC: the Apple /// BASIC costs $125 and the IBM PC

MS-DOS operating system costs $60. If we want to get the run-time p-System, we can expect to pay about $50 (if it is available), but the full UCSD p-System will cost substantially more: about $700 for the operating system and Pascal language. We will also encounter a substantial cost if we decide to use the CP/M operating system on any of these five machines other than the Osborne 1: from $195 to $600 added cost.

In our hypothetical low-budget case, we cannot afford the cost of using CP/M on any of the machines on which it is an extra-cost operating system. Therefore, we will reduce our low budget search to include only CP/M on the Osborne, TRSDOS on the Radio Shack Model 12, MS-DOS on the IBM PC, DOS 3.3 on the Apple II and SOS on the Apple ///. Our high-budget system will use the UCSD p-System. We will use BASIC with each of the provided operating systems, and Pascal under the p-System.

These six operating environments are summarized in Table 4.

APPLICATION SOFTWARE

Of course, the best microcomputer hardware and system software will be absolutely useless unless we have some application software to put it all to work for us. Whether our desired computer application is word processing, financial forecasting, inventory control or whatever, our computer configuration must include the appropriate application software to get the job done.

Good software is available in today's microcomputer marketplace to perform a wide variety of tasks. The trick is to pick good software and to do that we must know what to look for. This section will take a look at a few of the major application software categories and will identify some important features to look for in each. We will begin with data management, then move on to spreadsheets, word processors and terminal emulators.

MICROCOMPUTER	OPERATING SYSTEM	LANGUAGE
Apple II	DOS 3.3	Applesoft BASIC
Apple ///	SOS 1.1	Business BASIC
IBM PC	MS-DOS 2.0	IBM BASIC
Osborne 1	CP/M 2.2	MBASIC and CBASIC
Radio Shack Model 12	TRSDOS 2.0B	Model II BASIC
all of the above	UCSD p-System*	Pascal

* Different versions of the p-System are used on different machines

Table 4

Six Operating Environments

Data Managers

Many of the jobs that a public transportation agency might want to apply a microcomputer to are data management jobs. Computers are very good at sorting, tabulating and manipulating records and these are all tasks which take a lot of time if done manually. Consequently, it is likely that one thing many small agencies will want to do when they acquire their first microcomputer is computerize some of their existing paper files.

The kind of data management software that will be needed to maintain and manipulate these records depends on the nature of the records and what they want to do with them. Basically, there are two major categories of data management software:

- o File managers. These programs are good for managing small files (no more than 2,000 records) of simple information (e.g. information that might have been kept on index cards). Mailing lists and bibliographies are two good examples of the kinds of files that might be maintained with file management software.

- o Data base managers. These programs are good for managing larger files (up to 100,000 records on relatively fast microcomputers) of complex information (e.g. information that might be stored in several related files). Personnel files and vehicle histories could be managed with data base management software.

If you wish to obtain a file manager, then you might want to look for software which has as many of the following features as possible:

- o Few physical constraints. The ideal file manager can deal with files of any number of records and each record can consist of an infinite number of data fields and can be of any length. Every current file manager has constraints in each of these dimensions, but some have higher limits than others.

- Many data types. Virtually all file managers offer integer and floating point numeric data types and at least one kind of text data type, but some provide several kinds of integer fields, several floating point precisions and some special data types such as date, telephone, dollar, social security number and so forth. In general, the more types of data supported, the better.

- Flexible key construction. Records are organized for storage in some order which usually depends on the value of a "primary key". Some file managers require the primary key to be a single field, but the better file managers allow the primary key to be constructed from several fields. Ideally, the software will offer you a choice as to whether the primary key must be unique (i.e. whether duplicate records are allowed). Good file managers also allow you to specify "secondary keys" which are single fields or combinations of fields which enable records to be retrieved efficiently in sequences other than the primary key order.

- Good retrieval capabilities. The file manager should permit you to sort the records in the file any way you wish and to select records from the file based on selection criteria of arbitrary complexity.

- Flexible and easy-to-use input and output. The file manager should permit you to enter data from the keyboard via a formatted CRT screen and should be able to automatically load data that is already in processable form. Likewise, it should be possible to unload stored data into conventional text records for use by other software. Some method of producing reports should either be included or a good interface to a separate report generation package should be provided.

- Sound security and integrity safeguards. Data is valuable and some data (e.g. payroll information) is sensitive. The file manager should provide some mechanism that ensures that no unauthorized users will be able to view and/or modify sensitive data. Furthermore, adequate backup and recovery capabilities should be provided to minimize the damage done by a power blackout or a disk failure.

- o File modification capabilities. Files are dynamic entities and their structure will change over time as new data items are created or old ones redefined. A good file manager will allow you to change the structure of the file with minimal effort.

- o High-level language interface. If you file is large, you may find that the facilities for accessing and displaying the data provided in the file manager are inadequate and the process of unloading the data is too cumbersome. One solution is to produce your own software written in a high-level language (e.g. FORTRAN or Pascal) that accesses the data in the file directly. To do so, however, you must have a file manager that has a high-level language interface. Few of these currently exist.

All of these attributes are desirable for database managers as well as for file managers. In addition, if you are looking for a database manager, you might also look for the following characteristics:

- o Unrestricted interfile relationships. A database manager must permit you to specify relationships between records in different files. For example, bus driver accident histories might be kept in two files: a driver file and an accident file. Each driver record would "own" zero or more accident records. A good database manager will permit you to define any number of such relationships and will support both one-to-many relationships (as in this example) and many-to-many relationships. Ideally, the database manager would permit you to define relationships between a file and itself (e.g. an employee record could "own" several other employee records, showing who works for which supervisor).

- o Support for multiple users. File managers are usually designed for use by a single person, or by no more than one person at any time. Many database managers, on the other hand, anticipate being used by several persons simultaneously. Although none of the machines considered here are intended for use by multiple users, some machines

in the same price range are. If a data management application is successful, many people will want to use it frequently. You may want to plan ahead and obtain a database manager with multi-user capabilities.

- o Data independence. If several people are using the database manager, they may use different portions of the database and may, in fact, have different perceptions of what data is stored there. A good database manager supports these different user views of the data by allowing each to define his own data storage scheme. Each may change his own scheme without affecting any other user and the physical data structure may be changed without affecting any user. A database manager providing this kind of support is said to provide "data independence".

You might also want to look for device independence when searching for either a file manager or a database manager. It is particularly important to be able to change the kind of disk drive the data is stored on. This would permit you, for example, to move data from floppy diskettes to a hard disk if the volume of data grew too large for a floppy.

Probably the single most important characteristic to look for is ease of use. The software must have a simple and easy-to-use query facility and a pleasant data entry environment. If you don't like to use it, you won't.

Some of the available file managers are listed in Table 5 and a few of the microcomputer database managers are listed in Table 6. We cannot show all of the properties of each in one table, so we recommend you take a much closer look at ones you think might be adequate before you make your decision. This will possibly be the single most heavily used applications program in your software library, so be careful in making your selection.

PRODUCT	PRODUCER	MAX. RECORDS PER FILE	MAX. RECORD LENGTH	MAX. # FIELDS	DATA TYPES	SORT KEYS	NOTES	OPERATING SYSTEM	PRICE
Analyst	Structured Systems Group	?	255	75	4	?	a	CP/M	$250
DB Master	Stoneware Micro. Products	(k)	1020	100	10	6	a,b,c,d*, e*,h*	DOS 3.3	$229
Information Master	High Technology	?	?	20	3	?	a,d,e	DOS 3.3	$189
InfoStar	MicroPro	65,535	64,770	255	?	32	a,b,g,h	CP/M	$495
MAG/base1	Micro Applications	?	?	99	?	?	a,b,e	CP/M	$295
PFS	Software Publ.	?	?	?	?	?	a*,b,e,f	UCSD II.1	$125
								SOS	$175
								MS-DOS	$140
Profile Plus	Radio Shack	?	?	99	3	?	a,b,g	TRSDOS	$299
Quick File	Apple Computer	600	1140	15	?	?	a,b,e	SOS	$150
SuperData	Sorcim	32,000	1023	40	?	16	a,b,c,e, f,g	CP/M	$245
								MS-DOS	$245
VisiFile	VisiCorp	(j)	232	24(h)	2	?	a,b,d,e*, f,h	DOS 3.3	$250
								MS-DOS	$300

Notes:

a. report generator
b. computed fields
c. file passwords
d. recovery utility
e. restructuring possible
f. file limited to 1 diskette
g. word processor interface
h. spreadsheet interface
i. MS-DOS version allows more fields (up to 128 w/256K)
j. limited by diskette capacity
k. depends on record size

* optional

Table 5

Some File Managers

PRODUCT	PRODUCER	# OPEN FILES	# RECORDS PER FILE	MAX. RECORD LENGTH	MAX. # FIELDS	DATA TYPES	NOTES	OPERATING SYSTEM	PRICE
Condor 20-3	Condor Comp.	2	32,737	1,024	127	5	b,d,e,f,g, h,i,k	CP/M CP/M-86 MS-DOS	$995 $995 $995
dBASE II	Ashton-Tate	2	65,535	1,000	32	3	b,d,e,f,g h,i,k	CP/M CP/M-86 MS-DOS	$700 $700 $700
FMS-80	DJR Assoc.	19	65,535	(10,000)	255	3	a,d,e,f,g, h,i,k	CP/M	$995
LogiQuest	Software Products Intl.	5	32,000	1,024	55	5	b,d,e,f,n	p-System	$550
MDBS III	Micro Data Base Sys.	?	65,535	65,524	65,536	9	c,d,f,h,j, l,m	CP/M CP/M-86	($4,500) ($4,500)
T.I.M. III	Innovative Software	?	32,000	24,000	40	6	a,d,e,f,k	CP/M MS-DOS	$695 $450

Notes:

a. pseudo-relational
b. relational
c. network
d. query facility included
e. screen input and editing
f. report generator included
g. restructuring permitted
h. data dictionary included
i. text file input supported
j. multiple users supported
k. built-in language
l. FORTRAN interface
m. Pascal interface
n. spreadsheet interface
( ) indicates approximation

Table 6

Some Database Managers

Spreadsheets

"Electronic spreadsheet" is the popular name that has been given to software that provides its user with a blank "matrix" and permits the user to fill each cell with a label, a value or -- most importantly -- a formula which defines the cell's value as a function of other cell values. Spreadsheets have proven themselves to be tremendously versatile and powerful tools and are consistently among the most popular commercial software packages sold with microcomputers. They are extremely useful for a wide variety of financial applications, including budget preparation and monitoring. Because all cells functionally dependent on another cell are automatically recalculated when that cell's value changes, the user can instantaneously see the impact of any change. Many hypothetical ("what if...") scenarios can thus be played out in a short time.

Among the features to look for in a spreadsheet program are the following:

- o Matrix size. The larger the matrix that can be used, the better. Some spreadsheets are constrained to a fixed number of rows and columns; others are constrained by a limit on the number of cells in use or by the amount of memory available. A few are virtually unconstrained.

- o Matrix dimensionality. Most spreadsheets have two-dimensional matrices; a few use three-dimensional matrices.

- o Maximum formula length. Some spreadsheets have a low limit on the length of a cell's formula; a high limit or no limit at all is preferable.

- o Number of library functions. Your ability to construct useful functional relationships may be constrained by the set of functions the spreadsheet affords you. At a minimum, it should provide all of the trigonometric functions (sine, cosine, etc.), some basic statistical functions (maximum, minimum, sum, etc.), some basic

mathematical functions (square root, square, logarithm, etc.) and a few financial functions (net present value, compound interest, etc.).

- o Display constraints. The fewer the number of constraints on how the matrix display may be formatted, the better. Some spreadsheets require all columns to be the same width or limit the number of decimal places that may be shown for decimal values.

Spreadsheets also vary substantially in their display features with some offering split screen displays and row and column titles that remain fixed while the rest of the screen scrolls to display other parts of the matrix. A very few offer color displays.

You might also want to consider the diskette format of the stored matrix and the capabilities of the spreadsheet for loading data produced by other programs. In general, it is nice to be able to interface with other software. This includes the word processing software, since you might want to include your spreadsheet matrix in a report.

Finally, one of the most important considerations is processing speed. While speed of operation is important for any computer program, it is especially important for spreadsheets because they are highly interactive. You won't want to wait two minutes every time you change a cell value. This is an attribute that is difficult to measure objectively; you should try to get some "hands on" experience with all candidate spreadsheets before you make your decision.

Table 7 describes many of the most popular spreadsheet programs.

Word Processors

There is one thing you must do when selecting a word processing program: consult the person or persons who will use it. This is a good idea for all types of software, but is absolutely vital with word processing. You should also weigh their opinions heavily when evaluating the keyboard and CRT

PRODUCT	PRODUCER	MAX. ROWS	MAX. COLS	MAX. CELLS	FORMULA LENGTH	# LIBRARY FUNCTIONS	NOTES	OPERATING SYSTEM	PRICE
LogiCalc	Software Products International	255	127	1,400	27	10	a,b,c,d,e	p-System	$190
Multiplan	Microsoft	255	63	*	?	40	a,b,c,e,g,i	CP/M DOS 3.3 MS-DOS	$275 $275 $275
SuperCalc	Sorcim	254	63	*	110	31	a,f	CP/M MS-DOS	$295 $295
VisiCalc	VisiCorp	254	63	*	127	31		DOS 3.3 MS-DOS SOS TRSDOS	$250 $200 $250 $299

Notes:

a. variable column widths
b. sorting capability
c. on-line help
d. regression capability
e. selectable decimal precision
f. color-coding of values possible
g. naming of cells permitted
h. word processor interface
i. cell protection

* depends on memory size

Table 7

Some Spreadsheets

display of competing computer systems. If you want your microcomputer to be successfully used as a word processor, then the typist must be completely comfortable with both the hardware and the software.

Assuming that you do want some word processing software included in your configuration, here are some of the characteristics you might look for:

- o Document size limits. You will want to be able to work on an entire document. Some word processors limit the size of the document to the amount of free memory or impose some other limit.

- o Line size limit. Some word processors limit the length of a line to the width of the display -- usually no more than 80 characters per line -- while others permit wider lines with horizontal scrolling of the lines across the 80-column screen.

- o "What-you-see-is-what-you-get" (WYSIWYG). Preparing a document for printing is much easier if what you see on the screen is an exact replica of what will appear on the printed page. Some word processors do not have this feature.

- o Multiple column capability. Some text (e.g. newsletter text) is more readable if it is presented in multiple columns on a single page. Many word processors can deal with only one column of text on a page.

- o Background printing (a.k.a. "spooling"). Printing a long document can take an hour or more. If you are unable to use the computer during that time to edit other documents or do other tasks, then your computer will essentially be unusable whenever a document is being printed. To some extent, this problem can be overcome through the use of a large print buffer attached to the printer (see the discussion of the printer hardware below), but large documents can exceed the capacity of even the largest buffers. A more general solution is to use a word processor with a background printing ability which enables the typist to work on other documents while one is printing.

- o Underlining, boldface, superscripts, subscripts. These features are commonly used in documents of all types.

- o Italics and foreign character sets. These are required less frequently, but are still very useful.

- o Headers, footers, footnotes. These are all virtually required if any formal documents are to be produced.

- o Tabs. The ability to set and remove tabs from the document, as on a typewriter, is another virtual necessity.

- o Global search and replace. With this feature you can automatically replace all occurences of a word or phrase with a substitute word or phrase. This is a very handy feature.

- o Proportional spacing. This feature is of no use if your printer doesn't support it (see the discussion of printer features), but results in a very professional looking document if available.

- o Hyphenation. This is a frill unless you want to produce narrow-column newsletters.

- o Interfaces to a spreadsheet and/or a spelling checker. A data interface to a spreadsheet program is a convenient way to get numeric tables into your reports. A spelling checker can significantly reduce your proofreading time.

- o Form letter support. Many word processors permit you to use symbolic names in your text which are replaced with actual character strings which are taken from a separate file (usually a file of names and addresses). This feature is a real timesaver if you do mass mailings.

- o Print chaining. This feature allows you to edit sections of a document separately, then link them together for printing. Nice, but not vital.

- o Standard files. Word processors which store their documents as conventional text files are usually preferable because the documents are more easily accessible to other programs. Most importantly, they are accessible to the terminal emulator program and may be transmitted by phone to other offices.

Some of the key attributes of a few of the major word processor offerings are shown in Table 8. There are many other features not shown or mentioned here, so further study is strongly recommended.

Terminal Emulators

A terminal emulator is a program which enables your microcomputer to communicate with another computer -- another microcomputer or a mainframe -- by means of a modem. It is called a terminal emulator because it makes your computer look like a simple data terminal to the other computer. Using a terminal emulator, you can use your microcomputer to link into hundreds of sources of information, get access to numerous computerized bulletin boards and (usually) transmit data files over the telephone lines.

Some of the features you might want to look for in a terminal emulator are:

- o Variable baud rates. Your terminal emulator must be able to handle the communications speed used by your modem, but should also be able to handle faster communications speeds which can be used if the modem is bypassed. Ideally, speeds of 110 to 9,600 baud should be supported. It is also nice if the speed selection is software-controllable.

- o Variable communications protocols. Different computers use different communications protocols, so it is desirable to have a terminal emulator which can handle a wide variety.

PRODUCT	PRODUCER	MAX. FILE SIZE	MAX. LINE LENGTH	WYSI-WYG?	MULTI-COLUMN?	BKGRND PRINT?	NOTES	OPERATING SYSTEM	PRICE
AppleWriter IIe	Apple Computer	?	?	N	N	N	a,b,c,d,f,g,h, j,m,q,r,s	DOS 3.3	$150
AppleWriter ///	Apple Computer	?	?	Y	Y	N	?	SOS	$225
EasyWriter II	Information Unlimited	?	?	Y	N	Y	a,b,c,d,f,g,h, l,n,p,q,r,s	MS-DOS	$350
PeachText	Peachtree Software	?	?	N	Y	Y	a,b,c,d,f,g, l,m,p,q,r,s	CP/M	$500
Perfect Writer	Perfect Software	?	?	Y	Y	Y	a,b,c,d,f,g, l,m,p,q,r	CP/M MS-DOS DOS 3.3	$495 ? $389
Power Text	Beaman Porter	?	?	N	Y	N	a,b,e,f,g,m,q	p-System	$199
SCRIPSIT 2.0	Radio Shack	?	?	Y	Y	Y	a,b,c,d,f,g, m,q,r,s	TRSDOS	$399
Word Juggler	Quark Engr.	?	?	N	Y	Y	a,b,c,d,f,g, l,m,q,r,s	SOS	$295
WordStar	Micro Pro	*	?	Y	Y	Y	a,b,c,d,f,g, l,m,o,p,q,r,s	CP/M	$495

Notes:

a. underlining
b. boldface
c. superscripts
d. subscripts
e. italics
f. headers
g. footers
h. footnotes
i. indexing
j. tabs
k. hyphenation
l. spelling checker
m. form letters
n. print chaining
o. spreadsheet interface
p. proportional spacing
q. standard files
r. tutorial
s. global search and replace
t. uses 40-column display

* limited only by diskette storage capacity

Table 8

Some Word Processors

- o File transmit/save. You will want to be able to transmit text files with your terminal emulator and will very likely want to be able to transmit text files to computers which issue a prompt after each line of text (e.g. IBM's TSO editor). You will also want to be able to save entire sessions and/or parts of sessions (e.g. text files received). It is useful to be able to strip the incoming file of unprintable characters (e.g. null characters that are often attached to a transmitted line of text). It is also nice to be able to send and receive files other than text files (e.g. compiled program files and binary data files). If you are transmitting large files or are transmitting long distances, then the likelihood of transmission errors becomes very high. In those cases, it is advisable to use terminal emulation software which has error detection and recovery features.

- o Modem support. If you are using a programmable modem, then it is nice to use a terminal emulator which is compatible with the modem and can utilize its programmable features. If the modem has an auto-dial capability, for example, then it would be nice to have a terminal emulator which maintains a library of phone numbers, allowing you to select the number to call by simply pointing at it in a directory.

- o Clock support. If your computer has a calendar/clock, then it is sometimes desirable to use it, in combination with an auto-dial modem, to automatically dial a number at a specified time (usually at night when the rates are low) to transmit or receive lengthy files.

The features of some of the more popular terminal emulator programs are listed in Table 9. Again, the most important thing to look for is compatibility with both your modem and the computer systems you expect to be communicating with.

PRODUCT	PRODUCER	# BAUD RATES	MAX. BAUD	MAX. # LINES	BUFFER SIZE	NOTES	OPERATING SYSTEM	PRICE
Access ///	Apple Computer	6	9600	unlimited	*	i,k,m	SOS	$150
ASCII Express	Southwestern Data Systems	?	?	800	20K	a,f,i,k,l	DOS 3.3	$80
Connector	Context	2	300	unlimited	?	b	DOS 3.3	$180
Crosstalk	Microstuf, Inc.	7	300	unlimited	40K	a,d,f,i,k,l,n	CP/M	$195
							CP/M-86	$195
							MS-DOS	$195
Data Capture 2.0	Southeastern Software	?	300	500	18K	f,i	DOS 3.3	$90
DataLink	Link Systems	?	4800	?	?	a,i,n	p-System	$100
Data*Trans	Abt Micro.	2	1200	unlimited		a,b,c,d,e,f,n	DOS 3.3	$100
P.I.T.S.	Microsoftware Systems	2	300	unlimited	18K	f,i,k,l	UCSD p-System	?
TRSDOS	Radio Shack	9	9600	unlimited	?	?	TRSDOS	free
VisiTerm	VisiCorp	2	300	unlimited	15K	a,e,f,k,l	DOS 3.3	$125

Notes:

a. macro capability
b. DIF format conversion
c. simultaneous print and save
d. control character display
e. Hayes Micromodem support
f. Hayes Smartmodem support
g. source included
h. 40-column display only
i. exit while connected
j. clock interface
k. line send
l. block send
m. emulates DEC VT-100
n. logon support
* depends on memory size

Table 9

Some Terminal Emulators

Other Application Software

These four types of application software -- data managers, spreadsheets, word processors and terminal emulators -- will do many useful things for you and will be frequently used, but they represent only a few of the many kinds of application software. A complete library of software would include many other programs in addition to these. A few of the other types of software you might consider acquiring are:

- o Graphics. If your hardware has graphical display capabilities, then some software that would enable you to produce various kinds of charts and displays would be very useful. Look for software that is compatible with your hardware and can access the data you would like to display.

- o Statistics and mathematical modeling. Software which gives you data tabulation and cross-tabulation capabilities can be quite handy, as can a multiple linear regression program. Many other types of statistical analysis and mathematical modeling capabilities are available as well.

- o Integrated software products. A number of products have appeared in the microcomputer software market recently which offer a variety of diverse capabilities in one package. Generally, these products are offering word processing, data management, terminal emulation and graphics capabilities in one integrated program. This approach offers improved convenience of use (e.g. it is very easy to include graphics in a document produced by the word processor), but has the drawback of restricting your ability to pick and choose among competing products. Context's MBA and Lotus' 1-2-3 are the two leading integrated software products.

- o Transportation-related applications. There is a small, but growing, pool of software designed specifically for use by professionals in transportation-related industries. This software includes fleet maintenance analysis and scheduling capabilities, driver scheduling,

route and service planning and facility location analysis.

Summary of Application Software

Literally thousands of application software products are commercially available and they fall into perhaps hundreds of applications categories. We have looked at only four of the major types of application software -- data managers, spreadsheets, word processors and terminal emulators -- and have discovered that, in each case, there are many factors to be weighed before making a selection. Indeed, the selection of application software is more difficult -- and, arguably, more important -- than the selection of hardware. We have been necessarily brief in this discussion and we recommend that you investigate each application area more thoroughly before making a selection. The Bibliography provides references to recommended additional readings.

In our hypothetical search for software, we have constructed the six sets of application software that are shown in Table 10. In most cases, the lowest cost product included in the preceding tables was selected, except where it made sense to maintain product line consistency (e.g. "VisiTerm" was selected as the terminal emulator in the DOS 3.3 set to gain the intangible benefits of consistency associated with staying within the VisiCorp product line). We were also less concerned about cost in the UCSD p-System case because we are going to be able to afford it only within our high budget. We have therefore included a database manager instead of a simpler (and cheaper) file manager.

Obviously, many other configurations could be assembled that would meet our specifications. In the case of the Apple II or a machine running CP/M, the number of product combinations is practically infinite and is quite large even for machines having relatively little software (such as the Apple ///). The configurations presented here are merely illustrative examples.

OPERATING SYSTEM	FILE MANAGER/DBMS PRODUCT	PRICE	SPREADSHEET PRODUCT	PRICE	WORD PROCESSOR PRODUCT	PRICE	TERMINAL EMULATOR PRODUCT	PRICE	TOTAL
CP/M 2.2	SuperData	$250	SuperCalc	$295	WordStar	$495	Crosstalk	$195	$1,230
DOS 3.3	VisiFile	$250	VisiCalc	$250	AppleWriter IIe	$150	VisiTerm	$125	$775
MS-DOS	VisiFile	$300	VisiCalc	$200	EasyWriter II	$350	Crosstalk	$195	$1,045
SOS	Quick File	$150	VisiCalc	$250	AppleWriter ///	$225	Access ///	$150	$775
TRSDOS	Profile Plus	$299	VisiCalc	$299	SCRIPSIT 2.0	$399	--	--	$997
UCSD p-System	LogiQuest(a)	$550	LogiCalc(a)	$190	Power Text(b)	$199	DataLink(c)	$100	$1,039

Notes:

a. available on the Apple II under Version II.1 and on the Radio Shack Model 12 under Version IV.0 (versions for the IBM PC and the Apple /// are scheduled for Summer 1983)
b. available on the Apple II and the Apple /// under Version II.1
c. available on the Apple II under Version II.1 (versions for the IBM PC and the Apple /// will be available soon)

Table 10

Six Sets of Application Software

STEP 5: SEARCH FOR HARDWARE

When you have found systems and application software which meets your needs, you can turn your attention to the hardware. Your goal in this step is to identify hardware that will execute the software you have found, performs to your specified performance levels, and meets your standards for aesthetics, reliability, ease of use, maintainability, compatibility and cost.

In this section, we will look at the hardware that is currently available in the microcomputer marketplace. First, for each of the microcomputers we are considering -- the Apple II, the Apple ///, the IBM PC, the Osborne 1 and the Radio Shack Model 12 -- we will identify the hardware needed to obtain a basic configuration consisting of the microprocessor, 64K of memory, a keyboard with numeric keypad, a 24-by-80 CRT display and floppy diskette storage for 500K bytes of information. Later we will look at the separable hardware components (i.e. the modem, the printer and, in some cases, the monitor).

BASIC HARDWARE CONFIGURATIONS

The Apple II

Introduced in 1977, Apple Computer's Apple II was one of the first microcomputers. It has evolved through several design changes in its six years, but the changes have been relatively minor. The 1983 Apple II (now called the IIe in recognition of the most recent enhancements) is still very similar to the 1977 Apple II in appearance and operation.

The Apple II is built around a MOSTEK 6502 microprocessor operating at 1.2 MHz (megahertz or millions of cycles per second). As originally designed, it supported a maximum RAM memory of 48K bytes because the other 16K of the 6502's 64K limit was reserved for ROM (containing the Applesoft BASIC interpreter) and I/O locations. However, the Apple IIe now comes

standard with 64K of RAM.

No I/O ports (except a cassette port) are provided with the Apple IIe; serial and parallel ports can be added at extra cost. A keyboard is provided, but it has no keypad. Also, though a NTSC color signal for a CRT display is generated, no CRT is included. The signal produces a 24-by-40 character display with upper/lower case letters (older Apple II's generate upper case letters only); a display generator which produces the 80-column display required by our hypothetical specifications is available at extra cost.

The disk drives produced by Apple Computer for the Apple IIe (at extra cost) provide up to 132K bytes of storage space per diskette, so four drives are needed to obtain the 500K bytes of on-line storage required in our specifications. Each pair of drives requires a controller attachment (at extra cost), meaning that two disk controllers are needed.

A number of hardware features are provided with the Apple IIe at no extra cost:

- o low-resolution (48-by-40) graphics in 16 colors;
- o high-resolution graphics in black-and-white (192-by-280 or 192-by-560 with special software) or six colors (192-by-140 with certain limitations on which colors may appear next to each other on the screen);
- o a built-in speaker and single-voice (i.e. no chords or harmonics) tone generator;
- o a connection for game paddles or joysticks; and
- o eight expansion slots for extending the Apple II's capabilities.

To a great extent, the existence of these expansion slots accounts for the Apple II's great popularity (over 750,000 sold): so many expansion boards

exist for these slots that if there is something you would like to do with your Apple II, there is usually a board available that will let you do it. Want more I/O ports? Add serial and parallel interface boards. Is the 6502 processor too slow? Replace it with a Zilog Z80 processor or a Motorola 6809 simply by adding a board. You can configure the Apple IIe just about any way you like by plugging boards into its expansion slots. Six years after its introduction, the Apple II remains one of the most adaptable microcomputers on the market.

To configure an Apple II to meet our specifications using Apple Computer products, we will have to add a parallel and a serial interface board (or two serial interface boards), an 80-column display board and two disk controller boards, plus four disk drives. Since each of these five boards uses an expansion slot, we will use five of the eight available slots.

For a parallel port, some leading options are shown in Table 11. The Grappler Plus provides on-board software for printing graphics on a dot-matrix printer and is compatible with many of the more popular printers.

We have to be careful in selecting a parallel interface because it must be compatible with our printer which will use only one of dozens of parallel data transmission protocols. Many printer manufacturers make parallel interface boards for the Apple II that are guaranteed to be compatible with their printers, so that may be the safest course to follow, but the graphics printing capabilities offered by products like the Grappler Plus are very useful and should be considered. These capabilities are found only on parallel interfaces.

Just about every printer is available in both parallel and serial interface models. Since the serial protocol is much more highly standardized, there is also a good reason to opt for two serial interfaces rather than one parallel and one serial.

For serial interfaces, the cards listed in Table 12 are among those available. These cards offer switch-selectable speeds ("baud rates"; for all practical purposes, a speed of 1 character per second is equivalent to 10

MANUFACTURER	MODEL	NOTES	PRICE
Apple Computer Orange Micro	Centronics Interface Grappler Plus	Centronics compatible with graphics dump	$225 $165

Table 11

Some Parallel Interface Boards for the Apple II

MANUFACTURER	MODEL	NOTES	PRICE
Advanced Logic Systems (ALS) Apple Computer California Computer Systems	Dispatcher High-Speed Serial Interface Serial Interface Card		$139 $195 $175

Table 12

Some Serial Interface Boards for the Apple II

baud) ranging from 11 characters per second (110 baud) to 1,920 characters per second (19,200 baud) with intermediate settings at 30, 60, 120, 240, 480 and 960 characters per second.

There are also a few multi-port cards on the market for use with the Apple II. The advantage of these is that one card with two ports is cheaper than two cards with one port each, and an expansion slot is saved as well. Among the currently-available multi-port cards are those in Table 13.

The only 80-column display adapter card currently available for the Apple IIe is the one marketed by Apple itself. It retails for $125. This card is optionally available with an additional 64K of RAM (raising the maximum Apple IIe memory to 128K) and costs $295. However, few software products currently available for the Apple IIe can take advantage of this additional memory.

An Apple disk drive retails for $395 and an Apple disk controller card sells for $130. Since our configuration requires four drives and two disk controllers, the total cost for these items is $1840. Alternatively, we could use compatible disk drives and controllers from other manufacturers:

- four Rana Elite One disk drives ($379 each) with 163K of storage per drive or two double-sided Elite Two drives ($649 each) with 326K of storage per drive, plus one controller ($145); total cost $1443 to $1661; or

- two Micro-Sci A70 disk drives ($599 each) with 286K of storage per drive, plus one controller card ($100 each); total cost $1298.

However, some application software may not operate properly with these non-standard disk drives, so carefully check out your software with these drives before buying them.

We need two items to complete our Apple II basic hardware configuration: a numeric keypad and a CRT monitor. The only numeric keypad available for the Apple IIe is a $159 model produced by Apple.

MANUFACTURER	MODEL	NOTES	PRICE
Mountain Computer	CPS Multifunction Card	1 serial, 1 parallel, calendar/clock	$239
SSM	AIO-II	1 serial, 1 parallel	$225

Table 13

Some Multi-Port Boards for the Apple II

Monitors will be discussed in detail later. For now, we will pick a $200 green screen model.

Our Apple II basic hardware configuration is now complete. Since an Apple IIe with 64K of memory lists for $1,395, it will cost us between $3,402 (with a SSM AIO-II serial/parallel interface card, two Micro-Sci A70 disk drives with controller card, an Apple Computer keypad and 80-column display adapter and a CRT) and $4,139 (with Apple Computer serial and parallel interface cards, disk drives, controllers, 80-column display adapter and keypad, and a CRT) to obtain a basic hardware configuration based on the Apple II which meets our specifications.

A high-budget Apple II configuration, which uses Apple serial and parallel interface cards, one floppy disk drive and controller, 80-column adapter, a generic $400 composite color monitor and a generic $3,000 10M hard disk drive, costs $6,004.

The Apple ///

The Apple /// microcomputer is based on a MOSTEK 6502A microprocessor which is functionally identical to the Apple II's 6502, but is 50% faster. Even though the 6502 processor is able to handle only 64K bytes of memory, the manufacturer (Apple Computer, Inc.) has, through the implementation of a bank switching technique, given the Apple /// the ability to use 256K bytes of memory as if its microprocessor could recognize it all at once. The net result to the user is a faster machine (though still slow in relation to other microcomputers) with up to twice the memory of the Apple IIe.

The minimum memory size for an Apple /// is 128K.

The Apple /// provides, as standard equipment, a keyboard with numeric keypad, a disk drive with 135K bytes of file space with a built-in disk controller that will control up to four drives, one serial port, a speaker, joystick ports and monitor ports for both black-and-white and color monitors

(both NTSC composite and RGB color signals are supplied). No monitor is provided, but the output video signal produces a 24-by-80 text display on a standard monitor. The graphics outputs are similar to the Apple II's. The Apple /// has four expansion slots.

The list price for a 128K Apple /// is $2,495.

To get an Apple ///-based configuration that meets our specifications, we must add a monitor (we will assume a $200 green screen), a second port (serial or parallel), and more floppy disk drives. However, no additional disk controller card is needed if we use only the conventional floppy drives. We therefore will need to use only one of the four expansion slots.

Because the Apple /// has been in existence for only three years (compared to the Apple II's six) and has a much smaller installed base (about 75,000 units versus over 750,000 Apple IIs), the selection of Apple /// expansion cards is paltry compared to the Apple II's. No serial interface card is currently available, for example, so we cannot opt for two serial ports as we could with the Apple II. We must instead add a parallel interface and the only one available is the Apple Computer Universal Parallel Interface Card ($225).

All of the disk drives for the Apple /// are manufactured by Apple Computer. We have a choice of adding three 135K Disk /// drives which are identical to the built-in drive for $435 each (total cost $1,305) or one high-density (871K) Unifile drive (and additional controller) at $995. However, the Unifile drive uses different diskettes than the built-in drive, which would compound our supply problem.

The total Apple /// basic hardware configuration thus ranges in price from $3,915 to $4,225. A high-budget configuration, consisting of a one-disk Apple ///, an Apple parallel interface card, a generic $700 RGB color monitor, and a $3,000 10M hard disk, will cost $6,420.

The IBM Personal Computer

The IBM Personal Computer differs from all of the preceding microcomputers in that it is based on a microprocessor (the Intel 8088) which can directly use more than 64K of memory. It is its use of this newer, more advanced processor that makes the IBM PC one of the first of the "second generation" of microcomputers. But due to its design characteristics (it can have a maximum of 512K bytes of memory -- only twice the limit of the Apple ///) and clock speed (5 MHz), its performance and price are not very different than the others. It is still an entry-level business computer.

The basic "system unit" consists of 64K RAM, 40K ROM (which contains the BASIC language interpreter and hardware diagnostic software), cassette and keyboard ports, microprocessor, power supply, chassis with five expansion slots, keyboard with numeric keypad, a 160K disk drive and disk drive controller card (IBM calls it a "diskette drive adapter") that controls up to four drives, costs $1,864. A similar configuration incorporating a 320K double-sided disk drive costs $2,104. To obtain a hardware configuration that meets our specifications, we will have to add one serial and one parallel port, a CRT and CRT controller and at least one more floppy disk drive.

A second 320K IBM disk drive costs $529. The IBM "monochrome display adapter", which is the name IBM gives to the CRT controller which produces a 25-by-80 black-and-white display signal which can be input to any standard monitor, costs $335 and includes a parallel port. An IBM "asynchronous communications adapter" or serial port costs $120. Assuming we use the IBM green screen monitor ($345), we can obtain a basic hardware configuration based on the IBM PC and using only IBM components for $3,433. We use three of the five expansion slots in this configuration.

We can reduce this price somewhat if we use other suppliers of compatible components. For example, Tandon makes IBM-compatible double-sided disk drives that sell for about $300 each (compared to IBM's $529).

For a serial port, we could choose from the ones identified in Table 14, among others. Notice that many products exist for the IBM PC that combine several functions into a single board.

If we wanted to get our disk controller from a third party (see Table 15), we could buy the Maynard Electronics disk controller card for $195 or their combination disk controller/serial port for $269. However, IBM no longer sells its PC without at least one disk drive, so using third-party disk controllers is not as attractive as it once was.

We could, using a Tandon disk drive, put together a basic hardware configuration (IBM 64K one-drive system unit ($2,104), serial port ($120) and monochrome adapter ($335), one Tandon disk drive ($300) and a generic $200 monitor) that meets our specifications for only $3088. It also uses three of the five expansion slots.

Both of these configurations use the monochrome display which produces a fine quality text that can be displayed in two different intensities, in normal (white-on-black) or inverse (black-on-white), underlined and/or blinking. It can also produce text graphics, but cannot display high-resolution graphics.

For our high-budget option, we may want to consider the color graphics adapter which can generate good quality 25-by-80 text and/or high-resolution color graphics. It can produce black-and-white graphics at 200-by-640, four-color graphics at 200-by-320 or 16-color graphics at 100-by-160. These resolutions are comparable to those of the Apple II and ///. If we choose this option it will cost us an extra $59 ($244 for the color graphics adapter and $150 for a parallel port, minus the $335 for the monochrome adapter).

The Osborne 1

When the Osborne 1 microcomputer was introduced about two years ago, it was an immediate "best seller." It was the first portable microcomputer (24 pounds; fits under most airplane seats) having a full 64K of memory. It was

MANUFACTURER	MODEL	NOTES	PRICE
Datamac	DMS-1	50 to 9,600 baud, interrupts	$139
Davong Systems	DSI-ASYNC		$199
IBM	Asynch. Comm. Adapter	50 to 9,600 baud	$150
Maynard Electronics	Floppy controller & serial port	1 serial port, floppy disk controller	$269
Personal Systems Technology	Persyst	1 or 2 serial ports, 50 to 9,600 baud, interrupts	$130 (1) $195 (2)
Quadram	RS-232-C Async. Adapter	1 or 2 serial ports	$129 (1) $189 (2)
TecMar	Multifunction Card	1 serial, 1 parallel, 64K RAM, calendar/clock	$565

Table 14

Some Serial Port and Multifunction Port Boards for the IBM PC

MANUFACTURER	MODEL	NOTES	PRICE
IBM	Floppy controller		$220
Maynard Electronics	Floppy controller & serial port	controller, 1 serial port	$269
Maynard Electronics	Floppy controller & parallel port	controller, 1 parallel port	$269
Maynard Electronics	Floppy controller		$195

Table 15

Some Floppy Controller and Multifunction Controller Boards for the IBM PC

the first computer system to supply free software with the purchase of the hardware (see Step 6 for a description of the free software). And it was the first microcomputer package to include 64K of memory and two floppy disk drives for under $2,000.

The Osborne 1 is based on the Zilog Z80A microprocessor which operates at 4 MHz. It is a complete microcomputer package which, in addition to the 64K and two single-density floppy disk drives, includes a keyboard with numeric keypad, a serial port, an IEEE 488 port (a variety of parallel port which is not as widely used as the Centronics port), a 5-inch CRT and a port for an external CRT. The disk drives provide about 100K bytes of file storage each. No expansion slots and no graphics of any kind are provided.

The Osborne 1 lists for $1,795. Double-density disk drives (200K bytes of storage per diskette) may be substituted for the single-density drives for an extra $200. Note, however, that even with the double-density drives the maximum amount of on-line file storage is only 400K bytes -- 100K less than our specification. There is no option for substituting a Centronics parallel or RS-232C serial port for the IEEE 488 port, either. Strictly speaking, the Osborne 1 cannot meet our specifications. It comes close, though, and is worth considering in our low budget case because it has a very low pricetag.

The Osborne has one other problem in that the CRT displays only 52 columns of a 120 column screen and scrolls horizontally to display the full screen. An 80-column display option will reportedly be offered soon and is expected to cost about $200.

With the double-density disks, the 80-column display option and a $200 green screen external monitor (the 5-inch built-in monitor can be hard to read), the Osborne 1 costs $2,395. If we can live with the IEEE 488 port and the 400K of disk space, it is a very attractively priced low budget option. However, because it has no graphics and no hard disk option, it is not suitable for our high-budget system.

The Radio Shack TRS-80 Model 12

The Radio Shack TRS-80 Model 12 microcomputer, produced by the Tandy Corporation, is a highly integrated small business computer system that is an upgrade of the Model II which has been on the market for over three years. It is based on a Zilog Z80A microprocessor which operates at a 4 MHz clock speed. It comes with 80K of RAM, a keyboard with numeric keypad, a 24-by-80 black-and-white CRT display, two serial ports, one parallel port and a built-in 8-inch floppy disk drive providing 1.25M of file storage. No expansion slots are included in the computer chassis, but a "cage" providing six external expansion slots may be purchased for $200 plus installation costs.

A one-disk system retails for $3,199 and a two-drive system costs $3,999. The one disk model comes very close to meeting our specifications; only our specification of two disk drives is violated.

The standard Model 12 comes with a 72-by-160 black-and-white graphical display capability, implemented by means of a special set of graphical characters occupying 6 graphics cells each. A high-resolution (240-by-640) black-and-white graphics display capability which is implemented without the text character restrictions of the low-resolution graphics is available as a $499 option. However, it requires the expansion slot cage.

A high-budget configuration based on the Radio Shack Model 12 would consist of a one-floppy system with the expansion cage, graphics option and a $3,000 10M hard disk. It would cost $6,897.

Summary of Basic Hardware Configurations

The five basic hardware configurations are summarized in Table 16. Both low budget and high budget configurations have been assembled. In most cases, the low budget option is the lowest-priced configuration identified above, with the exception of the IBM PC configuration which uses only IBM products. Because we did not thoroughly investigate the hard disk options

COMPUTER MODEL	CLOCK SPEED (MHz)	MEMORY (K)	FLOPPY STORAGE (K)	SERIAL PORTS	PARALLEL PORTS	GRAPHICS PRICE	LOW BUDGET PRICE	HIGH BUDGET PRICE
Apple IIe	1.2	64	572/132	1	1	incl.	$3,402(a)	$6,004(b)
Apple ///	1.8	128	1006/135	1	1	incl.	$3,915(c)	$6,420(d)
IBM PC	5.0	64	640/320	1	1	$59	$3,433(e)	$5,998(f)
Osborne 1	4.0	64	400(*)	1	IEEE 488(*)	NA	$2,395(g)	--
Radio Shack Mod. 12	4.0	80	2500/1250	2	1	$499	$3,999(h)	$6,897(i)

Notes:

a. With SSM AIO-II serial/parallel interface card, two Micro-Sci A70 disk drives and controller card, Apple keypad and 80-column display adapter and generic $200 monitor
b. With Apple serial and parallel interface cards, one Apple disk drive and controller card, Apple keypad and 80-column display adapter, generic $400 composite color monitor and $3,000 10M hard disk
c. With Apple parallel interface card, an Apple Unifile disk drive and controller card and generic $200 monitor
d. With Apple parallel interface card, generic $700 RGB color monitor and $3,000 10M hard disk
e. With an IBM monochrome display adapter, two IBM double-sided disk drives, serial interface card and monochrome monitor
f. With IBM serial and parallel interface cards, one double-sided disk drive, IBM color monitor, color graphics display adapter and generic $3,000 10M hard disk
g. With two double-density disk drives, the 80-column display option and $200 generic monitor
h. With two disk drives
i. With one floppy disk drive, the expansion cage, the graphics option and a $3,000 10M hard disk

* Does not meet specifications.

Table 16

Comparison of Basic Hardware Configurations

available with each machine, we have included a generic $3,000 10M hard disk in each high budget configuration. You should be aware, however, that hard disk prices vary greatly, so you should be particularly energetic in shopping for a hard disk.

The Osborne 1 is the clear low-budget cost winner, but falls significantly short of our 500K disk storage requirement and its use of an IEEE 488 port instead of a more common Centronics parallel port could result in a difficult search for a compatible printer -- and probably a higher printer cost. Graphics, which are not required in our specification but which are desirable, are not available at any price on the Osborne 1, nor is a hard disk. Consequently, the Osborne 1 is not a suitable machine for our high-budget configuration.

The IBM PC configuration derived using all-IBM add-on components is the lowest-cost configuration meeting our specifications and is one of the lowest cost high-budget configurations. It is also based on the fastest and most versatile microprocessor (the Intel 8088) represented in this group of microcomputers.

The Apple IIe has the third lowest low budget configuration price and has one of the lowest high budget prices. It is probably the most versatile system in the group and the most tried-and-true. It is also the slowest. High-resolution graphics are included in the Apple IIe at no extra cost.

The Apple /// is $400 to $500 more expensive than the Apple IIe and the IBM PC in both budgets, but has twice the memory, is faster than the Apple IIe and includes color graphics.

A Radio Shack Model 12 with one disk drive would have had the third-lowest price at $3,199, but it doesn't meet our specifications and addition of a second drive boosts the price by $800. It also has no expansion slots in its standard configuration and adding slots costs $200 or more. Graphics are available as a $499 option, not counting the required slot expansion. A high-budget configuration which includes the expansion cage, the graphics option and the $3,000 10M hard disk, has the highest

high-budget pricetag at $6,897.

GENERIC PERIPHERAL DEVICES

To be useful to a computer, a peripheral device and the computer must share a common communications protocol; i.e. they must speak the same "language". Some of these languages are very specialized and are known only to a particular computer and a particular device; communications between a computer and a disk drive are usually of this type. Because their protocols are so specialized, disk drives can usually be connected only to the computer they were designed to work with. Other devices, however, tend to use more universal languages and, as a result, tend to be usable with many different computers; i.e. they tend to be "generic". This section looks at three types of generic peripheral devices: monitors, printers and modems.

Monitors

Three of the five hardware configurations described above require an external monitor and a fourth one comes with a monitor so small (the 5-inch Osborne monitor) that an external one is a practical necessity. In pricing those low-budget configurations, it was assumed that the external monitor would cost $200. This section looks at some of the available monitor products and their actual list prices.

Monitors come in both monochrome and color varieties. The color monitors are useful only to those computer systems which generate a color signal (i.e. the Apple II, the Apple /// and the IBM PC with the color graphics adapter option). We will look at the monochrome offerings first.

Monochrome monitors are distinguished primarily by their screen color (black-and-white, green or amber) and by their screen size (usually between 9 and 13 inches, although smaller and larger sizes are available). Secondary characteristics include the phosphor persistence (i.e. the length of time the image remains after the signal is removed; a high-persistence display has

less flicker, which is good, but more ghosting on changing displays, which is bad), the types of cable connectors provided and the types of user controls.

Supposedly the amber screen is the easiest to work with for extended periods of time, with the green screen close behind. But, as with so many computer-related things, much depends on personal preferences, so you should "test drive" each type before you buy.

Some of the more popular black-and-white models are listed in Table 17 while a few of the many green screens are shown in Table 18.

Amber screens are harder to find. The major model is the USI Pi-III 12" ($249).

If you want a color monitor, you must decide whether you want one that operates off an NTSC composite signal or an RGB signal. The Apple II outputs a composite color signal (an RGB output interface board is available for about $120) while the Apple /// and the IBM PC produce both types of signals.

If you decide to use an RGB monitor with an IBM PC, you must also be aware that that computer outputs a slightly non-standard RGB signal which requires a special type of RGB monitor (standard RGB monitors can be used, but only 8 of the 16 colors will be displayed).

Among the composite color monitors currently on the market are the ones presented in Table 19. Table 20 lists some of the popular RGB models.

Our hardware specifications included a black-and-white or green screen monitor. For the Apple II, the Apple ///, the Osborne 1 and the IBM PC, we assumed we would purchase a monitor costing $200. If we choose a more expensive model, we will have to add the extra cost to our configuration pricetags. Note that a desire to use only IBM equipment in an IBM PC configuration will cost us an extra $145.

BRAND	MODEL	NOTES	PRICE
Amdek	Video 100	12"	?
Sanyo	4509	9"	$190
Sanyo	8012C	12"	$250

Table 17

Some Black-and-White Monitors

BRAND	MODEL	NOTES	PRICE
Amdek	Video 300	12"	$249
Apple	Monitor ///	12"	$250
IBM	PC Monitor	12"	$345
NEC	JB1201	12"	$249
Sanyo	5109CX	9"	$200
USI	Pi-I	9"	$199
USI	Pi-II	12"	$199
Zenith		12"	$150

Table 18

Some Green Screen Monitors

BRAND	MODEL	NOTES	PRICE
Amdek	Color I	13"	$449
BMC		12"	$439
NEC	JC120	12"	$449
Sanyo		13"	$470

Table 19

Some Composite Color Monitors

BRAND	MODEL	NOTES	PRICE
Amdek	Color II	13", IBM-compatible	$899
Amdek	Color III	13"	$569
Electrohome	med-res	13", ? lines	$399
Electrohome	high-res	13", ? lines	$729
IBM			$680
NEC	JB1202	12"	?
NEC	JB1203	12", IBM-compatible	?
Sanyo		13"	$995
Taxan	RGBVision I	13", 380 lines, IBM-compatible	$399
Taxan	RGBVision II	13", 510 lines, IBM-compatible	$699

Table 20

Some RGB Color Monitors

Printers

The printer is the most expensive generic peripheral device in our configuration, and the most variable in price. Depending on our desires and needs, a printer will add between $300 and $4000 to our computer system cost.

In selecting a printer, our single most important consideration is compatibility: it must be compatible with the computer port (parallel or serial) to which it will be attached and it must be compatible with any software (most notably the word processor) which will use it. Once we have identified a set of printers which meet those basic compatibility requirements, we can select the one which has the most features and the best performance for the most attractive price. Among the features we may look for are the following:

- o Print quality. Do we need a letter-quality document, or can we get by with a lower quality (but faster and cheaper) model?

- o Print speed. How important is speed, especially if the computer will be unusable for any other work while documents are printing?

- o Buffer size. Most printers have a one-line buffer, which means they can be no more than one line behind the computer at any time, but others have larger buffers (as either standard or optional equipment) which lets them fall farther behind. A large buffer can increase the utilization of the computer, so how important is the buffer to us?

- o Form width. Will we need to print on 15-inch wide computer paper, or can we get by with a less expensive printer that cannot handle forms wider than 10 inches?

- o Friction/tractor feed. Can we use a printer that has only friction paper feeding (which is useful for printing single sheets of paper) or tractor or pin feeding (which is best for printing with continuous forms), or must we have both?

- o Single-sheet feeder option. If we plan on printing on single sheets (e.g. on memo paper), then how important is it to have a printer for which a single-sheet feeder is available? Manual feeding of single sheets is difficult, laborious and boring, but sheet feeders are very expensive ($1,000-$3,000).

- o Variable text fonts. Is a selection of 10-pitch/12-pitch adequate or must we have a wider variety of font sizes? Do we need alternate alphabets?

- o Proportional spacing. Must the printer be able to perform proportional spacing of text in which character widths may vary (e.g. a "w" may be wider than an "i") and both right and left margins may be simultaneously justified, or can we survive with a fixed-spacing model?

- o Programmability. Some printers make some of their features software-controllable while others provide only switch-selectable options (and sometimes the switches are inconveniently placed). How important is it to us to have printer features controlled by software? It is probably quite important if we plan on doing a lot of word processing.

- o Graphics. Do we want to print text only or would we like to have our printer be able to produce hard copies of graphical displays as well?

- o Color. There are now a few printers on the market which can produce both text and graphics in color, but they are more expensive than equivalent black-and-white models. Is the color worth the cost to us?

These are some of the major considerations we should take into account when making our printer selection. Some of the current printer offerings are described in Tables 21, 22 and 23 which show dot-matrix, color and letter-quality printers, respectively.

BRAND	MODEL	SPEED (cps)	MATRIX SIZE	CARRIAGE (inches)	GRAPHICS DENSITY (dpsi)	FRICTION TRACTOR FEED	MAX. # OF CHARACTERS IN A LINE	# OF CHARACTER SIZES	NOTES	PRICE
Apple	Dot Matrix	120	7x9	10	?	Both	132	3	a,d	?
C. Itoh	8510A	120	?	10	20,000	Both	150	?	a,b,d,e	$795
Coex	80-FT	80	7x9	10	NA	Both	132	1	a,b,c,g	$350
Epson	MX-80FT	80	9x9	10	6,000	Both	132	3	a,b,c,d,e,f	$645
Epson	MX-100	80	9x9	15	6,000	Both	233	3	a,b,c,d,e,f	$995
IDS	445	>150	?	10	6,000	Both	132	8	a,b,f	$775
IDS	460	150	?	10	6,000	Both	132	6	a,b,d,e,f	$995
IDS	560	>150	24x9	15	7,000	Both	233	6	a,b,d,e,f	$1,295
Mannesmann-Tally	160L	160	7x9	15	?	Friction	232	8	a,b,d,e,g,h,i	$1,995
MPI	88G	100	7x7	10	6,000	Both	132	8	a,b,c	$749
Okidata	82A	100	9x9	10	6,000	Both	132	?	a,b	$699
Okidata	150	150	7x9	15	6,000	?	231	?	a,b	$1,049

Notes:

a. parallel interface available
b. serial interface available
c. IEEE 488 interface available
d. programmable
e. proportional spacing
f. graphics cost extra
g. includes 2K buffer
h. tractor feed costs extra
i. has 40 cps correspondence mode

Table 21

Some Dot Matrix Printers

BRAND	MODEL	SPEED (cps)	MATRIX SIZE	CARRIAGE (inches)	GRAPHICS DENSITY (dpsi)	FRICTION TRACTOR FEED	MAX. # OF CHARACTERS IN A LINE	# OF CHARACTER SIZES	NOTES	PRICE
IDS	Prism 80	>150	24x9	10	7,000	Tractor	80	2	a,b,d,e,f,g	$1,547
IDS	Prism 132	>150	24x9	15	7,000	Tractor	132	2	a,b,d,e,f,g	$1,995
PrintaColor	GP1024	60	12x12	10	10,000	Tractor	?	?	a,b	$1,795

Notes:

a. parallel interface available
b. serial interface available
c. IEEE 488 interface available
d. programmable
e. proportional spacing
f. friction feed option
g. has foreign character sets

Table 22

Some Color Printers

BRAND	MODEL	SPEED (cps)	CARRIAGE (inches)	TRACTOR/ FRICTION FEED	MAX. # OF CHARACTERS IN A LINE	NOTES	PRICE
C. Itoh	Starwriter	40	15	Friction	163	a,b,d,f	$1,995
C. Itoh	Printmaster	55	15	Friction	163	a,b,d,f	?
Diablo	R0630 API	40	15	Friction	232	a,b,c,d,f	$2,695
NEC	3510/3530	35	15	Both	232	a,b,e	$2,290
NEC	7710/7730	55	15	Both	?	a,b,e	$3,055
Oume	Sprint 1140+	40	15	Both	132	a,b,c,d,e	$1,786
Smith-Corona	TP-1	12	12	Friction	?	a,b	$895

Notes:

a. parallel interface available
b. serial interface available
c. IEEE 488 interface available
d. programmable
e. proportional spacing
f. tractor feed optional

Table 23

Some Daisywheel and Thimble Printers

Modems

In shopping for a modem, your primary choice will be between the two main transmission speed options: 300 baud and 1200 baud. However, you must also pay attention to the protocol used by the modem. Because a modem is essentially a translating device, it speaks a distinct language. This language must be recognizable to the modem at the other end of the phone line. Most of the languages or "protocols" in use today were established by Bell Telephone (i.e. AT&T) and are identified by number:

- Bell 103A/113: 300 baud in both directions;
- Bell 202: 300 baud transmit, 1200 baud receive; and
- Bell 212A: 1200 baud in both directions.

However, one private company, the Racal-Vadic Corporation, has developed its own protocols which mean that many of its modems can speak only to other Racal-Vadic modems. They do, however, make Bell-compatible modems as well, so if you are looking at a Racal-Vadic modem, pay particularly close attention to the protocol it uses or you may wind up with a modem that won't work the way you expect it will.

It is probably also a good idea to avoid the Bell 202 protocol altogether. Not many commercial computer installations use it now and it is essentially an obsolete protocol. Use it only if a computer installation you know you will have to communicate with is using it.

That leaves the Bell 103A/113 and 212A protocols. The Bell 103A/113 protocol is actually two related protocols: the 103A protocol is used when communicating in "half duplex" mode (i.e. when sending and receiving alternately) and the 113 protocol is used when operating in "full duplex" (i.e. when information may be sent and received simultaneously). The 212A protocol can be used in either full or half duplex mode and can support both asynchronous (i.e. character-by-character) and synchronous (i.e. block) transmission. The 103A/113 protocol supports only asynchronous transmission.

Synchronous 120 characters per second transmissions are often required to communicate with large IBM computers via the IBM 3270 protocol.

Once you have decided on your preferred transmission speed and protocol, you can look for a modem to meet your needs. In evaluating modems, you may wish to look for some of the following additional features:

- o Direct connect: the modem connects directly to the telephone line via a modular plug (the alternative is to use an "acoustic coupler" into which the telephone's handset can be placed);

- o Auto answer: the modem can monitor the phone line for incoming phone calls and, when one is received, can automatically connect the computer;

- o Auto dial: the modem can be instructed by the computer to dial a phone number and, if answered, automatically establish communications; some modems can work with both touch-tone and rotary dial phones while others work with one type only;

- o Redial (available only with auto dial modems): if a dialed number is busy, the modem can be instructed to keep trying until the call gets through; some modems can also remember multiple numbers;

- o Audio monitor (available only with auto dial modems): allows the user to hear the number as it is dialed and the response (i.e. the answer tone, a busy signal or, if a wrong number is reached, an irate human voice); some modems also have a talk/data switch to facilitate data transmissions which must be preceded by human communication.

- o Self-test: the modem performs a series of tests on itself each time it is turned on and reports any errors it discovers.

- o Dual speed (available on 1200 baud modems only): supports both 300 baud and 1200 baud communications; some have a "speed sense" feature that automatically switches between rates to accomodate incoming

transmissions.

Some of the current offerings in the Bell 103A/113 and Bell 212A modem markets are described in Tables 24 and 25, respectively.

Left out of these tables were a number of products made for specific microcomputers, such as the Hayes Micromodem, a Bell 103A modem for the Apple II computer which plugs directly into one of the Apple's expansion slots rather than attaching to a serial interface. These products may be less expensive than the more conventional serial interface/modem combination (e.g. the Micromodem lists for $379 while a serial interface and a modem would generally run over $400), but the loss of the general-purpose serial port diminishes the flexibility of the computer system. In our opinion, the serial interface/modem route is well worth the slightly higher cost.

Summary of Generic Peripheral Devices

We assumed, in pricing the low-budget basic hardware configurations, that those systems requiring an external monitor (i.e. every one except the Radio Shack) would use a $200 model. Actual monitor prices range from $100 to nearly $1,000.

Our low-budget hardware specifications called for a 300 baud modem, so we can expect the modem to add between $100 and $300 to our low-budget hardware configuration's pricetag. The high-budget configuration will include a 1200 baud modem, at a cost of $500 to $800.

We also specified a 40 cps printer, a speed which can be achieved by every dot-matrix printer and most daisy-wheel printers. The prices of these printers can range from $300 to $4000 and must be added to the basic hardware configuration costs. We will pick a good quality dot-matrix printer for our low-budget configuration and a character printer for our high-budget configuration.

We are now ready to assemble complete hardware/software configurations.

BRAND	MODEL	FULL/HALF DUPLEX	AUTO DIAL?	REDIAL?	AUTO ANSWER?	AUDIO MONITOR?	NOTES	PRICE
Hayes	Smartmodem	Both	Y	Y	Y	Y	a	$289
Novation	Auto-Cat	?	?	?	?	?	?	$249
Novation	Smart Cat	?	?	?	?	?	?	$249
Rixon	R103J	?	?	?	?	?	?	$199
UDS	103LP	?	?	?	N	?	?	$229
UDS	103JLP	?	?	?	Y	?	?	$259
U.S. Robotics	AutoLink 300	Both	N	N	Y	N	d	$219

Notes:

a. programmable
b. touch tone dial only
c. pulse dial only
d. self-test

Table 24

Some Bell 103A/113 (300 Baud) Modems

BRAND	MODEL	300/ 1200	AUTO DIAL?	REDIAL?	AUTO ANSWER?	AUDIO MONITOR?	1200 SYNCH?	NOTES	PRICE
Cermetek	212A	Both	Y	?	Y	?	Y	b	$595
Hayes	Smartmodem 1200	Both	Y	Y	Y	Y	N	a,b,c,e	$699
Novation	212 Auto-Cat	1200	Y	N	Y	N	Y	b,c,f	?
Novation	103/212 Smart Cat	Both	Y	Y	Y	N	N	b,c,d	$595
Rixon	TA212A	Both	N	N	Y	?	Y	c	$795
UDS	212A	Both	?	?	?	?	?	?	$695
UDS	212LP	1200	N	N	N	N	?	?	$495
U.S. Robotics	AutoLink 1200	1200	N	N	Y	N	N	b,c,d,f	$549
U.S. Robotics	AutoDial 212A	Both	Y	N	Y	N	N	?	$599

Notes:

a. programmable
b. touch tone dial
c. pulse dial
d. self-test
e. automatic speed sense
f. full duplex only

Table 25

Some Bell 212A (1200 Baud) Modems

STEP 6: EVALUATE CANDIDATE MICROCOMPUTER SYSTEMS AND SELECT

In the preceding step you searched for hardware that could run the software packages that you assembled in the step before that. You may have been unable to find hardware that performed acceptably for each software package, but you must have found at least one acceptable hardware/software combination that meets your specifications to reach this point. If you have found only one such combination, your work is nearly over (although you may be faced with the task of writing a sole source justification for a competitive procurement). If you have found several acceptable hardware/software configurations, your last job depends on your situation:

- o if you must do a competitive procurement, you must write your specifications to permit the acceptable configurations to compete while excluding unacceptable configurations; or

- o if you are free to make an unconstrained choice, you must assemble complete configurations, obtain bids and perform a final comparitive evaluation.

In either case, it is a good idea to verify, before taking that final, irrevokable step, that the "complete" configurations are, in fact, complete and do operate as you expect. This means getting some "hands on" experience with each of the candidate configurations, preferably with some real applications that you intend to implement. Look for missing pieces of hardware and software that are needed to make the system perform to expectations.

Of course, the earlier you get "hands on" experience, the better. If you can obtain that kind of familiarity with the hardware and software early in your searches, you will be better prepared to do those searches. But it is entirely possible to perform an adequate search for hardware and software without ever touching a machine. We are simply recommending that you see all of the pieces in operation at some point before you buy them. That simple precaution can save you a lot of headaches later on.

In evaluating the complete configurations, you should certainly consider price and performance, but there are other important considerations as well:

- o Reliability: what is the reputation of the hardware and software for breaking down or "crashing"? Try to talk to some current users to assess this.

- o Standardization: how standardized are the various components? A non-standard piece of hardware or software is likely to have a shorter useful life. Pay particular attention to the operating system, the printer and graphics software. Standardization can be gauged by the number of other products on the market that will work with the component in question.

- o Quality of dealer technical support: when you need technical assistance, will your dealer be able to provide it? Your hardware/software dealer should be your first source of information, but many dealers know very little about the products they sell. A truly knowledgable dealer is, in our experience, worth a lot.

- o Availability of prompt repair service: how quickly will a component be repaired if it breaks down? This is an important question in general, but is particularly crucial if you are buying your first microcomputer. You can't afford to have your system inoperative for a week every time something goes wrong. Check out the maintenance terms for all of the system's hardware components.

- o Upgradability: how much room do you have for future growth? If your first applications are successful, you will soon want to implement more. You may want to add more memory or peripherals to you microcomputer, add more microcomputers or switch to a multi-user operating system. Maybe you will later want to link several microcomputers together by means of a network. Are these options available and can they be implemented with minimal disruption to your existing applications?

It pays to include these considerations in your initial evaluation.

As a final step in our hypothetical example, let's assemble some complete configurations (we will assume that we are not obliged to do a competitive procurement) and cost them out. We will start with the low-budget configurations, then go on to the high-budget configurations. In all cases, we will be using a generic printer and modem and, on the high-budget configurations, a generic 10M hard disk. This was done to keep the variability in the prices of these generic components from affecting the price comparisions. The printers and modems are totally interchangable and each system has comparable hard disk options. These components should be selected as a separate step following selection of the software and basic hardware.

COMPLETE HYPOTHETICAL LOW-BUDGET SYSTEMS

Our Apple II hardware consists of a 64K Apple IIe with an 80-column display adapter, SSM AIO-II serial/parallel interface card, Apple numeric keypad, two Micro-Sci A70 double-density disk drives and controller card and a generic $200 green screen monitor, plus a generic $300 300-baud modem and $1,300 printer. We will be running the DOS 3.3 operating system and the following applications: the VisiFile file manager, the VisiCalc spreadsheet, the AppleWriter IIe word processor and the VisiTerm terminal emulator. Our programming language will be Applesoft BASIC.

This configuration costs $5,777.

We have assembled an Apple ///-based configuration which consists of a 128K Apple /// with a parallel interface card, an Apple Unifile floppy disk drive (in addition to the built-in floppy disk drive), a $200 generic green screen monitor, a $300 generic 300-baud modem and a generic $1,300 printer. We will be using the Quick File file manager, the VisiCalc /// spreadsheet, the AppleWriter /// word processor and the Access /// terminal emulator. All of these applications run under the SOS operating system. We will use the Business BASIC programming language.

This configuration has a list price of $6,415 (which is over our budget).

Our IBM PC configuration consists of a 64K IBM PC with monochrome display adapter card and monochrome monitor, two IBM double-sided floppy disk drives and an IBM serial interface card, plus the generic printer and 300-baud modem. We will be running the MS-DOS operating system and using the IBM BASIC programming language. For application software, we have the VisiFile file manager, the VisiCalc spreadsheet, the EasyWriter II word processor and the Crosstalk terminal emulator. It will cost $6,138.

Many IBM PC applications require 128K of RAM. The extra 64K of RAM would cost us $165, which would put us over the budget, but would be good to get if we can arrange it. It would also be desirable to take the $59 graphics option.

Our Osborne 1 configuration is based on a 64K Osborne 1 with two double-density disk drives, the 80-column display adapter and a $200 generic monitor, plus the generic modem and printer. It runs the CP/M operating system and would include the following application software products: the SuperData file manager, the SuperCalc spreadsheet, the WordStar word processor and the Crosstalk terminal emulator. We have two programming languages: MBASIC and CBASIC.

The total cost is $4,435 -- an amazingly low price which is due largely to the fact that both SuperCalc and WordStar are provided free with the purchase of an Osborne 1. The MailMerge form letter support program for WordStar is also provided free of charge. This is a good example of the kind of "package deal" that can be found if you look around a little. It is worth your while to look.

The Osborne 1 does not meet our specifications, strictly speaking, as its 400K disk capacity is below our 500K minimum. But maybe our specifications can flex a little in the face of a bargain?

Our Radio Shack TRS-80 Model 12 configuration is based on an 80K Model 12 with two disk drives and the generic modem and printer. It uses the TRSDOS operating system. Our application software package includes the Profile Plus file manager, the VisiCalc spreadsheet and the SCRIPSIT 2.0 word processor.

This configuration costs $6,596. This exceeds our budget, but includes a huge 2.5M of floppy diskette storage. If the storage is important to us, maybe we could scrimp on the printer.

All of these low-budget systems are summarized in Table 26.

COMPLETE HYPOTHETICAL HIGH-BUDGET SYSTEMS

All of our high-budget configurations assume that we will be using the UCSD p-System (Version IV, except with the Apple ///) as our operating system and will be running the applications that we earlier selected for use with that operating system: the LogiQuest database manager, the LogiCalc spreadsheet, the Power Text word processor and the DataLink terminal emulator. Pascal is the chosen programming language in all cases. They also all include a generic $3,000 10M hard disk, a generic $2,500 printer and a generic $700 1200-baud modem.

It must be noted that, at the time of publication, the software included in this high-budget configuration will operate together only on the Apple II computer under the Version II.1 p-System. However, all of the vendors were working on versions of their products that would allow them to operate on the IBM PC and the Radio Shack Model 12 (under Version IV), as well as the Apple /// under the Apple /// p-System. This problem -- the shortage of software running under Version IV of the p-System -- is still a serious one, but can be expected to improve as time goes by and new products reach the market. Still, verifying that all products work together before buying, which is wise in any case, is a practical necessity when dealing with the p-System.

The Osborne 1 was excluded from the high-budget configurations because

	Apple II	Apple ///	IBM PC	Osborne 1	Radio Shack Model 12
Basic hardware	$3,402	$3,915	$3,433	$2,395	$3,999
Printer	$1,300	$1,300	$1,300	$1,300	$1,300
Modem (300 baud)	$300	$300	$300	$300	$300
System software	--	$125	$60	--	--
Application software	$775	$775	$1,045	$440	$997
	-------	-------	-------	-------	-------
Total	$5,777	$6,415	$6,138	$4,435	$6,596

Table 26

Hypothetical Low-Budget System Costs

it does not have a hard disk option. The remaining four high-budget configurations are summarized in Table 27.

The Apple II high-budget configuration differs from the low-budget configuration in that Apple boards and a single Apple disk drive were used and the monitor was upgraded to a color model. The modem and printer were also upgraded, as described above. The configuration costs $10,993. A similar configuration which uses the less standard Version II.1 p-System from Apple, would cost about $10,500.

The Apple /// configuration drops the Unifile floppy disk drive and upgrades the monitor to an RGB color model. The hard disk is added and the modem and printer are upgraded. This configuration costs $10,909, but uses the less standardized Apple /// p-System.

The IBM PC configuration drops its second floppy disk drive, includes the graphics option and the graphics display adapter (and the separate parallel interface card). The hard disk is added and the modem and printer are upgraded. This configurations has a list price of $11,162. Again, it would be wise to get the extra 64K of memory for $165.

Finally, the high-budget Radio Shack Model 12 configuration drops one of the floppy disk drives, adds the hard disk and upgrades the modem and printer. It costs $11,786.

Each of these configurations has its advantages and disadvantages. At this point, we would weigh these advantages and disadvantages, using our own values and priorities, and reach a decision on which is best for us. Which would you pick?

	Apple II	Apple ///	IBM PC	Radio Shack Model 12
Basic hardware	$3,004	$3,420	$3,298	$3,897
10M hard disk	$3,000	$3,000	$3,000	$3,000
Printer	$2,500	$2,500	$2,500	$2,500
Modem (1200 baud)	$700	$700	$700	$700
System software	$750	$250	$625	$650
Application software	$1,039	$1,039	$1,039	$1,039
	-------	-------	-------	-------
Total	$10,993	$10,909	$11,162	$11,786

Table 27

Hypothetical High-Budget System Costs

CONCLUSION

You will be pleased to hear that our Board of Directors was impressed with all the work we did and decided to let us buy the configuration we recommended. It is now installed and operational and we are using it happily ever after.

Fairy tales aside, selecting a single-user microcomputer system can be a difficult, confusing, time-consuming process. We know that we have not answered all of your questions, but we hope we have passed along some important messages, including these:

- o You should arm youself with some basic knowledge of microcomputer technology before setting out to buy one.

- o A rational microcomputer selection process is necessarily iterative in nature and involves identifying your needs, establishing your budget, searching for software, searching for hardware and evaluating complete candidate configurations.

- o A microcomputer system costs much more than a microcomputer. System costs are largely determined by the cost of the peripheral devices and the software rather than by the cost of the computer.

- o Ancillary costs -- for training, installation, furniture, maintenance and supplies -- are significant and cannot be ignored.

- o Many factors other than cost and performance should be included in your system evaluation.

The most important message of all, though, is that microcomputers are useful business tools that can help you do your job better. We hope that we have introduced you to a microcomputer system selection process that will help you select a single-user microcomputer system you will be happy with.

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Byte	BYTE Publications 70 Main Street Peterborough, NH 03458
Creative Computing	Creative Computing Box 789-M Morristown, NJ 07960
Datamation	Technical Publishing Co. 666 Fifth Ave. New York, NY
Dr. Dobb's Journal	People's Computer Co. Box E Menlo Park, CA 94025
InfoWorld	InfoWorld 530 Lytton Ave., Suite 303 Palo Alto, CA 94301
Interface Age	Interface Age 16704 Marquardt Ave. Cerritos, CA 90701
MICRO	MICRO INK Box 6502 Chelmsford, MA 01824
Microcomputing	Wayne Green, Inc. 80 Pine St. Peterborough, NH 03458
Mini-Micro Systems	Cahners Publishing Co. 221 Columbus Ave. Boston, MA 02116
Nibble	Micro-Sparc, Inc. Box 235 Lincoln, MA 01773
PC	PC 1528 Irving St. San Francisco, CA 94122
Personal Computing	Hayden Publishing, Inc. 50 Essex St. Rochelle Park, NJ 07662
Popular Computing	Popular Computing Box 307 Martinsville, NJ 08836

Small Business Computers	Small Business Computers Box 789-M Morristown, NJ 07960
Softalk	Softalk Publishing, Inc. 11160 McCormick St. N. Hollywood, CA

LIST OF VENDORS

Abt Microcomputer Software 55 Wheeler St., Dept. BCS Cambridge, MA 02138 (617) 492-7100	Data*Trans terminal emulator
Advanced Logic Systems 1195 E. Argues Ave. Sunnyvale, CA 94086 (800) 538-8177	ALS line of Apple II boards
Amdek 2201 Lively Blvd. Elk Grove Village, IL 60007 (312) 364-1180	monitors
Apple Computer, Inc. 20525 Mariani Ave. Cupertino, CA 95014 (800) 538-9696	Apple II microcomputer Apple /// microcomputer
Ashton-Tate 9929 Jefferson Blvd. Culver City, CA 90230 (213) 204-5570	dBASE II database manager
Beaman Porter Pleasant Ridge Road Harrison, NY 10528 (914) 967-3504	Power Text word processor
California Computer Systems 250 Carribean Drive Sunnyvale, CA 94086 (408) 734-5811	CCS line of Apple II boards
Centronics Data Computer Corp. One Wall St. Hudson, NH 03051 (603) 883-0111	printers
Cermetek 1308 Borregas Ave. Sunnyvale, CA 94086 (408) 734-8150	modems
Components Express, Inc. 1380 E. Edinger Santa Ana, CA 92705 (714) 558-3972	printers

Condor Computer Corp.
2051 S. State St.
Ann Arbor, MI 48104
(313) 769-3988

Condor 20-3 database manager

Context Management Systems
23864 Hawthorne Blvd., Suite 101
Torrance, CA 90505
(213) 378-8277

MBA integrated software
Connector terminal emulator

Corvus Systems, Inc.
2029 O'Toole Ave.
San Jose, CA 95132
(408) 946-7700

hard disk drives

Datamac Computer Systems
680 Almanor Ave.
Sunnyvale, CA 94086
(408) 735-0323

Davong Systems, Inc.
1061 Terra Bella Ave.
Mountain View, CA 94043
(415) 965-7130

IBM PC peripherals

Diablo Systems, Inc.
P.O. Box 5003
Hayward, CA 94545
(415) 786-5000

printers

Digital Research
160 Central Ave.
Pacific Grove, CA 93950
(408) 649-5500

CP/M operating system
CP/M-86 operating system
languages

DJR Associates, Inc.
303 S. Broadway
Tarrytown, NY 10591
(914) 631-6766

FMS-80 database manager

Electrohome Limited
809 Wellington St. North
Kitchener, Ontario N2G4J6

monitors

Epic Computer Corp.
7542 Trade St.
San Diego, CA 92121
(714) 695-3560

Epson America
3415 Kashiwa St.
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Software Publishing Corp. 1901 Landings Drive Mountain View, CA (415) 962-8910	PFS file manager
Sorcim Corp. 2310 Lundy Ave. Santa Clara, CA 95131 (408) 942-1727	SuperCalc spreadsheet SuperData file manager
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San Jose, CA 95131
(408) 946-7400

Apple II boards

Stoneware Microcomputer Products
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San Rafael, CA 94901
(415) 454-6500

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Structured Systems Group
5208 Claremont Ave.
Oakland, CA 94618

Analyst file manager

SuperSoft, Inc.
Box 1628
Champaign, IL 61820
(217) 359-2112

Systems Plus
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Palo Alto, CA 94303
(415) 969-7047

Tandon Corp.
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Chatsworth, CA 91311
(213) 993-6644

floppy disk drives

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(216) 464-7410

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