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USE OF AUDIOGRAPHIC TECHNOLOGY

IN CONTINUING GRADUATE-LEVEL SCIENCE EDUCATION

Annual Progress Report on NSF Grant GN-2628

VLADIMIR SLAMECKA
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July 1973

School of Information and Computer Science
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ABSTRACT

The report summarizes the progress made during the first year on NSF Grant GN-2628. The two-year project is concerned with the design and evaluation of a learning system based on audiographic technology in continuing science education at the graduate level.

As planned, the first year of the project has been devoted to the development of the physical facility and the base of self-instruction materials, in preparation for the experimental activities scheduled for the coming year. This first annual report describes in detail the hardware check-out and software characteristics of the Audiographic Learning Facility (ALF) which sustains the self-instruction process from remotely located audiographic (speech/line graphics) terminals.
ACKNOWLEDGEMENTS

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7.0 EVALUATION DESIGN

7.1 Evaluation of Student Satisfaction

7.2 Evaluation of Student Achievement

APPENDIX

Guidelines for the Preparation and Recording of Learning Materials for the Audiographic Learning System
1.0 INTRODUCTION

Audiographic technology permits inexpensive storage, telephone transmission, and synchronous replay of narrative and line graphic presentations, thus capturing the primary content of blackboard lectures. The Audiographic Learning Facility (ALF), a quasi-conversational self-instruction system utilizing this technology developed at the School of Information and Computer Science, strongly indicates the practicability of this economical, widely applicable approach to effective self-instruction by mature learners and groups of learners.

Based on early indications of promise gathered from limited usage of ALF at the high school, college and graduate levels of education, the Georgia Institute of Technology commenced, with support from NSF grant GN-2628, a two-year project seeking to implement and evaluate operationally an ALF system for continuing self-instruction at the graduate level. The project has been a cooperative effort between the School of Information and Computer Science and the Department of Administrative Services of the State Government of Georgia. The Department of Administrative Services is responsible, among other functions, for the planning, design and operation of information processing activities and facilities of the various agencies of the State Government, and it employs numerous professionals who are college graduates in the mathematical and information sciences.

The principal objective of this trial implementation of ALF is the evaluation of its cost effectiveness in programs of continuing graduate education. To meet this objective, the project participants have been engaged during the past year on the following major tasks: the development of a curriculum base; the design and implementation of a physical facility for self-instruction using audiographic technology; and the refinement of an appropriate experimental design for evaluation of the project results.

The first of these efforts, the on-going development of a curriculum
base, is discussed in section 2 of this report. The facility itself is described in sections 3, 4, 5 and 6, with section 3 providing an overview of user/system interaction, sections 4 and 5 providing information on the system's principal hardware design features, and section 6 documenting system software. The report concludes, in section 7, with a summary of the evaluation design as currently conceived.
2.0 A LESSON BASE FOR SELF-DIRECTED LEARNING

Each recorded audiographic learning unit contains as a minimum a graphic-supported narrative presentation on a single, self-contained topic. In addition to this "lesson," the instructor may include in the learning unit two other distinct elements: an example (or set of examples) and a test (and its solution).

Since ALF is a system for self-directed learning, instructors have been encouraged to make as much use as possible of this capability of the system for allowing the learner to verify his understanding of the material explicated by calling in a separately addressable example or self-test.

On the other hand, the learner may choose to by-pass the example and/or tests associated with a lesson or sequence of lessons. This he might do either because he has full confidence that he has mastered the material, or because he wants to achieve a quick survey of the material (either for review or for initial overview). Alternatively, the learner may by-pass the lessons themselves, and instead "browse" through a selected sequence of tests. In this way he can in effect sample the material, verify his understanding or lack of understanding of particular topics, and find his own level of competence (and thereby establish a starting point for a new learning goal).

As discussed in the next section of this report, the system has been developed to provide the learner with a substantial degree of control in accessing learning materials formatted in this manner. Thus, when a lesson segment is concluded the system will halt in anticipation of a response from the learner. The learner may repeat the lesson; call for the example or the test, by means of the simple mnemonic commands X or T; or call for the next lesson.

In selecting "the next" lesson, the learner will be guided by a printed directory of learning materials which identifies various suggested sequences of learning modules and characterizes those carefully
planned sequences according to their level of difficulty and according to the different learning goals to which they lead.

Each of these identified sequences may be considered a tutor-recommended learning strategy; however, there is nothing to preclude a learner from choosing from the directory of learning materials a sequence of lessons not officially sanctioned by an instructor as a recommended learning strategy (or packaged "course"). One of the interests of the experiment will be to determine to what extent students will choose to use the learning system to develop unique and personal learning strategies, as well as to gauge the effectiveness of those strategies as compared to standard courses. This evaluation will be made possible by a special log program which has been written for the PDP computer; the program will monitor and record both individual and group activity and tabulate it by user-code for subsequent statistical analysis.

The process of identifying recommended learning strategies to meet typical student learning goals will be finalized when the total lesson base is fully developed. The planning and development of the lesson base is an on-going effort, and actual recording of lessons has been in progress since March 1973. When completed, the lesson base produced for this experiment will include a collection of learning materials on 1) systems theory; 2) computer systems and computer systems management; and 3) information and data base systems design and management.

A comprehensive guide for the preparation and recording of learning materials for the Audiographic Learning Facility is included as an Appendix to this report.
3.0 OVERVIEW OF USER/SYSTEM INTERFACE

**Faculty Member**

prepares lesson. Whenever possible, prepares for each lesson an example (or series of examples); a test (to be used by the learner for self-testing); and a solution (to be used when the test requires a lengthy explanation of the methods used to derive solutions to problems in the test).

* Records lesson, example, test, and solution.
* Completes Lesson Documentation Form.
* Forwards Lesson Documentation Form and completed tape to recording technician.

**Recording Technician**

* Receives tape and Lesson Documentation Form.
* Assigns lesson a 4-digit (octal) number.
* Merges the recorded lesson onto a master tape.
* Inserts markers to indicate inter-segment gaps.
* Creates table providing the following information: Tape No. -- Lesson No. -- Track No. -- Relative Positions of: Lesson, Example, Test, Solution. (Tape numbering system is discussed below.) When recordings have been copied onto both sets of tracks, the recording technician converts relative positions to table entries which show the absolute number of markers passed.
* Builds duplicate tapes (if required) following the same procedure.
* Numbers each tape with a 4-digit (octal) number. The 4th digit indicates copy number: i.e., xxx0 refers to the master copy, xxx1 refers to the first duplicate, etc.

* Has table converted to machine usable form. This table will become the Master Library Table and be stored in an on-line file.

* Has Lesson Documentation Form converted to machine usable form (for catalog purposes).

**Operator**

* Receives and stores tape.

* According to a schedule determined in response to projected or known user needs, loads appropriate tapes and duplicates.

* Equates tape numbers with the numbers of the player unit on which it has been loaded (i.e., communicates with the operating system that a specified tape has been loaded on a specified device). When equating tape numbers with device numbers, the operator must make entries in ascending order by tape number—e.g., tape 1230 on device 4, tape 1231 on device 1, etc. The appropriate information will be loaded from the Master Library Table.

**Learner**

* Calls data station. (Two calls are necessary from the Touch-Tone equipment; one will establish audio contact; the other, video contact.)

**System**

* Automatically answers call, makes connection with user, and logs the call-in. When ringing ceases, connection has been established.

**Learner**

* Enters user authorization number. User authorization number is an
assigned 5-digit (octal) number beginning with 1, where the 1 is actually the command code.

(Note: The sign-on message will begin with an * and terminate with a #, as will all user messages or commands to the system.)

System

* Determines that authorization code is valid. (If not valid, sends error message.)

* Begins logging user activity. Logging consists of storing the time of each activity and the nature or specifics of that activity.

Learner

* Keys in request for lesson, or for the example, test, or solution associated with a lesson. Examples:

  *L1234# ("Play Lesson 1234.")
  *X1234# ("Play the example of Lesson 1234.")
  *T1234# ("Play the test of Lesson 1234.")
  *S1234# ("Play the solution of Lesson 1234.")

System

* Searches library table in memory to determine whether the desired segment is on line and the player unit on which it has been loaded is available.

(Note: As long as the number of terminals is not greater than the number of mounted copies of the requested lesson, at least one player unit will always be available to answer a learner's request for any on-line lesson.)

* If the described segment is not on-line or is not free, sends message referring learner to the manual.

* If the desired segment is on-line and is free, seeks location of
segment and initiates play when found.

(Note: The search for an available copy of the requested segment will always be made by searching tape numbers in an ascending order. Thus, a duplicate copy such as 1231 will never be used unless the master copy 1230 is in use at the time of the request. Subsequent tabulations of data from the activity log will therefore show to what extent, if any, duplicate tapes were actually needed during the period under review.)

Learner Options During a Learning Session

* At the end of a lesson segment, the player unit will come to a halt. If the learner wants to see the example, test, or solution associated with that lesson, he may key in an asterisk, followed by the appropriate command, followed by a pound sign; he does not have to key in the lesson number. Examples:

*E#  ("Play example associated with this lesson.")
*T#  ("Play test associated with this lesson.")
*S#  ("Play solution associated with this lesson.")

He may execute these commands in any order, and may even begin his learning session by calling first for an example and then for the lesson. In such a case, his request for the lesson would be keyed in simply as *L#. Thus a learner may go back and forth from one to another segment of a lesson as much as he likes.

* The learner who has called up a segment of learning material may also browse within that segment, by using the following commands:

*B#  ("Back, in fast rewind.")
*F#  ("Forward, in fast forward.")

The execution of the command will cause the player unit to continue the fast-forward or rewind until either an intersegment gap is reached, or until the user keys in the following command:

*G#  ("Go ahead playing, from this position.")
* The learner or tutor may pause during the playing of a learning segment by keying in an asterisk, which will always suspend all activity on the playing unit being accessed. To recommence playing, he can use a "Go ahead" command.

   *G#  ("Pause on * and continue on ".")

* If the learner desires to communicate with the system operator, he may key in the commands:

   *# (Zero, or "Operator")

This will type out a message on the operator console.

* If the learner wants to conclude his own activity at the terminal without disconnecting the terminal itself from communication with the system, he can key in the command

   *OFF# ("Finished.")

Interpretation of the System Error Message

* The system will generate only one type of message to the user, as follows:

   "Sorry -- your request cannot be processed. Please see the Error Listing in your ALF manual."

* The Error Listing in the ALF manual will consist of an easily interpreted list of possible errors or error conditions, in the following format:

Were You Trying to Log In?

   The system can not begin operation until you key in *, followed by your complete, valid authorization number, followed by a #.

   * - - - - 

Did You Want a Learning Segment?

   To play a learning segment, key in * (L,E,X,S), then the four-
digit lesson number **exactly as it is shown in your catalog**, then #. If you have requested the segment properly but have failed to receive it, then the lesson is either being used by another learner or is otherwise unavailable. (If you have continued at various times to have trouble getting some particular lesson, inform the system operator.)

**Did You Fail to Key in a Valid Command?**

All commands should begin with * and terminate with #. For the proper use of each command, consult the descriptive material found in this manual.
4.0 HARDWARE DESIGN FEATURES

The hardware for the ALF system is designed to connect a user to a pre-taped lesson efficiently while allowing as much user freedom as is practical.

In order to achieve this, the user is expected to have at his station a standard telephone Touch-Tone pad, in addition to the audio receiving device, the Electrowriter graphic receiver, and two phone lines. The Touch-Tone pad should be connected to the telephone line used for audio or voice transmission.

The user connects to the system by dialing (in any order) the graphics phone number and the audio phone number, on his respective phones. He then is expected to key in digits in a pre-arranged sequence that may inform the computer who he is, what lesson he desires, or any other pre-arranged information that may be coded in a combination of 12 digits.

Shifting attention now to the ALF site, the two telephones have been automatically answered through a relay circuit that triggers on the bell current. The audio phone line goes through a network which changes the telephone two-way transmission pair of lines into two pairs, one pair leading into the site hardware, one serving as output from the hardware to the user.

The input pair of lines goes through a tuned RC (resistor-capacitor) decoder (commercially manufactured) that detects which key the user depressed, and transmits this information to a load-in interface which generates an interrupt request to the PDP-8/I processor, and which, when serviced, informs the processor that a button has been depressed and identifies which one it was.

The software takes over at this point, until a recognizable sequence of digits has been transmitted. Suppose the sequence transmitted tells the machine the user wants to hear lesson X. Once the machine ascertains which tape deck contains the tape with lesson X, and where
lesson X is relative to the present tape position, the machine activates a load-out interface that signals the tape deck via a relay register, beginning a function. Suppose lesson X is 14 marks forward on tape unit 3. Then the load-out interface activates the "forward" solenoid on deck 3, while another interface selects the proper track. At the same time, a photo-transistor mounted on the tape deck is detecting the white markers placed on the tape. Each time a mark passes the photo-transistor, another interface informs the processor that a mark has passed. When 14 have passed, the processor activates the "stop" operation, then actuates "play" (again through the relay register). If marks are encountered as the tape is played, the processor is so informed; thus the position on the tape is always known. Now lesson X is playing. Another load-out interface operates a switching array which directs the output of tape unit 3 to the proper phone lines.

Associated with the output are two devices. The compensator unit alters the graphics output to compensate for tape deck wow and flutter, by comparing a reference frequency which was recorded on the tape with a standard oscillator. In addition, line devices are needed on each line, to serve as a control over the signal strength which is output over the telephone lines and to buffer the output signal to meet telephone company restrictions.

At this point the user is receiving the audio and graphics transmission that he requested. If at any time he desires to stop the tape, or perform any given operation, he merely keys in the appropriate sequence of numbers, and the same process described above is followed to carry out his wishes. It should be noted that the operations mentioned occur at microsecond-magnitude speeds, with the exception of tape operation on the decks themselves, which are obviously constrained to normal tape-deck-operation speeds.

At termination of connection, the user signals the machine, and the two phone lines are disconnected upon the reception of a user-on-hook signal.
5.0 HARDWARE CHECKOUT PROCEDURES

In order to effectively utilize a diagnostic, trouble and symptom should be carefully analyzed to ascertain the location of the fault. Once this is obtained, the appropriate section of this outline should be consulted for more explicit instructions. For instance, if everything functions properly except the tape positioning, the procedure in section 5.3 should be followed.

In the event that nothing responds, it will be necessary to start at the beginning of the diagnostics, and proceed sequentially.

(It is assumed that the initial check will include checks for connected power loads, good fuses, tight connections and all proper switches "ON.")

5.1 Reception and Decoding of Input

A. Determine that the neon bulb on answering check flashes and circuit answers when circuit number is dialed in. (Note: all input is on voice line.)

B. Use scope to trace input signal, by calling in to line from test phone.
   1. Call voice line.
   2. Check for input by keying in a character and checking with scope. If none, try another phone line (problem is with telephone company).
   3. Check past network on "receive" line for scope. If none, problem is in network. Switch wires to try another network.
   4. Check input point on Touch-Tone decoder network for strong signal, slightly dipped. If not, trouble is in network to decoder wiring train. If signal is weak, use input divider pot to adjust signal so it dips slightly.
C. Test decoding and voltage interface circuit.
   1. Use scope on proper output of decoder, and wait for level shift when character is depressed. If none, substitute spare decoder and recheck. Check all possible characters.
   2. Test output of voltage interface circuit. Each character depressed should cause a -3v to 0v level shift on the proper pin when connected to live (power-up) interface.

D. Test digital decoder interface.
   1. Check for an interrupt signal plus a load-accumulator signal when each character is pressed. A no-signal is an interrupt circuit fault. Test cards by substitution; use ITR Interface Test Routine (see section 5.6).

E. Perform software check.
   1. At this point, the proper signals are being transmitted by the interface, and the software input test should be run.
   2. If the software test fails, check input cables to processor, and check the program for the test.

5.2 Tape Deck Control Check

A. Use scope and a software test program to verify that the control interface is receiving the proper signal from the processor. Check I/O Cables.

B. Check relay registers for proper contact closure relative to test program output. If not, problem is in interface, and interface must be tested according to ITR Interface Test Routine (see section 5.6).

C. Test connector at each deck to verify proper contact closures and to assume proper cable connections. If this fails, check the tape deck connecting cables.

D. Test deck operation. Switch cables to verify faults in an individual deck. Tape deck problems must be handled by service engineer.
5.3 Tape Position Mechanism

A. Mount and start tape position TEST tape.

B. Verify presence of light on the sensor head, and pulses from the photo transistor when a spot passes. If not, fault is in power supply or component defect.

C. Verify input to 529K computer matches spot passage. If not, problem is in discrete components.

D. Verify output from computer. If not, comparator or circuit is defective. Check power on comparator, both + and - supplies, also + gate supply.

E. Verify pulses on output cable at circuit board. If not, transistor or associated circuitry is defective.

F. Check for pulses at input to interface. If not, check cable, and power to interface.

G. Verify that interface causes interrupt and loads appropriate line. If not, use ITR.

H. Utilize software spot test to verify input cables and interface timing.

5.4 Tape Output and Compensation

Output test tape must be played to make this test.

A. Use a speaker and photo pin plug to monitor deck output on both channels. If not, problem is in tape deck.

B. Trace tape output lines, monitoring at all junction points, up to line select interface. If not, problem is in cables.

C. Verify that line select interface selects proper lines. If not, use ITR.
D. Use Electrowriter receiver to verify that signal is coming through compensator, and is compensated. If not, refer compensator to Service Engineer.

E. Test signals at input to line driver using speaker and Electrowriter receiver. If not, problem is in cables.

F. Test signals at output of line driver. If not, problem is in line driver. Refer to Service Engineer.

5.5 Transmission and Remote Reception of Output (Continuation of 5.4)

A. Test signals at ("Trans" jack) of network. If not, cable is at fault.

B. Test signals at output of network (phone terminals). If not, problem is in network; interchange and retest.

C. Test for proper reception at test receiving station. If not, problem is in connections at receiving station, or in telephone company's circuits.

5.6 Additional Tests

ITR (Interface Test Routine). This test generally consists of tracing signals through an interface using the scope to determine the point at which they fail to operate properly. If a point fails, substitute the corresponding clip with a working clip to see if the problem is a defective part. If not, then wiring must be checked.

Miscellaneous Tests. Many trivial tests and voltage readings have been omitted since so much is learned from studying the schematic documentation. However, particularly in analog and power portions of the circuit, these are important. Also note parts which appear out-of-the-ordinary. Melted or hot components frequently yield valuable information.
6.0 SYSTEM SOFTWARE

The software for the Audiographic Learning Facility is designed to provide system users with the flexibility needed to utilize the system effectively, while still permitting the system to retain complete control over all hardware components and their respective functions. This design objective may be viewed as a problem in process control, with real-time system functions occurring at random times. The Control Program, described in sections 6.1 through 6.8., was written to provide software to satisfy this requirement. The Control Program is an assembly language program with three basic tasks: the first is to initialize the system with information from the operator on the location and contents of the lesson segments; the second is to control, based on established algorithms, the various operations of the system (i.e., tape recorder control and spot detection, phone line switching, Touch-Tone input and conversion, timing, etc.); the third is to log the important system occurrences for future reference.

Controlled response time to various system occurrences is made according to an established priority; because each of the hardware components has a unique set of operating speeds and characteristics, response must be dependent upon a priority basis to insure that firm control is maintained. This priority is established through software, utilizing the interrupt structure of the PDP-8/I computer.

An ancillary function of the software system is to provide a data-gathering capability for recording all important system occurrences, so that this data may then be used to formulate system statistics. The "log" function within the Control Program provides a basic data-gathering capacity by storing the raw log information in a disk file. A separate Log Program, described in section 6.9, then operates on this file to generate desired statistics.
6.1 Interrupt Handler

The Interrupt Handler is the routine in the Control Program which is at the heart of the control process. It is involved whenever a peripheral device has a transition in state, and the central processing unit, detecting this change (an interrupt request), passes control to the Interrupt Handler Routine. The Interrupt Handler services the interrupt request by detecting its cause (the particular device) and storing away the information transmitted in one of the status tables described in section 6.3. It is within this routine that priorities are established: the "spot-detector" hardware has first priority and, while being serviced, cannot be interrupted by any other device. The spot detectors are represented in a register as one bit for each tape recorder; detection of the spots on each recorder is the primary means of determining the status of each tape on each tape recorder. Because of the high speed operation of the tapes, and the possibility of near-concurrent spot detection on different recorders, it is necessary to designate the highest priority to the detection of spots, and to optimize the spot detection routine within the Interrupt Handler.

Next in priority are the Touch-Tone interfaces which receive characters keyed in by users, followed by the real-time clock which is used to simulate a time-of-day function and to control timed system operations; all other interrupts are subordinate to these.

At any interrupt request except one from the spot detectors, the system status is stored in a circular queue, and the interrupts are enabled, thus permitting the servicing of any device lower in priority than the spot detectors to be interrupted by any other device. (This is the only way on the current computer system to provide the absolute priority the spot detectors need.) By using a queue philosophy, the oldest interrupt pending service will be handled first, following identification of the latest interrupt; the latest interrupt is delegated to the end of the queue.

6.2 Action Routines

As mentioned above, the Interrupt Handler merely identifies and
stores a peripheral transfer or operation; action is taken, when necessary, after all interrupt requests have been satisfied. The action routines can thus be viewed as a background operation with the Interrupt Handler representing a foreground task. A special routine constantly monitors the results of interrupt handling (in "activity" words for recorder, data-line, and clock) to determine if action routines need to be initiated, and passes control to the appropriate routine as required. Actions consist primarily of tape recorder control, phone line switching, and certain time activities. When any action takes place, related activities are initiated: (1) the action is entered in the Log File; (2) the status tables are updated to reflect the new system status; (3) if any system or user errors are detected, transfer to an error routine takes place.

The particular type of action taken is dependent upon an analysis of the situation initiating the action. For the spot detectors, a comparison is made between the current spot count for the tape recorder in question and a projected target spot count that was calculated previously; the two being equal normally leads to the recorder being stopped and a time delay initiated, with possible further action after the delay, depending on settings in the status tables.

Touchtone inputs are treated as strings to be analyzed beginning with the first character, the syntax of the string determining which routine will handle the required action. All strings must begin with * and be terminated by #. Some examples might be: calling for a lesson segment (*L....#), which initiates motion on a recorder containing the lesson; entering a sign-on number (*1....#), which causes no action other than an entry in a status table and in the log; entering an *, at any time, which halts an affected recorder if it is in motion.

A clock routine is entered every 1/5 second to determine if action is necessary as a result of some timing function. Thus, systems timing will be accurate to within this 1/5 second constraint. An example of timing usage is the short delay after a tape recorder stop has been initiated that is necessary to allow the recorder to come to a complete stop before initiating any further action.
6.3 Status Tables

The status tables keep a complete record of the system status at any given point in time. These tables are updated by the Interrupt Handler and action routines as events take place. (The status tables are designed to reflect a potential hardware configuration of 6 data-lines and 48 tape recorders.) There are two status tables in the present configuration: the Data-Line Table and the Tape-Recorder Table, both described below.

**DATA LINE TABLE -- Six entries, each of the following format:**

<table>
<thead>
<tr>
<th>Word 0</th>
<th>Status word</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bit 0</td>
<td>Motion Indicator bit</td>
</tr>
<tr>
<td>1</td>
<td>Hangup/callup flip-flop</td>
</tr>
<tr>
<td>2</td>
<td>Signed on bit</td>
</tr>
<tr>
<td>3-5</td>
<td>Data-line number</td>
</tr>
<tr>
<td>6-9</td>
<td>Unused</td>
</tr>
<tr>
<td>10</td>
<td>Error on key-in</td>
</tr>
<tr>
<td>11</td>
<td>Activity indicator</td>
</tr>
</tbody>
</table>

| Word 1 | Current character entry |
| Word 2 | Pointer to tape recorder entry |
| Word 3 | Current lesson accessed |
| Word 4 | Pointer to string area |
| Word 5 | Displacement to string word |
| Word 6-13 | String buffer |

**TAPE RECORDER TABLE -- Forty-eight entries, each with the following format:**

<table>
<thead>
<tr>
<th>Word 0</th>
<th>Status word</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bit 0</td>
<td>Time activity bit</td>
</tr>
<tr>
<td>1</td>
<td>Motion indicator bit</td>
</tr>
<tr>
<td>2</td>
<td>Play indicator bit</td>
</tr>
<tr>
<td>3</td>
<td>Fast forward indicator bit</td>
</tr>
<tr>
<td>4</td>
<td>Rewind indicator bit</td>
</tr>
<tr>
<td>5</td>
<td>Stop indicator bit</td>
</tr>
<tr>
<td>6</td>
<td>Play indicator bit</td>
</tr>
<tr>
<td>7</td>
<td>Timing after stop bit</td>
</tr>
<tr>
<td>8</td>
<td>Error message use</td>
</tr>
<tr>
<td>9</td>
<td>Unused</td>
</tr>
<tr>
<td>10</td>
<td>Within lesson bit</td>
</tr>
<tr>
<td>11</td>
<td>Stop activity word</td>
</tr>
</tbody>
</table>
6.4 Library Table

The Library Table is a list denoting the lesson segment tapes currently mounted on the system. It will have a varying number of entries, depending upon information taken from a master table not core resident. The format of each library table entry is as follows:

Word 0        Lesson number
Word 1        Tape number
Word 2        Address of tape recorder entry
Word 3        Beginning and terminating spots for lesson
Word 4        Beginning and terminating spots for example
Word 5        Beginning and terminating spots for test
Word 6        Beginning and terminating spots for solution
Word 7        Expansion word

6.5 Error Notification

Any error situation noted by the control program (such as incorrect key-ins by a user, unavailable lessons, etc.) will cause control
to pass to a common error routine. This routine assumes that the initial lesson on each tape recorder contains the error message; the error routine will search through the status tables for an available tape recorder from which the error message may be transmitted. The search should find a tape positioned so as to minimize the access to the error message and thus send the message to the user as soon as possible.

6.6 Initialization

Because the requirements for the particular on-line lesson segments to be available will vary from day to day, a method has been devised to permit an operator to dynamically create the library table to be consistent with the actual tapes mounted. This takes place as the first operation of the Control Program before the system is made available to users.

To permit an efficient means of accomplishing this initialization, a master Library Table with all possible tapes and their lesson segments is stored as a disk file. The initialization sequence consists of equating a tape unit with a tape number, upon which the program will load the appropriate library information from the Master Table. One notable advantage of this technique is that it makes it possible to modify the master table by on-line means and thus keep up with changes in the available tape inventory.

6.7 Programming Notes

The following are some specific notes on programming the various interfaces as they are currently implemented:

Tape Recorder Control. The current hardware configuration of 8 tape recorders is controlled by 3 sets of input/output instructions, utilizing device codes 55, 56, and 57, with each device code controlling 3 recorders. 10P 1 is designated the clear pulse while 10P 4 is designated the set pulse (micro-programmable). The bits set in the accumulator when an I/O instruction of this type is given determine the
particular action taken on the particular recorder. A set of 4 bits within the 12-bit word completely controls the functions of one recorder as follows:

<table>
<thead>
<tr>
<th>Bit 0</th>
<th>Bit 1</th>
<th>Bit 2</th>
<th>Bit 3</th>
<th>No bits set</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local bit</td>
<td>Play bit</td>
<td>Fast forward bit</td>
<td>Rewind bit</td>
<td>Halt</td>
</tr>
</tbody>
</table>

Within each word, the local bit is used to continue the current function for a given recorder; in this manner, the programmer does not need to know a recorder's current function to continue it when he is altering the function of another recorder. In addition, the local bit must be set in conjunction with any function change except halt. Currently, device code 55 controls recorders 1-3, code 56 controls recorders 4-6, and code 57 controls recorders 7 and 8.

**Phone Line Switching Control.** Three additional I/O devices are designated for line switching. Device 30 controls recorders 1, 2, and 3; device 31 controls recorders 4, 5, and 6; while device 32 controls recorders 7 and 8. In the current configuration, 4 accumulator bits in a word are assigned for each recorder. Two pairs of bits control the two channels of audio and video signals, with one set functioning for data-line 0 and one for data-line 1 as follows:

<table>
<thead>
<tr>
<th>Bit 0</th>
<th>Bit 1</th>
<th>Bit 2</th>
<th>Bit 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data line 0 audio</td>
<td>Data line 1 audio</td>
<td>Data line 0 graphics</td>
<td>Data line 1 graphics</td>
</tr>
</tbody>
</table>

IOP 1 represents a clear, with 4 being a set as in function control; however, each bit must be set every time an I/O instruction is processed. To preserve continued functioning on each recorder, it is necessary to set up a status word for each of the three devices representing the current bit status.

**Touch-Tone Decoding.** One bit is set in the accumulator to
correspond to the character keyed in. The bit functions and corresponding characters are as follows:

<table>
<thead>
<tr>
<th>Bit</th>
<th>Character</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>9</td>
<td>*</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>11</td>
<td>#</td>
</tr>
</tbody>
</table>

No bits set Call-up or hang-up

The 10P sequence is a standard one with 10P 1 representing a skip on flag, 10P 2 being a clear, and 10P 4 a read into accumulator (micro-programmable). Device code 40 is designated to control data-line 0, while device code 41 controls data-line 1.

Spot Detection. In this I/O instruction, the accumulator bits are configured so that one bit is set for a spot detected on any of the corresponding recorders. The accumulator bit positions and their appropriate recorder are as follows:

<table>
<thead>
<tr>
<th>Bit 0</th>
<th>Recorder 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>7</td>
<td>8</td>
</tr>
</tbody>
</table>

The spot detection interface utilizes device 42 with the usual 10P designations.
6.8 The Log Program

The Log Program takes the raw log disk file created by the Control Program and computes statistics on usage from it. The first of three phases of the program produce (on the line printer) an edited raw log which gives a narrative description of each event as it occurs in chronological sequence, by user.

The second phase produces a breakdown by learning segment. For each lesson, example, test, and solution, the following data is summarized: number of successful accesses, number of terminations in this segment, number of normal terminations, number of back and forth browsing calls. This listing is also printed on the line printer.

The final phase gives a listing with further information on each learning segment: the number of times a failure to access occurred, and the number of times a backup tape had to be used.

Each of these reports may be printed out in any combination with the others by specifying a parameter to the log program in its initial operation.
7.0 EVALUATION DESIGN

The evaluation is divided into two sections. The first section is concerned with students' evaluation of the system in terms of general system characteristics, and the presentation variables associated with selected teaching modules. The second section of the evaluation is based on pre- and post-test multiple choice examinations of the students to determine achievement. These multiple choice tests will contain items designed to sample both ALF module content and assigned outside readings. The multiple choice test will be supplemented by an example-generating task and a teachback task which will be administered to a small sample of students and used to supplement the tests and which will provide additional evidence of the validity of the multiple choice examination. A general outline of the two phases of the evaluation design, subject of course to appropriate modifications determined necessary based on experience gained during the further development of the lesson base, is presented in sections 7.1 and 7.2 below.

7.1 Evaluation of Student Satisfaction

Evaluation of general system characteristics will be accomplished in part by allowing students to rate the system in terms of the following variables:

Presentation variables. Examples:
* Was audio (voice) clear?
* Was graphic display adequate in terms of size of screen, readability of writing, etc.?

Feedback variables. Example:
* Did you request interrupt or stop-and-play back capabilities?

Indexes and Retrieval of Relevant Modules. Examples:
* Did you obtain the module you requested?
* Was the system response time satisfactory?
Reliability of System. Examples:
* Were graphics properly centered?
* Were graphics displayed clearly?

Evaluation of individual modules will be accomplished by allowing the students to rate those modules according to criteria such as the following:
* Content at proper level of difficulty?
* Verbal presentation at proper rate?
* Graphics relevant to topic and clearly related to verbal presentation?
* Did you wish to interrupt and play back?
* Did you have any questions you wished to ask?
* Was initial portion clear, but final portion not clear?
* Was test material relevant, and were the examples good?

7.2 Evaluation of Student Achievement

To determine student achievement, a multiple choice test will be developed that is directly related to course content and assigned reading. An item analysis will be performed prior to use in the main evaluation. The specifications are as follows:

1) Approximately six items will be written for a 20-30 minute module. The generation of multiple choice items will be the responsibility of the author of each module, and should have a .5 difficulty level.

2) Three multiple choice items will be written for each assigned reading; specification as above.

Prior to use in the evaluation, a test containing all items will be administered to a sample of students similar to the population to be evaluated. Each item will be analyzed for its statistical characteristics. A cluster analysis will be conducted to clarify the content of the test. Based on the analysis new items will be written to replace unsuitable items.

Two equivalent forms of the test will be prepared. Each test will
contain 3 items for each of the teaching modules; in addition, 3 content items will be added to the test for any assigned reading associated with the module. The same items will be used for both of the equivalent forms. The statistical design will permit an evaluation of the test-retest effect on the same items.

The experiment group will consist of all students participating in the course at the Department of Administrative Services. The control group will be composed of students at Georgia Tech who are participating in courses whose content does not overlap with the ALF modules taught the experiment group. Both groups will be administered the pre-test. One half of the students in each of the groups will be administered form A while the other half is given form B.

On the basis of pre-test scores, students from the control group will be matched with students from the experiment group. This selected group will be retested at the same time as the experiment group is retested to provide a base line to determine the effect of the ALF course. Each group receiving the A form in the pre-test will be divided into two groups for the post-test measurement with one group receiving the A form and the other group the B form. This will permit an assessment of any test-retest effect on the same items.

Finally, to determine in depth the effectiveness of the course, students in the B group (assuming the evaluation demonstrates effective teaching) will be selected for high and low scores. Students from these two groups will be required to generate examples of concepts taught in the course and to teach selected topics to an examiner. (These protocols will be analyzed for content and evaluated; they are assumed to provide a more severe evaluation of teaching effectiveness than the multiple choice tests and should provide information on possible deficiencies of the teaching programs.)

The student rating of the system and course content will be coordinated with test scores to provide additional evaluation.
APPENDIX

GUIDELINES FOR THE PREPARATION AND RECORDING OF LEARNING MATERIALS FOR THE AUDIOGRAPHIC LEARNING FACILITY (ALF)

I. PREPARATION OF ALF LESSONS

a) Natural Units. To the extent possible, each ALF lesson should be restricted to a single concept, and should run no longer than 15 minutes. By "single concept" is meant nothing more than that the lesson should form a natural unit. To take an example from a course in grammar: a discussion of what a "noun phrase" is would be such a unit, as would a discussion of what a "verb phrase" is—whereas the two types of discussions would normally not be included in one and the same lesson. (Of course, a separate lesson could explain how noun and verb phrases combine to form sentences, but basic discussions of different kinds of phrases should be assigned to different short lessons.)

If a single concept requires a relatively long explanation (e.g., one hour of lecture), divide the lecture into a sequence of shorter lessons by identifying and explaining subconcepts. In other words, always break learning materials into natural units of no more than 15 minutes of explanation; it is largely irrelevant whether a particular natural unit is devoted to a single concept, a single subconcept, or a cluster of related subconcepts.

b) Modularity. Plan ALF lessons so that they will be as self-contained (as "modular") as possible. This requirement does not mean that an instructor preparing a lesson cannot presume that a student already knows certain material. It merely means that the instructor should not assume that the student has learned the material from some particular lesson or course.
c) **Use of Graphics.** Effective use of ALF requires an active graphics presentation, and the lesson should therefore be planned around the graphics. Write the notes or the script for the lesson in the following format:

* Page Change
* Identify the main topic
* Begin graphics and accompanying explanation
* Introduce next item of discussion (e.g., "Now that we have discussed the Legislative and Executive branches of Government, let's next consider the Judiciary.")

* Page Change
* Begin graphics and accompanying explanation.
  (e.g., "The Judiciary ....")

etc.

Plan graphics so that the illustrations will be as simple and as large as possible; don't crowd too much visual information on one page. In general, adjust your illustration so that it will be large enough to fill up the whole page—even if it is only one word (e.g., "Polynomials").

Most important of all, don't leave the page blank for long periods of time. Even the simplest graphics are preferable to an empty screen. Develop dynamical graphic illustrations to the extent that the illustrations support and explain your topic of discussion. Use simple graphic devices: \[ \text{boy meets } \] Avoid creating graphics which become ends-in-themselves.
II. RECORDING TECHNIQUES

Recording skill will come only after a few hours of experience. The following suggestions are meant merely to provide some very general guidance for your consideration as you proceed to develop your own styles:

* Speak in a natural voice, as you would speak to a class. To help you retain naturalness, you may find it preferable to speak from notes rather than from a word-for-word script. Practice psycho-cybernetics; picture yourself speaking to your class or a particularly enjoyable and interested student — and communicate.

* Write or print with smooth strokes, keeping the pen in touch with the paper as much as possible. Avoid jerky motions, and try not to write too fast.

* When you are not writing, slowly move the pen to the lower margin of your pad. Put it down completely or hold it still, so that meaningless motions do not distract the student.

* The tip of the pen on the transmitting unit corresponds to a writing point which is not at the tip of the stylus on the receiving unit. Therefore, to point at something, one should aim the pen about three-fourths of an inch below the object intended. (The best way to learn to do this is to record with the projector on, and to watch the projected graphics as you point. After you develop this facility, record without the receiver, and concentrate on your content.)

* Don't talk during a page change. Follow the format suggested previously: i.e., introduce the next item of discussion, then make a page change, then begin the discussion. (It will be good practice to disconnect the microphone prior to and during the page change to avoid the RONK!ing noise being recorded.)
III. DOCUMENTATION OF LESSONS

After each lesson has been recorded, enter the following information on a Lesson Documentation Form (see example on the following page):

* **Lecturer.** Print your name.

* **Topic.** Enter brief title of the lesson.

* **Description.** Describe the courses with terms or phrases which will suggest the content and level of difficulty of the lesson.

* **Keywords.** Enter two or three appropriate keywords.

* **Prerequisites.** Identify the prerequisites of the lesson—either by referring to other lessons or courses or by describing in words what knowledge you assume the student to have.
IV. DOCUMENTATION OF STRATEGIES OR "COURSE" PROFILES

Previous comments have pertained to "LESSONS"; this section will deal with "STRATEGIES" for learning.

A strategy will be defined by recording a specific sequence of lessons which a "tutor" suggests that a learner follow in order to reach some learning goal. The ALF system recognizes the need to allow for "tutoring" by three different kinds of individuals:

* **The Course Designer.** The individual in this role produces a sequence of lessons for an identified course in the curriculum of one or more schools.

* **The Tutor.** This individual prescribes a sequence of lessons for particular students whose needs or abilities suggest the desirability of special learning plans.

* **The Self-Learner.** In the ALF System, the learner is permitted to browse through the learning materials and discover learning strategies of his own.

Documentation of strategies will consist simply of completing a form which requires the identification of: the learning goal; the suggested sequence of lessons to arrive at that lesson goal; and various control information (strategy number; name of strategist; and date). An example of a form can be found on the following page.
GOAL:

LESSON SEQUENCE OF STRATEGY FOR THIS GOAL:

STRATEGY SUGGESTED BY:

□ Course Designer

□ Tutor

□ Learner

DATE: ______________________

STRATEGY EXPLAINED: ______________________

IF SO, GIVE LESSON NO: ______________________
V. OVERVIEW OF THE SYSTEM

Once the implementation of the ALF system has reached a more mature state of development, course designers, tutors, and learners will interact with the system as follows:

1. Each user or group of users will have a catalog of ALF learning materials. This catalog will be updated four times a year, and will provide descriptions of all lessons in the system and outlines of all documented learning strategies. (The format of the catalog will be discussed subsequently.)

2. After reviewing the available offerings listed in the catalog, a course designer who wants to introduce new material into the system will plan, record, and document the lessons and forward master copies of all work to the "central office" (School of Information and Computer Science, Georgia Institute of Technology).

3. At the central office, the material will be classified and lesson numbers will be assigned. The documentation will be used to update the catalog at the time of its next printing.

4. The central office will store the master tapes, and advise the course designers of the control numbers which have been assigned to each lesson.

5. The course designer will then document one or more learning strategies which he believes appropriate to certain identified learning goals. He is not restricted to the use of his own materials, but may exploit linkages to lessons found in other courses. (The partial set of linkages shown in Figure 1 shows that the designer of a course in American History has "borrowed" lessons from courses in Economics, Sociology, World History, and American Literature.)
FIG. 1

Example of Linkages Identified Between Lessons Prepared for Different Courses. Additional Courses or Strategies Could Be Defined to Meet Other Specific Learning Goals.

ETC.

AMERICAN RADICALISM IN 1930'S

MONOPOLY

STOCK MARKET

ETC.

STOCKS & BONDS

ECONOMICS COURSE

ETC.

PROHIBITION

SOCIOLOGY COURSE

ETC.

HOOVER ADMINISTRATION

1920's

ETC.

LITERATURE OF ALIENATION

AMERICAN LITERATURE COURSE

AMERICAN HISTORY COURSE

ETC.

INTERNATIONAL DEPRESSION

WORLD HISTORY COURSE

ETC.

THE GREAT DEPRESSION

ETC.

FDR'S NEW DEAL
6. The strategy documentation will then be forwarded to the central office, for conversion to magnetic tape and subsequent inclusion in the catalog.

7. A tutor or learner wishing to use the system will first consult the existing documented strategies found in Part I of the catalog. If he is unable to find a documented strategy suitable for his particular learning goal, he is permitted to browse through lessons in the system in any order he chooses. He uses Part II of the catalog (lesson documentation) to guide his selections.

8. Tutors and learners who are pleased with the results of their strategies will be permitted to document those strategies for inclusion in subsequent issues of the catalog. Those who fail to receive goal satisfaction will be requested to indicate and document the nature of their goal and the reasons for being unable to achieve it through the resources available.
THE AUDIOGRAPHIC LEARNING FACILITY: RESEARCH AND DEVELOPMENT

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JANUARY 1976
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Final Report
National Science Foundation Grant CN-2628

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January 1976
ABSTRACT

Departing from previous project reports which described the basic hardware and software of the Audiographic Learning Facility (ALF) of the School of Information and Computer Science at the Georgia Institute of Technology, this document addresses several issues in designing audiographic learning systems for continuing science education at the graduate level, including the technological feasibility and economics of an improved version of the ALF system. This document is the final report on NSF grant CN-2628.
ACKNOWLEDGEMENTS

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Vladimir Slamecka
Principal Investigator
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I. INTRODUCTION

The work described in this report has been addressed to the problems of designing and evaluating a learning system based on audiographic technology in continuing science education at the graduate level -- the Audiographic Learning Facility (ALF). Basic hardware and software features of the system were outlined previously by Slamecka [27, 28], Slamecka and Jensen [26], Ting and Badre [29], and Ting and Jensen [30]. In the present report we consider some fundamental questions about the nature of the system's users and about the environment in which the learning is to take place; we summarize the results of a controlled learning experiment conducted to effect a partial evaluation of the system's effectiveness; we examine the problems of transmitting audiographic data over voice-grade telephone lines; and we explore the important question of ALF economics.

Section II is concerned with the special difficulties of maintaining high student motivation in the particular environment in which remotely delivered instruction takes place: i.e., the actual real-world working environment. It is concluded that management can do much to assist (or to obstruct) the learner in his task.

Section III presents the results of a controlled experiment conducted at the Georgia Institute of Technology to supplement previous evaluations of ALF's "learning effectiveness." Those results indicate (and corroborate previous findings) that there is no significant difference between the learning gains made by students using the automated learning system and those in the control group (who attended traditional classroom lectures). The importance of this conclusion is that it suggests that decisions to employ the system for a particular purpose can be made largely in terms of an economic analysis: i.e., the system may be used whenever one can demonstrate that its use is less expensive than the use of alternate modes of instruction (such as traditional classroom lectures).

The work described in Section IV was motivated by the desire to eliminate the need for one of the two voice-grade telephone channels currently needed by the Audiographic Learning Facility (and thus to make the system readily accessible to the ordinary family, which possesses a single telephone and at least one TV set). To assess the problems of using only one telephone line to transmit audiographic materials, a systematic analysis was conducted in order to determine the minimum quality of voice and graphic signals necessary for audiographic learning.

Section V concludes this report with a discussion of the future of ALF and an evaluation of the system from the perspective of its attractive economic potential.
II. CONTINUING EDUCATION IN THE WORK ENVIRONMENT: THE QUESTION OF STUDENT MOTIVATION

The evaluation of any learning system designed to deliver instruction to learners at their place of work must begin with some discussion of the realities of the work environment in which the learning is to occur. Indeed, the realities of the work environment were found to be a principal determinant of student participation in the experiment which was conducted at the Department of Administrative Services of the State of Georgia, in order to evaluate the Audiographic Learning Facility. It is therefore fitting that this project report should commence with a consideration of certain characteristics of a learning variable of paramount importance to the success of any continuing education program in a work environment: student motivation.

The saliency of the role of student motivation in a successful continuing education program is emphasized by Stadt, Bittle, Kennecke and Nystrom [29], who characterize the motivating of students as one of the "special management tasks seldom developed in preservice or inservice training of leaders in occupational education." These authors distinguish, furthermore, between the motivation of employees in their role as workers and motivation of those employees in their role as students, and conclude that relatively little financial resources have been available for studying ways of motivating employee learning as contrasted with employee job performance.

Of course, the simple rubric "employee learning" can be used to marshal quite a variety of educational experiences. This diversity is noted by Nadler [23], who finds conceptual differences between training, education, and development. According to Nadler, a learning experience which is related to a job which an individual already has is training; a learning experience designed to prepare an individual for a different job in the future -- but an identifiable job nonetheless -- is education; and those learning experiences which are designed to provide general growth for the future can be called development. However, it is not necessary to adopt Nadler's precise terminology to perceive that differences of those kinds do indeed exist, and to agree that "if an organization does not identify the distinctions in the learning activities it provides, it is not likely to achieve the objectives for the learner as well as for the organization." Instead, artificial educational barriers will be constructed, such as the barrier which Gretler [13] sees existing between what he calls vocational training, on the one hand, and general education, on the other. Implicit in Gretler's understanding of the fundamental problem is the conviction that, whereas both kinds of learning experiences are valid and necessary, particular attention must be paid to ways of motivating general education -- education not for today but for tomorrow.
Researchers who have considered the question of student motivation in a work environment typically explore one or another of the following three main themes. The first theme is that all learning experiences -- whether they are to be categorized under "training," "education," "development," or any other heading -- are ultimately motivated by a demonstration of, or a belief in, their "relevance" to the individual learner. A second theme considers the educational reward structure, and emphasizes the value of providing real and tangible payoffs for employee learning achievements. The third theme is taken by those who propose a tighter coupling between education and jobs, so that learning motivations and job motivations will be inextricably bound together, and the educational process will become part and parcel of any working activity.

Educational Relevance as a Motivational Factor

A continuous theme in the literature of motivation is that learning must be "relevant," though "relevance" is never very well defined. Relevance seems to be calculated sometimes in terms of student interests, sometimes in terms of student needs, sometimes in terms of the requirements of specific jobs. Whatever it is, it is usually thought to be both highly desirable (Charters, [6]) and extremely elusive (Burgwardt, [5]). Burgwardt finds that the problem manifests itself in a poor academic/industrial interface, which often prevents a college or university from optimizing potential profits from its educational resources. "This constraint," Burgwardt claims, "is often created by stody academic traditions which can hamper the most heroic efforts to meet industrial program requirements of timeliness, flexibility, and relevancy."

Charters shares this concern, and asserts that the "characteristic" of continuing education is the importance of making it relevant: "The relevance of education to professionals and indeed all pursuits of life has always been a matter of earnest consideration. It is desirable in each of the stages, but perhaps of most significance in the continuing education stage." The problem which Charters notes is that the future of a profession is difficult to predict and the nature of the society in which it will be practiced is quite uncertain. Nonetheless, he insists that, even though the predictions must be tentative, some assumptions about the future must indeed be made, and simply urges that, in deference to the uncertainties involved, continuing education programs be designed to be open-ended. "The current curriculum needs to be cast in this perspective," Charters argues, "or the program will be terminal." Obviously, the need for a continuing education program to be relevant under such conditions implies continuous study and revision of the curriculum, and necessitates that educators and training managers be sensitive to changing environmental conditions and to the specific needs of students in real-world work settings. This sensitivity is never easy to acquire or maintain, and it is not uncommon for evaluations or
self-evaluations of continuing education programs to make an admission such as, "Our center has failed to some degree in not directing its attention to courses that are job-oriented or problem-solving" (Dada, [8]).

However, the equal valuation Dada gives to "job-oriented" courses and to "problem-solving" courses is somewhat curious, in that two entirely different kinds of relevance are equated: job-relevance is certainly a more immediate (and, as it were, a more objective) test of usefulness than is general problem-solving, and would, therefore, presumably be more relevant than general problem-solving ability. Yet some authors would deny this vehemently, and would challenge the whole notion that relevance must be immediate or even immediately apparent. For example, in examining the role of the teacher or administrator vis-a-vis the adult learner, Broudy [4] maintains that the ultimate responsibility of the instructor is precisely to provide authoritative instruction and firm guidance. According to Broudy, the implication of an educational program too concerned with the issue of relevance would be to make the fulfillment of felt wants of its diverse clientele the primary aim of adult education, and to adjust priorities so that the heart of adult educational thought would be located entirely in the problem of means, instruments and modes of organization. In rebuttal to this implication, he suggests that two considerations should make educators skeptical about obsessions with relevancy. First adults not only make procedural errors in choosing their educational fare, but frequently admit that they might have chosen differently had their value systems been as mature at the time of their choice as they later became. Second, and more basic in Broudy's view, is that the very notion of education loses its meaning if the learner retains full and literal autonomy in his choice of learning, for "to be a learner in any significant sense means to give up one's autonomy to the demands of the task being learned."

Yet learning tasks are not the only kinds of tasks which must be assessed by managers of continuing education programs. Also to be dealt with is the fact that adult learners are, at the time of their learning, engaged in work tasks and work-related responsibilities which must (and therefore will) take precedence over their learning endeavors. Thus, in a survey conducted by the University of Missouri to determine attitudes of continuing education programmers toward their job roles, Rowe [25] found that the additional job responsibilities of the programmers taking courses in the "traditional" (i.e., not job-related) extension areas constituted a definite impediment to the success of the program.

Therefore, some authors who explore the theme of relevance as a motivational factor in continuing education programs conclude that the exigencies of the world of work require that the learning process be conducted quite differently than it is conducted in traditional
academic environments. Church [7], for example, calls attention to what he refers to as "bad assumptions" about continuing career education. The first bad assumption is that professional careers in industry are extensions of academic study; the second is that the learning process in industry after graduation is the same as it is in a school environment. To the contrary, "the environmental factors are much different, affecting the urge to learn, the subject matter learned, and how it is learned...and each engineer is different in his ability to learn, his readiness to learn, and his urge to learn." Church therefore concludes that, since two engineering jobs are seldom alike, educational programs should discard stereotyped instructional packages, and should abandon the term "continuing education" in favor of "employment related education." And so, ultimately, all the proponents of the saliency of relevance in the hierarchy of educational values stress that learning must lead to doing and that education must lead to jobs.

Motivation Through Adjustments in the Reward Structure

The second theme explored by authors who have examined the question of student motivation in a work environment is concerned with the educational reward structure, and emphasizes the value of providing real and tangible benefits for employee learning achievements. According to those who hold this view, intangible rewards, such as the pleasures of self-fulfillment, are simply not sufficient for motivating the average employee, though this generalization applies primarily to the younger and middle-years segments of the workforce, rather than to older employees. Kuhlen [18] states that, as one views the course of human life, growth-expansion motivations (such as the search for more responsibility or more prestige) seem to dominate the first half of the adult years, whereas in later years the satisfaction of growth-expansion needs is accomplished more vicariously, thereby allowing more time and personal energy for learning "for its own sake," regardless of tangible benefits.

One kind of tangible benefit used to induce employees to continue their education takes the form of employer-paid instructional programs. However, studies have shown that, whereas low-cost or no-cost instruction may be a necessary condition for motivating employees to keep up-to-date educationally, it is by no means a sufficient condition. For example, Dubin and Marlow [11] presented the results of a survey in which 79% of the engineers interviewed reported that their companies had educational assistance programs (showing the widespread availability of company payment for educational assistance courses), but that 74% of the same group also acknowledged that this availability had no effect in motivating them to undertake additional work. The conclusion of Dubin and Marlow is that the availability of financial assistance for self-improvement is "obviously not a sufficient incentive for updating in employees."
Instead, adult learners seem, on the average, to want not educational opportunities so much as educational rewards. A study by Landis [19] found that engineers seek an immediate payoff from their continuing education — a payoff that assumes the highly specific form of recognition and salary. According to that author, most engineers are interested in performing better in the immediate, assigned job, but few are motivated to make the extraordinary effort required to keep up with the latest developments in their profession.

The Landis findings are corroborated by Johnstone and Rivera [16], whose survey of adult learners found that, other than the (vague) learning goal of "becoming a better informed person," the two other goals endorsed by sizeable numbers of participants were both directly vocational: a large percent indicated that they had enrolled to prepare for a new job, and another large percent indicated that they had done so to learn more about the job they already had. "Over and above the desire to become better informed," Johnstone and Rivera concluded, "vocational goals most frequently direct adults into continuing education, and, on the basis of the relative frequency of response to the job-connected items included in the list, it appears that slightly more adults take courses for job preparation than for job advancement."

If most continuing education students are job-motivated, but most are also preparing for jobs other than the ones they now have, it is not unreasonable to hypothesize that employers are not sufficiently motivating their own employees to participate in educational programs for which they will be rewarded within their own organizations. Research by Dubin, Alderman and Marlow [11] seems to suggest that such an hypothesis is correct, for the findings of these authors (based on a survey of middle-level management personnel) were that additional course work is not sufficiently rewarded in industry and that it is not a requirement for promotion or salary increase. (That same statement could be made about the organization of state government which served as the setting for the evaluation of the Audiographic Learning Facility; there is no program in that organization which rewards employees for successful completion of formal continuing education programs.)

Motivation and the Coupling Between Learning and Jobs

The third theme in the literature concerned with the motivation of students in a work environment subsumes the other themes by suggesting that the problem of ensuring that continuing education is relevant to the learner can both be solved by a coupling of education and jobs, a coupling which entails that the educational process become an integral, important, and continuous part of every job.
At the simplest level of their exposition, enthusiasts for this coupling point simply to the statistics of various manpower programs. Regan [24], for example, asserts that adult education program are most successful when they are conceived not as preparation for jobs, but as learning experiences concomitant with jobs. Noting that adult education and training programs at all levels "have contended that increased academic skills will enable the nation's poor and undereducated to compete more successfully in the job market," Regan claims, however, that labor statistics do not support this contention. The conclusions drawn from his own research are, to the contrary, that where meaningful employment is coupled with education, retention and successful course completion are significantly higher.

Though Regan's analysis of manpower statistics is intended to apply to a large range of skill-levels (including especially the relatively low skill-levels possessed by those at the lower end of the socioeconomic spectrum), the coupling of education and jobs has also been proposed at the very highest levels of professional expertise. Dubin [10] reports several interesting attempts to establish practical measures for motivating professional persons to keep up-to-date which have been established. One is that of the French Atomic Energy Commission, which initiated the practice of declaring that scientific diplomas lapse after five years, unless revalidated by attendance at refresher courses and success in passing further examinations. Another is that of the US National Advisory Commission on Health Manpower, which recommended in 1967 that professional societies and state governments should explore the possibility of periodic relicensing of physicians and other health professionals. Under this recommendation, relicensure should only be granted either upon certification of acceptable performance in continuing education programs or upon the basis of challenge examinations in a practitioner's specialty. Acting on this recommendation, the Oregon Medical Society subsequently passed a regulation requiring physicians to continue their education in order to remain in good standing in the Association.

The primary requirement for successful coupling of education and jobs is undoubtedly the attitude of an organization's management. Hughes and Wass [15] describe a company-installed management policy in which goal-oriented management behavior is rewarded "by task satisfaction, financial rewards and goal accomplishment." The system provides a means for continuous updating of employees whereby individual goal-setting is integrated with the organization's goal-setting (through the use of semi-annual goal-oriented performance reviews in which each employee participates). In these sessions, a great deal of importance is placed on identifying the individual's developmental needs, both present and future, to enable him to accomplish his specified goal.

Thus, although successful learning in a work environment may ultimately be the responsibility of the willingness and self-motivation of the learner, the fact is that management can do much to assist (or to obstruct) the learner in his task. If management values education, so will its employees. If it does not, its employees will either be stagnating or will be training themselves for new jobs in a different organization.
III. THE LEARNING EFFECTIVENESS OF THE AUDIOGRAPHIC LEARNING FACILITY: AN EXPERIMENT

One primary objective of the study reported in this document was to evaluate the learning effectiveness of the Audiographic Learning Facility as an educational delivery system. To accomplish this objective, an experiment was conducted at the Georgia Institute of Technology during the Winter quarter, 1974. Two groups of students were randomly selected for the experiment; one of the groups participated in the live classroom lectures and the other received instructions via the Audiographic Learning Facility. Both groups were given the same subject prepared by the same instructor during the two weeks of experimentations. Pre and post tests were administered to the subjects in both groups.

Experimental Design

A simple before-and-after experimental design was used to divide the subjects into two groups. One group took the conventional classroom lectures and the other group was scheduled in several half-hour sections for learning at an ALF terminal. The subjects were randomly selected from the School of Information and Computer Science, Georgia Institute of Technology. Twenty students participated in the live classroom lecture group and 17 in the ALF group. In order to control some of the instructor's effect, the same professor was employed in both groups to cover the same material during the controlled experimental period. The ALF instructional materials were prepared, tested and implemented on ALF before actual use. The same material was used to prepare the live classroom lectures.

A parallel test of two forms was developed (see Chart I). Form A was used for the pre-test and Form B was used for the post-test.

<table>
<thead>
<tr>
<th>Control Group</th>
<th>Experimental Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Live Class)</td>
<td>(ALF)</td>
</tr>
</tbody>
</table>

Pre-test

Post-test
Procedure

Students in the ICS 3601 Computer Systems II course were used as subjects. Those who did not wish to participate in the experiment were allowed to continue within the live classroom lecture group but did not take the tests. There were 4 such students. A random selection technique was used to assign the subjects into two groups. Twenty students were selected in the classroom group (the control group) and 17 students were asked to participate in ALF (the experimental group). All students were attending the same classes in conventional classroom lecture series before the experimental period. The students in the control group continued with the live classroom and those students in the experimental group were asked to use the ALF terminal for learning during the two-week experimental period. The students in the control group were kept away from the ALF terminal during the period of the experiment. On the other hand, the students in the experimental group were not allowed to participate in the classroom lectures. They were required to discuss or conduct their further studies with the students in the same group during the experimentation.

The students in the control group were given three 50-minute classroom lectures per week. The students in the experimental group were assigned into five 30-minute sections during the week per student for learning at the ALF terminal. All students but four were in individual sections, the remaining four students were assigned in small groups of two for interacting with the ALF terminal. The first week of the experiment was treated as a warming up period in order to familiarize the students with the ALF terminal. Only the material covered in the second week was included in the tests.

The subject matter used for the experimentation was the introduction to assemblers and loaders. The ALF learning modules were already prepared and ready to use. The same amount of the information was used to prepare live classroom lectures by the same instructor.

Data Collection and Analysis

A parallel test set was developed. The test items were generated by the instructor. The items were selected and rearranged through a validating procedure for the development of the parallel test set. One form was used as pre-test and the other was used as post-test. Both tests were administered in the classroom setting immediately before and after the experimental period.
Analysis of variance and analysis of co-variance techniques were used to test the difference in test scores between the groups. The results of both tests are presented in the following:

ANALYSIS VARIANCE (POST TEST ONLY)

Control Group

\[
\begin{align*}
  n_1 & = 20 & T_1 & = 222 \\
  \bar{X}_1 & = 11.1 & \sum X_1^2 & = 2846 \\
  (\sum X_1)^2 & = 49284 \\
  \frac{(\sum X_1)^2}{n_1} & = 2464.2
\end{align*}
\]

Experimental group

\[
\begin{align*}
  n_2 & = 17 & T_2 & = 218 \\
  \bar{X}_2 & = 12.824 & \sum X_2^2 & = 2852 \\
  (\sum X_2)^2 & = 47524 \\
  \frac{(\sum X_2)^2}{n_2} & = 3795.53
\end{align*}
\]

TOTAL

\[
\begin{align*}
  N & = 37 & T & = 440 \\
  \Sigma X_t^2 & = 5698 \\
  \bar{X}_t & = 11.892 \\
  \frac{\Sigma (\sum X_j)/n_j}{j=1} & = 5259.73 \\
  t^2/N & = 5232.47
\end{align*}
\]
\[ SS_A = \sum_{j=1}^{2} \frac{n_j^2}{n_j} - \frac{T^2}{N} = 27.30 \]

\[ SS_T = \sum X^2 - \frac{T^2}{N} = 465.57 \]

\[ SS_W = SS_T - SS_A = 438.27 \]

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>df</th>
<th>SS</th>
<th>Mean Square</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatments (A)</td>
<td>1</td>
<td>27.30</td>
<td>27.30</td>
</tr>
<tr>
<td>Within-Groups (W)</td>
<td>35</td>
<td>438.27</td>
<td>12.522</td>
</tr>
<tr>
<td>TOTAL (T)</td>
<td>36</td>
<td>465.57</td>
<td></td>
</tr>
</tbody>
</table>

\[ F = \frac{27.30}{12.522} = 2.18 \]
## Analysis of Covariance (Pre and Post Tests)

<table>
<thead>
<tr>
<th>Control Group</th>
<th></th>
<th>Experimental Group</th>
<th></th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-test (X)</td>
<td>Post-test (Y)</td>
<td>Pre-test (X)</td>
<td>Post-test (Y)</td>
</tr>
<tr>
<td></td>
<td>$EX = 145$ $\bar{X} = 7.25$</td>
<td>$EY = 222$ $\bar{Y} = 11.1$</td>
<td>$X = 122$ $\bar{X} = 7.176$</td>
<td>$Y = 218$ $\bar{Y} = 12.824$</td>
</tr>
<tr>
<td></td>
<td>$EX^2 = 1213$</td>
<td>$EY^2 = 2846$</td>
<td>$X^2 = 1008$</td>
<td>$Y^2 = 2852$</td>
</tr>
<tr>
<td></td>
<td>$(EX)^2 = 1051.25$</td>
<td>$(EY)^2 = 2464.2$</td>
<td>$(EX)^2 = 875.53$</td>
<td>$(EY)^2 = 2795.53$</td>
</tr>
</tbody>
</table>

|               |                      |                      |                      |                  |
|               | TOTAL                |                      |                      |                  |
|               | $N = 37$             |                      |                      |                  |

\[ Y \]
\[ \Sigma Y = 440 \]
\[ \Sigma Y^2 = 5698 \]
\[ \frac{2}{N} \sum_{j=1}^{t} y_{ij}^2/n_j = 5259.73 \]
\[ \frac{\sum_{j=1}^{t} y_{ij}^2/n_j}{N} = 5232.43 \]

\[ X \]
\[ \Sigma X = 267 \]
\[ \Sigma X^2 = 2221 \]
\[ \frac{2}{N} \sum_{j=1}^{t} x_{ij}^2/n_j = 1926.78 \]
\[ \frac{\sum_{j=1}^{t} x_{ij}^2/n_j}{N} = 1926.73 \]

\[ SS_{YA} = 27.30 \]
\[ SS_{YT} = 465.57 \]
\[ SS_{YN} = 438.27 \]

\[ SS_{XA} = 0.05 \]
\[ SS_{XT} = 294.27 \]
\[ SS_{XW} = 294.22 \]
\[ SP_T = \sum_{j=1}^{2} \sum_{i=1}^{n} x_i y_i = 21.139 \]
\[ SP_A = \sum_{j=1}^{n} \sum_{i=1}^{n} x_i y_i = -0.825 \]
\[ SP_w = SP_T - SP_A = 21.964 \]
\[ SS_{YW} = SS_{YW} - \frac{(SP_w)^2}{SS_{X}} = 436.63 \]
\[ SS_{YT} = SS_{YT} - \frac{(SP_w)^2}{SS_{XT}} = 463.93 \]
\[ SS_A = SS_{YT} - SS_{YW} = 27.30 \]

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SSx</th>
<th>SP</th>
<th>SSy</th>
<th>SS'</th>
<th>df</th>
<th>MS'</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1</td>
<td>0.</td>
<td>-0.825</td>
<td>27.30</td>
<td>27.30</td>
<td>1</td>
<td>27.30</td>
</tr>
<tr>
<td>W</td>
<td>35</td>
<td>294.22</td>
<td>21.964</td>
<td>438.27</td>
<td>436.63</td>
<td>34</td>
<td>12.55</td>
</tr>
<tr>
<td>TOTAL</td>
<td>36</td>
<td>294.27</td>
<td>21.139</td>
<td>465.57</td>
<td>465.57</td>
<td>35</td>
<td></td>
</tr>
</tbody>
</table>

\[ F = \frac{MS'_{YA}}{MS'_{YW}} = 2.17 \]

The results of the tests were analyzed. The analysis of variance and the analysis of covariance tests were applied, and the F ratios indicate that the differences in test scores were not significant at 0.05 level. This result leads us to conclude that the null hypothesis (i.e., that there is no difference in test scores between the students in live classroom lecture series and the students in ALF) was not rejected. However, the test scores of the ALF group may have been significantly higher than the live lecture group if greater Type I error was allowed at 0.1 level.

This general finding — i.e., that there is no significant difference between the learning gains made by students using the automated learning system and those in the control group (who attended traditional classroom lectures) — is important because it suggests that decision to employ
the system for a particular purpose can be made largely in terms of an economic analysis. That is to say, the system may be used whenever one can demonstrate that its use is less expensive than the use of alternate modes of instruction (such as traditional classroom lectures).
**FORM A**

1. Taking several objects programs and putting them together into one absolute program is called "binding."
2. "Relocating" refers to moving the loaded program.
3. A "Compile-and-go" system embeds the loader function into the compiler.
4. A "compile-and-go" system does not have to worry about relocating.
5. Using an absolute loader decreases the system's ability to have a library of user subroutines.
6. A "transfer vector" is a table of branch instructions.
7. All entry points are addresses to be branched to.
8. The relocating table causes the loader not to alter absolute addresses and data.
9. The assembler has a two-level task: translation and assembly.
10. Macro-instruction do not actually exist in the machine language.
11. Most assembly language instructions are divided into fields.
12. The location counter in an assembler tells where the assembler is located in memory.
13. The main disadvantage of one-pass assemblers is the size of the assembler.
14. The forward reference table in a one-pass assembler can be thought of as a set of linked lists.
15. A one-pass assembler can fill in forward references as the symbols referred to are defined.
16. Most of the forward reference table can actually be imbedded in the code generated by a one-pass assembler.
17. The object code of a one-pass assembler must fit in the part of central memory not used by the assembler.

**FORM B**

1. The purpose of a loader is to manipulate source and load it into secondary memory.
2. "Linking" refers to the connecting of references in one program to addresses in other programs.
3. When a loader transfers control it is branching to the loader program.
4. An absolute loader takes care of absolutely all loading situations.
5. An absolute object program may be executed at only one load point in the user's part of memory.
6. To facilitate linking, the creator of the object programs must produce a table of externals and a table of entry points with each program.
7. A linking loader generally searches the system library for entry points before searching the user-supplied entry point tables.
8. To relocate a program the relocating loader adds the load point address to every word in the program.
9. To facilitate loading the loader needs access to system tables relating to secondary memory (disks, etc.) if there is any secondary memory in the system.
10. Pseudo-instructions translate into several machine instructions.
11. Most assemblers output information to loaders which convert this information into viable machine-language programs.
12. The form of the operand field of an assembly language instruction is usually independent of the op-code.
13. The main problem causing the development of the two-pass assembler is the problem of backward references.
14. The symbol table is set up in the first pass of a two-pass assembler.
15. All pseudo-ops can be fully taken care of in pass one of a two-pass assembler.
16. The passes of a two-pass assembler are (1) definition and (2) generation.
17. The location counter is used only in the second pass of a two-pass assembler.
IV. AUDIOGRAPHIC DATA TRANSMISSION VIA VOICE- GRADE TELEPHONE LINES

Another primary objective of the present research was to determine the feasibility of simultaneously transmitting intelligible voice and graphic messages via a single channel of a voice-grade telephone line. The motivation for that study was the fact that one of the limitations of the present, prototype ALF system is the requirement of two voice-grade telephone channels for the transmission of both the voice and graphic messages. This requirement has stood as an obstacle to the delivery of electronically stored learning material to ordinary homes (which are rarely outfitted with more than one such channel). To assess the problems of using only one telephone line to transmit audio-graphic materials, a systematic analysis was conducted in order to determine the minimum quality of voice and graphic signals necessary for audiographic learning, and a prototype system has been developed based on the results of the analysis.

The Problem of Audiographic Data Transmission Via Voice-Grade Telephone Lines

In normal telephone use, the total frequency spectrum is dedicated to sending and to receiving voice signals. However, in an audiographic application, motion line-graph signals must be sent in addition to those of voice, and so that part of the telephone line spectrum which is dedicated to carrying voice must be reduced in order to allow graphic messages to be transmitted simultaneously using just one pair of lines.

The Characteristics of Voice-Grade Telephone Lines

The characteristics of the media must be examined. These characteristics define the limitations within which the audiographic data transmission system must be designed.

a. Distortion

There are many transmission impairments which may affect data transmission. The most common of these impairments is distortion. Distortion occurs when attenuation or delay varies as a function of frequency. Attenuation refers to a loss of amplitude or power and delay refers to a time shift in the signal. These data represent attenuation distortion relative to 1000 Hz with positive values representing more loss. (see Table 1). The loss due to local loops which must be added to those data is typically less than 10 db at 1000 Hz and approximately 3 db difference between 600 and 2750 Hz.
Table 2 gives the delay distortion for end-office to end-office respective to 1700 Hz when delay distortion is at a minimum. The local loop delay distortion is significant when compared to this data and, therefore, may be ignored. (The data in Tables 1 and 2 are taken directly from Bell System Data Communications PUB 41005, Data Communications Using the Switched Telecommunications Network.)

TABLE 1 — FREQUENCY RESPONSE IN db RELATIVE TO 1000 Hz

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Short</th>
<th></th>
<th>Medium</th>
<th></th>
<th>Long</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Std. Dev.</td>
<td>Mean</td>
<td>Std. Dev.</td>
<td>Mean</td>
</tr>
<tr>
<td>Hz</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>200</td>
<td>11.4</td>
<td>5.1</td>
<td>13.7</td>
<td>4.5</td>
<td>12.5</td>
</tr>
<tr>
<td>250</td>
<td>6.4</td>
<td>2.7</td>
<td>8.0</td>
<td>3.7</td>
<td>6.8</td>
</tr>
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<td>300</td>
<td>4.0</td>
<td>1.9</td>
<td>4.8</td>
<td>2.8</td>
<td>4.8</td>
</tr>
<tr>
<td>400</td>
<td>2.2</td>
<td>1.4</td>
<td>2.8</td>
<td>2.2</td>
<td>2.0</td>
</tr>
<tr>
<td>600</td>
<td>0.9</td>
<td>0.9</td>
<td>1.6</td>
<td>1.9</td>
<td>1.2</td>
</tr>
<tr>
<td>800</td>
<td>0.4</td>
<td>0.5</td>
<td>0.7</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>1200</td>
<td>0.1</td>
<td>0.3</td>
<td>-0.3</td>
<td>0.4</td>
<td>-0.3</td>
</tr>
<tr>
<td>1400</td>
<td>0.0</td>
<td>0.6</td>
<td>-0.3</td>
<td>0.6</td>
<td>-0.3</td>
</tr>
<tr>
<td>1700</td>
<td>0.3</td>
<td>0.9</td>
<td>0.1</td>
<td>0.8</td>
<td>0.2</td>
</tr>
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<td>2000</td>
<td>0.8</td>
<td>1.1</td>
<td>0.8</td>
<td>1.1</td>
<td>0.7</td>
</tr>
<tr>
<td>2300</td>
<td>1.4</td>
<td>1.3</td>
<td>1.4</td>
<td>1.4</td>
<td>1.7</td>
</tr>
<tr>
<td>2450</td>
<td>1.8</td>
<td>1.5</td>
<td>2.0</td>
<td>1.6</td>
<td>2.4</td>
</tr>
<tr>
<td>2750</td>
<td>3.5</td>
<td>2.5</td>
<td>4.1</td>
<td>2.2</td>
<td>4.7</td>
</tr>
<tr>
<td>2850</td>
<td>4.4</td>
<td>3.0</td>
<td>5.4</td>
<td>2.6</td>
<td>6.1</td>
</tr>
<tr>
<td>3000</td>
<td>6.4</td>
<td>4.0</td>
<td>8.1</td>
<td>3.6</td>
<td>9.2</td>
</tr>
<tr>
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<td>5.9</td>
<td>10.6</td>
<td>4.7</td>
<td>11.6</td>
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</tr>
<tr>
<td>3300*</td>
<td>17.6</td>
<td>10.00</td>
<td>20.0</td>
<td>8.0</td>
<td>19.8</td>
</tr>
<tr>
<td>3400*</td>
<td>21.2</td>
<td>9.8</td>
<td>24.4</td>
<td>6.4</td>
<td>25.1</td>
</tr>
</tbody>
</table>

*Distortion values at these frequencies are at least as great as shown.
**TABLE 2 — ENVELOPE DELAY DISTORTION IN uSEC WITH RESPECT TO 1700 Hz**

<table>
<thead>
<tr>
<th>Frequency Hz</th>
<th>Short</th>
<th>Medium</th>
<th>Long</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Std. Dev.</td>
<td>Mean</td>
</tr>
<tr>
<td>200*</td>
<td>4580</td>
<td>2461</td>
<td>7526</td>
</tr>
<tr>
<td>250*</td>
<td>3384</td>
<td>1727</td>
<td>5866</td>
</tr>
<tr>
<td>300</td>
<td>2816</td>
<td>1407</td>
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<tr>
<td>400</td>
<td>1695</td>
<td>930</td>
<td>3413</td>
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<tr>
<td>600</td>
<td>656</td>
<td>430</td>
<td>1467</td>
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<tr>
<td>800</td>
<td>290</td>
<td>263</td>
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<tr>
<td>1000</td>
<td>133</td>
<td>165</td>
<td>380</td>
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<tr>
<td>1200</td>
<td>48</td>
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<td>2000</td>
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<td>62</td>
<td>36</td>
</tr>
<tr>
<td>2300</td>
<td>152</td>
<td>122</td>
<td>226</td>
</tr>
<tr>
<td>2450</td>
<td>248</td>
<td>159</td>
<td>363</td>
</tr>
<tr>
<td>2750</td>
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<td>2850</td>
<td>616</td>
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</tr>
<tr>
<td>3000</td>
<td>889</td>
<td>456</td>
<td>1437</td>
</tr>
<tr>
<td>3100</td>
<td>1128</td>
<td>578</td>
<td>1903</td>
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<tr>
<td>3200</td>
<td>1319</td>
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</tr>
<tr>
<td>3300*</td>
<td>1526</td>
<td>917</td>
<td>3208</td>
</tr>
<tr>
<td>3400*</td>
<td>1935</td>
<td>1277</td>
<td>4040</td>
</tr>
</tbody>
</table>

*A significant percentage of connections were not measurable at these frequencies.

Another impairment is that due to nonlinearities which are caused by certain transmission techniques used by the telephone company. These include suppression in amplifiers, nonlinear elements in compandors, and foldover distortion and quantizing in pulse code modulated (PCM) systems. Data systems with line speeds less than 2400 baud are usually unaffected by the nonlinearities normally encountered. If high baud rates are to be used, one must limit the power outside the 300 to 4000 Hz baud and avoid designs which generate high signal levels at certain input frequencies within this band to avoid the nonlinear distortion caused by PCM systems. Also, amplitude modulation should not be used for data transmission since the design of the compandors used in the telephone system does not allow them to follow rapid changes in signal power.
b. Echo

Due to impedance irregularities along a transmission line or at its end, a portion of the originating signal is reflected back to the originating end. This phenomenon is commonly called "echo." In fact, the echo towards the originating end may itself be reflected back to the receiving end. The first echo is not a problem for data transmission since the send-station is not trying to receive signals at the same frequency as the one it uses to transmit. The secondary echo could be a problem if the delay and amplitude of this signal is sufficiently high, but normally it is not. In fact, the real problem to data transmission is not the echo itself but the suppression of the echo by the telephone company to produce a higher quality of voice transmission. On long distance trunks when a signal in one direction is sensed, a high loss is inserted in the return line to prevent transmission in the other direction thereby eliminating the echo.

c. Noise

The general, noise is not a significant problem in data transmission over the Direct Distance Dialing (DDD) telephone system. The received signal-to-noise ratio is high enough so that the noise does not interfere with signal detection. However, impulse noise can cause unsatisfactory performance. Impulse noise is characterized by relatively short bursts of high amplitude. Most impulse noise originates in switching equipment. At this time, most switching systems are adequate for data transmission; however, there are a few switching systems which are not satisfactory for data transmission.

d. Transmission Path

Another consideration is transmission path. Due to automatic switching equipment, consecutive calls between two given stations may be connected by very different paths. The different paths may cause considerable variation in transmission characteristics. If an unsatisfactory connection is made due to this problem, the only alternative, using the switched network, is to replace the call. Other factors being satisfactory, this should correct the problem.

e. Frequency Spectrum

Examining Table 1, frequencies from 600 to 2300 Hz can be used without experiencing excessive attenuation of the signal. Table 2 shows the envelope delay distortion to be minimal in this range also. In general, envelope delay distortion is not a problem for data rates below 300 baud.
From the characteristics discussed above, it has been reasonably determined that the band from 300 Hz to 3000 Hz may be used for transmitting audiographic signals.

The Limitations of Signal Transmitting Techniques

The signals must be transmitted and are called baseband signals. In our case, we have both voice and graphic signals, and if all baseband signals were just combined and transmitted there would be no way to recover the individual signals after receiving them. Furthermore, those frequencies lying outside of the band pass range of the telephone line would be lost. These signals must be relocated into the band pass area, 300–3000 Hz, before transmission by modulation, and must be recaptured after reception by demodulation.

a. Modulation

Modulation is the technique of modifying one signal called the carrier as a function of another signal called the baseband. This modified carrier is then transmitted and, after it is received, the baseband is recovered by demodulation. There are three basic types of modulation — amplitude, frequency and phase modulation.

Amplitude Modulation

Due to the characteristics of voice-grade telephone lines, the amplitude modulation technique is impractical.

Phase Modulation

Phase modulation techniques provide higher band rates, but are more complicated and expensive. Furthermore, our objective is to send several different signals, not to send one signal at a high band rate.

Frequency Modulation

Frequency modulation systems are reasonably simple and inexpensive, provide good performance and versatility, and represent the most widely used technique for low-speed data transmission. Frequency modulation is the technique of changing the frequency of the carrier signal from some reference frequency, called the center frequency, as a linear function of the baseband signal. The maximum range of the carrier around the center frequency is called bandwidth. The bandwidth should be at least twice the maximum frequency of the modulating signal, and the bandwidth of the carrier divided by the center frequency should be no less than 4%.
b. **Multiplexing**

Since several signals are being sent at the same time, some form of multiplexing must be used. Multiplexing is combining the signals before transmission and separating these signals once they are received.

Frequency division multiplexing accomplishes this by assigning each carrier a slot on the frequency spectrum with no overlapping of signals. These signals are then summed together and transmitted. When this total is received, it is passed through bandpass filters—that is, devices which accept, as input, signals which contain many frequencies but, as output, only that portion of the total signal which falls within certain frequency limits. These bandpass filters are turned to those slots of the frequency spectrum where the carriers were assigned.

It is required that the center frequencies of adjacent slots be separated by some function of the bandwidth of the widest carrier slot. This is done to guarantee that all frequencies outside of the slot are reduced in strength by the filter to a level where they do not interfere with the desired signal. Bandpass slots must be separated two and one-half to three times their bandwidth from low-pass filter cutoff frequencies in order to relax constraints on filter rolloff specs.

c. **Computer Interface**

The computer interface must be considered. In our case, three different types of signals are being transmitted at the same time: the voice, the graphics, and the input control signals. Special signals are required for input to the computer for directing the Audiographic Learning Facility to work properly. A mechanism must be provided at the computer site to select these signals for computer input.

The Determination of Audio Intelligibility

A study was conducted* to record a phonetically balanced list of 50 words spoken by both male and female speakers. The term phonetically balanced implies a list chosen such that all speech sounds are presented approximately according to their frequency of occurrence in normal speech. The list of words used was obtained from "American Standard Method for Measurement of Monosyllabic Word Intelligibility."

Figure 1. -- Power spectrum density of male voice
Figure 2. -- Power spectrum density of female voice
Figure 3. -- Power spectrum density of combined male and female voice
Figures 1, 2, and 3 show the resulting power spectrum density plots for the male speaker, female speaker, and the combined male and female speakers, respectively.

The plot of male voice spectrum, (Figure 1), shows that most of the power lies below 800 Hz. The plot of the female voice spectrum, (Figure 2), shows a higher range of power with the least significant band of power around 1000 to 1100 Hz. The composite plot dictates that a maximum frequency of 1000 to 1200 Hz is required to pass the major portion of the power of speech (see Figure 3).

The Determination of the Minimum Frequency Spectrum for Intelligible Voice Signals

The word intelligible is used here to mean easily understandable units of speech material which are complete and meaningful word phrases or sentences. According to the results presented in the previous sections, the normal voice range may include frequencies as low as 100 Hz and as high as 2500 Hz, but this wide range is not essential to having an intelligible signal.

A test was conducted to determine the required frequency spectrum for an intelligible voice signal. It was a simple "listening" test which consisted of having five different people listen to both male and female voices which were processed through the low pass filter with cutoff frequencies of 800, 1000, and 1200 Hz. The consensus of opinion was that: (1) there was a definite deterioration of the voice when using the 800 Hz filter; (2) the 1000 Hz filter allowed good intelligibility; and (3) an improvement in intelligibility was noticed in the 1200 Hz filter over the 1000 Hz filter, but not a significant improvement.

Based on the results of the test, a 1000 Hz low pass filter should be chosen as a minimum, and a 1200 Hz filter may be desirable.

The Transmission of Line Graphs

Motion line graphs are simultaneously transmitted along with the audio messages to learners in order to present the blackboard-like presentations in ALF-type systems. These graphic images are generated by the instructors and are electronically stored on magnetic tapes in a computer-controlled learning data base. The selected pre-stored line graphics are transmitted along with the narrative audio via regular telephone lines to the learning stations for display. The techniques used for the transmission of the motion line graphs via telephone lines are discussed in this section.
The Representation of Line Graphics for Transmission

A motion line graphic may be transmitted from an origin to a remote location via a telephone channel by sending three simultaneous signals: one represents the horizontal position; one the vertical position; and one controls the page change and other mechanical operations. Basically, the actual graphic message is represented as the change of \( x \) and \( y \) coordinates of the graphic surface in reference to the change of time. The prototype systems were developed for transmitting the graphic message. The first one uses a frequency modulation method, and it has already been implemented within the existing experimental ALF system. The second one is an improved prototype which uses a technique that may be called the period transmission technique. The latter has been tested in the laboratory and it will be implemented within the future ALF system. The first method uses a dedicated voice-grade telephone channel for transmitting the graphic message. The second uses a more narrow bandwidth which makes possible telephone link without the reduction of the quality of the graph. Both prototypes are discussed in the following.

Frequency Modulation Technique

The existing experimental ALF system uses a graphic data transmission technique which frequency modulates the \( x \) and \( y \) signals for transmission to the learning stations via a dedicated telephone channel. The change of \( x \) and \( y \) coordinates are expressed by the variations of frequencies in two separate carriers. The axes were chosen to be centered at 1400 Hz and 2200 Hz. The bandwidth of the frequency spectrum for both carriers was designed to be \( \pm 100 \) cycles of the center frequency. In other words, the \( y \) coordinate varies from 1300 Hz to 1500 Hz and the \( x \) coordinate varies from 2100 Hz to 2300 Hz. Control signals were specially designed within the two carriers. A high frequency on the high side of the \( x \) carrier, 200 cycles above the center frequency, signifies the "pen-up" position. A change-page signal can be transmitted by sending two high frequency signals, 200 cycles above the center frequency, on both carriers. The frequency spectra for these messages within a single telephone line are illustrated in Figure 4.

The existing ALF system uses regular audio stereo tape for storing both the audio and graphic messages on two parallel channels. In order to compensate the distortion generated by the speed change of the tape recorder, an additional reference signal was added at 3300 Hz on the tape. During the playback, the \( x \), \( y \), and reference signals are sent to a compensator which inverts the modulation on the reference frequency and adds it to the \( x \) and \( y \) modulation in order to correct the distortion caused by the tape recorder. This is done in the following fashion. The corrected \( x \) and \( y \) coordinates,
Figure 4. -- The frequency spectra for the frequency modulated graphic signals within a telephone link.
The ratio between the reference signal, \( f_r \), and the 3300 Hz. The compensation may be expressed as

\[
\frac{f_x}{3300 \text{ Hz}} = \frac{f_x'}{f_r}, \quad \text{and} \\
\frac{f_y}{3300 \text{ Hz}} = \frac{f_y'}{f_r}
\]

Only the corrected \( x \) and \( y \) signals, \( f_x \) and \( f_y \), are transmitted to the learning stations for displaying.

**Digital Transmission Scheme**

The present prototype graphic transmission system now under testing utilizes a new technique which codes and decodes graphic signals in digital forms during the transmission. This digital scheme codes the horizontal and vertical positions of a graphic message in \( x \) and \( y \) coordinates in digital forms which are stored in two digital words. These two numbers are updated in a fixed time interval. The prototype uses a graph pen device as the graphic input which stores the \( x \) and \( y \) coordinates in two storages of 10 bits each. These numbers are updated at a rate of 60 times per second. This allows having a picture with approximately 1000 line resolution and 60 frames per second. Since the projected ALF display system will employ regular home television sets for audiographic output, only 250 lines of resolution are required, and therefore the actual transmission requires only 8 bits information for the \( x \) and \( y \) coordinates. Therefore, in the present prototype graphic transmission subsystems, two digital signals of 8 bits each for \( x \) and \( y \) coordinates plus necessary control pulses are transmitted at a rate of 1/60 of a second. The signals equal to transmit 20 bits of information in every 1/60th of a second (or 1200 bits per second).

The digital scheme described here has several potential advantages: (1) Graphic messages generated by the input devices, a graph pen, can be stored in digital form on computer readable storage media, such as magnetic tape or disk; (2) A narrower bandwidth may be required by using a new method called period measurement technique (and, therefore, it is possible to transmit both the audio and graphic messages on a single voice-grade telephone channel); and (3) The graphic may be displayed on home television sets by using a scan converter or digital storage at the receiving stations.
Graphic Input Device

The graph pen is used as the input unit for the prototype. The pen position on the graphic surface is converted into two 10-bit binary numbers, the \( x \) and \( y \) coordinates. The graph pen is illustrated in Figure 5.

Figure 5. -- The graph pen converts the position of the graphic surface into two digital coordinates.
Period Measurement Technique

The binary coded x and y coordinates are transmitted at every 1/60th of a second. The digital storage will be updated at the receiving end by using digital counters. The traditional frequency modulation method is too insensitive to detect the difference in frequency change. For example, a frequency centered at 1000 Hz, during a period of 1/60th of a second less than 20 cycles, may be measured. The given frequency may change from 1000 Hz to 1100 Hz during the period but only two cycle difference may be found. A new technique called period measurement was developed. Instead of counting the number of cycles per every 1/60th of a second, a time period representing the value of the digital number is used to start and to stop a high-speed clock which generates 10 MHz signals. A single cycle for a frequency of 1000 Hz takes 1 millisecond to complete, and if the period of one cycle is used to gate the high-speed clock 10,000 cycles can be detected. A new frequency of 1100 Hz takes 0.91 milliseconds to complete a cycle which can cause the digital counter to detect 9100 impulses. This slight change in frequency yields 900 points difference.

By using the new technique, the values of the x and y coordinates are used to control the time periods of the signals. At the receiving end, the length of the time period is used to set the digital counter for obtaining the values of the coordinates.

A period transmitter was designed to generate a tone and the period of the signal is varied by the value of the input. The period transmitter is illustrated in Figure 6. The value of the input data word and a present constant determine the base for a presetable counter. The base indicates how far up the presetable counter starts and the counter stops when an overflow is generated. In this way, the period of the output signal is varied by the input value in the data word which is set by the graph pen. This type of digital graphic data transmission has high accuracy because the high-speed clock is crystal controlled and has 10^-7 stability. Another advantage is that it has a narrow bandwidth which provides the possibility of sharing a single telephone channel with the voice signal.

Graphic Display

At the receiving end a scan converter is used to drive the home television set for displaying the motion line graphics. The scan converter is basically a storage device that allows a graphics point to be written during the vertical retrace interval in a television casser scan. Every 1/60th of a second a new dot which is expressed by the x and y coordinates is written on the storage. The scan converter acts as a television transmitter and reads out the stored image that has been built up by the dots. Figure 7 shows a block diagram for the display unit. The digital signals of 8-bit binary words of x and y coordinates are converted into analog signals with D-to-A converters to drive the x and y position amplifiers in the scan converter every 1/60th of a second for writing a dot on a storage tube. The image on the storage is then read out to a television monitor.
Figure 6. -- The period transmitter.
Figure 7. — Graphic Display.

Figure 8 illustrates a timing diagram of the operation of the scan converter and the screen positions on a television monitor. Most of the time the scan converter is reading out the stored information that is written on the storage mesh of the tube. During the time of the vertical retrace of the television monitor, a new dot of graphic information from the input is written on the storage tube. The cycle repeats every 1/60th of a second.

Figure 8. — Timing of the operation of the scan converter and the screen position on the television monitor.
Vector Generator

One of the problems in the digital graphic data transmission scheme was that, if the graphs were drawn very quickly, the uniting dots failed to keep up with the handwriting and gave an unusual type of distortion that formed trains of dots rather than lines. Figure 9 illustrates this effect.

![Figure 9](image)

A vector generator was designed to eliminate the problem. A vector generator generates a scan or a series of dots between two points.

The Multiplexing of the Audio and Graphic Signals Over a Single Voice Grade Telephone Channel

The reduced audio signal and the digitally transmitted graphic messages are sent to the receiving station via a single voice-grade telephone link. A prototype audiographic data transmission system was designed. The voice bandwidth is from 300 Hz to 800 Hz which should provide a fairly good voice quality according to the data reported earlier. Frequencies above 1800 Hz will be filtered out. The remaining part of the spectrum was designed to transmit the graphic messages. The \( x \) axis is centered at 2200 Hz with 200 cycle bandwidth for transmitting the \( x \) coordinate, and the \( y \) axis is centered at 2800 Hz with the same bandwidth for the \( y \) coordinate. Figure 10 illustrates the frequency spectrum of the audiographic signals over a voice-grade telephone link.
The Prototype System

One of the most important features of the improved prototype audiographic data transmission system is the share of single voice-grade telephone link for simultaneously transmitting both the voice and the motion line graphics to remote learning stations. The overall system is illustrated in Figure 11.

Another feature of the system is that the graphic information is in digital form which can be stored on digital storage media for better computer control of the image. The quality of the graphic picture is also better than the original system which uses the Electrowriter as the graphic input and output device. But perhaps the most significant improvement embodied in the new system design is that it makes it possible to deliver well-tested, electronically stored instructional information via the existing telephone network to any American home that has in it a single telephone and a single TV set.
Figure 11. -- The improved prototype audiographic data transmission system.
V. ALF ECONOMICS AND THE FUTURE

In order to establish a perspective from which to consider the future of ALF-like systems, let us review the economic aspects of the Audiographic Learning Facility. The general approach by which the School of Information and Computer Science arrived at a meaning of the term 'economical' was to ask simply: What is the amount of money a customer is able and willing to pay for a learning system having specified performance and properties? The following example illustrates this 'marketing' approach to educational cost analysis:

Assume an academic department which offers, each academic quarter, 20 sections of a particular subject sequence (say calculus), where each 30-hour course section handles 25 students, for a total of 500 students per quarter (2,000 students per calendar year) or 60,000 student hours per year; assume also that an equivalent of five faculty members is assigned to this course load. Given an average faculty salary of $20,000 per 12 months (which includes the cost of support staff), the direct annual cost for offering these courses is $100,000 in Personal Services.

Assume now that the department chairman is prepared to offer the same courses via a conversational teaching system, providing this can be done without increasing his budget. Assume further than he has decided to retain two of the five faculty members to continue as full-time tutors in this subject matter, and to reassign the remaining three teachers and their support staff; this releases in his budget a sum of $60,000 which he is prepared to apply to cover the full annual cost of the teaching system — hardware, software, communications charges, operating expenses and author royalties. (We ignore certain one-time start-up expenses.)

We calculate that the total cost for the system and its operation, if amortized over a five-year period, must not exceed $300,000. Since the cost of student terminals in a conversational system can be substantial, it is of interest to determine the minimum number of terminals required to teach this student load in an individual learning mode. Assuming 2,000 working hours in a calendar year (250 eight-hour days), the minimum number of student consoles serving an annual load of 60,000 student hours is 30. (There are reasons why at times some students might prefer to learn in small groups using an appropriately designed student terminal; in such a case, fewer terminals would suffice.)

A rough cost analysis of this type is useful in that it forces recognition of the fact that there exists a pragmatic ceiling for the operating costs of realistic educational systems. For example, if "it appears both internationally and in the United States that an operating budget of approximately $250,000 to $300,000 a year is necessary merely to maintain facilities [of large-scale CAI centers] in operation" (Seidel and Kopstein, 1970), such facilities clearly do not meet our criterion of economic feasibility, and consequently may be eliminated from the range of devices which can be considered. If the learning materials were procured at a cost of,
say, $500, per lecture hour (the total cost of five 30-lecture courses is $75,000, or 25% of the total budget available), the annual operating costs associated with the physical facility cannot exceed $45,000. Given the lower bound on the cost of conversational terminals to be not less than $1,500 (or $9,500 per year for 30 terminals amortized over five years), it is possible to derive rather accurately the permissible and available cost items for control hardware, memory, communications, maintenance, and operator costs. This approach, while obviously not guaranteeing a widespread acceptance of learning systems, should nonetheless be able to preempt the argument of economics which has been frustrating a more rapid application of information technology to education—provided it is possible to design educational systems within the economic constraints so determined.

Pursuant to the goals of this concept of economics, two approaches to delivering ALF materials may be compared. The two approaches are represented by a Free-Standing ALF and a Ten-Terminal ALF, both employing the concepts used throughout this project. Analysis of such systems reveals that the cost per student hour for presenting ALF materials to a class of ten students is about $0.20 per hour. The cost per student hour for a class of one student (one terminal dedicated to one student) is about $1.95.

This cost per student hour is predicated on the technology of ALF as it now exists and is not based on assumptions about the reduction of costs through the development of mass markets. These figures therefore do not include economic advantages to be effected through the bulk buying of equipment or other benefits of the economy-of-scale.

If ALF in its current form were expanded to a size which would support 1,000 receiving stations, the cost of those receiving stations could be reduced by at least 40 percent.* Also, the unit costs of appropriate minicomputers, switch registers, magnetic tape decks, etc., could be reduced by a similar percentage. Although the cost of editing, managing, duplicating and maintaining the ALF tapes and equipment would increase and thus offset a portion of the savings on the order of 25%, a net reduction of the cost per student hour to a figure of $0.15 might be achievable.

In spite of these favorable economics, the state of ALF technology at this time leaves much to be desired. The Electrowriter Receiver units operate well, and with few maintenance problems, in a reasonably controlled environment. However, with environmental variations experienced when room air conditioning is turned on and off, the inking pen becomes clogged and the ink reservoir takes on moisture, causing difficulties which are hard to overcome at the user station. Also, the management, editing, formatting and duplication of magnetic tapes is tedious and costly. Further, the very nature of magnetic tape as a storage medium imposes annoying delays in servicing many requests and tends to limit the amount of "browsing" a learner is

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*Based on private conversations with Stewart Wilson of Polaroid Corporation regarding bulk-buying benefits from Victor Electrowriter Corporation.
inclined to do. While such problems (even the necessity of using two telephone lines) have not significantly impaired research-related activities, it is clear that future commitments to serving large segments of the public should not be made on the basis of current facilities. Hence it is appropriate to examine alternatives for future system development and use.

One obvious alternative is a digitally stored system interfacing a receiver unit which allows exploitation of the home-quality TV set. First, let us consider the problem of digital storage. The simplest approach to accomplishing a digital ALF (DALF) would be to convert the audio and graphic signals to digital values employing an adequate sampling rate and quantization level to preserve telephone-quality sound. For these purposes, it can be shown that about 30,000 bits per second of recording would be adequate (1,200 Hz for voice, 1,800 Hz for data, guardbands and control). Therefore, each hour of DALF recordings would require about 108,000,000 bits of digital data.

Employing current-day, off-the-shelf technology of the PDP-11/45, it is possible to construct a DALF capable of maintaining, on-line, 32 hours (a complete one-quarter course) and of serving 32 simultaneous learners for a central systems hardware cost of about $500,000. (Given current trends in bulk storage costs for small computer systems, it is conceivable that this cost could be reduced by as much as 20% in the next two to three years.) For estimating purposes, let us look at the cost of supporting 32 learning stations serving 32 individual learners.

First consider the terminal unit required. As has been discussed previously, the desired terminal unit should be capable of receiving multiplexed voice and graphic digital data on a single telephone line. This unit must then separate the voice and the line graphics data, submit the voice signal to an amplifier and speaker, and present the current data point in the form of two eight-bit values to a digital-to-analog converter which generates the input to a video scan converter for the production of a signal to a home-quality black-and-white TV set.

While no such unit exists as a standard product, its logic has been designed and to some extent tested. The principal item of cost is the video scan converter. The cost of video scan converters is still high (on the order of $2,500) when purchased one at a time; however, for reasonably large orders, the unit cost drops to about $1,500, and for very large orders (1,000 or more) the unit cost drops to $750.00. Also, it has been predicted that the units cost of such "refresh units" will drop to below $500 in the next two or three years.* The implications are, therefore, that

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*The Mitre Corporation, Technical and Economic Considerations of Interactive Television, February 1974, M72-200, Vol. II.
a desirable terminal unit can at this time be developed at a cost of $2,000-$2,500 per unit in small quantities and that the unit cost in production quantities might be less than $500 within a five-year period.

Thus, for estimating purposes, assume a terminal unit cost of $2,500, a central facility cost of $500,000, 32 simultaneously active terminals, 30 hours of digitized on-line ALF (DALF) type instruction, and a 2,000 hours-per-year utilization by each terminal. If we use $100 per hour as the cost of generating the course materials, allow only one user at each terminal, and amortize the capital costs over a five year period, the cost per student hour is $1.82.

If each learning station accommodates ten students per session, then the cost per student hour is about $0.18 per hour which is roughly the cost of ALF as it stands. However, these costs of digital ALF (DALF) are premised on strict data processing equipment standards today: it is reasonable to expect that in five years the cost of an equivalent central facility will be reduced to only $250,000 and the cost of terminals will drop to $500. Therefore, for the same system above, the cost per student hour would drop to $0.84 per student hour for one student per station and $0.09 per student hour for ten students per station.

These data place a DALF system in very favorable light from both the point of view of limited capital investment and the point of view of cost-per-student-hour. While this analysis has not explored the opportunity in depth, there is every reason to believe that a careful application of today's microprocessor and bulk storage technology could produce a DALF system with even greater cost advantages than those outlined above.
VI. REFERENCES


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