# University of Minnesota

# A Study of Graphic Data Entry Methods For the Minnesota Land Management Information Systems (MLMIS)



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Submitted to the
University of Minnesota's
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and to the Systems Director, MLMIS Project

by the
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Engineering Group
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# 1 INTRODUCTION

This chapter sets forth the objective and scope of the study, discusses the approach used and presents the outline of this report. The MLMIS is a computer based information system. It is used to process and manipulate files containing information about Minnesota's land parcels and allows extraction of information, according to specific classification, from these files. Vast amounts of data must be entered into the files in order to achieve the goals set forth for the system.

## 1.1 OBJECTIVE AND SCOPE

The objective of the study is to consider various approaches toward improving the data collection aspects of the graphic data entry requirements of MLMIS.

> The investigation was based on an analysis of MLMIS's approaches toward solving the data entry requirements of processing and manipulating files relating to Minnesota's land parcels.

Included in this study is the evaluation of current approaches and a limited evaluation of those which could be met in the future.

Although the study was to primarily consider approaches which make optimum use of hardware to ensure improved data collection and entry means, approaches making use of both hardware and software configurations were considered. Cost savings were an important, desired goal.

## 1.2 ORGANIZATION OF THIS REPORT

This report contains five chapters as follows:

1. Introduction

2. Current Status

This chapter discusses the MLMIS graphic application, the procedure currently used to enter data into the files (2.1) and the major problems, both technical and operational, encountered (2.2). A separate paragraph comments on the cost of the operation and the implications of the subsidy provided for the project (2.2.3). References to written material containing background information are given in the introductory part of Chapter 2.

3. Alternative Approaches

This chapter gives a definition of graphic data entry suitable for the MLMIS project. An ideal graphic data entry device in the form of a writing surface composed of touch-sensitive switches activated by finger or pencil (3.1) is then proposed. Further paragraphs describe in detail other avenues which are possible. Included are those based on staying with the CDC 3200 system (3.2.1) or those based on selecting another (the CDC 6600) system (3.2.2).

The possible data entry devices usable for off-line and on-line data entry, their combinations, availability on campus, etc. are described within the paragraphs of section 3.2 and include the input device proposed by UCC Engineering mentioned previously. Included in this discussion are different digitizers, CRT's, and storage media (punched card, paper and magnetic tape).

4. Equipment Requirements

This chapter contains comments on the devices considered in Chapter 3.

5. Hardware Presentation

This chapter presents the hardware surveyed. On-line and off-line equipment data are presented, including data on pricing.

## 1.3 APPROACH

Initial interviews were held on campus to gain an understanding of the work currently being undertaken and of its objective and scope.

Further meetings were held with MLMIS staff to identify major problems in the present arrangement for handling the graphic application.

- Meetings were held with the principal investigator of the project as well as with members of the MLMIS project.
- Exhibit I-1 lists the persons inverviewed (some persons listed were interviewed more than once).

- Based on these meetings the principle underlying the MLMIS graphic data entry application was formulated.
- The discussion of the needs of MLMIS in the following chapters is based on these applications identified.
- Conclusions and recommendations are presented.

EXHIBIT I-1
Lists of Persons Inverviewed

| FUNCTION | INDIVIDUAL |
| --- | --- |
| Principal Investigator<br>Appointed by Information, Research and Development Fund Budget Committee | Stephen Nachtsheim<br>231 Experimental Eng.<br>phone: 373-7878 |
| Systems Director<br>MLMIS | Kenneth A. Kozar<br>825 Social Science<br>phone: 373-5865 |
| Systems Programmer | John Schmitt<br>phone: 376-3503 |
| Research Analyst | Jack Shea |
| Graduate Research Assistants | Jeff Anderson<br>John Gross |

## 1.4 CONCLUSIONS AND RECOMMENDATIONS

The results of this study have produced a variety of alternative approaches, each with varying system, human and cost effectiveness factors. Viewing the alternatives from a short range plan, only two of the approaches analyzed seem viable at this time. However, each of these approaches has their limitations which are discussed more fully in the report. The first of these approaches accepts the proposed system configuration described in the Kozar memo of August 31, 1973. This approach assumes the use of a commercially available digitizer interfaced to an incremental tape recorder. The second approach considers the implementation of a "discrete" digitizer in the form of a writing tablet using commercially available "touch-sensitive switches" interfaced to an incremental tape recorder. This tablet would have to be designed and fabricated by UCC Engineering. Its chief advantage would be in our ability to design and fabricate a unit that most closely and efficiently meets the needs of MLMIS. An important disadvantage of this approach would be in the time required to implement the design and fabrication of hardware. However, consideration should be given to comparing this time to the time that may be required to obtain commercially available equipment. We have not attempted to get precise cost and time estimates in this report as we do not know which direction MLMIS may take. Comparison of costs between these alternatives is discussed briefly below. A more complete discussion of the advantages of the UCC approach are considered later in this report.

In order to implement either alternative, consideration must be given to current and future hardware and software requirements, which will be required to support the graphic data entry application of MLMIS. It is recommended that, if the commercially available equipment is seriously considered, the vendor be requested to permit a test of his equipment to ensure its suitability to do the job. Since the vendor may not be willing to ship the equipment without a guarantee of a purchase or lease, it is recommended that MLMIS visit a site where the equipment can be used on known grid patterns and data input. The generated tapes should then be analyzed using the CDC 3200, which has CDC 601 tape drives, to ensure the equipment will perform as prescribed and hoped for.

Aside from the discussion of the above two alternatives, other alternatives to solve the MLMIS application are considered, which include remote on-line data entry system approaches. These latter approaches should be seriously considered chiefly in terms of long-range goals. If the long-range goals are consistent with the short-range goals, then serious thought should be given to a plan which implements the on-line alternatives, even if it may mean a delay in present plans. However, it is possible that both the off-line and on-line approach may be viable if engineering considerations are considered and planned for in the early stages.

## 1.5 COST ESTIMATES

In this section we present estimates for two of the off-line approaches to data entry:

1. Commercially Available Equipment

With this approach the GRAF/PEN Digitizer manufactured by SAC is interfaced to an incremental tape recorder manufactured by Pertec. The cost of the Model 2021, consisting of a Pertec 1000 Series 7-track incremental tape drive with 8 1/2 inch reel and GP-2 BCD digitizer and Model 1341 interface, is at least $8575. The digitizer includes a tablet, stylus and control unit. For another $300 the coordinates can be visually displayed.

Although it is possible to buy the tablet and associated controls without buying the tape unit from SAC, it is our feeling it would be best to buy a complete system in this case.

2. UCC Designed Digitizer

Cost estimates are given here for the development and fabrication of a digitizer as proposed by UCC Engineering. These are only preliminary estimates. If MLMIS is interested in pursuing this avenue further, then a more precise estimate can be furnished based on a feasibility design. We have included the cost of purchasing a Pertec incremental tape drive to permit cost comparisons with the commercially available digitizer system.

As indicated in the report, the UCC approach to the data entry application can be designed to permit the multiplexing of several writing tablets with a single tape drive. It is in this case that a more cost effective system can be developed than is available commercially. The two cost estimates which include the capability of handling a complete township grid with irregularities are (regular township = 36 sections):

A. single writing tablet

| | |
|---|---|
| . touch sensitive switches* -- 64 sections | $2048 |
| . tablet to hold switches | 500 |
| . interface to Pertec formatter | 1000 |
| . electronics for tablet and interface | 500 |
| . Pertec 1000 series tape drive | 3380 |
| . formatter | 1295 |
| Net Cost for Unit | $8723 |
| . allowance for error in estimate (labor) | 4000 |
| Guesstimate | $12,723 |

It is our feeling that cost saving may be possible if one can combine the Pertec formatter and the interface which UCC would design into a common element.

B. use of multiplex with four writing tablets

1. single unit costs -- tablet

| | |
|---|---|
| . touch switches* -- 64 sections | $1600 |
| . tablet to hold switches | 500 |
| . interface to Pertec formatter | 1000 |
| . electronics for tablet and interface | 500 |
| Total | $3600 |

| | |
|---|---|
| 2. multiplexer | 2000 |
| 3. Pertec 100 series drive | 3380 |
| . formatter | 1295 |
| Tape Equipment Total | $4675 |

cost of four stations:

| | |
|---|---|
| . Pertec tape equipment | 4675 |
| . multiplexer | 2000 |
| . four writing tablets | 14,400 |
| Total | $21,075 |
| allowance for judgmental error in estimate | 4,000 |
| Total | $25,075 |

Thus, the unit cost per station in this case for the digitizer would be approximately $6250. However, if the design for the multiplexer interface to Pertec formatter and the formatter could be combined into a single unit, a reasonable reduction in cost may be possible.

* 16 switches/section; 1 section = 4 quarter sections = 16 40-acre parcels

# 2 CURRENT STATUS

This chapter describes briefly the MLMIS, its present application, discusses the current procedure and the major problems encountered. Additional information is available in the following two documents:

- MLMIS Data Structure, by K. Kozar, September, 1972.
- Possible Hardware Needs to Accomplish Data Entry Tasks for 1973-74, memo of K. Kozar to T. Anding and J. Borchert, August 31, 1973.

## 2.1 CURRENT APPLICATION AND PROCEDURE

In what follows it is assumed that the reader is somewhat familiar with the basic work of MLMIS.

### 2.1.1 Application

The MLMIS data are maintained in a data file stored on disk memory. The file for each county contains records for each 40-acre parcel (see "MLMIS Data Structure").

The data-base is maintained on the West Bank Computer Center's CDC 3200 Computer and may be queried after the mounting of the MLMIS disk-pack via cathode-ray-tube terminals interfaced directly to the CDC 3200.

Upon entering appropriate information via the terminal, such as identification of county, township, etc., the computer will display a "township grid" (only the upper or lower half of the grid, due to limitations introduced by screen size). This grid is the display of the 40-acre parcels as squares within the grid and may contain a symbol to characterize the parcel according to the selected classification (entered from the keyboard as a parameter) such as type of soil, zoning, etc.

### 2.1.2 Data Entry

Data entry into the system proceeds as follows:

- A township grid is selected and will be displayed on the CRT as described above.
- A quadrille ruled mylar sheet is attached to the face of the CRT terminal to indicate the grid pattern of the township grid. The

ruling of the mylar is such that the displayed characters fit into the squares of the grid.

- The cursor (underline sign) is moved to the desired position (parcel) and a symbol (to be associated with the parcel) is entered according to conventions (say an I for industrial, if zoning classifications are of interest).
- Parcels are selected and marked either one after the other or entire fields (row, quadrants, etc.) are selected and marked.

The operator decides which symbol, used for classification of the grid, predominates. He fills the entire grid pattern with the dominating character and then starts overwriting them with different characters where needed (entire rows, quadrants can be filled with a single command).

- The files are updated upon command from the operator via the keyboard.
- The annotated grid is then further processed by the computer and a plot of the township sections, indicating all the entries made for a particular category, is produced on the line printer. This print-out then serves as hard-copy output and also to check the correctness of the data entry if the plot is incorrect. New data entry process is initiated at a later date if required.

## 2.2 MAJOR PROBLEMS

The present procedure has both technical and operational problems. These problems will now be described.

### 2.2.1 Technical Problems

The technical problems, given the system as it is (a computer driven alphanumeric display terminal), are not caused by system design or programming. The major difficulty is caused by the use of the specific CRT terminal available; it has the following limitations:

- Terminal screen size: allows only one half of the grid to be displayed at one time. If the other half of the display is desired, it has to be recalled.
- Lack of Scrolling: the terminal does not allow "scrolling" that is, to refer to more than a full screen of data requires

shifting the grid up or down and examining the lower part of the upper half and the top of the lower half of the grid, thus "looking at the edges" of the two halves.

- Lack of grid generating capability: the terminal being used only generates alphanumeric characters. The grid is not produced by the display or the computer. A grid is drawn on a sheet of mylar (the quadrille ruling of which is such that it fits over the characters) which in turn is attached to the CRT. This process requires shifting the mylar sheet until it exactly fits over the characters (annotated parcels). An exact fit cannot be achieved because the surface of the CRT's face is curved.
- Visual effects: there is a finite distance between the surface where the characters are produced (phosphorous coated side of the CRT glass) and the one where the mylar grid is attached by the operator. This is clearly visible if one is not directly facing the terminal (even directly facing the CRT this can be seen at the edges of the grid).
- Physiological effect: operators working side-by-side, one reading and marking a map, the other keying the information, face the CRT at an oblique angle. The above mentioned distance between character and grid surface becomes very annoying. It strains the eye and causes headache after a few hours. The use of any terminal where the characters and the grid are produced at a "sizeable" distance from each other is discouraged because of the discomfort it causes the human operator.

### 2.2.2 Operational/Administrative Problem

A number of problems relating to system operation and administration can be accounted for. These include:

- The CRT is operated by two persons, one reading the maps and the other keying in the data for greater reliability. This form of operation is not cost effective (see Kozar's memo of August 13, 1973).
- The operating system of the CDC 3200, as used on the West Bank, does not effectively handle the MLMIS application. MLMIS is

used in conjunction with a modified operating system, which in turn limits the computer's usefulness for other users. Thus, the computer is not available at all times for MLMIS.

- The operators do not have a quiet work area. They work in a noisy environment, where all the other CRT users work and user consultation is performed. Obtaining another room is difficult. Further, new cables for the CRT terminal would be required.
  - It was observed that the operators were quite often distrubed by other users inquiring what they do, or simply asking why the operators can work while other users cannot run some programs. The operator then explains that the system has limited capabilities while the MLMIS program is running.
- Availability of the system is restricted to a few hours per day due to the structure of the operating system required (see above). Scheduling under these conditions is difficult.
- The number of available trained personnel does not permit efficient use of the resources, in particular all the CRT terminals which are available. Further, it should be noted that two trained operators are required per terminal.
- The system, limited as it is, makes the meeting of a deadline for data entry completion difficult when one has to work with restructions placed on machine, terminal and operator availability.

### 2.2.3 Cost of Operation

The hourly rate of the CDC 3200 is $125. The MLMIS application, when in use, requires more than half of the machine's resources. Even so, only $5/hour is charged for each CRT terminal used, and no charges are levied for the use of the central processor. Thus, MLMIS is heavily subsidized.

At present, the task of classifying one township grid according to some parameter requires about 20 minutes of terminal usage. Since there are 14,200 township grids, their classification according to only a single parameter would cost several hundred thousand dollars should subsidy be halted. Even assuming that the operation remains subsidized, the use of two trained operators, each being paid $3/hour, justifies the search for a method of data entry requiring only one operator per data entry station. Saving one operator's costs amounts to $14,400. This is computed for the project as 14,200 grids times $3/hour divided by three townships digitized per hour, assuming only a single classification. This sum could be used for the acquisition of more efficient equipment.

Any alternative solution proposed in this report should be evaluated in such a way that both true and subsidized costs are taken into consideration.

# 3 ALTERNATIVE APPROACHES

The principle of the graphic data entry operation corresponding to that being implemented by MLMIS and an ideal data entry device to achieve the desired goal is described in the first section. The second section discusses the alternatives open to MLMIS. Further sections contain more detailed descriptions of the equipment mentioned in section two followed by a discussion of on-line approaches to solving the data entry problem.

## 3.1 GRAPHIC DATA ENTRY

The graphic data entry as considered for MLMIS reduces, in essence, to the following procedure:

> Identification of an area (corresponding to a land mass), a square within a grid pattern, and assigning a particular symbol (or symbol combination), taken from a predefined alphabet, to the square selected.

### 3.1.1 Ideal Graphic Entry Device

The procedure as defined above allows the definition of an ideal input device for the application investigated. The input device would consist of a cluster of touch-sensitive switches, each switch top having the same area as a square on the map (township grid). All switch tops would be flush mounted and serve as a writing tablet. The size and form of the map would take the irregular forms of some maps into consideration. A single operator could point to any square of the map with his finger or pencil, activating the switch underneath it and key in the associated symbols using a keyboard. The keyboard might not be necessary if the cluster of switches is expanded and each of the additional switches is associated with a symbol of the alphabet.

The tablet should be provided with an enable/disable switch (it might be a foot activated one) in such a way that while the operator marks the map with a pencil and activates some switches, the output from these switches will not be generated unless the tablet is enabled. It should be noted that when, the operator has completed his work on a given grid network, he will have a map so marked that he will be able to verify that all data has been entered as requested.

Additional hardware is necessary to decode the output of the switches and to interface the device to a computer or an off-line storage device (magnetic tape, for example).

This previously described device should be contrasted with commercially available digitizers (described later), which use a rectangular coordinate system to identify points on a drawing or map. Points are established by different means - for example: (1) a cross-hair cursor mounted at the end of a moveable arm and the arm's position, relative to a previously established origin, gives the coordinates of the point; or (2) a point is identified with a system emitting ultra-sound. This sound wave is picked up by ultrasonic microphones placed alongside two wedges of the writing tablet and the position of the excited microphones gives the coordinates.

## 3.2 ALTERNATIVES

Two alternatives are available for the MLMIS project. These are:

- use the present CDC 3200 system throughout
- use a system other than the CDC 3200

It is obvious that the MLMIS project can be realized using the CDC 3200. Before considering the validity of changing from the present system to another, it is worthwhile to consider how the present or any other application is solved on the 3200.

The 3200's core memory, disregarding sections containing the resident parts of the operating system, has two partitions in which system programs can be run. One partition is occupied by the communications program handling high speed batch jobs to the CDC 6600; the second is available for local use. Depending on which program is run in this second partition, a number of users are inconvenienced, i.e. those who cannot make use of the running program but wanted to use the machine. When the MLMIS programs are run in this second partition, the number of users prevented from using the machine is rather substantial. For this reason, machine time is given reluctantly to MLMIS.

Any solution for the graphic entry problem proposed for the CDC 3200 will possibly require the use of the second partition to run programs related to MLMIS's application. In general, alternative solutions will differ only in the time required to process the graphics data. The use of off-line devices to collect data will reduce the computer time required on the 3200 for the data entry application. On-line solutions proposed will require an applications program to run while operators enter data. The software implications and user inconveniences, as described above, should be considered when evaluating the on-line solutions proposed.

### 3.2.1 Use of the CDC 3200

Let us consider solutions of our proposed problem through the use of the CDC 3200. Two choices are available, namely to:

- stay with the system as it is
- restructure (modify) the existing system

#### 3.2.1.1 Use of an Unmodified System

This approach corresponds to the current application as described in the second chapter, and one should try to alleviate the problems stated in that chapter in the "Major Problems" section (see 2.2).

#### 3.2.1.2 Restructuring of the Present System

This approach would consider the use of data entry devices other than the CRT terminals presently available. Off-line and on-line systems are both available. On-line systems would require the addition of hardware to the basic CDC 3200 system and entail software modifications. The system would not be interactive directly with the 3200 but rather through some front-end processor communicating with the 3200.

##### 3.2.1.2.1 Off-line Configurations

These configurations consist of combinations of one entry and one storage device.

Entry devices:

- ideal input tablet, built by UCC Engineering and described at the beginning of this chapter
- digitizer with ultrasonic stylus
- electromachanical digitizer

Storage devices:

- . punched cards
- . 1/2 inch magnetic tape (incremental tape recorder)
- . paper tape
- . 1/4 inch magnetic tape (tape cassette)

The individual equipment and pricing data is described in Chapter 5. Some combination of devices have advantages over others.

The input tablet as proposed by UCC Engineering has the advantage of being more "fool-proof" than any other. It could be built to MLMIS specifications and interfaced to any storage device or computer desired.

The graphic data entry application of MLMIS consists of identifying a particular square of the township grid and associating some symbol with that square. The number of characters used for this identification is important and partly depends on the design of the interface. In the case of this tablet four characters are sufficient to identify any square (2 digits for one of the 36 sections and 2 for the 16 quadrants). It could be handled by a single operator while assuring the same accuracy (or better) of data entry as it is achieved at present with two operators. Also, using pencils to activate the touch-sensitive switches and making the drawing, an instant hard copy of the input operation would be available.

This previous approach should be contrasted with the way control units of both digitizers (ultrasonic or electromechanical, mentioned above) present coordinate values. For these digitizers in general four BCD digits and a possible decimal point may be required since the resolution of the digitizers is a fraction of an inch for each coordinate. Thus, the use of commercial digitizers for data entry substantially increases the storage requirements. Also, for the proposed UCC unit several of these entry devices could be attached to (multiplexed onto) a single storage device, provided the control unit is designed with a multiple-user approach in mind. This would imply higher volume of data entry if more operators are available.

The only disadvantage envisioned for the input device proposed by UCC is its cost and date of availability. However, since UCC Engineering does not operate on a profit-making basis, its charges being only parts and labor, the overall costs in case several units are manufactured would be lower than those available commercially.

Digitizers with ultrasonic stylus are available and can be interfaced to all storage devices mentioned. Company representatives of electromechanical digitizers claim that the positional sensor microphones are humidity sensitive and the stylus, when dropped, may break. (It costs $200 to replace one.)

Electromechanical digitizers may be less sensitive to vibration and humidity. A cross-hair cursor (or a pen in place of the cross-hair) to identify points on maps might not be as easy to handle as a stylus. Only demonstration of these units could answer this problem.

Punched cards are a readily available and processable storage medium. Assuming that each card is individually marked, about 60 columns are left for data entry purposes. This would roughly correspond to information about 4 to 5 points using a digitizer: 4 digits and decimal point for each axis, a separating comma or slash, the symbol(s) associated with the point, and new entry marker (5 + 5 + 1 + 1 + 1 = 13 characters), depending on control unit design (compare this decoding with the one proposed by UCC). Reduction in the number of digits may be possible if different encoding schemes are utilized.

Half-inch magnetic tape is also a very common medium. The selection of the incremental tape recorder is not trivial. The control unit associated with the tablet, the interface electronics and the controls of the tape recorder must be such that they will generate the same record format (number of characters per block, other markers and gaps on the tape) and will record with such a method that the tape recorded can be read using the tape units of the CDC 3200. Problems of selecting an incremental tape transport are described in Appendix 1.

Paper tape is a very inexpensive storage medium. Recording format is similar to the one shown for punched cards. However, carriage return, line feed and two rubout characters have to be inserted after each (or a few) point stored if the use of the tape in conjunction with a time-sharing computer is considered. The disadvantage of paper tape is that a paper tape reader might not be available with the system in use.

Cassette tape recorders should not be seriously considered. Cassette equipment either as direct input or as converted to another suitable input storage medium is not available on the 3200 or any other system on campus -while paper tape to magnetic tape conversion is possible either at the Hybrid Lab or Health Sciences Computer Centers. Also, incremental cassette records are not available on the market.

3.2.1.2.2 On-line Configurations

We have been considering previously off-line data entry systems for the MLMIS application. In this section we shall consider the suitability of the use of on-line configurations of equipment. These approaches should only be considered with a long-range MLMIS program in view.

A minicomputer, possibly a DEC PDP-8, would be used as a basic constituent of these systems. The minicomputer could be interfaced either directly to the high speed I/O channel of the 3200 (the 3206's) and transfer data in blocks between the two computers. The minicomputer could emulate the operation of a tape unit and be interfaced to the tape controller (3234) of the 3200 since the controller is capable of driving more than the presently available three drives. The direct channel-to-channel interface is preferable since it can have a high data transfer rate and places less data formatting restrictions on the minicomputer than the tape unit emulation does.

Another possibility to be considered is to enter the 3200 via its high speed communication link to the 6600. Assume the minicomputer, working as a remote batch terminal emulating a CDC 200UT or UNIVAC 1004, communicates with the CDC 6600. The files sent by the minicomputer and accepted by the 6600 would then be sent to the 3200. This would require the modification of the batch communications software of the CDC 6600. Means of entering the 3200 this way will be discussed further in the section dealing with approaches other than those using the 3200 system.

Data entry devices mentioned in conjunction with off-line systems are usable with the minicomputer. Hardware is available (or can be designed as far as the UCC data entry device is concerned) which allows the connection of the data entry devices to the minicomputer. If needed, several identical units can be attached to the minicomputer via multiplexers. The minicomputer allows the use of cathode-ray-tube terminals to be used as data entry devices. There is a variety of CRT terminals available. They may also be used as monitors in conjunction with previously mentioned data entry devices. Using the more expensive variety of CRT terminals, the problems associated with them (see 2.2.1) can be eliminated. Further, the use of CRT's allows some interaction between the operator and the user.

### 3.2.2 Use of the CDC 6600

An alternative on-line approach to the use of the CDC 3200 would be to make use of the CDC 6600 facilities and its remote terminal capabilities.

The analysis of the necessary software development effort, in order to change from one system to another, is not attempted here. It is obvious that the change is feasible. The reasons such a change should be considered are as follows:

- Since the 6600 is capable of running several jobs concurrently, user inconvenience caused by MLMIS programs would be insignificant, and the CDC 3200 would no longer be required for the MLMIS applications.
- Additional data entry approaches would be available.
- All data processing would be made on the same machine. (Large amounts of data used by the MLMIS projects are maintained on the CDC 6600 at present.)

#### 3.2.2.1 Possible System Configurations

All possible off-line solutions suggested for the 3200 are usable in conjunction with the 6600. Off-line systems using punched card or 1/2 inch magnetic tape (provided the tapes are recorded to be read on the 6600's tape drives) storage are immediately usable, while a paper tape input facility could be implemented.

CRT terminals (fully buffered alphanumeric) may also be used immediately if required. The CRT terminal available is the Dataspeed 40, made by Teletype Corporation. It is fully buffered. More sophisticated models can display 72 lines of data (at 80 characters/line). It is equipped with a 300 line/minute printer and generation of instant hard copy of input or output data is possible. The terminal is treated as a remote batch terminal and communicated with the 6600 via telephone lines at 1200 baud.

More sophisticated systems could include a minicomputer, a PDP-8 for example. The PDP-8 could act as a pre-processor for the data to be collected. It could be equipped with any data entry device mentioned previously (one or more of each providing for multiple work stations). The PDP-8 could also emulate the operation of one of the remote batch terminals, say a UNIVAC 1004 or CDC 200UT. It would call upon the 6600 when "enough" data are collected, transmit these data to the 6600 where the proper applications program would be called to process the data sent and send information back to the PDP-8 if needed. This system, as far as the minicomputer is concerned, is very similar to the one described for the 3200 where a channel-to-channel interface between the 3200 and the minicomputer was suggested.

Assuming that the minicomputer is programmed to emulate a remote batch terminal, it would be possible to send data back to the 3200 via high speed batch link if the processing of data is not to be done on the 6600 but rather on the 3200.

# 4 EQUIPMENT REQUIREMENTS

This chapter discusses the requirements concerning the different graphic data entry devices.

## 4.1 DIGITIZERS

The digitizer is a device that converts information contained in pictures, maps or sketches into data that can be analyzed, restructured, edited, and transmitted by a computer. The positional element's (cursor or stylus) position is served by the digitizers as the operator moves the positional element to a position of interest and activates a switch to record the position on some storage medium (magnetic tape, paper tape, punched card), or enter it directly into a computer. The process is repeated, point by point until the "picture" is completed.

Additional switches or similar means are provided to denote the end of one contour and the beginning of another, to describe special labeling associated with a given contour, etc.

Input accuracy of such systems is limited by the precision of the source document on the one hand and by equipment design on the other.

Sophisticated semi-automatic or automatic (scanner type) digitizers are not considered here. As described in the first part of this chapter (see ideal input device) a manual digitizer as described in the previous paragraph is sufficient for the accomplishment of the graphic data entry task.

The digitizer is most cost-effective in high volume, repetitive application where a relatively small number of elements must be repeated many times without omission. This is similar to a plotting problem and in many instances a digitizer with simultaneous plotting would be the best solution for graphic entry. Ideally the output should be plotted at the same time the input is generated, so the operator can view the effect of his work immediately.

In any event, the position sensor is moved about the input surface and the operator selects the symbols that will appear at each point.

Using an interactive, on-line system might result in economies. This could result in improvements in throughput and reduction in work-cycle time* when compared to a system using off-line storage and subsequent processing and map generation on a computer.

## 4.2 COMPUTER CONTROLLED DISPLAYS

The computer controlled display field may be divided into these categories:

. alphanumeric only

. alphanumeric and graphic output

. versatile graphic input and output in addition to alphanumerics

This classification into these categories is determined by the application and economics and not by the techniques used for image generation which can cross the respective boundaries.

Alphanumeric only displays were partially described in previous sections since the current MLMIS application is based on the use of such display terminals.

Some features, not available with the presently used displays, could enhance the use of the CRT terminals. It should be emphasized that these features cannot be added to the current display used on the 3200 without considerable hardware modification. Useful features available on other displays are:

. those which were described as missing from the present terminal, such as scrolling (ability to refer to more than a full screen of data)

. transmission of partial display -- permitting transmission of selected portion of the display versus those having to transmit the full display each time (this is an editing feature)

. split screen -- permitting previously displayed data to be retained while new data is being entered or received

. buffering capability -- off-line data accumulation reduces the cost of data transmission. Data can be gathered until the whole grid is processed and then transmitted to the computer.

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* Enter data, obtain hard copy, check validity of data, make corrections if needed.

Displays with alphanumeric and graphic output capability pose a greater economic problem than the previously mentioned display. They fulfill the need for graphic output as suggested earlier by providing the capability of generating the grid pattern needed for the MLMIS application.

Displays with graphic input/output in addition to alphanumerics are the most versatile and also the most expensive. They are considered for completeness of discussion and because they are available on campus. Computer graphic display systems impose substantial requirements upon software, especially on input. One such requirement is pattern recognition. Another of substantial magnitude is the graphic language required for communicating graphically rather than in conventional terms. Hardware is frequently employed in graphic input/output systems to perform certain processing functions that would be very time consuming under program control, such as pre-processing, character and line generation, etc. Detailed specifications are discussed in Appendix 2.

# 5 HARDWARE PRESENTATION

## 5.1 DATA ENTRY DEVICES

### 5.1.1 Discrete Digitizer

This device was presented as the ideal input device. The major component of the system, the touch sensitive switches, is available from Magic Dot. Incorporated, a local manufacture, and could be assembled into tablets by UCC Engineering. The development costs of this writing tablet would be justified for an order of a multiplexer and four or more tablets.

### 5.1.2 Ultrasonic Digitizer

This digitizer, called the GRAF/PEN, is manufactured by Sciences Accessories Corporation (and used by a number of other companies as part of their system). It consists of a 14" x 14" tablet with ultrasonic sensors mounted on two of its perpendicular edges and a stylus combined with a ball point pen. An ultrasonic pulse transmitter built into the stylus generates signals which are picked up by the strip sensors. The output from the strip sensors is interpreted by a control unit to provide X-Y coordinate values. As an option, the coordinate values can be displayed. Several models are available in the range of $2800-3700 for the tablet, stylus and control unit.

### 5.1.3 Desk Top Digitizer

This digitizer, manufactured by Numonics Corporation, is a 20-pound portable device. It consists of a control unit with a four digit display for each axis. One axis is a flat metal guide. The other is a moveable arm equipped with a cross-hair or pencil cursor moveable alongside the guide and perpendicular thereof. The area covered is 24" x 24". It works on the pulse counter principle. The movement alongside any axis will increment or decrement pre-setable (to set the origin of the coordinate system) counters. The outputs from the counter will be interpreted and displayed by the control unit as X-Y coordinate values.

Numonics digitizers sell for $1895-2195. Several options are available for $300 at most.

## 5.2 DATA STORAGE DEVICES

Data storage devices can be interfaced to one of the data entry devices in order to store the entered information until its final processing.

### 5.2.1 Punched Card

This is one of the least expensive modes of storing the information involved. Its major advantage is that it is not restricted to any computing system where the stored data can be processed. Interface between a card punch and digitizer costs about $1000 ($750 for the Numonics digitizer, $1575 for the SAC digitizer).

### 5.2.2 Incremental Tape Recorder

This device is widely used with digitizers. Its selection requires careful consideration. In order to be useful, it must be assured that the recorded tapes can be read back on the tape drives of the computer used for processing the data. An interface between an incremental tape recorder and digitizer costs about $1200. Depending on the tape transport, price of a transport with interface is between $4000-5500.

The problems of selecting the proper tape transport are described in the Appendix.

Should a tape transport be the final choice of MLMIS, UCC Engineering will assist MLMIS to ensure the selection of a tape transport which is compatible with the tape transports of the computer installation specified by MLMIS.

### 5.2.3 Tape Cassettes

The use of these devices is similar to the use of tape transports. One additional difficulty is finding a computer system which is equipped with a compatible cassette drive. If such a system cannot be found, SAC sells an interface from a cassette reader to an IBM 026 keypunch for $1325, but this solution should be discouraged because of the many processing steps involved.

### 5.2.4 Paper Tape

Paper tape is also a very inexpensive storage medium. A paper tape punch can be interfaced to any digitizer mentioned previously. The interface to a paper tape punch or teletypewriter costs about $900-1000, depending on options selected.

SAC offers an off-line system, including a Facit 4070 punch for $6700. Numonic's offer, which is quite similar, is about $1000 less expensive.

It has to be mentioned that a paper tape to magnetic tape conversion step is required before data can be presented to the CDC 3200 or 6600 (although a paper tape facility could be implemented for the CDC 6600).

## 5.3 SYSTEMS

In this section the equipment is described which will work in conjunction with a computer.

### 5.3.1 Digitizers

All digitizers mentioned can be interfaced to minicomputers. Equipment is available which allows the connection of up to four digitizers to a computer (DEC PDP-8).

<u>Science Accessories Corporation</u> sells interfaces to connect their equipment to DEC PDP-8's, 11's, 12's, and 15's for $1500.

<u>Numonics, Inc.</u> also sells similar interfaces and a similar amount of money is needed to interface a Numonics digitizer to the same machines.

<u>Digital Equipment Corporation</u> offers the SAC digitizer, now called VW01-AP writing tablet, attachable to the PDP-8 External Positive I/O bus (the bus costs $270 if not available on the PDP-8) for $3600 which compares well with the SAC offering of $2800 + $1500. DEC also offers a multiplexer for $1000 in addition to the tablet described above which is able to accommodate three more tablets at $2000 each. The DEC approach might have merit when several work stations are considered. Some software is available through DECUS, the DEC Computer User's Organization.

Input Output Computer Services, Inc. offers the "Anagraphic" Data Digitizing system consisting of the aforementioned SAC digitizer, interfaced to a PDP-8-E with 4K memory and an ASR 33 teletype with a software package permitting point-by-point digitization for $17,500 or $372/month on a 60-month basis. The system is also available without the PDP-8 and teletype for $9,995 or $212/month.

Another system, similar to the one above but incorporating a tape cartridge recorder, sells for $22,050 or $465/month.

A third system with an IBM compatible tape unit instead of the tape cassette sells for $31,500 or $669/month.

Autotrol, Inc. flatbed digitizer is available at Hybrid Computer Laboratory. It is interfaced to a Kennedy 1600 incremental tape transport. The tape generated is readable by the CDC 601 tape transport attached to the CDC 1700 computer (or CDC 3200). The Hybrid Computer Lab also has equipment to produce tapes readable by the CDC 6600's tape transports.

### 5.3.2 Interactive CRT Terminals with Light-pen

These terminals, although the most expensive and time-consuming to program, are mentioned because a number of them are available on campus.

Hybrid Computer Lab's sophisticated "Digigraphic" system (CDC): the terminal is part of a CDC 1700 based system (with disk and magnetic tape storage). It is also connected via high speed (40,800 bits/second) communication lines to the CDC 6600 of the University.

Computer, Information and Control Sciences: CICS has an IDIIOM/II (for Information Displays, Inc. input/output machine) interactive graphics system built around a Varian 620/i minicomputer. It is equipped with a communications controller which allows it to be tied to any time-sharing system which accepts teletypewriter terminals (for example, the CDC 6400 on campus).

### 5.3.3 Other Display Terminals

Data Speed 40 is a buffered CRT terminal with a line printer made by Teletype Corporation. It could display up to 72 lines (24 lines at present) by 80 characters each and print at 300 lines/minute (80 characters/

line). There are currently two of these terminals on campus which are connected to the CDC 6600. Additional units could be made available from the Bell Telephone System.

Direct-view Storage Tube Displays: terminals incorporating a direct-view storage CRT are also available. The surface of the display unit acts as the console's memory and serves the double purpose of image storage and viewing screen. Once data is written on the screen it remains there for long periods of time (tens of minutes) without noticeable degradation. Some of these terminals incorporate vector drawing capability and would allow the display of the grid and the character on the same screen. The majority of these terminals use the Tektronix 611 storage tube as their basic component. Prices for such units start at about $3500 (Tektronix 4010) and may go as high, depending on options, as $5000.

## 5.4 PDP-8 TO COMPUTER INTERFACES

### 5.4.1 PDP-8-E to CDC 3200 Interface

This device is a channel-to-channel interface between a PDP-8 with negative I/O bus and a CDC 3200 made by DEC's Special Systems Division (see Appendix 3 for a description). This unit would cost about $15,000; the negative/positive bus converters needed for a PDP-8-E is included. UCC Engineering has offered DEC to design a state-of-the-art PDP-8-E to CDC 3200 interface (program compatible with the one described above) using DEC parts throughout which, when completed, would be maintained by DEC. At present DEC is considering this proposal.

The Applications Group of the Health Sciences Computer Center has built and uses a PDP-12/CDC 3300 channel-to-channel interface. They are now building one for the PDP-8-E. According to Mr. Alan Moore (373-0335) of that computer center, part's cost will be about $3000 for DEC parts, $1000 for CDC parts and cable costs (which might cost another few hundred dollars). Their group is willing to build one for cost (parts and labor) if needed. Maintenance of such a unit should be investigated.

Also, UCC Engineering is capable of designing, building and maintaining such an interface. Interfacing the PDP-8-E to the 3200 as if it were a tape unit would cost about the same, considering also the development costs of such a unit.

### 5.4.2 PDP-8-E to CDC 6600 Interface

The interface would be by way of telephone lines and requires the addition of a PDP-8-EA synchronous dataset interface to the PDP-8-E for $1500. Monthly costs amount to about $70 for the telephone line and dataset. The PDP-8-E has to emulate the operation of a CDC 200UT or a UNIVAC 1004. A good programmer could write the necessary software to emulate the 1004 for the PDP-8 in about two man weeks.

APPENDIX 1

INCREMENTAL TAPE TRANSPORTS

Nearly all magnetic tape equipment in use today uses standard 1/2 inch wide magentic tape.

Tape recorders must produce records on tape which can be accepted by all standard computer tape transports (which in turn may or may not be IBM compatible). Tape compatibility requires a number of markings and gaps to be generated on the tape, as well as compatibility of coding (NRZ1, PE, RTZ, etc.) error checkup (VRC-LRC, VRC-LRC-CRC, WRC-ID burst) character density (200, 556, 800 bpi) and number of tracks on tape (7, 9).

Incremental tape recorders accept asynchronous, randomly generated, information as it is presented. In order to generate, say an 800 bpi tape, the tape is incremented (or stepped) 1/800 of an inch each time a byte is recorded.

Data are usually recorded in the field and processed later by a large computer.

- It follows then, keeping the compatibility requirements in mind, that the controller and recording electronics of the incremental tape transport must be selected in full knowledge of the characteristics of the tape transports (where the tapes will be read) of the computer system choosen for processing the collected tape recorded data.

## APPENDIX 2

## DISPLAY SPECIFICATIONS

Reasonable specifications should be near the state-of-the-art.

Writing speed determines the maximum size of a message. If the refresh rate is a minimal 30 frames per second, each frame must be written in 33.3 milliseconds.

### Speed Factors

The three major speed factors are deflection rate, character writing and vector generation.

- Deflection of the beam from any point to any point should occur in 10-15 μ seconds.
- If a message content will ever go as high as thousands of characters or character plus vectors, characters should be written in 10-15 μ seconds. However, a character generator may be as slow as 100 μ seconds if the system will never be required to write more than 300 characters per frame. (This is not the case for the current application.)
- Full screen vector should be drawn in less than 100 μ seconds.

### Resolution

A dominant and troublesome specification is resolution. A 1024 (10-bits) resolution is adequate for practically all purposes. However, a 10-bit resolution specification is meaningless if the CRT cannot define it:

- assuming a 10 x 10 inch quality area, points must be defined to 100 per inch. Therefore, a 10-mil spot size at most is necessary for non-overlapping points. Yet 10-bit specifications are commonly identified with systems having 30-mil beams on 5 inch tube.

### Versatility

To achieve versatility, a full choice of hardware options is mandatory. The expected list includes:

. incremental as well as random plotting
. character generators (fast and slow)
. vector generators
. programmable size and intensity controls
. light-pens
. keyboards
. refresh memories

Further useful options are:

. circle and circle arc generators
. vector line structure
. Rand Tablet
. means for superimposing background data

Visual Standards

The most important is lack of ambiguity: vectors should connect at precise points; a continuous straight line should be just that; symbols should be drawn with clarity.

If the display is viewed for long periods, operator comfort is important. Fatigue is reduced by elimination of flicker and broken structures and minimization of interferences that cause "swim".

Minimal Software

It should be expected from the control computer that it handles:

. a light-pen tracking function
. store graphic routines
. filter inputs from light-pen, from stylus of tablet
. control the input and output of the refresh memory

These functions can be handled by a minicomputer which might be tied to a remote, large time-shared computer for bulk storage, special tracking programs and complex calculations.

# APPENDIX 3

# DEC PDP-8/CDC 3200 INTERFACE*

## INTERFACING THE DEC PDP-8 COMPUTER TO A CDC 3200 SYSTEM

The interprocessor buffer, which was designed by DEC to interface between the DEC PDP-8 and the Control Data Corporation Model 3200, transfers 12-bit words bidirectionally from one processor to another under program control. The control and status lines of each processor are sufficient to control this interface device from either processor. The PDP-8 transfers data through its accumulator and the CDC 3200 transfers data via a bidirectional data channel.

The six control conditions used in this interface device are: A Sending, B Sending, Busy, A Data Flag, B Data Flag, and End.

### A. A Sending

This control condition can only be set from Processor A (PDP-8). Processor A transfers information to Processor B (CDC 3200). This control state remains for the entire transfer period and is dropped by a deselect control signal from Processor A. A Sending is comparable to B Receiving.

### B. B Sending

This control condition can only be set from Processor B. Processor B transfers information to Processor A. This control state remains for the duration of the transfer and is dropped by a deselect control signal from Processor B. B Sending is comparable to A Receiving.

### C. Busy

This control condition can be set by either A Send or B Send, but not both simultaneously. The Busy condition locks out any select signal from either processor and ensures that only one of the two Send states exists. Busy will be cleared by A Send or B Send being cleared.

D. A Data Flag

This control state can be set by any of the following conditions:

(1) When Processor B wants to receive data from Processor A, Processor B generates a B set A Data Flag signal, setting the A Data Flag interrupt. This interrupt condition can then be interrogated by Processor A.

(2) When Processor A is transmitting, B Data Flag is set, and Processor B data signal accepts information from the interface to its data channel.

(3) When Processor B is transmitting, Processor B data signal transmits information into the interface buffer.

This control state can be reset by any of the following conditions:

(1) A Sending and Processor A transmits a word into the interface buffer.

(2) B Sending and Processor A accepts a word from the interface buffer.

(3) Processor A generates a Clear A Data Flag IOT.

E. B Data Flag

This control state can be set by any of the following conditions:

(1) When Processor A wants to receive data from Processor B, Processor A generates an IOT signal (A Set B Data Flag), which sets interrupt line 7 of the Processor B data channel. This interrupt condition can then be interrogated by Processor B.

(2) When Processor A is transmitting, Processor B generates a data signal which takes a word from the interface buffer.

(3) When Processor B is transmitting, A Data Flag is set, and Processor A generates a data signal which takes a word from the interface buffer.

Resetting this control state can be accomplished by any one of the following conditions:

(1) B Sending and Processor B puts a word into the interface buffer.

(2) A Sending and Processor B takes a word from the interface buffer.

(3) Processor B generates a clear external interrupt signal.

F. End

This control state indicates that the last word of the transfer is in the interface buffer. The condition is set by Processor A with an IOT, A set End, or by Processor B when the write level drops at the end of a B send block transfer. The End control is cleared by Busy being set, or either Read or Write being set.

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*from: <u>DEC Communications Equipment Handbook</u>, DEC-00-GWZA-D, 1970.