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Feasibility Study for a Remote Terminal Central Computing Facility Serving School and College Institutions. Volume II, Preliminary Specifications.

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Preliminary specifications of major equipment and programing systems characteristics for a remote terminal central computing facility serving 25-75 secondary schools are presented. Estimation techniques developed in a previous feasibility study were used to delineate workload demands for four model regions with different numbers of institutions and total enrollments. The general design features of a system capable of meeting estimated demand patterns was then described and equipment specifications (e.g., number of terminals, storage capacities, printer-reader speeds) were developed for each model region. Detailed descriptions of operational characteristics and schematic illustrations of the configuration of specified central site and control and communication are included. (SS)

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Feasibility Study for a Remote Terminal Central Computing Facility Serving School and College Institutions Volume II: Preliminary Specifications

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Section 1: INTRODUCTION

This preliminary system specification defines the major equipment and programming system characteristics required for the central site and for the equipment at the schools, colleges, and administrative center locations. Since the preliminary specifications have been developed from studies of hypothetical model regions, details will be reviewed and modified as necessary to meet the requirements of a specific regional area.

Section 2: WORKLOAD

The workload requirements of the system will include problem-solving functions, data processing training, and administration tasks. Volumes have been established per 1000 students enrolled. Model regions having a mix of school sizes are shown in Table 1. Data processing equipment and communication network configurations are specified later in this section for each model region. Although these regions are hypothetical, they represent typical school mixes within the total U. S. enrollment.

Table 1. MODEL REGIONS

	A		B		C		D	
Students per Secondary School	No. of Loc's	Total Enrolled	No. of Loc's	Total Enrolled	No. of Loc's	Total Enrolled	No. of Loc's	Total Enrolled
500	2	1,000	3	1,500	5	2,500	-	-
1,000	5	5,000	10	10,000	15	15,000	-	-
1,500	6	9,000	14	21,000	20	30,000	-	-
2,000	10	20,000	20	40,000	30	60,000	50	100,000
2,500	2	5,000	3	7,500	5	12,500	-	-
Total enrolled 9-12	25	40,000	50	80,000	75	120,000	50	100,000
Total enrolled K-8	-	120,000	-	240,000	-	360,000	-	300,000
Total enrolled K-12	-	160,000	-	320,000	-	480,000	-	400,000
Total enrolled Jr. College (2,000 students per college)	1	2,000	2	4,000	3	6,000	2	4,000
Grand Total	26	162,000	52	324,000	78	486,000	52	404,000
District Admin. Centers	1	-	2	-	3	-	2	-

Section 3: WORKLOAD PROCESSING

The system will be capable of processing the stated workloads within a 300-hour-per-month period for model regions A and B. For region C and the USOE model region, the system will be capable of processing the stated workloads within a 400-hour-per-month period. These workloads will be applicable nine months per year; for the remaining three months, the system will operate during a single shift of 176 hours per month. (Monthly utilization figures are based on typical economic usage of systems of this size.)

3.1 PROBLEM SOLVING

Tables 2 and 3 show the remote terminal problem-solving workload. (The secondary school workload assumes that 80% of the students are paired during a session at the terminals, and 20% of the students are alone. The junior college workload assumes that all students are alone at the terminal. A problem session is assumed to be 20 minutes long with a turnaround time of no more than five (5) minutes.) The system will also possess a 100% overload capability for batch processing the same total number of problems as defined for remote terminal problem solving. This capability will be available to the student at the central site by batched job entry and sequential job processing. However, in the batch mode, all problems are assumed to be individually prepared.

Table 2. REMOTE TERMINAL PROBLEM SOLVING

(Secondary School Requirements per 1000 Students Enrolled)

Grade	No. Students in Grade	Course	Students in Grade		Annual Problem Sessions			
			%	No.	No./ Course	Tot. Ind.	Tot. Paired	Grand Total
10	333	Geometry	40	133	10	266	532	798
		Biology	80	266	10	532	1064	1596
		Algebra I	20	67	5	67	134	201
		Grade Total	-	-	-	865	1730	2595
11	333	Elem. Functions	25	83	20	332	664	996
		Algebra II	25	83	10	166	332	498
		Chemistry	37	123	10	246	492	738
		Grade Total	-	-	-	744	1488	2232
12	333	Elem. Functions						
		Calculus	12	40	30	240	480	720
		Gen. Math	12	40	5	40	80	120
		Physics	25	83	15	249	498	747
		Grade Total	-	-	-	529	1058	1587
		School Total				2138	4276	6414

3.2 DATA PROCESSING TRAINING

Jobs produced by students enrolled in data processing training will be batch-processed and entered at the card reader attached to the administrative terminal in the school or at the central site. Tables 4 and 5 show the volume estimates for data processing training.

Table 6 summarizes the instructional workload for both problem solving and DP training.

3.3 ADMINISTRATIVE PROCESSING

The administrative workload is shown in Table 7. Administrative jobs requiring entry from a remote terminal for high-priority batch processing will be differentiated from those administrative jobs entered at the central site. High-priority batch jobs will be run in the multiprogrammed mode when the central processing unit is not processing the problem-solving workload. The remainder of administrative tasks will run in batch mode after school hours during the second and third shifts.

Table 3. REMOTE TERMINAL PROBLEM SOLVING

(Junior College Requirements per 1000 Students Enrolled)

Grade	No. Students in Grade	Course	% of Students in Grade	Students in Grade	No. Probs. per Year	Annual Total
13-14	1,000	Math A	10	100	20	2,000
		Math B	15	150	15	2,250
		Math C	25	250	10	2,500
		Physical Science	10	100	15	1,500
				Total		8,250

Table 4. DATA PROCESSING TRAINING

(Secondary School Requirements per 1000 Students Enrolled)

Grade	No. Students in Grade	Course	% of Students in Grade	Students in Grade	No. Probs. per Year	Total Annual Problems
10-12	1,000	Computer Concepts	15	150	4	600
11-12	667	Basic Programming	7.5	50	6	300
12	333	System Design	3	10	4	40
12	333	Business System Programming	3	10	4	40
		School Total				980

Table 5. DATA PROCESSING TRAINING

(Junior College Requirements per 1000 Students Enrolled)

Grade	No. Students in Grade	Course[1]	% of Students in Grade	Students in Grade	No. Probs. per Year	Total Annual Problems
13-14	1,000	Computer Concepts	15	150	4	600
13-14	1,000	Basic Programming	10	100	6	600
14	500	System Design	10	50	4	200
14	510	Business System	10	50	4	200
		School Total				1,600

Table 6. INSTRUCTIONAL WORKLOAD SUMMARY

Model Region	No. of Schools	Problem-Solving Sessions		DP Training Problems	
		Annual	Daily	Annual	Daily
A					
Secondary School	25	256,560		39,200	
Junior College	1	16,500		3,200	
Total	26	273,060	1,517	42,400	236
B					
Secondary School	50	513,120		78,400	
Junior College	2	33,000		6,400	
Total	52	546,120	3,034	84,800	472
C					
Secondary School	75	769,680		117,600	
Junior College	3	49,500		9,600	
Total	78	819,180	4,551	127,200	708
D					
Secondary School	50	641,400		98,000	
Junior College	2	33,000		6,400	
Total	52	674,400	3,747	104,400	580

Table 7. ADMINISTRATIVE WORKLOAD (1 of 2)

Major Tasks & Master Files	Time Period	Master Files		Activity	
		Read	Write	Input	Output
Remote Entry Processing:	(volume per 1000 students)				
1. Attendance	Daily				
-Student File		200	200	200	200
2. Guidance	Daily				
-Student File		80	-	80	80
3. Registration	Daily				
-Student File	-	10	10	20	20
-Census File	-	10	10	-	-
-Class File	-	20	20	-	-
Major Batch Entry Tasks:	(volume per 1000 students)				
1. Student Processing					
-Attendance	Monthly				
Student File		1,000	1,000	-	1,000
-Report Cards	Quarterly				
Student File		1,000	1,000	200	2,000
-Student File Org.	Annual				
Student File		1,000	1,000	-	-
-Student Scheduling	Annual				
Student File		1,000	1,000	-	5,000
Course File		200	200	-	800
-Testing	Weekly				
Student File		-	-	1,000	2,000
-Census	Annual				
Central File		1,000	500	500	1,000
2. School Administration					
-Supplies Requisition	Weekly				
Supply File	-	50	50	50	50
Budget File	-	5	5	5	-
Requisition File	-		5	50	50
-Budget	Weekly				
Budget File	-	30	-	-	30
	(volume per center)				
3. Central Administration					
-Enrollment Projection	Semi-Annual	25,000	-	-	500
Census File					
Student File	-	25,000	-	-	-

Table 7. ADMINISTRATIVE WORKLOAD (2 of 2)

Major Tasks & Master Files	Time Period	Master Files		Activity	
		Read	Write	Input	Output
-Personnel Processing	Monthly				
Applicant File	-	120	60	60	180
Substitute File	-	600	600	600	600
Employee File	-	5,000	5,000	1,250	10,000
-Fiscal Operation	Monthly				
Budget File	-	6,000	2,500	3,500	10,000
Vendor File	-	2,000	1,000	2,000	2,000
Order File	-	500	500	500	1,000
Warrant File	-	350	350	350	1,050
Maintenance File	-	2,000	2,000	2,000	3,000
-Property	Monthly				
Audio-Visual File	-	1,000	1,000	200	1,000
Supply File	-	10,000	8,000	8,000	12,000

Section 4: GENERAL DESIGN FEATURES

4.1 CENTRAL COMPUTER

4.1.1 Adequate Internal Speed. Able to service all terminals installed with adequate response time, without excessive unused CPU capabilities, and be capable of handling data rates of input/output devices.

4.1.2 Adequate High-Speed Storage. Able to store the required program, with terminal-user work areas, so as not to slow the response time excessively because of too much storage swapping with external devices.

4.1.3 Adequate Secondary Direct Access Storage. Able to store all data files, workspaces, and program library in a device with appropriate access times and character rates to the task required.

4.1.4 Terminal Line Input/Output Capabilities. Able to enter data from communications lines, originating from terminals, with automatic response capabilities back to the originating terminal. Able to send to administrative terminals on an unattended basis. An adequate number of lines must be able to be attached, with flexibility for growth over a reasonable period.

4.1.5 High-Speed Input/Output Capabilities. Able to read data from cards or magnetic tape at high speeds at the computer center, and punch cards or print reports at high speeds.

4.1.6 Mark-Reader Capabilities. Able to read documents, on which data has been encoded through marking in appropriate positions. The rate of reading must be adequate for the workload projected as necessary for this device, without requiring excessive operator time during use.

4.1.7 Operating System Capabilities. Able to run under the control of an operating system; capable of controlling the operations of many devices simultaneously.

4.1.8 Program Language Capabilities. Able to be programmed using such high-level languages as FORTRAN, COBOL, and PL/I.

4.1.9 Low Cost (Price/Performance). Cost commensurate with the quantity of work required, and capable of being produced.

4.2 SHARED-LINE CAPABILITY

4.2.1 Ability to use a single communication line, of minimum cost, for more than one low-speed terminal device.

4.2.2 Total price of shared-line device, plus the line, must result in economies over separate lines for each terminal.

4.2.3 Must not introduce any complications in the operations of the terminal, in any respect.

4.3 INSTRUCTION TERMINAL

4.3.1 Ease of use for conversational problem solving. Terminal operation must be efficient and straightforward.

4.3.2 Rate of Data Transfer. Transmit and receive data at a rate commensurate with the reading rate of the student when undertaking problem-solving tasks. This will be at approximately 15 characters per second.

4.3.3 Reliability. Relatively trouble-free and easy to maintain.

4.3.4 Durability. Must stand up under moderately heavy use, and possible abuse.

4.3.5 Portability. Must be easily relocated by teachers and students and connectable to phone jacks provided throughout the school.

4.3.6 Capable of Using Multiple Character Sets. Various users -- administrative, problem-solving, DP training -- require more than one character set.

4.3.7 Hard Copy. Data entered and data received must be printed to permit student review of material covered at a later time.

4.3.8 Low Cost (Price/Performance). Given all of the above qualities, the terminal must be available at a cost within the school's ability to pay.

4 4 ADMINISTRATIVE TERMINAL

4.4.1 Ease of Use without Special Training. Advantage must be taken of current skills and training.

4.4.2 Typewriter Input. Must transmit data at approximately the maximum typing speed of a skilled typist.

4.4.3 Reliability and Durability. Must be especially rugged, capable of prolonged output at maximum speed, and inexpensive to maintain.

4.4.4 Hard-Copy Output. Must be able to produce printed hard copy on an attended or on an unattended basis. Printing speed must be adequate to accomplish the output requirements with adequate overload capabilities.

4.4.5 Capability of Automatic Card Input and Output. Must be able to input data on the terminal from decks of punched cards, automatically fed. In addition, must have punched-card output capabilities.

4.4.6 Low Cost (Price/Performance). Given all the above qualities, the terminal must be available at a cost within the school's ability to pay, even for the smallest secondary school.

Section 5: GENERAL EQUIPMENT SPECIFICATIONS

5.1 The computing system is a medium- to large-scale central processing unit with connections for a variety of input and output devices. Figure 1 shows a diagram of the system components. Table 8 summarizes equipment characteristics by category of model region.

5.2 General requirements for both central site and school equipment are modularity, compatibility, low cost, and balance of device performance within the system. These requirements will be satisfied with equipment that is generally announced for availability within a two- (2) year period.

5.3 In establishing equipment configuration and programming packages for each central site, the data processing manufacturer will emphasize system compatibility.

5.4 Because of potential student population growth or decline within a given region, a central site equipment change will be possible without a substantial reprogramming effort. As terminals in schools are added or deleted because of population adjustments or changes in course material requirements, adjustments must be readily adapted. Furthermore, a situation may occur where geographic boundaries have been modified and a given school is now receiving data processing services from another central site. This leads to the requirements for compatibility among sites.

5.5 The favored method for achieving compatibility is through equipment selection. Equipment will be members of a program-compatible family, allowing a central site to be configured to match the projected workload changes for that site. User program libraries that exist for one particular site will be readily installed at another site with compatible equipment. Also, as substantial workload changes occur within a given site, replacement of the central processing unit with the next-level processor within the compatible family will be accommodated.

5.6 The alternate method for achieving compatibility is through programming in higher-level languages, such as COBOL, FORTRAN or PL/I. Through recompilation, machine code will be produced from standard source programs. This method implies: (1) programming standards will be established for such items as data definition, and (2) equipment-dependent features will not be an integral part of the main programs. Although this method is not as desirable as that of achieving compatibility through equipment, an acceptable degree of compatibility may exist by programming with higher-level languages. Because of economic factors, 100% availability of the system is not required. However, the system will possess reasonable reliability and maintainability within the constraints of present computing technology.

5.7 The central processing unit and its associated high-speed storage will provide the operating control of the system. These units will contain the logic controls and primary storage to execute the computer program, with simultaneous control of all attached devices through data channels. The central processing unit will maintain, at any given moment, the status of each program being executed, as well as the status of each device controlled by the processing unit. Auxiliary, or secondary, storage will be provided to the central system via direct access storage devices. These devices will provide for storage and retrieval of large volumes of data in sequential or direct access modes. The direct access storage device will store the system and user program library, student programs under development, and administrative data contained in the master administrative files. The program library and data files will be capable of being accessed and used as required during the performance of each task of the computer. Further, historical data will be recorded on sequential auxiliary storage devices, such as magnetic tape, placed in shelf storage, and made available for subsequent uses as required.

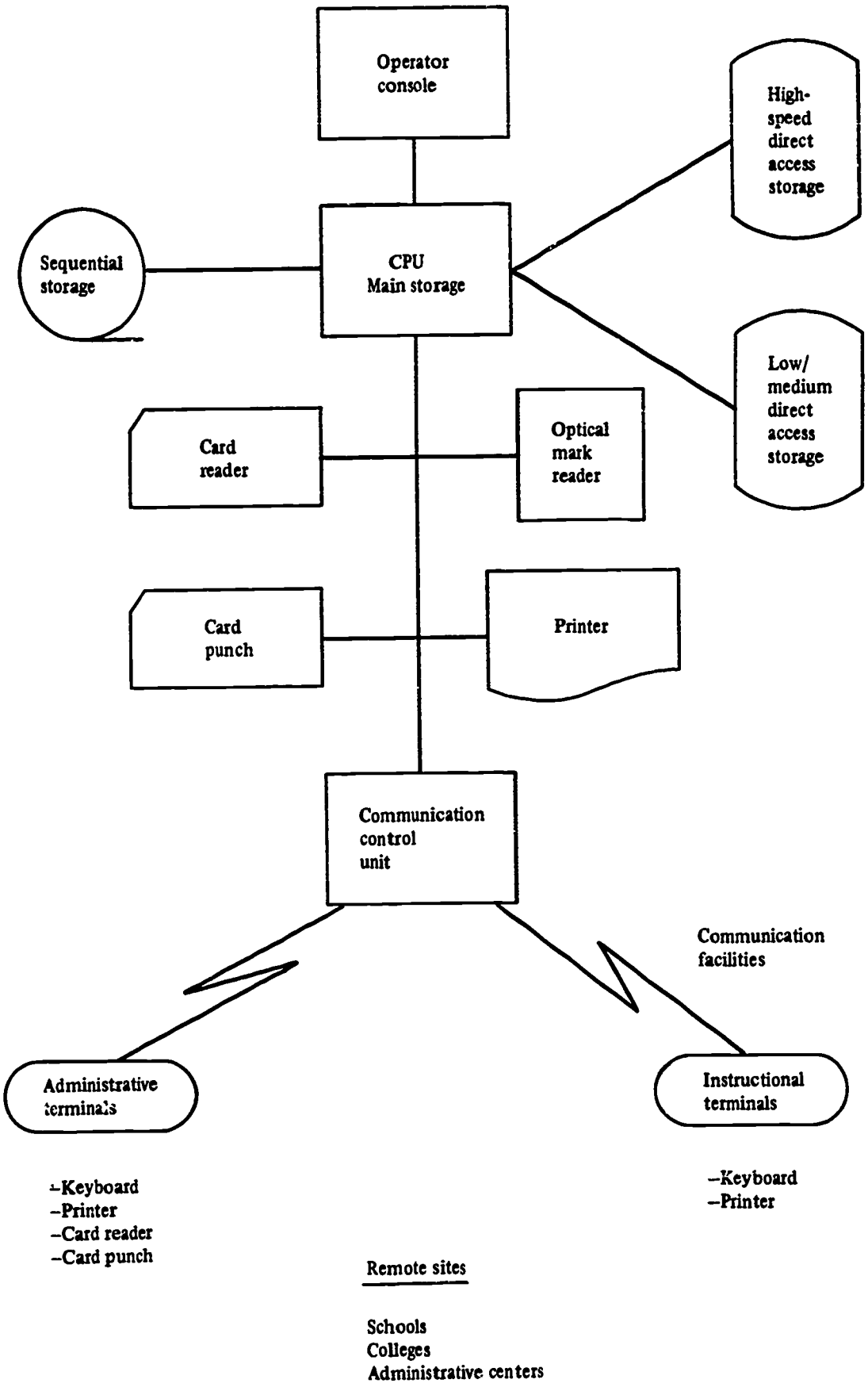

Figure 1. Equipment configuration

Table 8. EQUIPMENT CHARACTERISTICS BY MODEL REGION

ITEM	Model Regions A	B	C	D
Central Site				
-CPU (Approx. size main storage in characters)	250,000	250,000	500,000	500,000
-Direct access storage (characters)				
-High-Speed . Online	100 million	150 million	200 million	200 million
-Low/medium-speed . Online	125 million	250 million	400 million	300 million
Sequential storage units (magnetic tape equivalent)	2	2	2	2
Card input/output				
-Card input	1 @800 cpm	1 @800 cpm	1 @800 cpm	1 @800 cpm
-Card output	1 @200 cpm	1 @200 cpm	1 @200 cpm	1 @200 cpm
Printers	1 @600 lpm	1 @1000 lpm	2 @1000 lpm	2 @ 1000 lpm
Optical Mark Reader	2	3	4	4
Communication Control Unit* -Control Lines (assume one control line per terminal and local monitor terminal)	88	175	262	215
Average monthly usage (hours)				
-Summer (3 mos.)	176 hrs.	176 hrs.	176 hrs.	176 hrs.
-School year (9 mos.)	300 hrs.	300 hrs.	400 hrs.	400 hrs.
Secondary Schools*				
-Instructional terminals	55	110	165	150
-Admin. terminals	25	50	75	50
TOTAL	80	160	240	200
Junior Colleges -Instructional terminals	3	6	9	6
Administration Center Equipment -Printer/keyboard terminal	4	8	12	8

* As described in functional equipment specifications, the number of instructional terminals assumes that the administrative terminal has the characters required for instructional use. Should this capability not exist, the number of instructional terminals and control lines must be increased to meet the workload.

5.8 A high-speed card read-punch will provide for a large-volume input and output of card files at the central site. A high-speed printer will be utilized to prepare large-volume printed reports. These devices will be used primarily for the batch processing workload inputted at the central site. The batch processing workload will generally consist of processing large volumes of card input to generate printed reports, where the processing to be performed is such that it can be scheduled off prime shift, and data transmission over the communication network is not appropriate.

5.9 A communication control unit will provide the necessary connections and controls between the terminal devices at the school, via the communication network and the central processing unit. The communication control unit will provide for a two-way transmission of data messages, with character structure manipulation and recognition of special control characters that are applicable to the communication devices.

5.10 Equipment in the school will consist of computer-controlled terminals. Their number and function will depend upon the size of the student population. Depending on the functions, data entry will be via keyboard and/or punched card reader. Output from the computer will be provided by a computer-controlled typewriter providing hard copy and/or card-punch capabilities.

5.11 Common carrier facilities that provide for data transmission speeds to match job throughput required by the terminal specified will be assumed. For economic purposes, preference will be given to devices that can share a single common carrier transmission line among multiple terminals installed at one location.

5.12 Detailed characteristics for each component are described in the remainder of this specification. Certain internal physical characteristics of the equipment, such as instruction repertoire, will not be described, as these are a function of system implementation. However, the physical characteristics of speed and size will be such that overall system requirements are met.

Section 6: CENTRAL SITE EQUIPMENT

6.1 CENTRAL PROCESSING UNIT AND MAIN STORAGE

6.1.1 The organization and data representation within the central processing unit and main storage will be character-oriented with data fields of variable length. High-speed storage that has an access rate within microseconds will be of sufficient size to contain the system control program, along with communications control, input/output control and the problem programs in process of being executed. Additional storage will be made available to the central processor from auxiliary storage, to be described later. Storage size is a function of implementation; guidelines are given in Table 8 for each model region configuration.

6.1.2 The central processing unit will provide data paths and connections with input/output devices connected to the system. Input/output (I/O) devices will be controlled by channel commands that relieve the processing unit of communication directly with I/O devices, and provide for I/O operations concurrently with the central processor operations. Arithmetic capability will provide for high-speed handling of both decimal- and floating-point numbers.

6.1.3 Since the central computing system will be accessed by many schools simultaneously, the central processing unit will have the capability for multiapplication processing, which includes control switching from one core-resident program to another. This requirement leads to a multiprogramming capability that will be satisfied with sufficient equipment registers so that all status indicators of a given program will be saved to restore the program operation at a later time. In addition, the registers will obtain the status indicators of the next program to be executed. An extensive interrupt capability will be provided by the central processing unit to recognize an occurrence of interrupts from the communications network, attached devices at the central site, timer, and external sources. The processing unit will recognize equipment malfunctions and set indicators as to the source and type of error observed.

6.1.4 Since the central processing unit and main storage may contain more than one unrelated user program at any one time, a storage protection capability will be provided. The storage protection feature will provide a means of preventing one program from inadvertently modifying instruction or data areas belonging to another problem program or the system control program.

6.1.5 An interval timer will be provided to record elapsed time automatically, with the capability for the timer to be read by a program. The timer will be incremented at least every 25 milliseconds.

6.1.6 The central processing unit will include an operator's console with appropriate displays and switches for system control.

6.2 AUXILIARY STORAGE

6.2.1 Auxiliary or secondary data storage of both sequential access and direct access characteristics will be available at the central site. The sequential auxiliary storage will be satisfied by magnetic tape units, or by direct access devices that have a sequential access capability with a removable storage medium that may be placed in an offline shelf storage status for subsequent use. These devices will also be utilized for high-volume input/output data files as required. The sequential auxiliary storage device will have an efficient method of recording and reading data with records of variable lengths and of alphameric characters to achieve an efficient and economic storage medium. The number of sequential access devices depends upon the data record organization and volumes, as well as the type of direct access auxiliary storage provided.

6.2.2 Direct access storage devices will provide users with a capability for record retrieval based upon input queries submitted on a random basis. The direct access storage device will have the facilities for recording and retrieving data records, with an addressing capability for each storage location. A variable-length recording capability will be inherent in this device to provide record design flexibility as well as an efficient utilization of storage.

6.2.3 The direct access storage devices may be provided in two forms: (1) for high-speed access and data-rate transfer for those records most frequently utilized, the average access time will be typically 100 milliseconds, with a transfer rate of at least 125,000 characters per second; (2) for a medium-to-low-speed direct access device for those records that are not frequently utilized, the average access time will be typically 600 milliseconds, with a transfer rate of at least 40,000 characters per second.

6.2.4 Table 8 shows the estimated total direct access storage, excluding program library storage, required online in the system as a function of model region. Storage estimates for the program library are not provided, since these estimates are a function of a specific implementation; this storage will be in the form of high-speed, direct access storage, such as disk or drum, and will generally not be available for data storage.

6.2.5 Since many users of the direct access storage will be on a scheduled basis, large portions of this storage will be removable and replaceable with other direct access storage elements to reduce the total online storage requirement.

6.3 INPUT/OUTPUT CONTROLS AND CHANNELS

6.3.1 The central site equipment will contain the facility for the input and output of large-volume punched card files and generation of printed reports.

6.3.2 The card reader and card punch that is capable of processing 80-column punched cards and operating in an overlapped (buffered) operation with the central processing unit will be provided. The minimum-rated card punching speed will be 200 cards per minute.

6.3.3 The minimum card character coding structure for both the card reader and the card punch will represent the character graphics defined for FORTRAN by the American Standard Basic FORTRAN, X3.10-1966.

6.3.4 A high-speed line printer, with rated speeds shown in Table 8, will be located at the central site. The printer will operate in an overlapped manner with the central processing unit. The minimum printable character set will be that specified for FORTRAN by the American Standard Basic FORTRAN X3.10-1966. Characters will be spaced ten to the inch, with a minimum of 120 characters per line with line spacing of six or eight lines to the inch under operator control. Form spacing and skipping will be controlled by the program under execution in the central processing unit and/or a carriage tape on the printer. In addition, the character set of the printer will be augmented to print those characters specified for the problem-solving language, to be described later.

6.3.5 An optical mark page reader will be provided to read 8-1/2 x 11-inch marked sheets under control of the central processing unit. Rated speed will be at least 1500 sheets per hour.

6.3.6 All input/output devices attached to the central processing unit will contain sufficient controls to advise the computer as to device status (error indicators, ends of file, replenish paper supply, etc.). The attachment will be through data channels or buffers to allow a minimum of central processing unit interruption while the input/output device is operating.

6.4 COMMUNICATION CONTROL UNIT

6.4.1 The communication control unit will provide the interface between the central processing unit and the communication network. This device will provide connection for communication lines in modular increments. Table 8 contains the number of control lines required by user population. The overall requirements for this device will depend upon the number of terminals to be serviced and the distribution of processing functions between the central processing unit and the communication control unit. The specific requirements of the communication control unit may be satisfied by hardware and/or programming.

6.4.2 The communication control unit will be capable of providing connection to common-carrier switched networks, common-carrier leased networks, and privately owned networks. Communication connections will be through modems, either provided by the common carrier or data processing manufacturer and other vendors.

6.4.3 All necessary bit-to-character and character-to-bit conversion and data control will be provided by the communication control unit.

6.4.4 Line buffering will be provided either by character or by complete message. Buffering will be available for input and output communication traffic. Individual characters or completed messages will be transferred between main storage of the central processing unit and the communication control unit. Sufficient message buffer areas will be maintained in storage to meet the required response times for the terminal. At a minimum, there will be a buffer size of one character per communication line connected. The communication control unit will operate with minimum interference to the central processing unit. Transmission to and from remote terminals will occur simultaneously with processing in the central unit.
A computer-controlled typewriter terminal will be attached to the communication control unit at the central site for communication monitoring purposes.

Section 7: PROGRAMMING SYSTEMS

7.1 Many required functions of the central computing system can be met by either programming systems or computer equipment. Since many of these function assignments are applicable to a specific implementation, no attempt has been made to differentiate the manner in which the function is provided. However, the systems specifications that follow are highly programming-oriented, and are addressed within the programming system specification.

7.2 The central site system will be provided with an integrated programming system that will control the workflow through the system, provide assignments to the individual equipment components in the system, manage the data files available within the system, and provide for an extensive library of programming language processors and utility programs. Figure 2 shows a schematic of the programming system components.

7.3 The minimum functions that will be provided are as follows:

a. System Control Monitor
   - Supervise workflow
   - Multiprogramming with priority control
   - Input/output control services
   - Communication control
   - Operator messages and restart controls
   - Interrupt handling

b. Language Processors
   - Assembly Language
   - FORTRAN
   - COBOL
   - Report Generator
   - Problem-Solving Language

c. Utility Programs
   - Sort/Merge Program
   - Input/Output Utility
   - Support Operations Utility

d. System Diagnostics

e. Generalized Data Management

f. Accounting System

7.4 The following subsections describe the minimum functions that will be provided by the programming system.

7.4.1 System Monitor. The system monitor is the key control element within the programming system. All elements of the programming system will operate under control of this monitor as well as the user programs. Major functions of the system monitor are as follows:

7.4.1.1 Supervise Workload. A supervisor function will be available to maintain the operational status of all tasks within the system. This function will accept tasks to be performed, place the tasks on the input task queue, and automatically schedule their entry into the central processing unit for execution. The task scheduling will include locating the program in the program library, transferring the program to the assigned locations in main storage, and directing the program to commence execution.

7.4.1.2 Multiprogramming with Priority Control. A multiprogramming capability for controlling a minimum of two independent programs in the central processing unit will be available. One program storage area will be identified as the highest priority and will receive priority access to equipment resources as required. Should the multiprogramming function be capable of providing for more than two user tasks, a priority control that identifies the highest to the lowest priority will be provided for each program area. The monitor will automatically take control from one completed program, search the library for the next program, transfer the new program to main storage, and transfer control to the new program with minimal operator intervention. Additional requirements for defined priority storage areas depend upon a specific implementation. The multiprogramming controls will also support a conventional storage protection feature and control its functions.

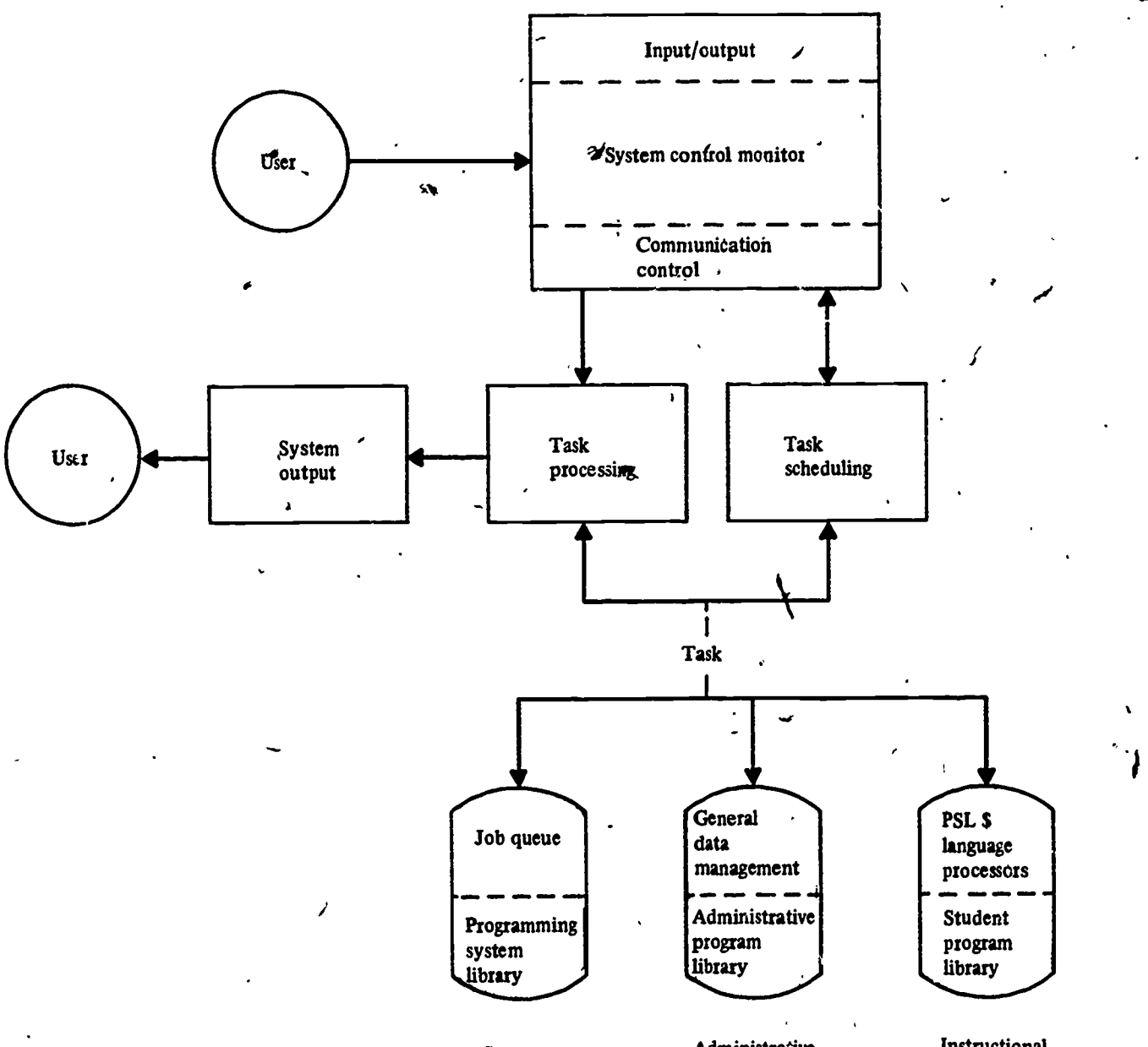

Figure 2. Programming system component flow

7.4.1.3 Input/Output Control Service. Extensive input/output control services will provide the instructions for reading and/or writing data to and from devices attached to the central processing unit. Available with the input/output services will be organization and access routines for the storage and retrieval of data records in auxiliary storage. These routines will provide capabilities for sequential file organization, direct access organization, and sequential organization with indexing that provides for record accessing in either a sequential or a direct manner. A data record add and delete capability will be included in these routines. A security check will be provided to assure that only authorized users are accessing a given data file.

7.4.1.4 Communication Control. The monitor will also include an extensive set of routines to control the communication control unit. These routines, which will normally operate in a multiprogramming environment as the highest-priority program, will provide the necessary instructions to transmit, receive, and post the completion of messages for each communication line. Upon completion of a message, the communication control routines will notify the appropriate problem program for processing. The routines will store control records when a terminal connection has been made and when the terminal has signed off. Transmission error indications will be identified by the routines; transmission retry will be attempted, if applicable. The monitor routines will recognize the type of message traffic, such as administration or instructional, and route the message to the appropriate task. Since more than one input message of a given type may be ready for processing, a queue will be maintained for incoming messages. An output message queue will be produced for messages awaiting transmission. An online terminal test facility will be included in the communication routines. The terminal test facility will operate concurrently with the problem program and not impact the problem program operation, other than the brief time required to perform the test. Tests will be capable of being requested from a terminal, with control returned to the terminal after the test.

7.4.1.5 Operator Messages and Restart Controls. The system monitor will provide for operator messages and controls. A checkpoint/restart capability for problem program use will be provided within the system monitor. The system restart point will be identified at the last checkpoint established by the system.

7.4.1.6 Interrupt Handling. All normal system interrupts will be recognized by the monitor and routed to the applicable routine for interrupt processing. Interrupts originating from equipment malfunctions will be processed by error-handling routines, where possible, that include error recovery techniques dependent upon source and type of error indicated.

7.4.2 Language Processors. A library of language processors that are controlled by the system control monitor will be provided. The following lists the minimum capabilities of the library:

7.4.2.1 Assembly Language. The Assembly Language will process programming statements written in a symbolic programming language and will produce object programs to be executed. Auxiliary functions to provide program documentation assistance and macro-instructions will be provided in the assembler.

7.4.2.2 FORTRAN IV. A FORTRAN IV compiler that meets the minimum specifications of the American Standard Basic FORTRAN IV, X3.10-1966 will be provided. The compiler will include a diagnostic capability for analyzing source input statements and identifying invalid syntax to the user. The programming system will accept input data for FORTRAN compilation from an input device at the central site. The system will also accept FORTRAN jobs from remote terminals for data processing training. The results of the compilation will be automatically returned to the

source of input; namely, the central site or a school location, by transmission of the processed data to appropriate terminals on a scheduled basis.

7.4.2.3 COBOL. A COBOL compiler that meets the minimum specifications of the proposed United States of America Standard Institutes (USASI) standard as defined by COBOL Information Bulletin (CIB) number 9, January 27, 1967, will be provided. The COBOL compiler will also include diagnostics and remote job entry as described for FORTRAN.

7.4.2.4 Report Generator. A report-generating language and compiler will be provided for the rapid definition of special reports. The language will have the facility to define and access multiple input and output files, with provisions for logical testing and arithmetic calculation.

7.4.2.5 Problem-Solving Language. A problem-solving language processor will be included in the programming support available to the central computing site. Major characteristics of the problem-solving language that will be provided are as follows:

7.4.2.5.1 Natural Expression. The language notation will reflect the natural expression of the problem, whether it be a natural science or social science expression.

7.4.2.5.2 Concise. Simple symbols will be used for all primitive operations. No lengthy descriptive data will be required, but some flexibility of data organization will be possible.

7.4.2.5.3 Machine-Independent. The notation will be capable of use to test and solve problems by manual methods.

7.4.2.5.4 Data Organization. The language will provide for manipulation and expression of all data, whether it be homogeneous (i.e., vector and matrices) or heterogeneous (i.e., data organization of mixed data types). The language will also handle numeric and nonnumeric data structures.

7.4.2.5.5 Algorithmic. Definition of functions (programs) will be easily accomplished.

7.4.2.6 The problem-solving language processor will be integrated to operate in a multiprogrammed environment with the system monitor. Operational overhead will be kept to an absolute minimum in order that a maximum number of users may be serviced simultaneously. Specific implementation criteria that will be met are as follows:

7.4.2.6.1 Immediate Processing. The language processor will provide a conversational line-by-line interpret and execute capability. This capability may also be achieved through the use of incremental compilers if equivalent results are achieved.

7.4.2.6.2 Time-Sharing Interaction. The language processor will provide for continuous message interchange between all the terminal users and the central system at the same time.

7.4.2.6.3 Immediate Response. In conversational mode, the processor will provide immediate response to the terminal. The implementation objective will include an average response time of five (5) seconds or less. (Response time is defined as the elapsed time between transmission of the last character of the message input and the first character of the computer response.)

7.4.2.6.4 Visual Fidelity. The processor will process character strings in the same manner that they appear on the terminal, regardless of the sequence in which keystrokes were made.

7.4.2.6.5 Explicit Diagnostics. All entries that are applicable for diagnostic analysis will receive edit tests. Diagnostic messages to the user will be brief and self-explanatory.

7.4.2.6.6 Simple Terminal Command Language. The terminal sign-on and sign-off procedures will be simple and explicit. Task control instructions will not be required for the terminal user. Execution and format statements will be implicit to the system.

7.4.2.6.7 Library Facility. The language processor will incorporate facilities for library access to previously defined and commonly used programs.

7.4.2.6.8 Batch Processing. The processor will provide a batch processing capability for problem entry at the central computer. The batch entry is from marked paper sheets read by the optical mark reader or other machine-sensible media. Processed data will be automatically returned to the school location (or to the high-speed printer, if appropriate) over the communication lines on a scheduled basis.

7.4.2.7 To facilitate the user's transition from the problem-solving area to other computing activities, the problem-solving language will be consistent with conventional programming languages. The programming system will also provide for other higher-level language processors, such as PL/I. This language should possess characteristics applicable to both the business- and the science-oriented tasks within the structure of a single language.

7.4.3 Utility Programs. The following generalized utility programs will be provided for use with the system monitor:

7.4.3.1 Sort/Merge Program. The sort/merge program will have the facility to sequence data files on a minimum of six (6) alphameric data fields, with a total of forty (40) characters. The data records, data fields, and device location of data records of input will be specified by simple control statements. The parameter specified in the control statements will adjust the sort/merge program to perform the specific sequencing required.

7.4.3.2 Input/Output Utility Programs. A set of input/output utility programs will perform the following functions:

a. Peripheral Operations. Read data from an input device and place in auxiliary storage. Retrieve data from auxiliary storage and transfer to an output device. (Examples of these operations are card reader to auxiliary storage, auxiliary storage to printer, auxiliary storage to card punch.) This group of utility programs will have the capability to operate in a multiprogramming environment that allows for executions simultaneously while another independent program is being processed. Data formats will be specified by simple control statements.

b. Support Operations. The support operation utilities contain the functions for a file copy (copy one data file to another file) and the functions to clear auxiliary storage. Control statements will be available to indicate to these routines the location of data and functions to be performed.

7.4.4 Diagnostics. The data processing equipment manufacturer will provide diagnostic routines to exercise various components within the system and test for equipment failures.

7.4.5 Generalized Data Management. A generalized data management system will be provided to operate with the system monitor. This system will provide maximum flexibility to the administrative user for data definition, data retrieval, and report formats.

The data management system will provide fast access and processing of a data record that is stored within the system in a standard format. The system will contain a library for each user that describes the input data conversion parameters and report format parameters. The system will also contain a common library of frequently used programs to generate additional reports as specified. The following general management functions will be provided:

7.4.5.1 Input Transaction Format. As each user transaction is received by the system, the user transaction data will be referenced to the appropriate translation table that describes the translation parameters for a given user. Data elements will be converted to the particular standard internal transaction format that is established for the task to be processed.

7.4.5.2 Data Retrieval and Report Preparations. As requests are received from users for data and reports, the user descriptive parameters will be converted to the standard processing formats for the task. The report will be prepared in accordance with the report parameters set forth in the user's library.

7.4.6 Accounting Routines. Accounting routines will be included with the programming system. The data captured by the accounting routines is required for current utilization statistics and performance measurements that will be used for projecting future workloads. In addition, the data will be available for use in determining the contract rates to be billed during the next fiscal year. A third alternative provides for a combination of the previous two described. Portions of the work will be on a fixed rate determined in advance from prior statistics. The remaining amounts will be on a usage basis. (For example, administrative work could be on a fixed-price basis, and instruction on a usage basis.) The following minimum data will be provided by the accounting programs:

7.4.6.1 Remote Location Activity by Terminal. Accounting data will be recorded for each terminal connected to the system. This information will represent the total time that the terminal is connected to the system and the total central processing unit time utilized by the terminal. The times accumulated will be distributed by a job number (or student/teacher number) assigned to each task: problem solving, data processing training, and the various administrative tasks.

7.4.6.2 Remote Location Activity by User. Accounting data will be recorded individually for each instructional user. This information will represent the total clock time that the user is on the terminal, by activity (i.e., problem solving or data processing training), and the total central processing unit time utilized by the terminal. These times will be made available to the instructional staff. (For example, student progress evaluation requires this information, and it is also required to determine whether adequate access has been afforded to each student.)

7.4.6.3 Central Site Batch Activity. Each job processed in the batch mode at the central site will be handled by accounting routines. If the job involves problem solving or data processing training work submitted on marked forms or punched cards for central processing, an identical accounting will be made for the user as though the activity originated on a terminal. Other work will be recorded according to the job performed. Time will be recorded in this case only for the central processing unit utilization required to process each job, since no terminal connection time is involved.

7.4.7 The time summaries for each job will be maintained on a month-to-date and year-to-date basis. Summary records will be stored in direct access storage, and will be available for inquiries as required.

Section 8: REMOTE TERMINAL EQUIPMENT

8.1 Each school authorized to receive computer services from the central site will be equipped with remote terminals for two-way communication with the computer. Students, teachers, and administrators will be the users and operators of the remote equipment. This section describes the functional characteristics of the terminal equipment at the remote locations.

8.2 INSTRUCTIONAL TERMINALS

8.2.1 The instructional terminal for problem solving will be a low-cost, computer-controlled typewriter with a functional keyboard for input and hard-copy output. It will be oriented particularly toward handling textual messages.

8.2.2 Each keyboard key will be identified with the appropriate graphic character representations.

8.2.3 The terminal will have an upper- and a lower-case capability, with shift keys. The graphic character structure that represents the alphameric and special character capability of the terminal will also support those as required by the student problem-solving language.

8.2.4 The keyboard will contain appropriate interlocks that provide controls against accepting input data when the terminal is in a status to receive messages from the computer.

8.2.5 Printed output will be spaced ten characters to the inch. The print line capability will be at least eight inches. When the terminal is in a receive status, the message output speed will be at least ten characters per second.

8.2.6 The terminal attachment to the central site will provide the flexibility for transmission via common-carrier, switched or leased communication networks, as well as privately owned networks. Also, the terminal attachment will provide flexibility for a direct, limited distance, wire attachment to the central site.

8.2.7 The student terminal will be mobile within the school building. To provide flexibility in classroom use and individual student sessions, a capability will be provided to move the terminal from room to room. The terminals will be connected to the communication network by conventional telephone jacks installed in the room.

8.3 ADMINISTRATIVE TERMINALS

The administrative terminal will be oriented primarily for machine-sensible data transmission, with the added capability of handling textual messages. Thus, this terminal will provide functional capabilities for the reading and writing of machine-sensible documents, as well as keyboard message entry and character-by-character printing.

8.3.1 A single control unit will provide the necessary logic for controlling the attached input/output devices, as well as for providing the connection to the communication network. Character translation will be provided for common code to appear on the communication network for all input/output devices attached. On receipt of data from the central site, a control character will identify the output device scheduled to receive the transmission. Minimum input/output devices attached are:

8.3.1.1 Keyboard. A functional typewriter-type of keyboard for entering messages will be available at the terminal. All keys will be appropriately labeled to identify the functions available from the keys. Interlocks will be established for the keyboard to prevent input data from entering the terminal when in a receive status.

8.3.1.2 Printer. The output printer will provide format compatibility with the printer at the central site. To meet this compatibility specification, printing will be spaced at ten characters per inch, with a minimum of 120 characters per line. The minimum number of printable characters will be such as specified for

the printer at the central site. A form control will be available, either by the printer recognizing certain control codes from the central computer or by a carriage control mechanism on the printer.

8.3.2 Further consideration, for economic purposes, will be given to using the administrative terminal as an instructional terminal. In this manner, student use of the terminal for problem solving could be utilized when the administrative terminal is not being used for administrative traffic. By providing for a capability to modify the print element characteristic, either within the element or by interchangeable print elements, and by providing functional keys on the keyboard as required by the problem-solving language, student use of the terminal will be satisfied.

Additional features of the administrative terminal are:

8.3.2.1 Card Reader. A card-reading capability will be provided with the terminal. The card reader will recognize the card code character set as the minimum specified for the card reader at the central site.

8.3.2.2 Card Punch. The administrative terminal will have the capability to receive messages in punched card form. The minimum card code character set will be that specified for the card punch at the central site.

8.3.3 Since the administrative terminal is heavily involved in data transmission traffic, a capability for data checking will be provided, such as parity and/or longitudinal checks. The terminal will connect to the communication networks in the same manner as the student terminal. The rated speed of the terminal is dependent upon the data message traffic from a particular school location.

8.4 ADMINISTRATIVE CENTER TERMINALS

Each administrative center will have up to four keyboard printer terminals. These terminals will be used primarily for inquiry. The keyboard and print characters will be those as specified for the school administrative terminal. Printing speed will be rated at a minimum of ten characters per second. Machine-sensible data input and output will not be required for this terminal.

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