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ABSTRACT

More and more secondary schools are becoming interested in introducing their students to computers and computer concepts. A central problem for such schools, however, is obtaining reliable computer service with capacity for all the students who are interested, but at a cost the school can afford. Although many schools use commercial or small-scale time-sharing services, providing computer services to more than a few students becomes very expensive. Accordingly, various types of minicomputer systems are discussed in relation to the needs and capabilities of the schools. While a wide range of features are considered, special attention is paid to the peripheral equipment whose cost and reliability is so crucial to secondary school computer systems. (RH)

Putting
Research into
Educational
Practice

Developing Specifications for a Low-Cost Computer System for Secondary Schools

PREP Report No. 38

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE / National Institute of Education

PREP

PUTTING RESEARCH INTO EDUCATIONAL PRACTICE

- *a synthesis and interpretation of research, development, and current practice on a specific educational topic*
- *a method of getting significant R&D findings to the practitioner quickly*
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- *an attempt to improve our Nation's schools through research*

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Developing Specifications for a Low-Cost Computer System for Secondary Schools

PREP Report No. 38

by
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U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE/National Institute Of Education

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Introduction

Until recent years, education in the computer sciences has been the domain of colleges and universities. However, secondary school educators, aware of the growing role of computers in our technology-oriented society, have been interested in introducing computers, computer concepts, and computer-related materials into the secondary level curriculums. Teachers, particularly in mathematics and the sciences, have pursued course work, inservice programs, and summer institutes in order to acquire or expand their working knowledge and abilities with computers and related subjects. Students in the Secondary Science Training Program (SSTP) have been most enthusiastic in their response to computer-oriented programs. In some instances it has been these students who have provided the impetus to involve tneir schools in a computer education program. In addition, a great deal of interest has been aroused and stimulated by a number of the programs funded at the secondary and university levels.

Most programs start with modest ambitions. A relatively small number of students, usually honor students and/or seniors, are selected at the start of a program. Either a time-sharing service and terminals or a computer is obtained as a computing resource for the program. So long as the group remains relatively small, the program proceeds fairly well. The inherent limitations of the computing resource, common to most programs, become evident as attempts are made to extend the program to broader segments of the school's population. The major limitation then encountered is the number of student problems which can be processed by the available computing resource. When the students are learning the elements of a programing language, the size of their computer programing is relatively small. However, they must have repeated access to the computing facility to collect syntactic as well as logical errors in their computing program. The type of computing resource available and how it is managed has an important bearing on how many student problems can be processed. The number of student computer programs grows quite rapidly as the students begin to explore the use of the computer to solve problems in their other courses and laboratory work. Teachers who did not originally contemplate using the computer in their subjects soon realize the pedagogical value which the computer may afford them. Most educators appreciate the value of permitting students the freedom to explore the world of computers, within appropriate limits. Thus, the demand for computing resources can easily grow beyond the capacity of the initially chosen resource. This forces the school to limit student access to the computing resource.

Note—At the end of this report is a "Glossary of Commonly Used Computer Terminology" for those with little or no background in computer technology.

Computing Resources

It is worthwhile to examine the approaches which secondary schools have taken to obtain a computing resource. In general, three basic approaches are available; a commercial time-sharing service, a small-scale time-sharing service, and a mini-computer system.

Commercial Time-Sharing Service—The first and easiest computing resource to start with is a commercial time-sharing service. Teletypewriter terminals are used in a classroom to communicate with a remotely located computer over ordinary telephone lines. The teletypewriter is a typewriter-like device which can operate at a maximum speed of 10 characters per second (cps). A data set (or a coupler) interconnects the teletypewriter and the telephone line to the remote computer site. The student dials the number which will connect him to the time-sharing computer. Using the terminal, the student supplies information which identifies him to the computer as a valid user of the time-sharing service. This initial dialog is usually termed "logging into the system." The student then specifies some additional information, such as which programing language he wishes to use and whether he will enter a new program or modify a previously entered one. At this point the student may actually begin working on his programing problem by typing statements in the programing language. At some point, depending on the time-sharing system employed, the computer will notify the student of syntactic errors in the statements entered. The student must either recognize the error, consult a manual or book, or ask someone for help. Once past all the language errors, the student may still find that his program does not give him the correct answers. This usually indicates a lack of problem understanding on the part of the student. The student may have a clue as to what went wrong or he may seek clarification and assistance from the instructor. Before the student leaves the terminal he is usually required to "log-off the system." For a student to accomplish any meaningful work, he will have to spend a minimum of 20 minutes at the teletypewriter terminal.

In general, several sessions at the terminal will be required to solve most problems. This time restriction has a natural tendency to restrict the number of students who can have access to the computing resource. The number of terminals can be increased to handle additional students, but this raises the question of costs. The costs for operating with time-sharing terminals will include the cost of rental of a terminal with a suitable data set or coupler, supplies (such as paper, paper-tape, inribbons), telephone line charges, connect-time (i.e., the length of time the terminal is actually connected to the computer), actual compute usage, and use of the computer's storage facility. Actual costs will depend on basic telephone line charges from the terminal to the computer, and on the time-sharing vendor's rate schedule; however, the range and typical cost the user might expect to encounter are:

	Range	Typical cost
Terminal, telephone coupler, supplies, and maintenance	\$65 - \$100	\$85 rental per month
Telephone and line charges	\$ .60 - \$3	\$1.50 per hour
Connect time	\$6 - \$12	\$7.50 per hour

If the teletypewriter terminal and a time-sharing service is used 4 hours daily, 5 days a week, for a 9-month school year, the cost will be about \$7,250 per terminal per year. The largest single factor contributing to the cost of operation is the connect-time charge. This can be reduced by seeking educational discounts, bulk usage rates, and "shopping around." It does not take many students to exceed the capacity of a single terminal; it does help to have at least one or two additional teletypewriters which are used solely for the purpose of preparing programs on punched paper-tape. Placing the programs on punched paper-tape is done independently of the remote time-sharing computer. It is analogous to punching IBM punch cards. When the student is ready to enter his program, he reads it in on the terminal's paper-tape reader at 10 cps. In reducing the length of time to enter a computer program, the connect-time charge for a given program is reduced and the number of student problems processed increases somewhat. Once a computer education program is underway, even for a short time, the demand for access to the computing resource will outstrip the capacity of a single terminal operated for 3 or 4 hours a day. However, operating several terminals with time-sharing services quickly becomes prohibitively expensive. There is also the economic disadvantage that the school does not gain equity for the monies it expends. Other disadvantages are that the students cannot obtain "hands on" (i.e., hands on the computer) experience and that most time-sharing services do not have assembly or machine languages available from a terminal.

Small-Scale Time-Sharing Service—Most commercial time-sharing services are based on large-scale computer complexes costing millions of dollars. However, recent technological advances have led to the introduction of small-scale time-sharing systems costing in the neighborhood of $100,000. Typical of these systems are Honeywell's HTSS-16, Hewlett Packard's 2000A/B, and Digital Equipment Corporation's TSS-8. They are capable of supporting 16 to 32 terminal users simultaneously. Although these systems do require a large capital investment, they can reduce the time-sharing costs over those using commercial sources. This may seem an attractive approach, especially where several schools and/or school districts can pool their financial resources to acquire such a system. The major advantage over a commercial time-sharing source is that costs are fixed without limiting the amount of terminal usage. Under these circumstances students could be encouraged to experiment and explore during periods when the terminals are not under scheduled use.

The disadvantages of a small-scale time-sharing system are similar to those of commercial time-sharing services. Students will require a minimum of 20 minutes at a terminal to accomplish a rudimentary amount of work. Students who are assigned problems will have to be scheduled for time. Someone will have to be assigned responsibility for taking care of the system and tracking down and reporting malfunctions to the appropriate maintenance people. Although students very quickly learn to operate the computer system and can operate it during their free time, some full-time staff member should thoroughly acquaint himself with the entire system so that transitions from semester to semester and year to year can be made smoothly.

All of the small-scale time-sharing systems support the BASIC programing language. BASIC is easily learned by students and will serve as an excellent tool in solving a variety of problems, demonstrations of concepts, and simulation of experiments. However, BASIC, because of its simplicity and convenience, does have some limitations. Students, once they have mastered BASIC, will wish to use something more flexible. In addition, if the educational program intends to teach students computer science, assembly language will be required. Of the small-scale time-sharing systems generally available, only Digital Equipment Corporation's TSS-8 has the capability of offering assembly language programing in a time-sharing environment. Even in this case, the student does not gain the stimulation of hands-on experience. The student at a remote teletypewriter cannot observe or manipulate the computer's registers, and hence does not develop a sense of "what the computer is doing." The terminal user is under control of the time-sharing computer, but the hands-on computer user is in control of the computer. For many students this is very exciting, stimulating, and a strong point in their motivation.

Minicomputer System—The third alternative for computing resources is a computer system. Until recently, the computer systems offered to secondary schools, with the exception of the IBM 1620 and IBM 1130, were primarily designed for business data processing rather than for instructional needs. Generally, these computer systems were too large and expensive for a school and usually required trained personnel to operate and program for them. Even when such machines as IBM's 1620, 1130, and 1401 were acquired they were not suitable for general use throughout the school. These systems could not provide adequate support for significant numbers of students unless they were expanded at a prohibitively high cost.

Prior to 1966 only a few secondary schools could afford a computer of their own, and then they were usually private schools. In early 1965 Digital Equipment Corporation introduced the PDP-8 at a cost of $18,000. In late 1965 Digital Equipment announced the PDP-8/s for $10,000 complete with a teletypewriter. The development of these two machines ushered in the age of the minicomputer. However, it was not until about 1967 that the low-cost minicomputer gained acceptance as a general-purpose computing tool. In 1967-68 several large projects were undertaken to introduce computer concepts into the secondary educational program. Project LOCAL in Massachusetts, the Huntington Project in New York, and the Computer Instruction Network in Oregon were but a few of the many programs initiated throughout the Nation. Most of these programs utilized a commercial time-sharing service or purchased one of the PDP-8 family of computers (PDP-8, PDP-8/2, PDP-8/i, PDP-8/1). At that time choosing a minicomputer was a relatively simple task; a member of the PDP-8 family was the only logical choice. In 1967 there were less than half a dozen manufacturers of computers selling for less than $15,000. Today there are over 50 manufacturers with 65 different computers selling for $15,000 or less.

The Minicomputer in the Secondary School

Secondary schools which have acquired a minicomputer, through purchase or lease, operate them either as a single-user batch system or as a multiuser system. Both approaches are limited in the number of student problems which can be processed by the computer.

Single-User-Batch—The single-user batch system is often the lowest in cost and is to be found in a large number of secondary programs. It consists of a minicomputer with 4096 to 8192 words of core storage and a teletypewriter (with an attached paper-tape reader/punch). The cost of typical systems ranges from $8,500 to $12,000. The programing languages which are generally available, for the student's use, are FORTRAN, BASIC, FOCAL, or an assembly language for that machine. The comparative inefficiency of the single-user system arises because of the inherent slowness of the teletypewriter, which is used as the primary communications (input/output) device, as compared to the high-speed processing capability of the minicomputer. The teletypewriter can operate at a maximum rate of 10 cps which is many hundreds of times slower than the typical minicomputer. To input the FORTRAN, BASIC, or assembler system into the computer may require as much as 10-12 minutes using the teletypewriter's paper-tape reader. This step may be required more than once during a computer session, especially when using the FORTRAN or assembly language usage system. The student, who may have previously punched his program on paper-tape on an off-line teletypewriter, must still spend a minimum of 15-20 minutes at the computer in solving his problem. The addition of a high-speed paper-tape reader (300 cps) has helped to improve the efficiency of these systems. However, students will then require the availability of off-line teletypewriters to prepare their programs. Paper-tape handling, itself, can become somewhat of a nuisance. A single-user system, as described, can usually process from 25 to 35 student problem-programs per day.

Single-user batch systems can provide in-depth computer training and hands-on experience for the student. To the student it is both challenging and exciting to see exactly what the computer is doing, to be able to start and stop it, and to examine and/or alter the value of a register or memory location. By being in such intimate contact with the computer, the student develops a level of understanding he could not otherwise attain. In addition, there generally exists a user library of previously written programs which can only be run on a single-user batch system.

Multiuser System—A typical multiuser system will consist of a minicomputer with either 8,196 or 12,288 core memory locations, from two to four teletypewriters, and special equipment to connect the several teletypewriters to the computer. Multiuser systems generally cost between $18,000 and $25,000. All of the multiuser systems currently available have only single language capability, primarily BASIC. Multiuser systems behave as a very limited time-sharing system. The student user must enter his program at the teletypewriter terminal (from either the keyboard or the attached paper-tape reader) at each session, since there is no provision for the storage program within the computer system. This means that a student who begins a program must punch his program onto paper-tape at the end of his session. The next time he is ready to work on that program he must read in the paper-tape. If he has made any program changes or corrections he must again punch a paper-tape copy of his program at his terminal. As with the other terminal-oriented approaches, the student will require a minimum of 20 minutes to make meaningful headway in solving his problems. The program space available to each user is also limited by the size of the memory and the number of users which must share it. This is generally not a problem with beginning students, but it can be a restraint when students attempt advanced problems. Programs with up to 50 statements should present no difficulty. Another point which will affect terminal availability is how the multiuser programing system is loaded. From time to time the multiuser system will "crash" or fail; this will vary from once every 2 days to several times a day, depending on a variety of circumstances. To reload the multiuser program system from a teletypewriter paper-tape reader (cps 10) requires from 15 to 20 minutes. During this time all the terminals are unavailable. A high-speed paper-tape reader (about $3,000) will reduce reloading time to about 1 minute.

A multiuser system can accommodate more students than a single-user batch system and provides greater economies than commercial time-sharing or a small-scale time-sharing system. The level of computer expertise, on the part of the school staff, required to support and maintain a multiuser system is much less than for a small-scale time-sharing system. A multiuser system can also operate as a single-user batch system to provide advanced students with assembly language and hands-on experience.

The multiuser system can provide a reasonable compromise between time-sharing ability to handle several students with a single language and a single-user batch system's greater versatility but limited student handling capacity.

Objectives of This Project

The purpose of this project was to develop a set of general specifications or descriptions for low-cost computing systems which would have greater processing capacity than the computing resources presently used. The increased processing capacity would permit more students to have access to the computing facility. In developing configurations for low-cost computer systems, a strong effort was made to make the computer system as modular as possible. This was done so that a school could start with a modest investment and then expand as its experience and needs grew. Each step in the modular expansion would provide an increase in the number of student programs processed by the computer system. Another objective was to keep the cost of the expanded system to about $25,000 while still providing a highly effective computer system. The objective was to be achieved by integrating suitable low-cost peripheral equipment, which has recently become available, with a suitable minicomputer. In selecting equipment it was recognized that secondary schools, generally, have no engineering expertise and very little, if any, professional programing experience. Thus any equipment considered must be easily integrated with a previously chosen computer. Every effort was made to choose equipment with the greatest reliability commensurate with cost and performance. In most schools, a single computer system will have to satisfy a variety of educational roles. Hence, the computer systems were developed to satisfy as many educational functions as possible with an overall consideration to processing as many student programs as possible.

Although the major objective was to design low-cost computing system configurations with the capability to process large numbers of student programs, the systems would also permit the support of some administrative work. Only simple administrative tasks such as attendance statistics should be attempted, however. Large data-processing tasks are likely to tie up the minicomputer and thus defeat the entire purpose—that of having a computer system which has a high availability for student use. The specifications and configurations developed in this project are intended to serve only as a guide for those planning to introduce computers into their schools. For those schools which already have an educational computer system, this report can also be used in planning for future expansions.

Another area which has important implications for low-cost educational computing systems is the availability of peripheral equipment. Peripheral equipment consists of such devices as punched-card card readers, printers, auxiliary storage disks, magnetic tape drives, and cassette tape storage systems. Peripheral equipment is used to communicate both input and output with the computer. It is the utilization of peripheral equipment which permits the computer to process large numbers of programs and great volumes of data. Without the proper peripheral equipment it would be impossible to realize the full potential and capabilities of the modem digital computer. Traditionally, peripheral equipment has almost always cost more than a minicomputer itself. Because of the prohibitively high cost of peripheral equipment, secondary schools were limited to using the teletypewriter or at best a high-speed paper-tape reader/punch as the input/output device for their minicomputer.

Before late 1969 there was little in the way of low-cost peripheral equipment for the minicomputer. However, since that time there has been a rapid growth in the availability and variety of peripheral equipment for the minicomputer. This growth has been due partly to technological developments and partly to the widespread acceptance of the minicomputer. The availability of low-cost peripheral equipment permits greater effective use of the inherent processing capabilities of the minicomputer. The educational computer system in the secondary school, utilizing low-cost peripheral equipment, will be able to process many more student problem programs than it could using the teletypewriter alone.

An extensive survey of the minicomputer and peripheral equipment market was undertaken to determine what suitable equipment is currently available. The survey was conducted in two major parts. The first part consisted of determining which of the minicomputers has suitable characteristics for a low-cost educational computing system. The second part was essentially a search for suitable low-cost peripheral equipment which could be easily integrated with a minicomputer to attain the desired goals. Since peripheral equipment forms the input-output interface between the students and the computer, it was quite natural to examine the media used in input-output together with the devices with the view of improving the student-computer interface.

Although manufacturers are named and approximate prices given, it is not the intention of this report to endorse or recommend any specific manufacturer or specific equipment. One should bear in mind that computer technology is a rapidly developing and highly competitive field. The price and equipment availability picture is likely to change in 6 months or a year. The general trend, however, is for prices to drop and for a greater variety of equipment to become available. Computers and/or equipment which were not considered suitable (e.g., because they lacked adequate software) at the present time could become a suitable choice in the future.

Minicomputers

To determine what minicomputers were currently available, 46 minicomputer manufacturers were contacted for information concerning their computers. Of this number five manufacturers and/or their minicomputers were not included in the survey for one of the following reasons: withdrawal from the market, inadequate documentation, and computer designed for special or limited purpose application. A list of the remaining 41 manufacturers, their computer models reviewed, and their cost follows:

Manufacturer	Model	Minimum system cost[1]
Atron Corp. 1256 Trapp Road St. Paul, Minn. 55118 (612-454-6150)	Atron-501	$ 7,600
BIT, Inc. 5 Strathmore Road Natick, Mass. 01760 (617-237-2930)	BIT 483	11,700
Cincinnati Milacron, Inc. Process Control Div. Lebanon, Ohio 45036 (513-949-5444)	CIP 2100	7,815
Clary Datacomp Systems, Inc. 404 Juniper Serra Drive San Gabriel, Calif. 91776 (213-283-9485)	DATACOMP 404	9,950
Compiler Systems, Inc. P.O. Box 366 Ridgefield, Conn. 06877 (203-438-0488)	CSI-16 CSI-24	10,750 17,250
Computer Automation, Inc. 895 West 16th Street Newport Beach, Calif. 92660 (714-642-9630)	Model 116 Model 216 Model 816	11,990 9,980 7,990
Computer Logic Systems, Inc. 49 Pollard Street North Billerica, Mass. 01862 (617-729-2703)	CLS-18	10,950

[1] A minimum system consists of a computer processor, 4096 words of memory, and a console teletypewriter with integral paper-tape reader and punch operating at 10 characters per second. The costs were compiled from manufacturer-supplied price lists and are current as of January 1971.

Manufacturer	Model	Minimum system cost[1]
Data General Corp. Route 9 Southboro, Mass. 01772 (617-485-9100)	NOVA 1200* [2] NOVA 800* SUPER NOVA	$ 6,700 8,200 10,850
Datamate Computer Systems, Inc. P.O. Box 310 Big Spring, Tex. 79720 (915-267-6353)	Datamate 16 Datamate 70	16,600 10,200
Digital Computer Controls 23 Just Road Fairfield, N.J. 07006 (201-227-4861)	D-112IA	5,200
Digital Equipment Corporation 146 Main Street Maynard, Mass. (617-897-5111)	PDP-8/L PDP-8/i PDP-8/e* PDP-11/20*	8,500 12,800 6,490 10,800
Digital Scientific Corp. 11455 Sorrento Valley Road San Diego, Calif. 92121 (714-453-6050)	Meta-4	15,650
Electronic Associates, Inc. 185 Monmouth Pk. Hwy. West Long Branch, N.J. 07764 (201-229-1100)	EAI-640	24,000
Elron, Inc. Bldg. 812, Raritan Ctr. Edison, N.J. 08811 (201-225-1900)	ELBIT-100	6,600
Foto-Mem, Inc. 2 Mercer Road Natick, Mass. 01760 (617-655-4600)	CENTAUR	12,000
General Automation, Inc. 1402 E. Chestnut Avenue Santa Ana, Calif. 92701 (714-835-4804)	SPC-16 SPC-12	11,250 9,700

[1] A minimum system consists of a computer processor, 4096 words of memory, and a console teletypewriter with integral paper-tape reader and punch operating at 10 characters per second. The costs were compiled from manufacturer-supplied price lists and are current as of January 1971.

[2] A minicomputer model followed by an asterisk indicates that the author considers it acceptable for an educational computing environment.

Manufacturer	Model	Minimum system cost[1]
GRI Computer Corp. 96 Rowe Street Newton, Mass. 02166 (617-969-0800)	GRI-909	$ 8,400
Hewlett-Packard Co. Cupertino Division 11000 Wolfe Road Cupertino, Calif. 95014 (408-257-7000)	HP2114C*[2] HP2116C	10,500 22,000
Honeywell Computer, Control Div. Old Connecticut Park Framingham, Mass. 01701 (617-235-6220)	H-316*	10,400
Information Technology, Inc. 164 Wolfe Road Sunnyvale, Calif. 94086	ITI 4900	11,150
Infotronics Corp. 8500 Cameron Road Austin, Tex. 78753 (512-454-3521)	mini/max	14,400
Interdata, Inc. 2 Crescent Place Oceanport, N.J. 07757 (201-229-4040)	I 4*	10,100
Lockheed Electronics Data Products Div. 6201 E. Randolph St. Los Angeles, Calif. 90022 (213-722-6810)	MAC 16 jr	9,500
Microdata Corp. 644 East Young St. Santa Ana, Calif. 92704 (714-546-7160)	MICRO 810	9,415
Modular Computer Systems, Inc. 2709 N. Dixie H'way Fort Lauderdale, Fla. 33308 (305-563-4392)	Modcomp II	11,500

[1] A minimum system consists of a computer processor, 4096 words of memory, and a console teletypewriter with integral paper-tape reader and punch operating at 10 characters per second. The costs were compiled from manufacturer-supplied price lists and are current as of January 1971.

[2] A minicomputer model followed by an asterisk indicates that the author considers it acceptable for an educational computing environment.

Manufacturer	Model	Minimum system cost[1]
Motorola Instrumentation & Control 3102 North 56th Street Phoenix, Ariz. 85030 (602-959-1000)	MDP-1000	$ 9,250
Multidata, Inc. 7300 Bolsa Avenue Westminster, Calif. 92683 (213-598-1377)	Mod A	15,000
Philips Business Systems, Inc. 100 East 42nd Street New York, N.Y. 10017 (212-697-3600)	P-350	
Raytheon 2700 South Fairview St. Santa Ana, Calif. 92704 (714-546-7160)	703 704*[2]	13,950 10,950
Redcor Corp., Inc. 21200 Victory Blvd. Woodland Hills, Calif. 91364 (213-348-5892)	RC 70	16,400
Spiras Systems, Inc. 332 Second Avenue Waltham, Mass. 20154 (617-891-7300)	SPIRAS-65	14,600
Systems Engineering Labs. 6901 West Sunrise Blvd. Fort Lauderdale, Fla. 33301 (305-587-2900)	SEL 82 SEL 72	9,600 15,000
TEC, Inc. 6700 South Washington Ave. Eden Prairie, Minn. 55343 (612-941-1100)	520-PCP	13,490
Tempo Computers, Inc. 1550 So. State College Blvd. Anaheim, Calif. 92806 (714-633-3660)	TEMPO 1	15,600

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[2] A minicomputer model followed by an asterisk indicates that the author considers it acceptable for an educational computing environment.

Manufacturer	Model	Minimum system cost[1]
Texas Instruments P. O. Box 66027 Houston, Tex. 77006 (713-526-1411)	TI-960	$15,460
Unicomp, Inc. 18219 Parthemia St. Northridge, Calif. 91324 (213-886-7722)	Comp-16	9,300
Varian Data Machines, Inc. 2722 Michelson Drive Irvine, Calif. 92664 (714-833-2400)	620/L*[2] 620/i 620/f	7,200 11,750 12,400
Viatron Computer Systems Corp. Route 62 Bedford, Mass. 01730 (617-275-6100)	2140/50	
Westinghouse Electric Co. Computer Department 205 Route 46 Totowa, N.J. 07512 (201-785-1560)	2500*	11,850
Xerox Data Systems 701 South Aviation Blvd. El Segundo, Calif. (213-772-4511)	CE-16A	13,000
Wang Laboratories 836 North Street Tewksbury, Mass. 01876 (617-851-7311)	Wang 3300	9,700

[1] A minimum system consists of a computer processor, 4096 words of memory, and a console teletypewriter with integral paper-tape reader and punch operating at 10 characters per second. The costs were compiled from manufacturer-supplied price lists and are current as of January 1971.

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Elimination Criteria

A number of criteria for evaluating minicomputers for use in an educational setting were established. For example, the hardware, software, and miscellaneous information, as supplied by the manufacturers, was reviewed against four major areas of characteristics:

- Design architecture and operation
- High-level language availability
- Peripherals available, modularity, and ease of expansion
- Price and service availability.

Those minicomputers primarily designed for special markets were eliminated from further consideration, unless they had some other outstanding characteristic. Some minicomputers were also eliminated if they were not really in production.

The availability of service and maintenance was considered to be very important for the secondary school computer systems. Even the most reliable of computers will fail from time to time. Peripheral equipment is even more prone to failure than the computer itself. It is neither likely nor wise for the secondary schools to undertake the sole responsibility for the maintenance of the computer system by themselves. Therefore those manufacturers that did not have adequate maintenance and service facilities were also eliminated.

Computers were compared against their minimum system costs. It was found that most computers costing $12,000 or less were more than adequate. Computers which cost more than $12,000 did not offer significant advantages. Thus computers with a minimum system cost of over $12,000 were also eliminated from further consideration.

Another major criterion was the availability of a high-level language such as BASIC, FORTRAN, or ALGOL. From the software information supplied by the manufacturers those computers which did not have at least one high-level language were eliminated. None of the manufacturers has a high-level language specifically for business data processing. However, BASIC is quite acceptable for many businesses and commercial types of problems.

The Selected Minicomputers

The 10 minicomputers which were judged by the above criteria to be suitable for use in a secondary school educational computing system are indicated by an asterisk following the model designation in the preceding list. Following are some general observations on these computers:

- World size: All of the recommended minicomputers have a word size of 16 bits with the exception of the PDP-8/e, which has a word size of 12 bits. The smaller word size is of little importance in an educational computer. This is especially true when a high-level language—such as FORTRAN, BASIC, or FOCAL—is used.

- Number of instructions: The number of instructions which a given computer has is also not very important in an educational computer. Overall the minicomputers have about the same basic computer instructions. Some computers are more efficient for certain kinds of problems than others, but this doesn't really matter for most student problems.

- Cycle time: The basic speed of the computer is a yardstick often used by computer salesmen in comparing computers. Speed may be of primary concern in an industrial application, but in the secondary school environment it is of less concern. A well-written BASIC system on a slow computer will perform better than a poorly written BASIC on a faster computer.

- Educational institution support: Only Digital Equipment Corporation and Hewlett Packard have made formal corporate commitments to the secondary school education market. Data General also appears to have some orientation toward the education market.

- Third generation: Computer salesmen use the term "third generation" to mean several things. All of the recommended minicomputers are of third-generation technology, integrated circuits. "Third generation" is also used to allude to IBM-like design. However, of all the minicomputers, only the Interdata 14 resembles the IBM 360 series in design philosophy.
- Equipment costs: All peripheral equipment devices will require controllers, a separate electrical power supply, connecting cables, and cabinetry. Be sure to obtain complete costs when planning a computer system.
- Software support for peripherals: All the manufacturers supply basic software support for the peripherals they sell. However, one should be certain that there is sufficient support for the intended use of the peripheral device. For example, a junior college was sold a minicomputer and a magnetic disk storage unit. There was insufficient software for the school to utilize the disk in its computer education program.
- Semiconductor memories: Semiconductor memories are a new development and are meant as a replacement of core memories. Besides their being more expensive, semiconductor memories have another characteristic which makes them less than desirable in an educational environment. When the computer is shut off, all of the programs (i.e. bootstrap loader, loaders, or the BASIC interpreter) stored in a semiconductor memory are lost. Core memories generally retain information stored in them even when the computer is shut down.

Figure 1 shows, for easy comparison, selected characteristics of the 10 acceptable minicomputers.

Peripheral Equipment, General

Investigating the low-cost peripheral market was somewhat more difficult than the minicomputer market. Peripheral equipment manufacturers are oriented toward and prefer to deal with the computer manufacturers, manufacturer representatives, and engineering firms specializing in custom-designed computer systems (sometimes referred to as systems houses). Peripheral equipment manufacturers generally do not provide an interface to a minicomputer. Most peripheral manufacturers will rely on computer manufacturers or systems houses to design and manufacture controllers for their peripheral devices. Even when controllers and interfaces are available for a given minicomputer, the only software to support the peripheral device may be diagnostic programs. A peripheral device will require a different interface and software package for each minicomputer. Therefore, peripheral equipment manufacturers usually leave the design and manufacture of interfaces and software programs to the computer manufacturers and systems houses.

The peripheral equipment survey was in two broad categories. The first category included those devices which are directly involved in student interaction, such as paper-tape handling devices, printers, and card readers. The second category included bulk storage devices such as magnetic disk, drum, and tape storage devices. The computer manufacturers as a whole offered nearly the same types of equipment at roughly the same prices for equivalent equipment. Since the computer manufacturers rely on peripheral equipment manufacturers for the devices they offer, it was not surprising that a number of computer manufacturers offered the same devices, e.g., printers manufactured by Data Products, Inc. Only three computer manufacturers offer peripherals of their own design and manufacture. Digital Equipment Corporation (DEC) offers DECtape, DECdisk, and DECwriter for their PDP-8 series and PDP-11/20 computers. DECtape is a proprietary magnetic tape system utilizing

Figure 1—Selected characteristics of the acceptable minicomputers

Machine	Bits per word	Cycle time[1]	No. of accumulators	No. of index registers	Add time[1]	BASIC	Multiuser system	Cost of 4K storage (Additional)	Minimum storage for FORTRAN
Nova 1200	16	1.2	4	2H/16M[2]	1.35	Yes	BASIC	$2,700	8K[3]
Nova 800	16	0.8	4	2H/16M	1.8	Yes	BASIC	3,000	8K
PDP-8/e	12	1.2	1	8M	2.6	Yes	BASIC/ FOCAL	3,000	4K and 8K
PDP-11/20	16	1.2	8	7H	2.3	Yes	BASIC	3,500	8K
14	16	1.0	16	15H	3.2	No	FORTRAN	3,200	8K
HP2114C	16	2.0	2	NONE	4.0	Yes	BASIC[4]	4,500	8K
H316	16	1.6	2	1H	3.2	No	No	3,500	8K
704	16	1.5	1	1H	2.0	No	No	4,000	8K
620/L	16	1.8	2	2H	3.6	Yes	No	2,300	8K
2500	16	.75	2	2H	2.0	Yes	No	4,500	8K

1 Time is given in units of microseconds. One microsecond = 10^{-6} seconds.

2 H— Actual hardware index registers. M— Memory locations used as index registers.

3 K— One K equals 1024. Thus 8K = 8(1024) = 8192.

4 The BASIC multiuser system is available from Hewlett-Packard, but it is not part of their standard software.

4-inch diameter reels of 3/4-inch wide magnetic tape. DECtape has been available for DEC computers for about 5 years and appears to be highly reliable and relatively low in cost when compared to other magnetic tape systems. DECdisk is a small system comparable with other disk systems. The DECwriter is a teletypewriter-like device which prints at 30 characters per second. It appears to be an attractive alternative to Teletype Corporation's KSR-35, a heavy-duty teletypewriter, at least for the DEC PDP computer systems. Hewlett-Packard also manufactures and markets sense card readers which are interfaced to the HP2114C computer. Interdata has designed and manufactures a magnetic tape cassette system, called INTERTAPE, which is interfaced to their 14 minicomputer.

In considering any piece of peripheral equipment for inclusion in an educational computer system, one must take into account several points: how it will be used in the educational computing environment, that is, what purpose will it serve; what additional hardware is necessary; whether the manufacturer can supply adequate software; and who will provide maintenance. An actual case history will serve to indicate why these questions are important.

> *An educational institution was given a grant to purchase a minicomputer system. They choose one of the minicomputers (included in our recommended list) with 12K words of core memory and communications hardware to support a four-terminal multiuser BASIC system. In addition, they purchased a 262K word disk storage system from the computer manufacturer. The thought was to run the manufacturer's disk-operating system (a supervisory program) to reload the multiuser system from the disk when required, to keep program files from the multiuser BASIC system, and to run the manufacturer's FORTRAN compiler. After the allocated funds were spent and the system was delivered, it was found that the disk could not be used after all. The multiuser BASIC system did not support program files on disk. There was no software available to load the multiuser system from disk, and the manufacturer's disk operating system required 16K words of core memory to be used at all. The net result is that the disk storage device is unused at present.*

When planning for peripheral equipment one must bear in mind why and how the peripheral equipment is to be used in the educational computer environment. Despite the best representations of the computer manufacturer's salesmen, it is best to be skeptical and take a "show me first" attitude. The purchase contract should briefly indicate how the peripheral is to be used and what software support is expected of the manufacturer. This approach should also be used when purchasing from a peripheral manufacturer.

Consideration can now be given to which peripherals and under what circumstances they should be purchased from the computer manufacturer or from an independent equipment manufacturer. In general it is advisable to obtain peripheral equipment from the computer manufacturer except when there is a substantial price differential or when the computer manufacturer does not offer a type of peripheral. The reason for this advice is as follows:

- The computer manufacturer has equipment made to his specifications, and he is responsible for its quality.
- The computer manufacturer has to make the peripheral work with his computer. Manufacturers often make subtle modifications to the original peripheral.
- The computer manufacturer is in the best position to supply adequate software for utilization of the peripheral equipment. The manufacturer can also be pressed for any additional software support for the peripheral device.
- The computer manufacturer is obligated to provide maintenance service for all his equipment. He cannot shift the

blame to someone else when some equipment fails to function as specified.

- Members of the computer user's group are likely to contribute programs and routines for the manufacturer's line of peripherals.

Disks

All the computer manufacturers of the recommended computers have a broad line of disk storage devices to choose from. Although there are a number of independent equipment manufacturers who offer very attractive disk-systems, this author believes that it is still best to obtain the systems through the computer manufacturer. This is especially true for the secondary school with its limited engineering and programing experience. Disks are among the more difficult devices to program for; therefore, the educational institution should depend upon the programing resources of the manufacturer to provide the disk software. Once again the need is emphasized for planners of an educational computing system to be certain that the computer manufacturer has adequate software to utilize the disk storage device in the intended manner, and that the planned computer configuration will support both the disk and its software.

Disk storage systems generally are either fixed head with a nonremovable storage media or moving head with removable storage media (referred to as disk pack or disk cartridge). The latter provides for a more flexible and expandable storage system. Moving head disk devices, however, may require greater maintenance service than fixed head devices, since they incorporate electromechanical head positioners. Advancing technology has made them considerably more reliable than they have been in the past. The most common disk cartridge in use with minicomputers is the IBM 2315 disk cartridge. Although IBM 2315 disk cartridges may be physically interchanged between disk drives of different manufacturers, the recorded information generally is not.

None of the independent disk manufacturers or systems houses offering disk systems is listed because of their uncertain software support and maintenance. One last point should be made with regard to systems houses. While they may supply disks, controllers, and interfaces and may claim "plug-to-plug compatibility," it is possible that their disks may not be software compatible with the computer manufacturers' software or disk operating system. In some cases, a computer manufacturer can be persuaded to provide a disk system not normally in his equipment list.

Magnetic Tapes

The IBM compatible magnetic tape storage devices do not appear to be especially attractive for a low-cost educational computer system. The major use of IBM compatible magnetic tape in an educational computer system has been to transfer data from the smaller computer to a larger data processing facility. This has been primarily in the area of administrative data processing. Another use for magnetic tape storage devices has been to reload programing systems from magnetic tape rather than from paper tape. However, this latter use can be accomplished by cassette and cartridge magnetic tape systems at lower cost and with greater convenience. Cassette and cartridge magnetic tape systems are discussed below. An IBM-compatible magnetic tape device should also be purchased from the computer-manufacturer for very much the same reasons already stated for disk storage devices.

Cassette Tape Systems

Cassette and cartridge magnetic tape storage systems provide many interesting possibilities for the low-cost educational computer system. For purposes of this report Digital Equipment Corporation's DECtape system with the cassette and cartridge systems is also included. Figure 2 lists those manufacturers of cassette or cartridge storage devices who provide both computer interfaces and supporting software. Although interfaces exist for other computers, interfaces generally do

Figure 2—Manufacturers of computer interfaces and supporting software

Manufacturer	Model	Approx. price	No. of drives	Interface and software for
DICOM Industries 715 N. Pastoria Avenue Sunnyvale, Calif. 94086	344 CTMOS	$7,250	3	DEC PDP-8 series HP 2114 NOVA 1200/800
Digital Equipment Corp. 146 Main Street Maynard, Mass. 01754	TC08 Controller TU56H DECtape Drive	5,900 2,350	1-8	PDP-8
Interdata 2 Crescent Place Oceanport, N. J. 07757	Intertape	2,500	2	I 4
SYKES Datatronics, Inc. 375 Orchard Street Rochester, N. Y. 14606	Compu/corder 100	2,950	1	PDP-8 series NOVA 1200/800 Varian 620/L
Tennecomp Systems 795 Oak Ridge Turnpike Oak Ridge, Tenn. 37830	TP-1351	2,000	1	PDP-8 series
Tri-Data Corp. 800 Maude Avenue Mountainview, Calif. 94040	Cartrifile 4196	6,500	4	PDP-8 series HP 2114 NOVA 1200/800

not have supporting software and hence are not included in this list. DICOM, SYKES, and Tri-Data provide maintenance ans service directly or through a sales/service representative. Digital Equipment will also provide maintenance for the Tennecomp TP-1351. Tri-Data and Tennecomp use proprietary cartridge designs. Additional cartridges of tape are available only from the manufacturers. DICOM, Interdata, and SYKES use a standard Philips-type cassette but of computer quality. These cassettes are available from the device manufacturers or from a number of independent sources.

Magnetic tape cassette/cartridge systems can be used as a high-speed substitute for paper-tape or as a low-cost replacement for the standard magnetic tape transport. In the simplest applications, the cassette storage system would be used to load in the BASIC or FORTRAN system. This can represent a significant saving in time over the use of a paper-tape reader. For example, to load the BASIC interpreter from a teletype paper-tape reader would require about 13 minutes. Using a high-speed paper-tape reader would require about a half minute. A cassette storage device would require about 15 seconds. The cassette would reduce the amount of paper-tape handling. It could also be used to store BASIC programs for later use. Here again, the computer system planner must make sure that the cassette manufacturer has adequate software to support this kind of use on the selected computer. A more sophisticated application would employ multiple cassette transports. One cassette would contain all the system software including, say, a FORTRAN compiler. The user would load in the FORTRAN compiler from the systems cassette, read in his FORTRAN program from the teletypewriter, and compile his program onto another cassette in binary form. The binary program would then be loaded into the computer and executed. The multiple cassette transports could be used in applications requiring updating sort/merging of data files. This could all be done more or less semiautomatically, assuming an operating system existed for the computer-cassette combination. Such an operating system does indeed exist for Interdata 14-Intertape and for the DICOM-HEWLETT Packard 2114, Data General NOVA 1200/800, DEC PDP-8 series, and for DECtape—PDP-8 under the PS/8 DECtape monitor system. The cassette/cartridge magnetic tape storage devices integrated with a minicomputer can provide a low-cost computing system for the educational environment. Some useful configurations will be discussed later, together with approximate costs.

Input Devices—Mark Sense Readers

The next areas discussed are the devices and media used by the students to communicate with the computer. For minicomputers this has traditionally been the teletypewriter and paper-tape. This is the usual situation whether the minicomputer is operated as a single-user, multiuser, or time-sharing system. The teletypewriter still remains the lowest cost input-output device for the minicomputer, although it is not the most efficient. The teletypewriter, because of its slow 10-characters-per-second speed, is inefficient in terms of the computer's speed and also in terms of student's utilization. The limitations imposed by the use of a teletypewriter on computer resources were discussed earlier in this report. High-speed paper-tape readers (200-300 characters per second) and offline teletypewriters do help to increase the number of student problems processed by the minicomputer system. These high-speed paper-tape readers are available from the computer manufacturer at a reasonable price. However, offline preparation of programs still leaves much to be desired. Typing errors are difficult to correct; they must be corrected by copying and repunching, by "scissors and paste," offline, or by use of an interactive editor at the computer, online. This is in contrast to the ease in using the punched card in programing for the larger machines. It is relatively easy to repunch and correct a card. However, the use of punched cards generally entails the use of an expensive card reader and the rental or purchase of key-punching equipment. Recent advances in technology have led to lower cost card readers suitable for use with minicomputers. These card readers are designed to read cards (and input them to the computer) at the rate of 150-200 cards per minute. Key-punching equipment has three drawbacks: it is a recurring expense; it requires maintenance; and most importantly, students must have physical access to it in order to punch their programs. The development of the mark sense card reader obviates all three disadvantages in the use of a card reader with a minicomputer system. The mark sense card reader has a number of distinct advantages over other forms of input to the computer, in an educational environment. It permits input speeds compatible with the processing speed of modern minicomputers. The student can do his "programing" almost anywhere by marking his cards with a soft lead pencil. The student can edit and correct his program using an eraser and pencil. Corrections can be made as easily as erasing the unwanted marks and adding new ones. Mark sense cards are designed so that the student can easily mark the proper codes for letters, numerals, and special symbols. The student can easily read the mark sense card, unlike paper-tape, and visually verify what he has recorded on the cards. Mark sense cards can also be punched, if some keypunch training is desired, and read by the mark sense card reader provided certain restrictions are met. Mark sense cards can be designed for efficient use with a particular programing language such as BASIC or FORTRAN.

Some typical examples of unmarked and marked cards are included in figures 3-7. Several other standard card forms exist and are available from the computer and/or card reader manufacturer. The Motorola MDR mark sense reader can also read page size forms with the mark sense information along the side edge. This can be extremely useful in test and questionnaire processing since the answer form can be a part of the test or questionnaire.

In addition to the above uses, mark sense cards can also be designed for testing and questionnaire scoring. Attendance reporting, grading, class ranking, registration, and other administrative functions can be automated. In this connection, it should be pointed out that mark sense cards can be partially punched and partially marked. The classroom teacher can be given a set of cards with the student names prepunched on the cards. The teacher would then mark sense the required information such as attendance or grades. Programs, of course, would have to be written to process the cards.

Figure 8 lists the four most widely used low-cost mark sense card readers. Digital Equipment Corporation is on the list although they do not manufacture the mark sense card reader offered; they in fact use the card reader manufactured by GDI. If a computer manufacturer does not offer a mark sense card reader, he can usually be convinced to provide one of the first three card readers listed, together with a suitable interface. The interface should cost between $800 and $1,500. The mark sense reader and interface should be program compatible with the computer manufacturer's punched card card reader so that existing software can be utilized. The principles by which the mark sense card reader operates, the use of reflective and nonreflective inks, etc., is best left to the manufacturer's literature.

Digital Equipment Corporation and Hewlett Packard have recognized the many virtues of mark sense cards. Both have recently developed educational computer systems around the mark sense card.

Output Devices—Printers

For minicomputers the standard output device has been the teletypewriter. The slow speed of the teletypewriter is a greater limitation on the computer system as an output device than as an input device. The amount of information to be output generally

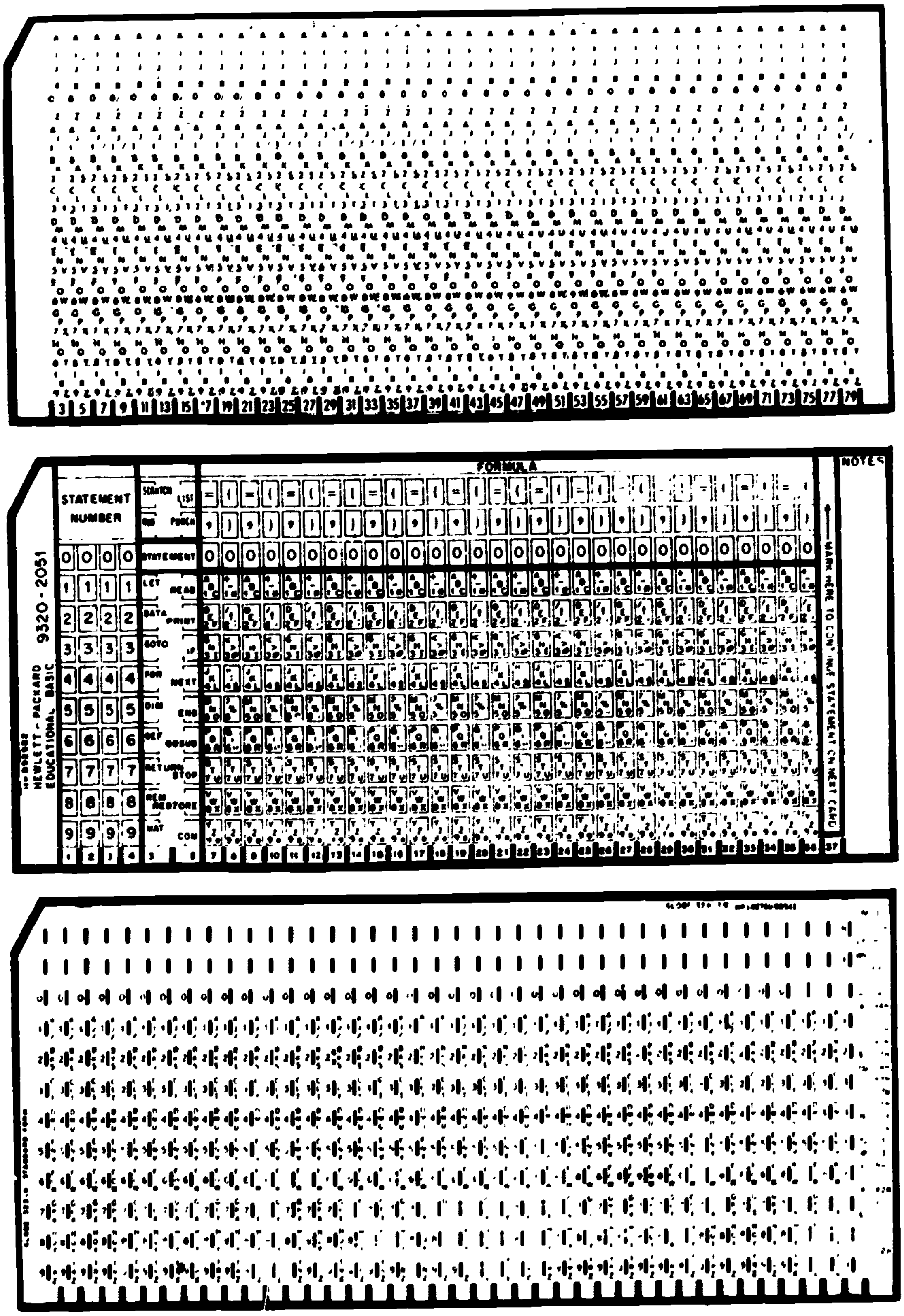


Figure 3—Blank mark sense card forms (size reduced by 75 percent)

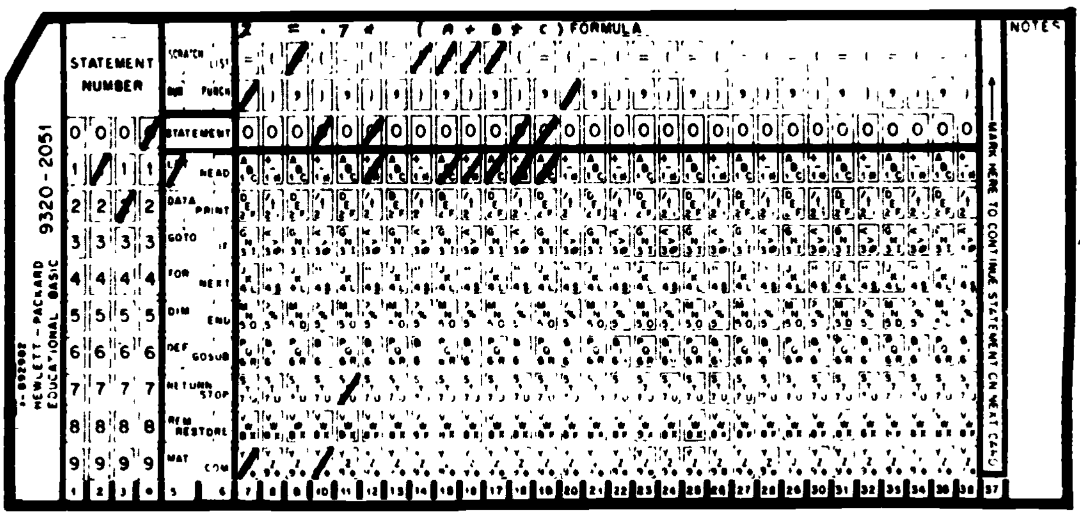


Figure 4—Special purpose mark sense card used in the Hewlett-Packard Educational System 2007A BASIC: 120 Let Z = .7 * (A + B * C)

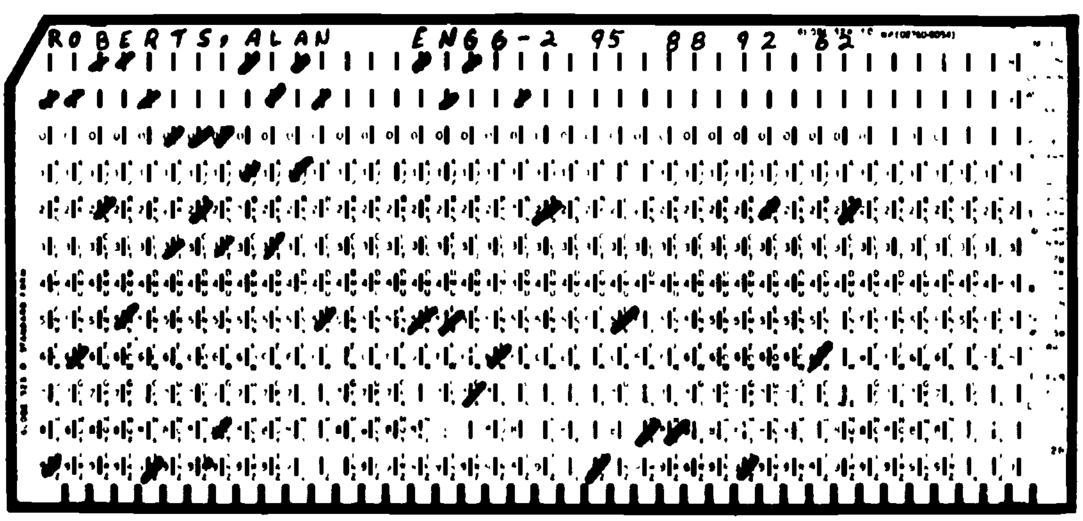


Figure 5—A multipurpose mark sense card in a grade reporting application

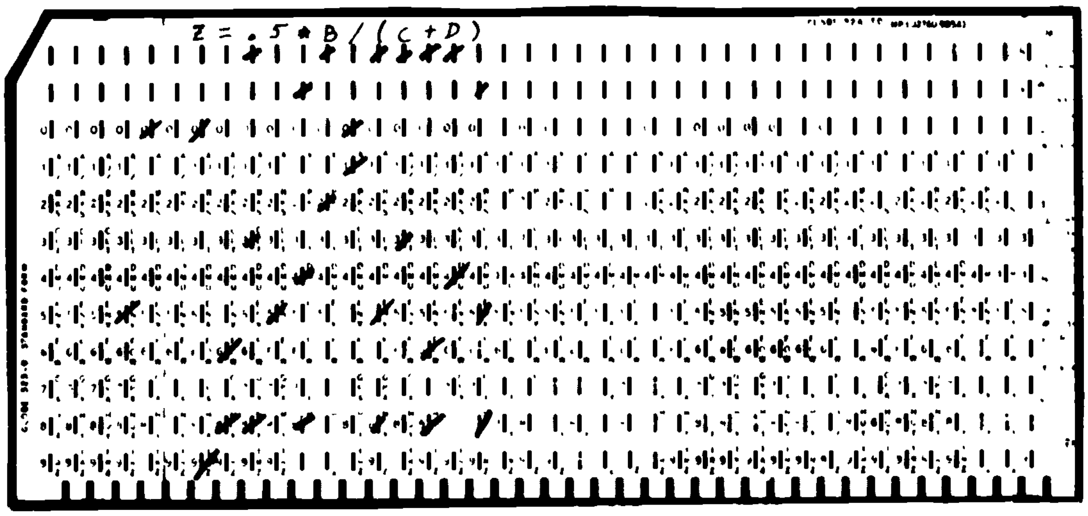


Figure 6—General purpose mark sense card
FORTRAN statement: 50 Z = .5 * B/(C + D)

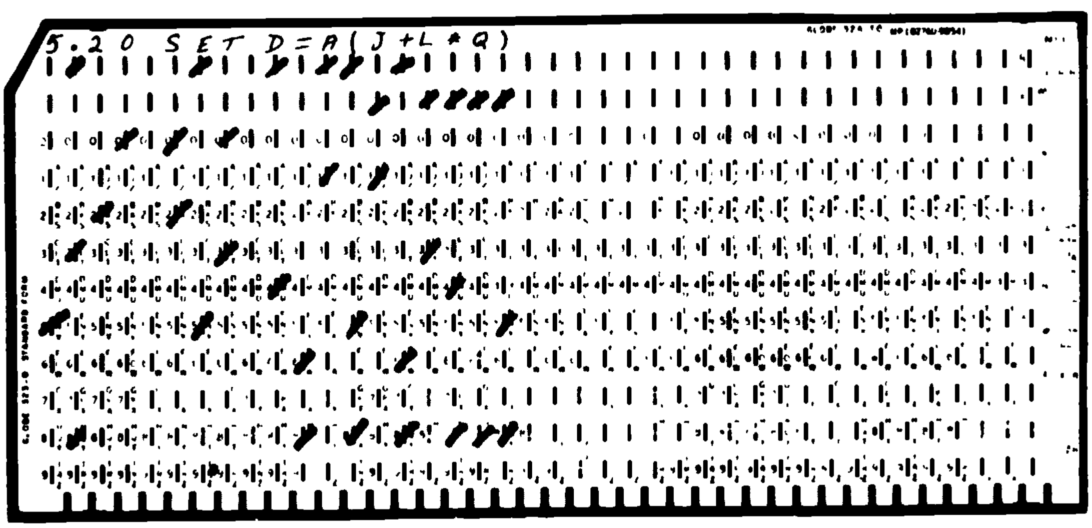


Figure 7—General purpose mark sense card
FOCAL statement: 5.20 SET D = A (J + L * Q)

Figure 8—Mark sense (optical) card readers

Manufacturer	Model	Approximate cost	Reader rate
General Design, Inc. (GDI) 2361 NASA Boulevard Melbourne, Fla. 32901	GDI-100-MS	$2,500 exclusive of interface	200 cpm[1]
Hewlett-Packard Cupertino Division 11000 Wolfe Road Cupertino, Calif. 95014	HP2761A	3,700 interfaced to HP2114C	200 cpm
Motorola Instrumentation and Control, Inc. P. O. Box 5409 Phoenix, Ariz. 85010	MDR-8000	4,500 exclusive of interface	150 cpm
Digital Equipment Corporation 146 Main Street Maynard, Mass. 01754	CM8-E[2]	4,900 interfaced to PDP-8/e	200 cpm

[1] cpm—cards per minute.

[2] The CM8-E is manufactured by GDI.

exceeds the input information. The information output of a minicomputer system will depend on its mode of operation. In the single-user batch mode, the output may consist of binary information, punched on paper-tape, as well as alphanumeric characters to be printed. In the multiuser mode, all information between the users and the computer is information to be printed. In the case of input, high-speed paper-tape readers are available at a reasonable cost. Although paper-tape readers can operate reliably at 300 characters per second, the fastest paper-tape punch generally available will operate at only 60 characters per second. The speed of paper-tape punches is quite adequate for the binary information, but teletypewriter printing speeds limit the processing capacity of a minicomputer system.

High-speed paper-tape punches are available from the computer manufacturer and are often combined with a high-speed paper-tape reader. The reader-punch combination will often cost less than when purchased as individual units. Since the high-speed paper-tape punch is adequate at handling binary output, this survey concentrated on devices for printing information. It is in the area of printing devices that the greatest variation of technologies and approaches is to be found. The most popular printers among the computer manufacturers appear to be the Data Products printer 2000 series and 4000 series. From the computer manufacturers these printers range in price from $12,500 to $17,500, depending upon speed, number of print columns, and other features.

For surveying the available printing devices four criteria were established:

1. 300 lines per minute was established as the maximum useful speed for printers operating with a minicomputer. The cost of printers is generally proportional to their speed, and little benefit will be gained by faster printers.
2. $10,000 was established as the absolute maximum cost for any printing device interfaced to the computer.
3. Reliability. Printers are electromechanical devices and have been traditionally the least reliable of the peripherals. A strong effort was made to identify those printing devices which have been designed with a strong emphasis on reliability or which utilize inherently reliable technology.
4. Service availability. The manufacturer of the printing device must be able to provide service nationwide.

Printers can print a single character at a time or a whole line at a time. The teletypewriter is the most common example of a character-at-a-time device. Printers which print a character at a time are lower in cost as well as speed, while line printers are higher in cost and operate at higher speeds. A strip printer prints characters on a strip of paper (3/8-1/2 inch wide), and a page printer uses paper 8-1/2 inches wide (72 or 80 print columns) or full-width computer paper 15 inches wide (120-130 print columns). Strip printers are not suitable for an educational environment.

Impact printers strike a print element against a ribbon and the paper. The print elements may be on a rotating wheel, cylinder, drum, chain, or oscillating bar. Nonimpact printers use thermographic (heat sensitive) or electrostatic techniques, which generally means specially treated papers. Another nonimpact printer technique is the ink jet. In this approach a jet of ink droplets is squirted onto ordinary paper to form the characters. Nonimpact printers are generally more reliable than impact printers. Impact printers can produce multiple carbon copies, while nonimpact printers can produce only one copy. This does not appear to be a limitation for the general educational environment. The specially treated papers used in nonimpact printers are fairly expensive. The ink jet printers are favored by the author because they combine a moderate speed with an inherently reliable technology, use ordinary paper, are relatively quiet, have been interfaced to a large number of minicomputers, and are reasonably priced.

A number of the character printers are designed to substitute for the teletypewriter normally used with the minicomputer. All of these devices cost more than the teletypewriter but operate substantially faster and are generally more reliable than the model 33 teletypewriter.

Figure 9 lists some low-cost output printing devices, divided into two categories—devices including keyboard and printers. This is not a complete list of available equipment (there are well over 100 different types), but it represents those printing devices which the author feels will best service the educational environment.

Most of the printing devices listed have been developed over the last 2 years. Some of the printer manufacturers, such as Nortec and Centronics, provide a minimum of interface electronics and rely on large system houses such as Daconics to interface, sell, and service their printers. Most manufacturers can provide the interface to the more popular minicomputers. Almost all of them have an interface to the PDP-8.

Figure 9—Low-cost output devices

Manufacurer	Model	Speed[1]	Character	Line	Cost
Devices including keyboard					
Teletype Corporation [2] 5555 W. Touhy Ave. Skokie, Ill. 60076	KSR33 ASR33	10cps 10cps	72 72		$ 650 800
IBM Corporation Data Processing Div. 1133 Westchester Ave. White Plains, N.Y. 10604	2740/41	15cps	121		3,500
SYNER DATA 133 Brimbal Ave. Beverly, Mass. 01915	Beta	10/15/30cps	132		6,000
REPCO, Inc. 1940 Lockwood Way Orlando, Fla. 32804	120	120cps	80		2,500
Sperry Rand UNIVAC Communication & Terminal Division 1290 Ave. of the Americas New York, N.Y. 10019	DCT-500	30cps	132		4,500
Digital Equipment Corp. 146 Main St. Maynard, Mass. 01754	LA-30	30cps	80		2,500

1 cps—characters per second; lps—lines per second.

2 Virtually all minicomputers have a standard interface to the teletype ASR (KSR) 33.
The ASR33 includes a paper-tape reader/punch and is used as the standard input-output device. The teletypes supplied by the computer manufacturer usually will be slightly more expensive.

Manufacturer	Model	Speed[1]	Characters	Line	Cost
Texas Instruments, Inc. P.O. Box 66027 Houston, Tex. 77006	710	15/30cps	80		$3,800
General Electric Speciality Control Div. General Electric Dr. Waynesboro, Va. 22980	300	10/15/30cps	75		3,700
Litton, ABS Div. 600 Washington Ave. Carlstadt, N.J. 07072	30	25cps	192		2,200
Printers					
Centronics 1 Wall St. Hudson, N.H. 03051	101	165cps	132	Impact	2,500
Data Printer 225 Msgr. O'Brien Hwy. Cambridge, Mass. 02138	F80 F132	600lpm 600lpm	80 132	impact impact	8,000 11,000
A.B. Dick 5700 W. Touhy Chicago, Ill. 60648	Videojet 960	250cps	132	ink jet	7,500
Nortec Route 9 Southboro, Mass. 01772	B64	200lpm	132	impact	6,500
Odec Computer Systems 877 Waterman Ave. East Providence, R.I. 02914	801	150	80	impact	6,500

[1] cps—characters per second; lps—lines per second.

Figure 9—Low-cost output devices—Continued

Manufacturer	Model	Speed[1]	Characters	Line	Cost
Printers (cont.)					
Potter Instruments 532 Broadhollow Rd. Melville, N.Y. 11746	LP-300	300cps/135lpm	132	impact	$4,500
Teletype Corporation[2] 5555 W. Touhy Ave. Skokie, Ill. 60076	Inktronic	120cps	80	ink jet	5,500
Vogue Instruments 131st St. & Jamaica Ave. Richmond Hill, N.Y. 11418	880c	400lpm	80	impact	9,800
Versatec 10100 Bubb Rd. Cupertino, Calif. 95014	Matrix 300	300lpm	80	electrostatic	6,000
SYNER DATA 138 Brimbal Ave. Beverly, Mass. 01915	ALPHA	300lpm	80	impact	2,000

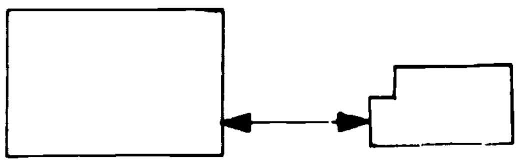
[1] cps—characters per second; lps—lines per second.

Some System Configurations

The objective stated earlier was to design a computer system with a high processing capacity in order to serve as many students as possible. These computer systems have to be modular, expansible, and low cost. In this section all the pieces are put together to meet the objective. All the computer systems to be described can serve a variety of purposes, but a few will have characteristics or software suitable to some very special educational goals. For example, in a vocational program, one of the goals might be to teach assembly and machine language programing skills which can be transferred to the IBM 360/370 series of computers. In this situation an Interdata 14 would be a better choice than any other minicomputer. The 14 is the closest in architecture and structure to the IBM 360/370 computers. In addition, the computer system based on the 14 could meet most of the other educational objectives of the secondary school. For the secondary school desiring to emphasize commercial data processing, the Varian 620/L configured to support RPG IV might be the best choice. Before some possible configurations are presented some specifications and guidelines should be established:

- The basic computer should cost under $10,000 except when the computer can meet some special educational requirement.
- The computer must have at least one higher level language, preferably one in wide use, in addition to assembly language.
- The computer manufacturer should be able to provide adequate maintenance from a nearby service center.
- The computer manufacturer should provide adequate software support in order to utilize his equipment.
- The computer should support a multiuser system as well as a single-user system.

Following are some configurations, costs, and information on how they can be expanded to process larger numbers of student programs. For purposes of illustrating the configurations and approximate pricing a particular machine is specified. It should be understood, however, that a number of the minicomputers and equipment listed earlier could be substituted as well.



Computer
with 4096 words
of core memory

Teletype
ASR Model 33

PDP 8/e with 4K memory	$4,990
Teletypewriter ASR Model 33	1,500
Total	$6,490

Figure 10—Single-user system also supporting the BASIC language

The computer system illustrated in figure 10 is the least expensive system to acquire. It is the most common configuration to be found in the secondary school environment. In some instances the configuration may include an 8K memory to permit the use of a FORTRAN compiler. These computer systems can support 40 to 60 students, per semester, using an interpretive programing language such as BASIC. If assembly language or FORTRAN compilers are also used, then 20 to 40 students can be accommodated. This difference is due to the nature of interpreters and compilers. Interpreters such as BASIC remain in the computer from student to student. The time required to load BASIC (about 13 minutes) is relatively insignificant since it may be done once or twice a day. On the other hand, assemblers and compilers are reloaded from student to student. The loading time (about 10 minutes) is now a significant portion of time, and thus fewer students can be accommodated.

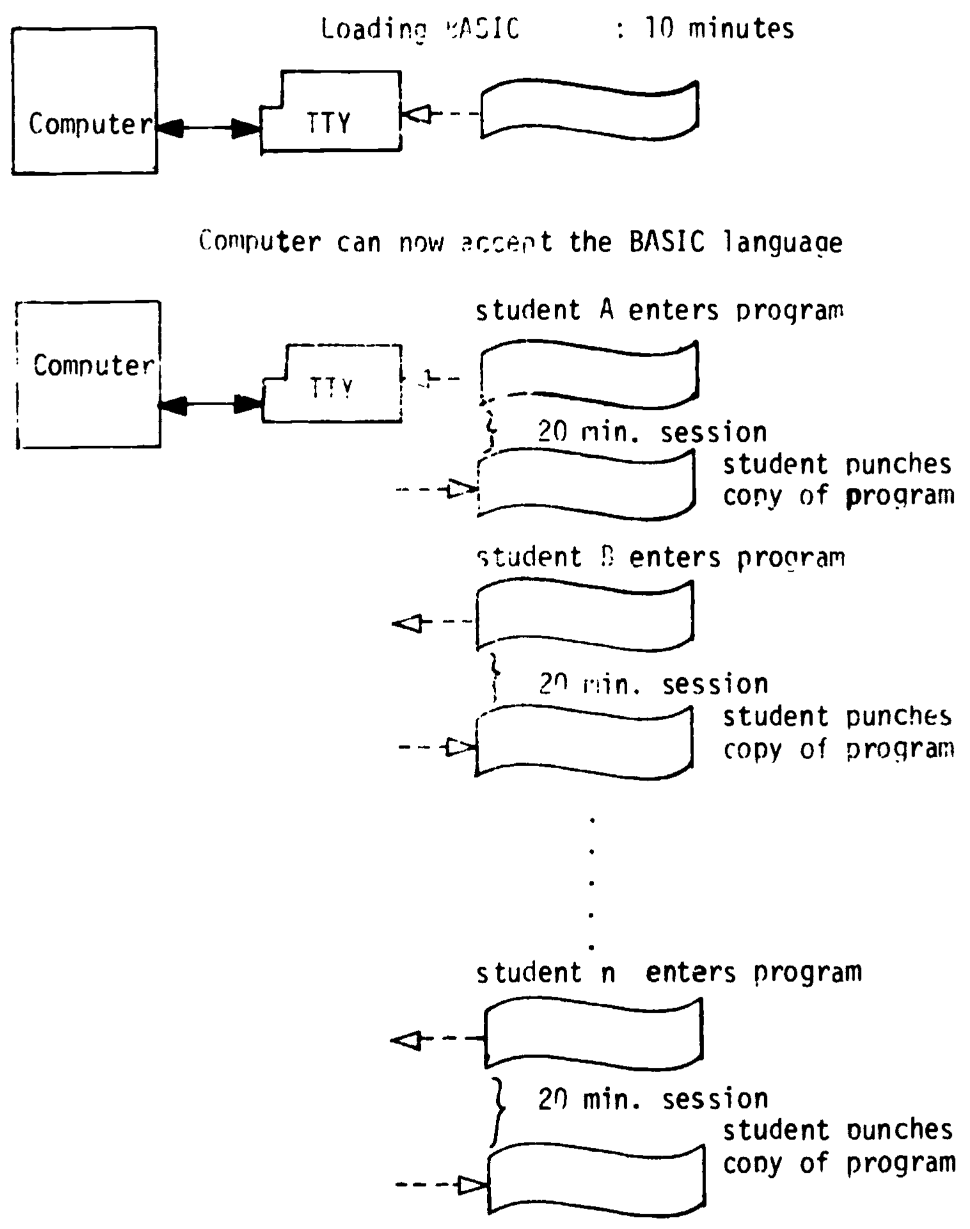
Figures 11 and 12 illustrate how the computer is utilized with an interpreter and with a compiler. The addition of an offline teletypewriter would permit one student to punch his program onto paper-tape while another student occupied the teletypewriter attached to the computer. The student would then read in his paper-tape at teletypewriter speed during his computer session. The addition of the offline teletypewriter would thus permit more students to be accommodated. A high-speed paper-tape reader or a tape cassette storage system is almost a necessity when using a FORTRAN compiler or assemblers. Without a high-speed paper-tape reader or a tape cassette storage system, it would be difficult to run more than a half dozen programs a day. A tape cassette storage device with a monitor can support 40 to 50 students.

Figure 13 illustrates a basic computer system augmented with a tape cassette storage system and monitor. The operating characteristics of this system are similar to the operating behavior of a disk-based operating system.

As students gain programing experience and sophistication, they will attempt more difficult problems, which will entail increasing demands for computer time. Additional students may be entering the computer education program, which will also make additional demands on the computer system. If the increased demand can be met using an interpretive language such as BASIC, the basic configuration can be expanded along the lines of figure 14.

Once additional memory and data communications hardware has been obtained, up to four teletypes can be added as the need arises. In some multiuser systems there is a limit to the number of teletypewriters which can be added, usually four. Other multiuser systems will accommodate up to 16 terminals provided sufficient memory capacity is added. The multiuser system can also operate as a single-user system to provide training in assembly language and FORTRAN. As pointed out in the preceding paragraphs, a high-speed paper-tape reader or tape cassette system would greatly facilitate computer use with assembly language or FORTRAN. It would be very useful if the users of a multiuser BASIC system could also save their files on the tape cassette storage system. This would reduce the need for a student to punch his program on paper-tape at the end of his computer session. However, at the present time, no one seems to have adequate software to perform this task. Each terminal in a multiuser system should support no more than about 50 students at an introductory level where programs will not exceed 25-50 statements.

Another approach which expands on the basic system of figure 10 utilizes a mark sense (optical) card reader. This is shown in figure 15. It has potential for high processing capacity. The mark sense card reader is utilized for input and the teletypewriter for printing output. The student, instead of typing or punching his program at the teletypewriter, would mark sense his program onto the mark sense cards. This could be done almost anywhere and at any time prior to



Note—A student may require several sessions to complete a problem. Between sessions the student may analyze his errors.

Figure 11—Computer operation using the BASIC interpreter

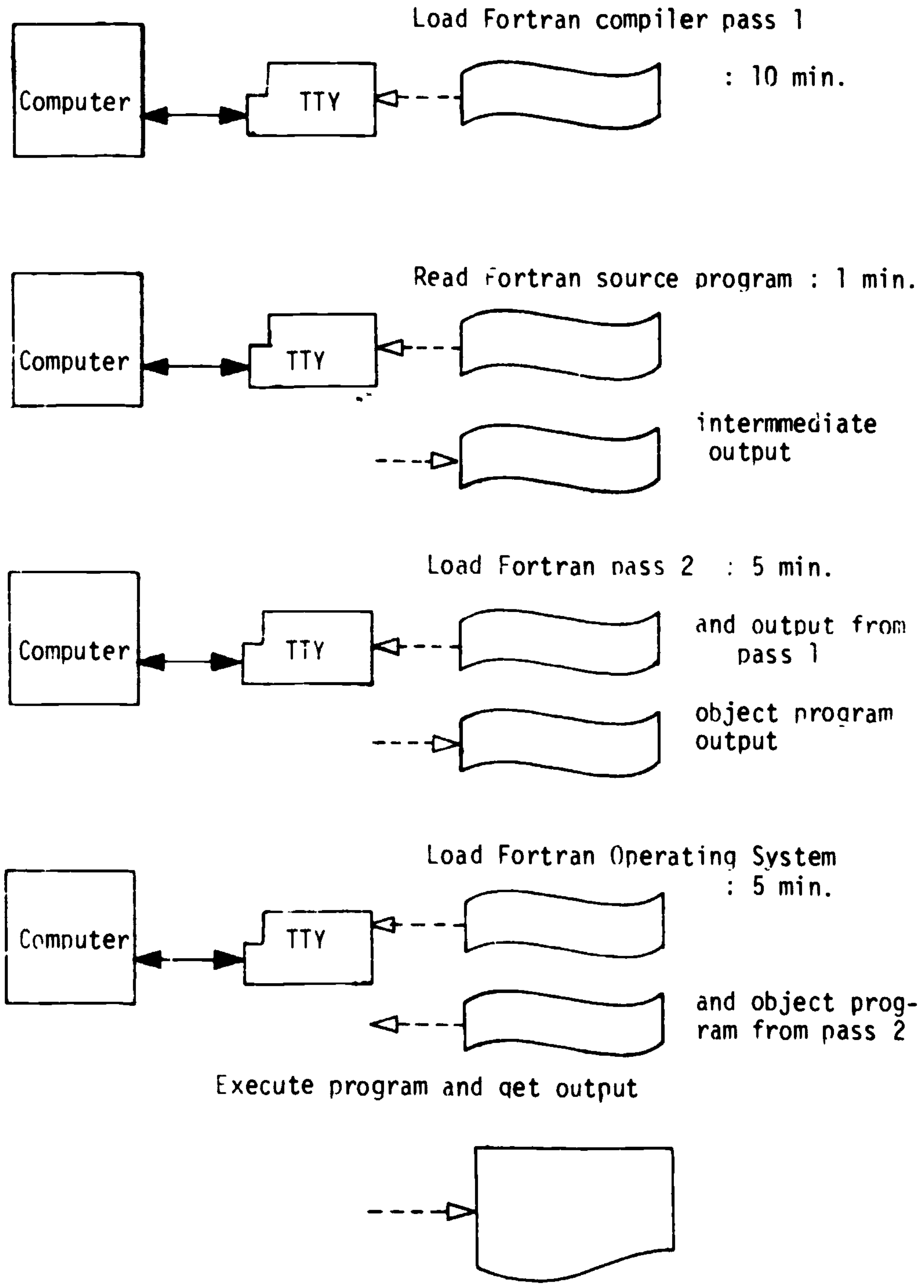


Figure 12—Computer operation using the FORTRAN compiler

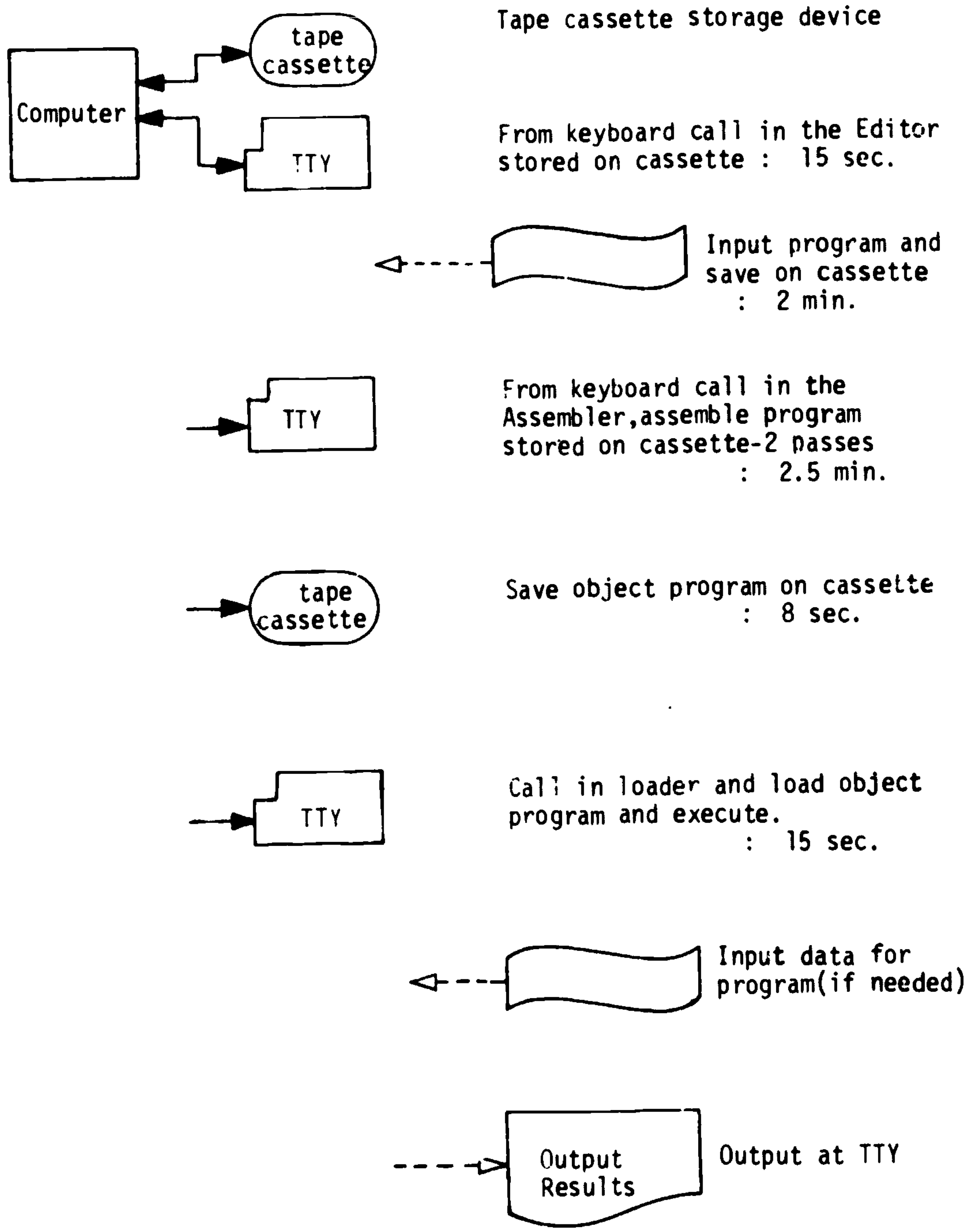
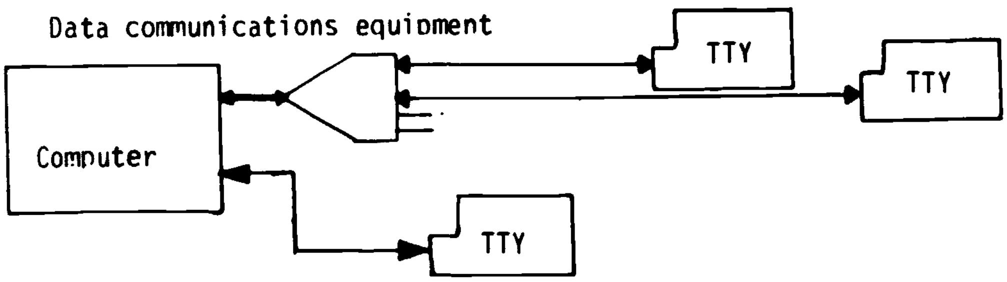


Figure 13—Computer operation with a cassette tape monitor for an assembly

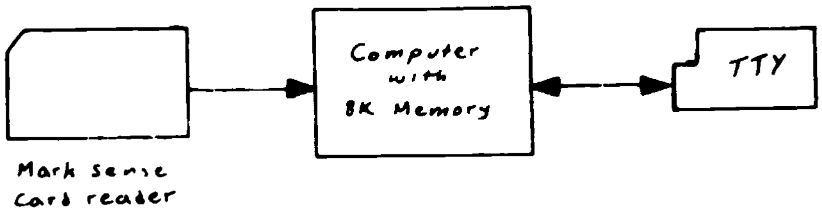


4K PDP-8/e with teletype	$6,490
Additional 4K memory	3,000
Data communications for up to 4 TTYs	1,000
1-3 additional teletypewriters $1,500 @	1,500-4500

Totals

with 2 teletypes	$11,900
with 3 teletypes	13,490
with 4 teletypes	14,990

Figure 14—A multiuser computer system



BASIC 4K PDP-8/e with teletype		$ 6,490
Additional 4K Memory		3,000
Mark sense card reader		4,900
	Total	$14,390

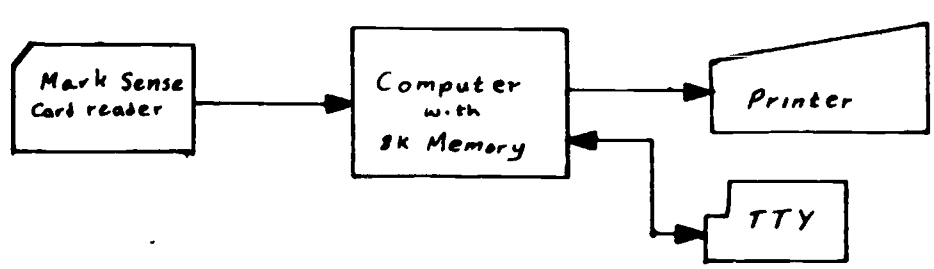
Figure 15—Single-user computer system and mark sense card reader

approaching the computer. At the computer, the student would drop his cards into the mark sense reader. The computer would read his cards, and a listing of his program together with its results would be printed at the teletypewriter. The student could take the program listing and output to his desk, locate his errors, and make the appropriate corrections to his cards. This approach has a number of operational advantages. First, the student does not require a keypunch nor an offline or online teletypewriter to prepare his programs. Second, the student does not tie up a teletypewriter while he is thinking and correcting his program. Third, correcting a program can be done with eraser and pencil. Fourth, the problem associated with the handling of paper-tape is virtually eliminated. Fifth, the information on a mark sense card can be read by humans with a minimum of effort, while paper-tape is difficult to read and requires knowledge of the paper-tape punch code.

In an earlier section some educational and administrative uses of mark sense cards were discussed. Either a general-purpose or special format card can be used for BASIC, FORTRAN, or assembly language. Mark sense card formats can be designed for almost any administrative or testing application. In most cases the mark sense card reader can make use of the same existing software used by the computer manufacturer's punched-card reader. Digital Equipment Corporation and Hewlett-Packard both have BASIC interpretive systems using mark sense cards. However, any of the other computer manufacturers should be able to provide the necessary software to support a mark sense card reader.

This approach will process programs at relatively high rates of 250 to 400 programs per day. This of course assumes that the programs are simple (20-50 statements) and the output of each program is limited to about a page. To handle larger programs (50 to 250+ statements) will usually require additional memory and/or a disk storage unit with supporting software. However, the primary processing limitation in this approach is the printing speed of the teletypewriter. Programs can be processed much faster than the teletypewriter can print the results. By employing higher speed printing devices the program processing capacity can be increased. The increase in capacity will be proportional to the speed of the printing device. Three to four hundred lines per minute is the probable upper useful limit for educational systems. Faster printers are very costly, generally less reliable, and would not increase system performance significantly. Figure 9 lists only those printing devices which operate at speeds faster than the teletypewriter's 10 characters-per-second.

Figure 16 expands on the basic configuration with a mark sense card reader (figure 15) by adding a printing device. The



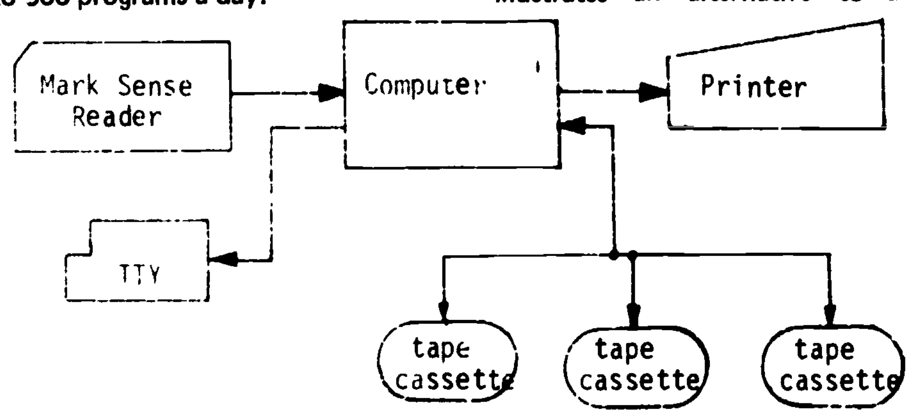
Configuration in figure (15)	$14,390	$14,390
DECwriter	2,850	
A.B. Dick Videojet Printer		8,000
Total	$17,240	$22,390

Figure 16—Single-user computer system, mark sense reader, and printing device

printing device can be a character-at-a-time printer with a keyboard, e.g., DEC's DECwriter; or without a keyboard, e.g., Litton's ABS model 30, printing at about 30 characters per second; or a higher speed printing device such as A.B. Dick's Videojet or Potter's LP 3000 printer. Printers with speeds of 100 to 250 lines per minute will provide about the best cost to performance ratio.

As students progress and gain programing experience they will attempt problems which require more and more output. The teletypewriter quickly becomes the system bottleneck. The computer systems presented in figures 10, 14, and 15 will be limited by the teletypewriter's speed. For example, it will require up to 7 minutes to print a page of output on a teletypewriter. Using a 30-character-a-second printer, e.g., the DECwriter, the time is reduced to about 2 minutes. A line printer device, e.g., LP-3000, reduces the time to print a page to seconds. Thus, using a high-speed printer the system configured in figure 16 should handle large numbers of student programs. If a mixture of simple programing exercises and reasonably complex programs in mathematics, physics, chemistry, and statistics is included, this commuter system should be able to handle from 300 to 500 programs a day.

The systems presented in figures 15 and 16 work best with interpretive languages such as BASIC. The BASIC interpreter remains in the computer's memory from program to program. However, assemblers and compilers, e.g. FORTRAN, must be loaded into the computer with each new program. To alleviate the time-consuming process of loading in assemblers and compilers an auxiliary storage device such as magnetic disks or some form of magnetic tape can be added. Depending on the computer manufacturer and the peripheral devices selected, it may be possible to use an operating system. An operating system (sometimes called a monitor) can improve the overall performance by helping to automate some of the manual operating functions in addition to loading the system programs. The computer manufacturers generally tend toward disk operating systems. However, some manufacturers do have operating systems which will work with either magnetic disks or tapes. In general, the hardware requirements for disk-based operating systems vary greatly from manufacturer to manufacturer. By way of example, Digital Equipment's monitor requires a minimum of 8K memory and a 32K word disk, while Data General requires 16K memory and the 128K word disk. Figure 17 illustrates an alternative to a disk-based



8 K PDP-8/e with TTY	$9,500
Potter LP3000 Printer-135 lpm	4,600
GDI Mark Sense Reader	3,100
DICOM 3 tape cassette system	6,400
Total	$23,600

Figure 17—Computer, mark sense reader, printer, and three-tape cassette system

operating system using a cassette storage device and a cassette operating system.

The computer system in figure 17 is a powerful computer system with the capacity for handling large numbers of student programs of varying complexity. It could operate in the following manner provided the software is available. One tape cassette will contain all the necessary "system" software, e.g., executive or monitor routines, BASIC, FORTRAN, assemblers, editors, loaders, input-output programs, and any other frequently used programs. The student would place his cards in the mark sense card reader and type in commands at the teletype. For example, the student might type in "BASIC" to run a BASIC program. The monitor would search the cassette containing the system programs for the BASIC interpreter and load it into the computer's memory. The cards would then be read, the program run, and the results printed out. If the student wanted to do an assembly he would type "ASMB." Since the assembler requires three passes (or scans) of the source program, the monitor reads the cards and copies them onto another cassette tape. The monitor searches for and loads the assembler. The assembler makes its three passes over the source on the tape cassette. During the third pass the assembler prints an assembly listing of the program at the printer's speed. The assembler writes the binary object program onto another cassette tape. The student then directs the monitor to load and run his object program.

The compilation of a FORTRAN program would follow a similar procedure. At this point at least two of three tape cassette transports are available for use by the program in the computer. For example, students could be asked to perform statistical computations on data recorded on a tape cassette. Several students can be given the same problem or variations of the same problem using the same tape cassette as input data. The tape cassettes can be used to provide realistic problems in data processing such as sorting and merging of files, file updating, etc. Since tape cassettes are easily mounted and dismounted, and are easily locked in a desk drawer, they can be used to keep administrative records such as grades, test scores, attendance records, etc., in complete security. The tape cassettes can be used to store programs and subroutines which the students can retrieve and use. Student programs stored on a tape cassette can be edited on the tape until a correct version is obtained. Thus an entire class can have all their programs on one or two tape cassettes.

Program modification under the BASIC system would be quite simple. The student would call in BASIC, tell it his program's file name, read in the mark sense correction cards, and run his program. The BASIC statements on the mark sense cards would be merged with the statements in the student's program, following the normal BASIC rules; then the program would be executed with the results appearing on the printer. The student could direct the monitor to save his new updated program and delete his old copy.

Although the computer priced in figure 17 is a DEC PDP-8/e, DICOM has almost identical cassette tape monitor systems for Data General's Nova 1200 and Nova 800 computers and for Hewlett-Packard's HP-2114C computer. Digital Equipment Corporation also has a monitor system for the PDP-8 computer a family called PS-8 (Programing System 8). PS-8 can use either disk or DECtape. Interdata has a monitor system called OS-Loader which will operate with Interdata's Intertape cassette storage devices. The card readers, printer, and cassette tapes permit the computing system to be used in a realistic manner by simulating and behaving as a large-scale computing system would. This type of system has many characteristics in common with larger scale computing installations.

Although any of the computers in figure 1 can be substituted for the PDP-8/e in figure 17, the Varian 620/L and the Interdata 14 can lead to systems suitable for commercial and vocational programer training.

The Varian 620/L will support RPG (Report Program Generator). Although the

620/L-RPG System requires a card punch in addition to a card reader and printer, the RPG software can be modified to output the binary object program on the teletypewriter's paper-tape punch. This will save the cost of a card punch.

RPG is a widely used business and data processing language. It is relatively easy to learn, to program in, and to debug. It is available for almost all of IBM's 360/370 series of machines and on IBM's System 3 computers which are marketed for business applications. Several other large computer manufacturers—such as Control Data, RCA, and Honeywell—offer RPG on their computers marketed for business data processing. It is especially useful for those computers which are too small for a COBOL (Common Business Oriented Language) compiler.

Since the Varian 620/L also has the BASIC and FORTRAN languages as well as RPG it could be a very suitable choice. This would be especially applicable for those schools which plan to incorporate computer education for their academic and commercial programs. However, there is still another approach which can also provide valuable vocational training. IBM's 360/370 series of computers has been very successful. It would be most advantageous to provide training on a low-cost computer system which would be close to an IBM computer in as many characteristics as possible. The Interdata Model 14 is very close in design principle and architecture to IBM's 360 computers. The differences are in word size (32 bits for the IBM 360 and 16 bits for the 14), base registers, and storage-to-storage instructions. In the smallest of the IBM 360 computers, the IBM 360 model 20, the first two differences with the 14 disappear. Interdata has developed a simulator program for the 14 which will simulate the IBM 360 model 20. This permits the 14 to run programs written for the IBM 360 model 20. Thus, IBM's assemblers RPG and tape sort merge programs can also run on the 14 with its model 20 simulator. Interdata's simulator, FORTRAN IV compiler, assembler, and operating system could make for a viable educational computer system. It could be used to provide computer services for vocational, commercial, and academic programs. By including the mark sense card reader, line printer, and Interdata's Intertape cassette storage devices, one would have a computer system with sufficient processing capacity to handle large numbers of students. The changes in figure 17 to reflect this system are as follows:

Computer — Interdata 4 with 8K words and TTY	$13,300
2 Cassette transports — Intertape	2,500
or	
4 Cassette transports — 2x Intertape	5,000

Using the same card reader and line printer, the system described above would cost $23,500 with two cassette tape transports or $26,000 for four cassette tape transports.

Although the computer systems in figures 10 through 17 reflect some of the ways in which an educational computer system can grow, they do reflect an orientation toward the batch approach rather than a time-sharing approach. The batch approach can handle a sufficient number of student programs and still provide time in which students can be given hands-on experience. The configuration in figure 14 is a multiuser system. It too can be extended by adding a card reader, line printer, and auxiliary storage devices. Although the hardware interconnections are possible, no software is available from any of the manufacturers for concurrent multiuser and batch operations. However, a combined configuration (say figure 14 and figure 16) could be operated part time as a multiuser system and part time as batch system. The major use of a multiuser (or time-sharing) system which is not available to the batch system user is the interactive facility. The interactive facility is useful in CAI (computer-aided instruction) or in game playing and simulation situations in which student-machine dialogs take place. In all other aspects, the batch approach can provide for more efficient utilization of the computer.

Conclusions and Recommendations

In a multiuser system, as in time-sharing, the number of students which the computer system can accommodate during a session depends upon the number of teletypewriter terminals available. The cost of expanding beyond four or five users becomes as great as the cost of adding peripheral devices such as card readers and line printers. A batch or single-user system is capable of accommodating larger number of students during the same time period. However, the actual number of students handled will depend more upon how fast programs can be entered intc the computer and how fast they can print out than upon the computer's actual speed.

Although manufacturers and salesmen often quote memory or computer speed, it is the combination of computer and software which is of importance. It is the software—i.e. compilers, assemblers, interpreters, editors, operating system, loaders, etc.—which will determine how useful a computer system will be. For example, a FORTRAN compiler which does not have good diagnostics (indication of a programing error) will be difficult to use effectively, especially for the beginning students. A BASIC interpreter which does not have "string variables" may be a severe handicap to its educational utility.

BASIC appears to have a large following in the secondary schools. This is due to its wide availability. A good deal of secondary school level materials are available from a great many sources—ranging from books to simulation programs available from regional computer education projects. BASIC is easy to learn and simple to use. It is simple enough to be taught to elementary school children yet powerful enough to solve many problems in science and commerce.

FORTRAN is still favored for scientific and engineering problems in industrial and university environments. FORTRAN is a more powerful and flexible language though more difficult to learn and use. ALGOL (Algorithmic Language), though widely used in Europe, has few followers in the United States, especially at the secondary school level. FOCAL is a language of considerably greater power than BASIC; however, it is available only on DEC's PDP-8 series of computers. RPG is used in business and commercial applications. It is suitable for small computers; it is also easy to learn and use. However, Varian and Interdata are the only manufacturers to make it available.

It is likely that BASIC will continue to serve as a teaching vehicle for commercial applications in the high school curriculum. Many high school programs in computer education start out with a single language, usually BASIC. Within a year a number of students will be clamoring for assembly language and FORTRAN. Some of them will be so eager to progress that they will learn assembly language on their own. Therefore, it is important to plan on a computer system which will have as great a variety of programing languages as possible.

In choosing the computer itself, one should consider the software available rather than memory cycle time, number of bits in a word, number of registers, and the number of instructions. Another very important consideration in choosing a computer is the availability of maintenance. It is usually preferable to obtain the maintenance directly from the manufacturer rather than from independent sources. Even changing a lamp in the computer's display panel may require a maintenance man in most of the minicomputers; so don't plan on doing your own maintenance. In purchasing any options, such as hardware multiply-divide, be sure that the software to be used will actually make use of the purchased option. An option which should be considered is the automatic bootstrap loaders. This will save endless frustration in starting up the computer.

Peripheral equipment in general should be purchased from the computer manufacturer for the sake of maintenance and software support and compatibility. The exception to this general rule is when the computer manufacturer does not offer that type of peripheral, e.g., tape cassette unit, or the manufacturer has only a prohibitively expensive, high-performance peripheral device, e.g., line printer.

Three types of peripheral devices considered in the study fall under this exception. Mark sense card readers, if not available from the computer manufacturer, are generally compatible with the manufacturer's own card reader. In some instances the computer manufacturer will yield to prodding and supply a mark sense card reader. It is important to be sure of maintenance and adequate software support for the mark sense card reader. Digital Equipment Corporation and Interdata manufacture their own special tape systems. In both cases, the tape systems interface to their respective computers and are fully supported with software, including operating systems. The other cassette tape systems in figure 2 can be electronically connected to any one of a number of minicomputers. However, adequate software is provided for only the more popular minicomputers, as indicated by the last column of figure 2. Here again one must be sure that the level of software support for a given computer will be sufficient to utilize the cassette tape system in the intended manner. Both DEC and Interdata will of course maintain their own tape systems; however, with the other cassette tape system manufacturer's maintenance may be somewhat more of a problem, especially for schools which are distant from major urban areas. Fortunately, however, most of the tape cassette systems seem to be conservatively designed and should provide fairly reliable operation. Those tape cassette systems which are sold through a manufacturer's representative can usually be serviced through the representative.

Printing devices also deserve careful consideration. Generally electromechanical equipment such as printers requires a high degree of maintenance. However, recent improvements in technology have lead to new printer designs with improved reliability, especially in the low and medium speed range. These printers are also significantly lower in cost than older printers. Nonimpact printers using an ink drop technology, such as A.B. Dick's Video Jet Printer or Teletype's Inktronic Printer, may be the most suitable for the educational environment. They are quiet, inherently reliable, low-cost, and use ordinary paper. Interfaces are available as is software to support them for most minicomputers. Maintenance and service are nationwide and should be available in most communities.

By following the guidelines, considerations, and specifications in this report, one can build a highly effective educational computer system in a modular fashion. Planning should be done over a 3- to 5-year period so that all of the equipment purchased can be used at each stage of the expansion. The configurations illustrated in the previous section indicate how such expansion can take place.

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________. "A Paradox: The Promises and Pitfalls of CAI," *EDUCOM, vol. 5, no. 2*, March 1970. Discusses advantages and disadvantages of CAI.

Harmon, H.H.; Helm, C.E.; and Loye, D.E. "Computer-Assisted Testing, Proceedings of a Conference." Princeton, N.J.: Educational Testing Service, 1968.

Hickey, A.E. *Computer-Assisted Instruction: A Survey of the Literature*. 3d ed. Newburyport, Mass.: ENTELEK, Inc. 1968. Contains abstracts, papers, reports, and other documents primarily from October 1966 to July 1968; includes a discussion of CAI applications, major CAI centers, system, programing languages, program evaluation, and the administration of CAI.

Holtzman, W., ed. *Computer-Assisted Instruction, Testing and Guidance*. New York: Harper and Row. (In press)

Holznagel, D. *Computer Education Resource Catalog*. Salem, Oreg.: Computer Instruction NETWORK. 1968. Includes a serial bibliographic listing of books, pamphlets, and periodicals in general categories according to their major content or purpose, an annotation of selected works, and a list of films and reviews.

Journal of Engineering Education, vol. 50, no. 6, February 1969, part I. Contains 12 articles from the ASEE Symposium on the Applications of Technology to Education; a variety of views on the role of computers in education, systems analysis in education, and managing change in educational institutions. Participants included engineering teachers, learning theorists and educators, and representatives of instructional hardware and software manufacturers.

Kochen, M. "Information Sciences and Computer Aids in Education," *The Information Bazaar*, L. Schultz, ed., Medical Documents Service, Philadelphia, Pa., May 1969, pp. 209-20. Describes progress in computer-aided instruction, computer-aided question answering, and computer-aided information retrieval.

Kopstein, F.F., and Seidel, R.J. "Computer-Administered Instruction Versus Traditionally Administered Instruction: Economics." Alexandria, Va.: Human Resources Research Office. 1967.

Lekan, H.A. *Index to Computer-Assisted Instruction*. Boston, Mass.: Sterling Institute. 1970. A comprehensive compilation of 910 CAI programs from 85 sources at several levels of education, including universities; programs are cross-referenced according to subject, computer required, programing language, instructional logic, and institutions producing the program.

Levien, R.E., et al. *The Emerging Technology: Instructional Uses of the Computer in Higher Education*. Santa Monica, Calif.: The Rand Corporation. 1970. Report comprised of three sections: an introduction to the computer's use in higher education, including research, administrative, library, and instructional uses; the state of the art of computer use in instruction; and future prospects for computer use in instruction projected over the next two decades.

Library of Congress, Congressional Research Service. *New Technology in Education, Selected References*. Washington, D.C.: U.S. Government Printing Office. 1971. An extensive bibliography of references on educational technology, which divides the literature into 29 separate categories.

Meimer, R., ed. *Computer-Assisted Instruction and the Teaching of Mathematics*. Washington, D.C.: National Council of Teachers of Mathematics. 1969. Report of a conference held in September 1968; includes an article, "Characteristics of CAI Configurations from an Author's Viewpoint," by Max Jerman on the capabilities and limitations of existing CAI hardware, particularly terminal services.

Morgan, R. "A Review of Educational Applications of the Computer, Including Those in Instruction, Administration, and Guidance." Stanford, Calif.: ERIC Clearinghouse on Educational Media and Technology. 1969.

Pierce, J.R., et al. *Computers in Higher Education: Report of the President's Science Advisory Committee*. Washington, D.C.: U.S. Government Printing Office. February 1967. Presents general recommendations for computer use for teaching and student research in all curriculum areas.

Relationship of Automatic Data Processing Trainers, Curriculum and Methodology in the Federal Government. Washington, D.C.: U.S. Government Printing Office. Report of a conference held in May 1967; contains chapters on the need for ADP training, ADP personnel needs in the Federal Government, training needs in industry and higher education, and recommendations for curriculums.

Scheepmaker, B., and Zinn, K.L. *Preliminary Proceedings of the World Conference on Computers in Education*, International Federation for Information Processing, Amsterdam. (In press.)

Silberman, H.F., and Filep, R.T. "Information Systems Applications in Education," *Annual Review of Information Science and Technology*, vol. 3, ed. by C.A. Cuadra, Encyclopaedia Britannica, Inc., Chicago. 1968. pp. 357-95. A heavily referenced review of the use of computers in education, including CAI, CMI, counseling, testing, administration, and educational data processing; discusses current operational systems and areas of R&D activity.

Silvern, L.C. *Systems Engineering of Education VI: Principles of Computer-Assisted Instruction Systems*. Los Angeles, Calif.: Education and Training Consultants Co. Reviews equipment, systems, and strategies along with a presentation of Silvern's approach to course development, production, and tryout.

Stolurow, L.M. "Computer-Assisted Instruction," *The Schools and the Challenge of Innovation*. New York: McGraw-Hill Book Co., Inc. 1969. pp. 270-319. Discusses the various purposes of CAI, its advantages, and financial costs.

Utall, W. "Computer Teachine Machines," *Real-Time Computers: Techniques and Applications in the Psychological Sciences*. New York: Harper and Row. 1967. pp. 234-69. Discusses the psychological foundations and types of teaching machines.

Vinsonhaler, J. *Index for Bibliography of Computer Applications in Education*. East Lansing, Mich.: Michigan State University, Information Systems Laboratory. Printed version of a computer-based file of an annotated bibliography on computers in education.

White, P.T. "Behold the Computer Revolution," *National Geographic*, vol. 138, no. 5, November 1970. pp. 593-633. Describes the broad range of applications, including education, for which computers are being used.

Zinn, K. L. "A Comparative Study of Languages for Programing Interactive Uses of Computers in Instruction." February 1969. Boston, Mass.: EDUCOM. An interpretive report on existing programing languages.

________. "An Evaluative Review of Uses of Computers in Instruction" (Project CLUE), final report of USOE project 8-0509, 2 vols., August 1970. Bethesda, Md.: ERIC Document Reproduction Service. A study of the technology, applications, cost effectiveness, and trends for uses of computers in instruction at all levels of education. Discusses various topics of concern, including operating procedures and costs, instructional strategies and programing languages, research studies evaluating the technology, and strategies for developing computer-based learning materials. Contains a guide to relevant literature and other sources of information, and a selected sample of instructional materials and learning exercises.

_________and McClintock, J. "A Guide to the Literature on Interactive Use of Computers for Instruction." 2d ed. Stanford, Calif.: ERIC Clearinghouse on Educational Media and Technology. Presents various uses of computers in instruction, types of lessons, systems and computer languages, existing literature surveys, meetings, conferences and symposia which have been held, professional organizations, publishers and commercial information services, a glossary of common terms, and a list of individuals responsible for development and demonstration projects.

Professional Organizations, Publishers, and Commercial Information Services

Academic Press Incorporated, 111 Fifth Avenue, New York, N.Y. 10003. Since January 1969, the *International Journal of Man Machine Studies* has been published quarterly. The content includes instructional use of computers along with man-machine interaction, the man-machine interface, mathematical and engineering approaches to the study of man and biological approaches to the development of machines ($7 per year).

American Educational Research Association (AERA), 1201 16th Street, N.W., Washington, D.C. 20036. The *American Educational Research Journal*, published quarterly ($8 per year) frequently carries articles related to computers in education.

The *Review of Educational Research* includes in its five issues per year two or three chapters on educational technology and computers ($10 per year).

American Federation of Information Processing Societies (AFIPS), 211 E. 43rd Street, New York, N.Y. 10017. The Fall Joint Computer Conference (FJCC) and Spring Joint Computer Conference (SJCC) include sessions relevant to instruction, but often under such headings as system design, programing languages, and natural language processing, as well as under computer-assisted instruction. The *Conference Proceedings* of FJCC and SJCC are published by the AFIPS Press at the time of the meetings (usually November and April).

American Psychological Association (APA), 1200 Seventeenth Street, N.W., Washington, D.C. 20036. The *Journal of Educational Psychology* is a bimonthly publication which includes articles and reports associated with problems of learning and teaching ($10 per year).

American Society for Engineering Education (ASEE), Suite 400, One Dupont Circle, Washington, D.C., 20036. *Engineering Education*, published eight times a year ($16 per year), has been devoting entire issues to computers, information processing, and effective teaching. *ERM*, a publication of the Educational Research and Methods Division, is published quarterly ($2 per year). It regularly contains articles on the use of computers in engineering education.

Association for Computing Machinery (ACM), 1133 Avenue of the Americas, New York, N.Y. 10036. A number of the monthly issues of *Communications of the ACM* include articles on use of computers for instruction. Often these are concerned with the training of computer programers, technicians, and users. Sections on programing languages and computational linguistics occasionally are relevant to instructional programs ($20 per year).

The *Journal of the ACM* includes relevant material only occasionally, but issues of *Computing Reviews* frequently have abstracts of technical reports and papers from projects using computers for instruction.

Computing Surveys began publishing quarterly in March 1969 as the survey and tutorial journal of the ACM ($7).

The Association has a Special Interest Group on computer uses in education. A bulletin, *Interface,* is issued five times a year with membership at $4 per year. It contains technical reports, material on the technical programs of ACM, and information about special meetings and workshops in the field of computers and education.

Association For The Development of Instructional Systems (ADIS), CAI Laboratory, Sutton Hall, University of Texas, Austin, Tex. 78721. *ADIS Newsletter,* issued monthly, provides for the exchange of system programs and instructional materials among its members ($6 per year). The Association, which meets at least twice a year, is presently limited to users of IBM equipment for instruction, but is likely to broaden its scope.

Association for Educational Data Systems (AEDS), 1201 Sixteenth Street, N.W., Washington, D.C. 20036. *AEDS Monitor,* the magazine of the Association, is published 11 times each year; most material has been on data processing ($15 per year).

The *Journal of the Association of Educational Data Systems,* published four times each year, includes many articles on computers and education ($10 per year).

The annual meeting of the Association in March or April always includes sessions on computers and instruction.

Automated Education Center, P.O. Box 2658, Detroit, Mich. 48231. The *Automated Education Handbook* ($35) and a newsletter, *Automated Education* ($18 per year) provide information about programed instruction, audio and visual media, and computer assistance. Most of the material in the newsletter is selected from news releases and other publications for potential educational users of computers. The *Handbook* includes research reports, discussion of procedures, and summaries of technology and applications. AEC recently started a monograph series reprinting technical reports and tutorial materials.

Berkeley Enterprises, 815 Washington Street, Newtonville, Mass. 02160. *Computers and Automation* is a monthly journal; articles are usually informal and descriptive. Sometimes information about a new project appears here before it is reported more formally. Usually each March issue carries a set of articles on "Computers and Education" ($15 per year). Berkeley also publishes books and monographs bearing on computers in education.

Berkeley and *Computers and Automation* operate and maintain a PDP-9 computer (made by Digital Equipment Corporation) using more than half a dozen interactive programing languages, including LISP, FOCAL, DDT, and EXPL. One of the main purposes of this installation is research and investigation in learner-controlled computer-assisted instruction.

Computer-Assisted Instruction, Inc. (CAI, Inc.), 111 West Monroe Street, Chicago, Ill. 60603. CAI, Inc. specializes in design development and implementation of training systems. One-day seminars directed to business, industry, government, and schools consider the present and future potential for use of computers in the educational and training process. Subscription fees vary.

Computer Education Group, an affiliate of the British Computer Society and Schools Council Project Technology, c/o Chairman, North Staffordshire Polytechnic, Department of Mathematics, Science and Computing, Beaconside, Stafford, England. The two organizations collaborate in the publication of the quarterly bulletin, *Computer Education.* Originally intended for readers in the United

Kingdom, recent issues have increasing relevance for an international audience.

Data Processing for Education, 1309 Cherry Street, Philadelphia, Pa. 19107, is a monthly newsletter (formerly published by the Automated Education Center). It discusses current and projected programs and publications in the field of computers in education of both national and international scope ($16 per year).

EDUCOM (Interuniversity Communications Council, Inc.), 100 Charles River Plaza, Boston, Mass. 02114. The central office distributes a bimonthly publication, *EDUCOM: The Bulletin of the Interuniversity Communications Council,* without charge to the faculty of its 105 member institutions of higher education. *The Bulletin* is also available on a subscription basis at $10 per year or $5 per year to educational institutions.

Needs in the area of computer uses for instruction are reviewed, along with other topics, by panels concerned with technology and applications. A set of documents on programing languages and technical assistance for authors was prepared in cooperation with the Center for Research on Learning and Teaching, University of Michigan. Copies of this comparative study of languages, partially funded by the Office of Naval Research, are available from EDUCOM.

The recently organized Educational Information Network (EIN) is administered by EDUCOM. Funded by USOE and NSF, EIN is developing a pilot network which will assemble directory and information services, recommend standard practices, and facilitate cost sharing of communication circuits and special computer facilities for remote use or for information exchange.

ENTELEK, Inc., 42 Pleasant Street, Newburyport, Mass. 01950. ENTELEK conducts a CAI/CMI Information Exchange originally contracted for by ONR which periodically distributes abstracts of CAI and CMI research documents, summaries of operational CAI programs, and descriptions of individual CAI facilities. Five- by eight-inch data cards are mailed in multiple copies for cross-indexing and are accompanied by author, subject, KWIC, and bibliographic indexes. ONR originally paid the costs for about 60 institutions active in the CAI field and in the exchange; subsidy is no longer necessary and all participants now subscribe at $150 per year. ENTELEK has proposed a new journal called *Computers in Instruction.*

ENTELEK assists with CAI interest group meetings, publishes summaries, and distributes an occasional newsletter, entitled CAI/CMI Letter.

ERIC Clearinghouse on Educational Media and Technology, Institute for Communication Research, Stanford University, Stanford, Calif. 94305. The current report literature is indexed and abstracted in *Research in Education* ($21 per year, U.S. Government Printing Office, Washington, D.C. 20402), while journal literature is indexed in *Current Index to Journals in Education* ($39 a year, CCM Information Corp., 866 Third Avenue, New York, N.Y. 10022).

Supported by the Office of Education, it has been chartered to collect, review, and abstract publications and documents of importance in the various media areas, including computer-assisted instruction, and to prepare them for indexing and storage in a computer-accessed data base. While the clearinghouse does not collect actual teaching materials, it does prepare and publish summary papers on the state of the art in different parts of the field. Documents are available from the ERIC Documents Reproduction Service, P.O. Drawer O, Bethesda, Md. 20014 in microfiche and hard copy. ERIC at Stanford's regular newsletter is free upon request.

Education and Training Consultants Co. (ETC), 12121 Wilshire Boulevard, Los Angeles, Calif. 90049 (Mailing: Box 49899, Los Angeles 90049). Three-day to two-week training programs in "CAI Systems" and "Advanced CAI Systems" are presented in Los

Angeles each February, July, and November. The same courses are given at various locations in the United States on a contract basis. This commercial organization publishes technical reports in the Systems Engineering of Education Series, filmstrips, sound-slide presentations, CAI courses, and news releases in the area of education, training, and systems techniques.

Hayden Publishing Company, Inc., 850 Third Avenue, New York, N.Y. 10022. *Computer Decisions* is a monthly magazine which includes articles on information systems, automated processing, and problem solving.

The Institute for Advanced Technology (IAT), CEIR, Inc., of the Central Data Corporation, 5272 River Road, Washington, D.C. 20016. CEIR holds 3-day seminars on Computer Assisted Instruction for those involved in education and training functions. No prior computer knowledge is necessary.

Institute for Computer Assisted Instruction (ICAI), 42 East Court Street, Doylestown, Pa. 18901. This commercial organization holds a number of conferences, meetings, training workshops for instructional programers, and public 1-day briefings each year. It plans to publish an annual state-of-the-art review and also the CAI Newsletter (8 issues, $12 per year).

Institute of Electrical and Electronic Engineers (IEEE), 345 E. 47th Street, New York, N.Y. 10017. *Proceedings of the IEEE* occasionally is devoted entirely to computers and related subjects. The last such issue was December 1966, which contained some papers on computer-aided instruction. The November 1967 issue was devoted to computer-aided design ($22 per year; single copy of special issues $4). *IEEE Transactions on Man-Machine Systems* (name changed from *Transactions on Human Factors in Electronics), IEEE Transactions on Education* and *IEEE Transactions on Systems Science and Cybernetics* often include relevant papers. A special issue of the first journal, June 1967, contained eight articles focused on computers and education. Subscription prices vary (single copy $5).

Instructional Media Laboratory (IML), University of Wisconsin-Milwaukee, Wisconsin 53201. The laboratory is primarily concerned with the University of Wisconsin System; nevertheless, it prepares an *Index to Computer Assisted Instruction.*

International Federation for Information Processing, 6 Stadhouderskade, Amsterdam 13, The Netherlands; Congress Office, 23 Dorset Square, London, N.W. 1, England. Proceedings of the IFIP triannual congresses often contain technical papers related to computer applications in education. Proceedings of the 1962-65 and 1968 congresses should be available from the North-Holland Publishing Company, P.O. Box 3489, Amsterdam. Special meetings are held occasionally, such as the World Conference on Computer Education in Amsterdam, August 24-28, 1970.

The National Association of Secondary School Principals (NASSP), 1201–16th Street, NW, Washington, D.C. 20036. During 1970 the Committee on Computers in Education of the NASSP offered a series of seminars on potential uses of the computer in various parts of the country. Co-sponsored by Sterling Institute, the seminars included an explanation and actual use of CAI programs in various curriculum areas, use of the computer in the classroom as a problem-solving tool, exploration of CMI and IPI as well as exposure to and use of new instructional technologies. The seminars are intended primarily for secondary school principals. Registration fees range from $115 to $170 for a 2-1/2 day session.

National Association of Users of Computer Applications to Learning (NAUCAL). Program Research and Design, Cincinnati Public Schools, 320 East 9th Street, Cincinnati, Ohio 45202. This group was organized by large school systems having CAI projects. The initial purpose was to present a defined, unified market to hardware and software vendors interested in CAI. Plans include a centralized dissemination of information on CAI to members.

National Catholic Education Association, One Dupont Circle, N.W., Washington, D.C. 20036. The association publishes a calendar of all national and regular educational meetings each year. Entries give dates, places, tentative agendas, discussants, etc. ($1.80 per year).

National Council for Educational Technology (NCET), 160 Great Portland Street, London W 1, England. The *Journal of Educational Technology* is the official publication of NCET. It began publishing three issues per year in January 1970. The periodical is concerned primarily with the theory, applications and development of educational technology and communications, and includes editorials, research reports, and articles ($8.40 per year).

National Education Association, 1201 16th Street N.W., Washington, D.C. 20036. The Association for Educational Telecommunications and Technology (AECT), an affiliate of the NEA, publishes *Audiovisual Instruction* ($12 for 10 copies per year). The *Audiovisual Communications Review,* published quarterly by AECT, occasionally includes research reports and survey articles ($13 per year). AECT holds an annual conference each spring.

National Society for Programmed Instruction, Trinity University, 715 Stadium Drive, San Antonio, Tex. 78212. The annual meeting usually is scheduled for April and includes sessions on instructional use of computers. *NSPI Journal* is the official monthly publication of the Society (not published in January and August). It contains articles on all facets of instructional programing as well as som newsnotes; computers are receiving increasing attention. Annual subscription is $20 for nonmembers, $5 for members.

North American Publishing Company, 134 North Thirteenth Street, Philadelphia, Pa. 19107. *Data Processing Magazine* is a trade journal that appears monthly. It contains a section on the use of computers in education ($8.50 per year).

Organization for Economic Cooperation and Development (OECD), Centre for Educational Research and Innovation (CERI), 2 Rue Andre Pascal, Paris XVIe, France. Originally concerned with economic redevelopment of Western Europe, OECD is now focusing its attention on social and educational problems. CERI is reviewing computers and other technology for educational innovation. The proceedings of meetings held in March 1970 are likely to be available soon.

Technical Publishing Company, 94 South Los Robles Avenue, Pasadena, Calif. 91101, publishes *Datamation*. This trade journal includes occasional articles on the use of computers in instruction. A special issue on computers and education appeared in September 1968. Subscription inquiries should be directed to *Datamation*, 35 Mason Street, Greenwich, Conn. 06830. Issued 24 times per year ($25 per year).

Glossary of Commonly Used Computer Terminology

This glossary contains only the most commonly encountered terminology. A more comprehensive listing can be found in *Vocabulary for Information Processing,* published by the American National Standards Institute, Inc., 1430 Broadway, New York, N.Y. 10018.

Absolute address (or **coding**) - An address (or coding, i.e., machine instructions) written or expressed in the basic numeric language acceptable to the computer without any further modification.

Access time - The time duration required to obtain information from a storage device (read time) or the time duration to place information into a storage device (write time).

Accoustic coupler - A device used to transfer information to and from a terminal (e.g., teletypewriter) via an ordinary telephone set over telephone lines to a remote computer. An accoustic coupler may be used in place of a data set to provide portability to the terminal.

Accumulator - A part of the arithmetic logic unit of a computer. It is a register which temporarily stores information and is used to perform manipulation upon the information such as summing it with a second quantity. The accumulator may also be used in the transfer of data to and from storage or external devices.

Adder - A device (a part of the arithmetic-logical unit of a computer) capable of forming the sum of two or more digital quantities; the device whose function is implied in an add instruction.

Address - A label, name, or number which designates a register, memory location, or device. An address may be either absolute or symbolic; it may be direct or may require further modification. It may refer to data or an instruction or a device.

Address modification - The process or means of changing an address part of an instruction for actual use by the machine. The types of address modification are as follows:

- Direct: no modification of address.
- Indexed: adding an index value (or the contents of an index register) to the specified address.
- Indirect: the actual address used by the instruction is taken from the location specified in the address part of an instruction.
- Relative: the address is relative to the value contained in some register.

ALGOL - ALGOrithmic Language. A computer language allowing the programer to communicate with the computer using a mathematics-like notation. ALGOL is similar to other programing languages such as JOSS, FOCAL, BASIC, and FORTRAN.

Algorithm - A finite set of step-by-step rules or procedures for the solution of a given problem (assuming that a solution is possible). The rules for long division or a computer program which gives consistent answers are examples of algorithms.

Alphanumeric - Characters which consist of the letters of the alphabet, numerals, and/or special symbols which are represented in some form for use in and manipulation by the computer.

Analog computer - A computer which uses physical quantities (e.g., voltage, force, fluid volume) to represent numeric quantities in performing computation.

Arithmetic unit - That functional part of the computer involved in arithmetic and logical operations such as addition, subtraction, multiplication, address modification, shifting, etc.

ASCII - American Standard Code for Information Interchange. A standard established to represent alphanumeric characters in computers and for the interchange and communication of computer intelligent information. ASCII has been adopted by almost all minicomputer manufacturers.

Assembler, assemble - A computer program that operates on a symbolic input (assembly language program) to assemble or produce machine instructions. The assembler assembles or translates the symbolic instructions of the program into machine instructions. The assembler is the most basic program supplied by the manufacturer.

Assembly language - This is the most elementary (but most difficult to learn and use) symbolic language of the computer. Assembly language is translated by the assembler into machine instructions which the computer may execute.

Automatic programing - The approach or process of using the computer to perform some of the work and effort in preparing a computer program to solve a problem.

Auxiliary storage - Storage (or memory facility) which supplements the computer's main memory. Auxiliary storage is usually provided by means of magnetic tape or magnetic disk or drum device.

Base - A number base, a quantity used implicitly to define a system of representing numbers by positional notation, also termed Radix. Ordinary numbers use base 10 or decimal notation, while computers generally use base 2 or binary notation. The octal or base 8 notation is also frequently encountered.

Base page - Minicomputers generally have their main memories divided into units termed pages. The pages are numbered sequentially, and each page contains a fixed number of storage locations. The lowest numbered page is called the base page or page zero.

BASIC - Beginner's All-purpose Symbolic Instruction Code is a programing language developed at Dartmouth College. It uses an English- and mathematics-like notation. It is an easy-to-learn-and-use programing language and has been widely accepted. A good deal of secondary school curriculum materials have been developed using BASIC.

Baud - A unit of information transmission. In data communications it refers to the number of bits (pulses) transmitted per second. A teletypewriter is a 110-baud device, that is, it can transmit or receive information at the rate of 110 bits per second.

Batch processing - A mode of operating a computer system in which all the resources of the computer are available to a single program until that program is completed. The next program can begin only when the prior program is completed. This is in opposition to time-sharing in which a number of programs, in various states of completion, are competing for or sharing the computer's resources.

Binary - A positional number system employing the base two representation. The binary digits are 0 and 1. Most minicomputers employ the binary number system for representing numbers. Machine instructions (language) are in binary form, that is, composed of zero's and one's.

Binary device - Any device capable of having two distinguishing states is termed a binary device. Examples are a hole or no hole (in a punch card or paper-tape), voltage or no voltage (in an electronic circuit), a switch either on or off.

Bit - A contraction of Binary Digit; sometimes used to denote the binary digit of one.

Boolean - Generally in reference to the logical operators of AND, OR, and NOT with respect to binary values.

Bootstrap - A short sequence of instructions, manually entered into the computer's memory, which enables it to operate a device (usually paper-tape reader) which will read into the computer's memory a larger program - usually called a loader. Some manufacturers call the bootstrap a RIM loader.

Branch - An instruction which causes the computer to switch from one sequence of instructions to another sequence of instructions. A branch may be an unconditional branch or the branch may occur only when specified conditions arise. Some computer manufacturers use the terms "jump" or "transfer" instead of branch.

Buffer - A storage device used when transmitting data between a computer and a device to compensate for a difference in rate of flow of data.

Bus - A path or channel along which data or control signals can be sent. A memory bus is the path from the memory to the computer processor itself. An I/O (input-output) bus can be a path from a magnetic tape device to memory.

Byte - The smallest sequence of bits (binary digits) which may be operated upon as a unit. A byte may also represent a character (usually six or eight bits).

CAI - Computer-Aided Instruction or Computer-Assisted Instruction. Generally it refers to the use of the computer interactively with the student to provide him with drills, tutorials, and problem solving.

Call - To transfer control, temporarily, to a defined sequence of computation steps (a subroutine).

Calling sequence - A basic sequence of instructions used to begin, initialize, transfer to and/or return from a subroutine.

Carry - The digit, or signal, which occurs when the sum, or product, of two digits equals or exceeds the number base.

Central processor unit - That part of a computer system which consists of the arithmetic-logical unit, control unit, input-output control, and memory. The central processor unit is conveniently abbreviated to CPU.

Channel - A path along which electrical signals can travel between points, e.g., between a device and memory. The terms channel and bus are used in similar ways.

Character - One of a set of elements (digits, letters, or special symbols) which may be arranged into groups to convey information. Each character may be represented by a unique group of binary digits such as in the ASCII code.

Clear - Reset to an initial condition or state. To clear memory is to reset memory to its initial state of all zero's.

Clock - A computer device which generates periodic signals. The clock may be used to synchronize internal operations of the computer.

Closed shop - A mode of operating a computer system wherein the programer may only submit his programs to the machine's operator. The programer is not permitted to exercise physical control over the computer.

CMI - Computer-Managed Instruction. In CMI, the role of the computer is to assist the teacher in planning individualized instructional sequences.

Code - (1) The representation of one set of symbols by another, e.g., ASCII is a binary code for letters, numerals, etc.

(2) Sequences of computer instructions which perform some action or computation.

Coding - To prepare a set of computer instructions to accomplish an action, task, or computation. Coding may be absolute (to be used without modification) or symbolic. Also, a sequence of computer instructions.

Compile, compiler - To prepare a machine language program from a symbolic language program by means of a computer program called a compiler. The compiler allows for the automatic translation of symbolic expressions, understandable by human beings, to sequences of instructions intelligible to the computer.

Computer - A device or instrument capable of accepting and storing information, applying a sequence of prescribed processes to that information, and making the results of those processes available.

Configuration - A particular assembly of a computer, memory input-output devices, and storage devices.

Connect time - With respect to time-sharing, it is the elapsed time of use, from the time of connecting with the time-sharing computer, to the time of disconnecting.

Contents - The information contained in a storage location.

Control panel - That part of the computer which contains indicator lights and switches, upon which the computer's operator may direct and interact with the computer.

Control unit - The portion of a computer which directs (controls) the automatic operation of the computer, controls the flow of information, interprets instructions, and initiates control signals to other portions of the computer in executing instructions

Controller - The device actually responsible for the operation (e.g., starting, rewinding, reading, etc.) of an input-output device such as magnetic tape. The controller receives its instructions from the computer and directs and controls the operation of the specified device. A controller can usually control several devices of the same type.

Core memory - A fast, random-access storage device of the central processing unit; usually made of many small ferromagnetic rings (cores) strung on wires in a matrix of arrays.

CPU - Central Processing Unit. *See entry for Central processor unit.*

Crash - Refers to a computer or program failure which prevents further or continued normal operation.

Current page - In computers which have their memories divided into pages, it refers to the memory page which contains the current instruction being executed.

Cycle - (1) A sequence of operations regularly repeated.

(2) The time it takes for one sequence to occur, i.e., cycle time.

Cycle stealing - When a device prevents the CPU from reading or writing into memory so that it can read or write memory itself.

Data - A collection and representation of information and facts by alphabetic and numeric characters, which can be processed or produced by a computer.

DATA-PHONE - A trade mark of the Bell System for the data sets they manufacture and supply. DATA-PHONE service is the Bell System service mark for the transmission of data over the regular telephone network.

Data set - A device which permits a terminal to receive and transmit information over telephone lines. Data sets, generally, are not portable.

Debug - To locate and to remove errors (bugs) or mistakes in a computer program.

Diagnostic - A program or series of programs supplied by the computer manufacturer, used to detect, identify, and locate malfunctions in the computer itself and attached input-output devices.

Direct memory access (DMA) - A means (or feature) which permits the direct transferring of blocks of data between an external storage device and the computer's memory. Some computer manufacturers include DMA in their basic price while others will supply DMA at additional cost. DMA is necessary for devices such as magnetic tape drives or disk-drive systems.

Disc/disk - A magnetically coated platter (disk) for the storage of information. A removable disk is termed a diskpack. A disk will require a device called a "controller" for operation with a minicomputer. Generally DMA will also be required.

Double precision - Data requiring two adjacent memory locations (or words) to gain greater accuracy than would be available from a single word or location.

Downtime - The time during which the computer system is unavailable for use because of equipment malfunction. Downtime is a measure of the reliability of the computer system. As a general rule the larger and more complex a computer system is, the greater will be its expected downtime.

Driver - An input-output program to provide for automatic operation of a specific device with the computer.

Drum - A cylindrical device, magnetically coated, used to provide auxiliary storage for a computer. A drum is similar to the disk.

Dump - To record the contents of the computer's main memory onto an external device such as a printer or magnetic tape.

Duplex - A communications link which permits two-way operation.

(1) Full duplex: Two-way communication simultaneously

(2) Half duplex: Communication one-way or the other, but not both ways simultaneously.

Effective address - The address that is derived by applying any specified indexing or indirect addressing rules to the address part of the instruction. The effective address is the address of the location actually used by the instruction.

Enable - To set a signal or condition which will permit a specified event to proceed, whenever it is ready to do so.

Error - The difference in value between a computed or measured quantity and its known or theoretically correct value.

Execute - To carry out or perform a specified operation such as an instruction or program.

Execute cycle - A state of the internal logic which causes the computer to carry out a sequence of elementary steps to produce the results specified by the instruction.

Execution time - The length of time the computer is actually processing the user's program. With respect to timesharing, the execution time will generally be a fraction of the connect time.

Executive control program - A main system program designed to establish priorities and process and control the execution of other programs. It provides a degree of automation to the operations and management of a computer system. It is also synonymous with monitor, operating system, and supervisory control program.

File - An organized collection of related information items to be treated as a unit. A program, the student attendance records, or an inventory list are examples of files.

Fixed point - A numerical representation or arithmetic system in which the radix (fractional) point always appears in a constant, predetermined position.

Flag - An indicator of a signal or condition recognized by the computer, e.g., printer ready flag. A flag will generally be in one of two states (binary) - set or reset, on or off.

Floating point - A numerical representation and system of arithmetic in which quantities are expressed by a fraction (mantissa) and some power of the radix (exponent or characteristic). Thus the implied radix point may be shifted by adjusting the exponent. Minicomputers do floating point arithmetic by software rather than by hardware, although some have floating point hardware.

Flow chart - A graphic representation of an algorithm or procedure in which symbols are used to represent individual operations. The lines interconnecting the symbols represent the flow of information.

FOCAL - FOrmula CALculator. A proprietary language developed by Digital Equipment Corporation for use on their PDP-8 series of computers. FOCAL is similar to BASIC but has greater capabilities.

FORMAT - A predetermined arrangement of bits, characters, and groups of characters into a specified pattern.

FORTRAN - FORmula TRANslator. A programing language developed to express numerical problems with an algebra-like notation. If a FORTRAN compiler exists for a minicomputer, it generally requires at least 8,192 storage locations and operates in single-user batch mode.

Frame - The recording position across the width of paper-tape, perpendicular to the direction of its travel.

Full duplex - *See entry for Duplex.*

Gap - An interval in space or time associated with the processing of data. A gap may be used to separate units of data (records) or to signal the end of a group of data units (file).

Garbage - The production or recording of unwanted and meaningless information in some memory or storage area.

General purpose computer - A computer designed to handle a wide variety of problems by means of programs stored in its memory.

Half duplex - *See entry for Duplex.*

Hardcopy - Refers to any computer-generated output which can be meaningfully interpreted by humans. Most commonly it refers to printed output.

Hardware - Physical equipment, mechanical, magnetic, and electronic devices which compose the computer system. Hardware is in contrast to software (computer programs).

Head - The electromagnetic device which writes, reads, or erases data on magnetic recording devices, such as a disk, tape, or drum.

Heuristic - An intuitive approach to problem solving in which an evaluation of the progress made toward the desired result is used in discovering the solution.

Hexadecimal - A positional number system employing the base 16. The hexadecimal digits are represented by 0 through 9 and A, B, C, D, E, F.

High-level language - Any programing language capable of expressing an algorithm or procedure more concisely than assembly language. BASIC, ALGOL, and FORTRAN are common examples of high-level language.

Hollerith - A 12-bit character code for recording information on punch cards.

Index register - A memory device containing an index value for modifying an instruction address prior to or during the instructions execution.

Initialize - To set registers, switches, and memory locations to prescribed starting values.

Input - The data or information supplied to the computer for processing. A device containing data for input to the computer is termed an input device.

Instruction - A set of bits which cause the computer to perform a specified operation. An instruction consists of three parts: an operation code, an address part, and address modifiers.

Interface - A common boundary between two devices having different functions. The interface may be as simple as a connector plug or a complex device in itself.

Interpreter - A program for a user language (e.g., BASIC or FOCAL) translation, which translates and executes each statement before translating and executing the next one.

Interrupt - A hardware feature which allows the computer to break its normal sequence of instructions to process data that requires its immediate attention. The normal sequence can be resumed later.

I/O - An abbreviation for input-output, i.e., transmission to and from the computer. It also refers to devices such as a teletypewriter.

K - Signifies the prefix "Kilo" meaning a thousand. When used in connection with computers it denotes 1024 rather than 1000. Thus, a 4K memory implies 4 x 1024 or 4096 memory locations.

Label - An arrangement of alphanumeric symbols used symbolically to identify an instruction, a group of instructions, a program statement, a quantity, a data area, or a program.

Language - A set of symbols, rules, and conventions for combining symbols used to generate statements for the purpose of conveying information. A programing language is used to express algorithms or procedures for use by a computer.

Library - A collection of commonly used programs, such as a SINE program. The computer manufacturer may supply a basic library of programs and the users will contribute additional programs.

Line printer - A printing device capable of printing an entire line of characters all at once. A teletypewriter prints one character at a time and hence is not a line printer.

Linkage - A means of connecting and communicating information between two separate programs.

Load/loader - To read into memory a binary program under the control of a *loader* program.

Locations - Refers to a position in storage (or memory) uniquely specified by an address. A location, usually, is a full computer word.

Logical - Pertains to the boolean algebra with the operations "AND," "OR," "NOT" and the values "TRUE" and "FALSE." All minicomputers include logical operations in their capability.

Loop - A sequence of instructions whose execution is repeated a specified number of times.

Machine - Referring to the computer.

Machine language - The most elementary binary language which contains no symbolic information. Machine language is directly acceptable to the machine. *See entry for Absolute.*

MACRO - An advanced assembly language feature which can generate many machine-language instructions from a single MACRO instruction.

Magnetic core - *See entry for Core memory.*

Magnetic disk/drum - *See entries for Disk and Drum.*

Magnetic tape - A widely used storage medium, consisting of a magnetically coated plastic tape. It is similar to the magnetic tape used in home tape recorders.

Mainframe - Refers to the computer CPU as distinct from any associated peripheral equipment.

Maintenance - The necessary support to keep the computer (also large programs such as compilers) in good working order. A separate maintenance contract is usually required for purchased equipment while rental or lease prices usually include maintenance.

Mark sense - A means of recording information on a media, such as a punch card, with a pencil or marking device, as opposed to punching holes in a card. Also pertains to the device capable of reading from mark sense media.

Memory - A device for storing information in a form that can be accessed by the computer hardware.

Memory cycle time - The minimum length of time between two successive accesses to the memory device.

Memory protect - *See entry for Storage protect.*

Minicomputer - A small-scale, general-purpose digital computer with a word length of from 12 to 18 bits, the most common length being 16 bits. A major characteristic of minicomputers is their low price, less than $10,000 for the CPU. In many respects they are very similar to their larger cousins.

Mnemonic - Abbreviations, for the symbolic instructions of the computer, designed to assist human memory.

Mode - Refers to the method of operations: time-sharing vs. batch, open shop vs. closed shop, fixed point vs. floating point, etc.

Modern - Synonymous with data set. *See entry for Data set.*

Monitor - *See entry for Executive control program.*

Multiplexor - A device for sampling several input (output) channels and interleaving their signals on a single output (input) channel. A multiplexor may give the appearance of simultaneous communications, as in time-sharing.

Normalize - A computer operation which automatically shifts left so that a maximum number of bits are accommodated in a specified register or location. The normalize operation is usually associated with floating-point arithmetic.

Object code - The absolute or binary output of a compiler or assembler, as opposed to a source or symbolic program. The object code is in a machine language form.

Octal - A positional number system employing base 8. Binary numbers are easily expressed as octal numbers by expressing successive groups of three binary digits as a single octal digit.

OEM - Original Equipment Manufacturer: The manufacturer who supplies equipment to be included in a second manufacturer's product line. For example, the Teletype Corp. is the OEM supplier of the teletypewriters supplied and sold by most minicomputer manufacturers. Most computer manufacturers' OEM peripheral equipment come from manufacturers who specialize in the design and manufacture of computer peripheral equipment.

Offline - Refers to the use of peripheral device independently of the computer. A teletypewriter may be used offline to punch a program onto paper-tape.

One's complement - Refers to the binary value obtained in subtracting the original value from a string of all one's. A computer generates the one's complement by changing one's to zero's and zero's to one's.

Online - Pertains to a peripheral device used under the control of the computer.

Open shop - A mode of operating a computer system whereby the programer may exert physical control over the computer. *See also entry for Closed shop.*

Operand - The quantity or data specified in an instruction to be processed.

Operating system - *See entry for Executive control program.*

Operation code - The part of an instruction specifying the operation to be performed.

Output - The data or information (or the process itself) transmitted from the computer to a peripheral device.

Overflow - The condition arising in which the quantity generated exceeds the capacity to store it. In an arithmetic operation it refers to a number generated which is too large to be contained in a register or storage word.

Packed word - Compressing two or more independent information units for storage in a computer word; for example, storing two ASCII characters in a word, or converting several words of decimal digits to a single binary integer.

Page - A segment of memory with a fixed number of storage locations, dictated by the direct addressing range of memory referencing instructions. Generally all minicomputers have their memories segmented into uniform size pages. Depending upon the manufacturer, the page size will vary from 128 locations to 1024 locations.

Page zero - Page zero is the lowest numbered page in a segmented (paged) memory. Usually instructions in any page may reference page zero. In some minicomputers, page zero may have special addressing characteristics. *Also see entry for Current page.*

Panel - *See entry for Control panel.*

Pass - One complete cycle in processing a set of recorded information. Typically, assemblers and compilers require two or three passes over the source program.

Parity - An error detection technique in which a bit (parity bit) is appended to a byte, character, or word so that the number of bits in the information unit is either even (even parity) or odd (odd parity). By this means it is possible to detect errors in transmitting information to and from a computer, its memory, or an external device.

Perforator - A paper-tape punch is sometimes referred to as a perforator.

Peripheral - Input and output equipment which transmits information to and from the central processor units (including memory) is referred to as peripheral devices, peripheral equipment, or peripherals. Examples would be magnetic tape reader, high speed paper-tape punch, teletypewriter, etc.

POL - Abbreviation for Problem Oriented Language. *See entry for Problem-Oriented Language.*

Port - The electronic facility for connecting the computer to a telephone line through a data set.

Preventive maintenance - Maintenance performed to detect possible faults before they actually occur. The intention of preventive maintenance is to reduce the likelihood of faults occurring during normal operations of the computer system.

Priority - The automatic regulation of events so that specified activities will be taken over other activities with respect to time.

Process - A sequence of related activities and manipulations on information for a specific purpose.

Processor - Synonymous with central processing unit.

Problem-oriented language - A programming language designed to conveniently express a class of related problems, e.g., BASIC and FORTRAN and languages for mathematical problems, while COBOL is a language for business problems.

Procedure-oriented language - Synonymous with problem-oriented language.

Program - A computer program is a plan for and the construction and arrangement of the necessary statements, instructions, and data to achieve the solution to a specific problem by the use of a computer. A program will include all the necessary steps and instructions needed to solve a given problem by means of the computer.

Program library - The collection of available computer programs. *Also see entry for Library.*

Program listing - A computer-printed record of the instructions in a program. A compiler or assembler will usually produce a copy of the program (program listing) indicating any instructions that are in error.

Programer - A person who writes or specifies a computer program; a professional person who engages in writing programs.

Programing - The act of creating a computer program.

Pseudo-instruction - A symbolic instruction which has the same general form as a computer instruction, but which is not executed by the computer. The purpose of a pseudo-instruction is to supply information to the assembler or compiler about the program itself.

Punched card - A card punched with a pattern of holes to represent information. A punched card can be read by an input device (connected to the computer) called a card-reader. A punched card is commonly called an "IBM card."

Punched paper-tape - A strip of paper on which information is punched as a pattern of holes. Paper-tapes are perforated by a paper-tape punch and read by a paper-tape reader. Punched paper-tape is the most common form of external storage used with mini-computers.

Pushdown list - A list that is constructed and maintained in such a manner that any item retrieved from the top of the list was the last item stored. Pushdown lists are very useful for compilers and interpreters and in the evaluation of arithmetic expressions. Some mini-computers have instructions specifically for the manipulation of pushdown lists, while those that do not achieve the same result using a sequence of instructions. Pushdown lists are sometimes characterized as "last-in, first-out."

Queue - A list constructed and maintained such that the next item to be retrieved is the oldest item in the list. Queues are sometimes characterized as "first-in, first-out."

Radix - Synonymous with base.

Random access - The ability to access information from a storage device, rapidly and independently of the previous access. Core memory, magnetic drums, and disks are examples of random access devices, while magnetic tape and paper-tape are examples of sequential access devices.

Reader - Refers to input devices such as a card reader or paper-tape reader.

Read only memory - A storage device whose information can be accessed but not altered. Information is stored in the read only memory by the manufacturer and not changed nor destroyed by a computer program. Micro-programed computers such as IBM's 360 series, Interdata's 14, Micro System's 810, etc., employ read only memory as part of the computer's design. Some minicomputer manufacturers offer a read only memory with the bootstrap program.

Record - A collection of related information units or data items which is treated as a unit. An assembly language instruction, all information pertaining to an inventory item, a line containing a BASIC statement would all be considered a record. A collection of records constitutes a file.

Register - A device within the computer used to store information temporarily and to manipulate the contained information. A computer contains several registers interconnected and under the control of the control unit. Registers are used in a variety of computer operations such as arithmetic, logical, and transfer instructions.

Relocatable - Refers to programs which can be placed anywhere in the computer's memory. However, programs which are relocated must have the address references of instructions suitably modified. A relocating loader must be able to make the appropriate address modifications.

Remote access - Communicating with a computer by means of a terminal located some distance from the computer site. The communication is usually accomplished by means of a telephone line. Time-sharing is the most common example of remote access.

Remote terminal - A device for communicating with a remote access computer facility. A remote terminal must be convenient for humans to use and yet communicate in a manner acceptable to the remote computer. A teletypewriter is a very common example of a remote terminal.

Reset - To restore to an initial state or condition.

ROM - An abbreviation of Read Only Memory.

ROS - Read Only Storage, synonymous with read only memory.

Rotate - A (right or left) shift of all bits in an accumulator in which bits lost off one end of the accumulator are carried around to enter the vacated bit positions at the other end.

Routine - A sequence of computer instructions which accomplish a limited task. A program may use several routines. Routines which have a common use among several users may be placed in a library of routines for ready access by other users.

Sequential access - Refers to a facility or device in which all information must be scanned, up to the desired item, before an access is made.

Set - To establish a condition or value, e.g., to set a counter to the value one, to set a switch on, etc.

Shift - A serial motion of bits in a register (right or left). In some types of shifts, bits shifted off the end of a register are lost, while in other types of shifts, bits shifted out of a register end re-enter at the other end.

Sign - A symbol or bit occupying the sign position, indicating an algebraically positive or negative number.

Significant digit - A digit which contributes to the precision of a number. The most significant digit is the leftmost nonzero digit.

Simulate - By means of a computer program and computer, represent the functioning and behavior of another computer, device, or physical, biological, or social system.

Software - Compilers, assemblers, supervisory routines, programs, routines, and documentation used in the operation of a computer system; the collection of programs as opposed to the computer hardware.

Source language - A program written in symbolic form for input to an assembler or compiler. A source language program will be translated into an object program (in machine language).

Starting address - The address of the first instruction of a program stored in the computer's memory. Minicomputers often require programs to be started by entering the program's starting address.

Statement - A meaningful expression or instruction in some symbolic programing language.

Storage - The facility and devices for retaining information, within the computer system, for later retrieval by the computer. Core memory, magnetic drums, disks, and tape are all examples of storage devices.

Storage protect - A hardware feature which prevents the inadvertent destruction of stored information. Different types of storage devices have their own kinds of protection mechanism.

Subroutine - A sequence of instructions designed to accomplish a specific task. A subroutine also includes the instructions necessary for other programs to make use of it. Subroutines which are widely used are usually placed in the program library. Subroutine, subprogram, and routine are used synonymously.

Subprogram - *See Subroutine.*

Supervisor - *See Executive control program.*

Symbol table - A table of symbolic labels and their corresponding numeric values.

Symbolic address - An address expressed in terms of symbols, convenient to the programer, which will be translated into an obsolute address by a compiler or assembler.

Symbolic coding - Usually refers to symbolic assembly language coding, in which instructions and addresses are represented symbolically rather than in absolute or numeric language.

Symbolic editor - A program designed to facilitate the corresponding and updating of other source programs by permitting automatic test editing features. These features might include adding, deleting, searching, and inserting of symbolic text.

Syntax - The structure and the rules governing the structure of expressions or sentences in a language. Programing languages have their own definite syntactic rules for construction or analysis of valid sentences.

System - The collection of hardware components, software, and programs organized to function as a unit.

Systems house - A company which specializes in the design and integration of computer equipment and software for special purpose applications. Systems houses can often provide devices and interfaces for a given computer which the computer's manufacturer does not offer.

Table - A collection of data items in which each item is uniquely identified by a label or by its relative position within the table.

Teletype - A trademark of the Teletype Corporation for the teletypewriters they manufacture and supply. Teletypes are manufactured in a number of models for various communication applications. The nomenclature most closely associated with the teletypewriters commonly used with minicomputers and time-sharing is as follows:

KSR:	**Keyboard Send Receive** - refers to the basic teletypewriter which includes a keyboard and printer mechanism.
ASR:	**Automatic Send Receive** - refers to the paper-tape reader and punch attached to the keyboard-printer teletype.
Model 33:	Standard duty model, i.e., moderate service life, and using the ASCII code.
Model 35:	Heavy duty model, i.e., heavy duty use and longer service life, and also uses the ASCII code.

Thus, an ASR Model 33 is a standard duty teletype terminal consisting of a keyboard, printer, paper-tape reader, and punch. It is the most commonly encountered input-output device for minicomputers and time-sharing. There are additonal features which may or may not be required in a particular application.

Teletypewriter - Refers to any typewriter-like device used to communicate electronically with a computer or other similar device. Generic for the teletype or other similar keyboard printer device. "Teletypewriter" is frequently abbreviated to TTY.

Terminal - Any device designed for humans to communicate (two way) with other humans or with a computer.

Time-sharing - A mode of operating a computer system in which several users obtain interleaved use of the computer system. To each user, it appears as though he is the sole user of the computer.

Translator - A computer program which accepts input, usually in symbolic form, and transforms it to an object form. Assemblers and compilers are examples of translators; they accept a symbolic language program and produce an object language program.

Trap - An unprogramed conditional branch to a known location. It is automatically initiated by the hardware due to some new condition being sensed by it. The location from where the trap occurred is automatically stored in memory.

Truncate - To terminate a computational process according to some rule.

TTY - A common abbreviation for a teletypewriter or a teletype.

Two's complement - The radix or base complement in binary notation. A binary numbering convention for positive and negative numbers such that subtraction can be accomplished by the addition of the two's complement. Computers generate the two's complement by adding one to the one's complement (inverting one's and zero's).

User - One who makes use of a computer system.

Utility program - A standard program or routine which accomplishes some basic function in the operation of the computer system. Typical of utility routines are loaders and programs for the reading and writing of peripheral devices.

Variable - A symbolic representation of a quantity which can assume any one of a given set of values.

Word - A set of bits comprising the common unit which the computer manipulates. Minicomputers have word lengths of from 12 to 18 bits. Some computers can also manipulate subword units such as the character, byte, and half-word.

Write - To deliver and record information on a storage device or medium such as a magnetic tape.

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