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ABSTRACT

A computer-managed instructional (CMI) system is being developed for use in investigating a CMI environment for Air Force technical training using the PDP 11/20 minicomputer. Software and hardware interfaces are now available for 24k core memory with an additional 128k random access disc storage. Hardware interfaces are complete for the student key-readers, an interactive graphic terminal, a test form reader and a computer-controlled slide projector. The CMI system also uses the manufacturer's hardware such as the cathode ray tube terminal, card printer and line printer. Key reader devices, capable of reading data from a coded key, identify the user and his location to the system and monitor the use of instructional materials and media not controlled by the computer. Computer software to operate the hardware is ready, and a series of short lessons is available which demonstrate how an instructional course can be managed using a sample adaptive model with pre-tests, lesson options based on student characteristics, course tests and feedback for students and instructors. (Author)

AFHRL-TR-73-57

# AIR FORCE HUMAN RESOURCES LABORATORY





## AN EXPERIMENTAL CMI SYSTEM ON THE PDP 11/20

By

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TECHNICAL TRAINING DIVISION
Lowry Air Force Base, Colorado 80230

December 1973

Approved for public release; distribution unlimited.



AIR FORCE SYSTEMS COMMAND
BROOKS AIR FORCE BASE, TEXAS 78235

## NOTICE



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This technical report has been reviewed and approved.

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Technical Training Division

Approved for publication.

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BLOCK 20 (Continued)

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AN EXPERIMENTAL CMI SYSTEM ON THE PDP 11/20

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## INTRODUCTION

The Advanced Instructional System (AIS) is an advanced development effort to demonstrate and test the feasibility of a large scale computer-based instructional system for Air Force technical training. This system will develop methods for integrating the latest advances in individualized instructional systems management, and computer technology in order to improve the cost and effectiveness of Air Force training and education. The AIS development will be centered initially around three training courses presently taught at Lowry Technical Training Center. These high-flow, high-cost courses have been selected to provide a representative cross section of the types of technical training currently being conducted by the Air Training Command.[1]

In-house and contractual studies were conducted to refine and update the information base required for final program definition. One such study was a survey of the state-of-the-art in computer-based education and training.[2] The system will also provide a training research facility to allow systematic evaluations of innovations in instructional technology. Investigations into component elements of the system required close and rigorous evaluations, which could best be accomplished with a small computer. Thus, the experimental computer managed instruction system (CMI) came into existence. The CMI is a small prototype system to allow for experimentation with instructional materials and various media; for example, to test a hypothesis involving the type of instructional presentation and media for students as a function of various proficiency tests, attitude tests, and past performance. The system was developed under contract with the Denver Research Institute.

The system has been designed to be used in conjunction with all existing media and materials, such as programmed instruction, sound-slide presentations, and microfiche. The command language of the system has the capabilities to create its own computer-assisted modules as well as controlling on-line devices while a student is at the terminal.

The command language also has the capabilities to direct and keep records for many students simultaneously. The system maintains records for each student and compiles statistical data on each test with built-in capabilities for analysis of test results. A reporting capability will provide for the instructor a synopsis of the student's progress in the course, identification, time spent on each segment of the course, test results, the student's own analysis as to the difficulty of the material and any other comments the student wishes to make.

## THE KEY-READER SYSTEM

There are a number of functions to be considered for a meaningful management system. A prototype system can by no means incorporate the large number of variables desired, such as those that will be a part of the AIS, and would also defeat the purpose of a small scale system before it became operational. Working within the framework of a small system, the hardware developed and implemented should meet the minimum requirements of the system as well as fulfill the basic philosophy of a working model.

One of the basic issues of the AIS has been the management and allocation of human and equipment resources to maintain efficiency. In order to do this, it is necessary to be cognizant of what resources are being used by a particular student at any particular time. Several possibilities exist to link the identification to internal log records; e.g., prepunched or magnetic strip plastic ID cards, passwords, code words, etc. The plastic coded key was selected for an in-house investigation.

The adjunct hardware developed for the CMI system is the key-reader which identifies, controls and records the performance of students associated with this system. The physical appearance of this device is a small metal box with a keyhole and indicator light. As an individual approaches the key-reading station, a lighted indicator will notify the person that the system is operational. When the key is inserted, there will be a "momentary" flicker of the light as the key is verified and the proper commands given. If the individual is at an incorrect key-reading station, the light will stay off and the station is non-operational until the key is removed and the indicator will return to the "on" state.

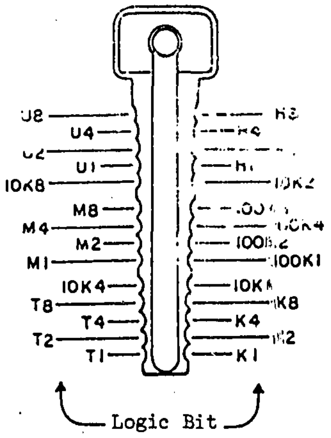


FIGURE 1 CODED PLASTIC KEY

The keys are notched plastic keys using the Addo-X Key-Reader Assembly. A coded plastic key using a BCD code structure is shown in Figure 1. This key has all twenty-eight positions notched. Each notched position represents a binary one and provides seven decimal digits of information. This configuration within the key-reader assembly can be changed by alteration of jumper connections in the Addo-X assembly.

Figure 2 illustrates the data format of the key-reader to be compatible to the DR-11 of the PDP-11 computer. The first five bits are the identification code of the station. Each reader contains five toggle switches on a multiplex switch circuit board to provide the information necessary for unique identification of each key-reader. This allows for thirty-one stations in series to be identified. There exists in the series a last station known as the terminator. It is a non-keying device, but does

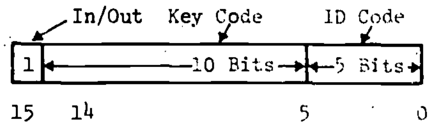


FIGURE 2 FORMAT OF KEY-READER DATA

contain station identification. Bits five thru fourteen give us ten bits to identify the key code allowing 1023 students to be uniquely identified. The all blank key is reserved for closing the system when keyed in at the main station. At this point, we remind you that software design will be a major factor in control of the system.

The buffer driver is also provided as a line driver having only a visible light and no identification. The buffer driver (although optional) is an integral part to recondition the signals when long distances occur between key readers. This completes the hardware items of the system which are interfaced to the PDP-11 for system control. The interface used is the DR11-A, a product of Digital Equipment Corporation. This general purpose digital device permits the bi-directional transfer of sixteen data bits in parallel between the unibus of the PDP-11 and the key-readers.[3]

Control signals of the individual key-readers need to be coordinated and formed into compatible signals for the DR11-A. Also, the signals from the PDP-11 via the DR11-A to the key-readers need to be coordinated by the control circuits; e.g., interrupt request and enable, read clear, reset, light on or off, etc.

The following excerpt is taken from the Denver Research Institute report[4] in order to illustrate a typical operation:

"As a typical operation assume that no other Key Reading Stations are attempting to be read. Prior to insertion of the key, the multiplex switch will be transferring low priority data to its output. The READ ENABLE and READ LOCK input lines will be at a level which indicates that no other Key Reader is attempting to be read. Upon insertion of the key, the Key Status flip-flop changes state to indicate that a key has been inserted. The output of the flip-flop is then routed to the INTERRUPT REQUEST circuit and this change in state is then used by the circuit to produce a level on that line which by virtue of OR gates in higher priority Readers is transferred to the Control Circuit which in turn creates a flag in the PDP-11 indicating that a Key Reader needs to be read. The DATA READ DECISION circuitry is then enabled by the indicated status of the READ ENABLE, READ LOCK, and internal INTERRUPT REQUEST lines to produce a level which is used by the multiplex switch, the READ LOCK circuitry, the INTERRUPT ENABLE circuitry, and the READ CLEAR circuitry. The READ LOCK circuitry uses this level to generate an output signal which is used in the higher priority Key Readers DATA READ DECISION circuitry to inhibit them from overriding this particular Key Reader until it has been read by the computer. The INTERRUPT

ENABLE circuitry is then 'primed' by this level to allow the PDP-11 to use program control to turn off the LED via the LIGHT OFF line upon the event an invalid code is read off the key. Such an action, in addition to that described above, would indicate to the operator that he is not being read by the computer. The multiplex switch is then forced by this level to transfer local code data to its output, and finally, the READ CLEAR circuitry uses this level to prepare for the 'trapping' of the READ CLEAR input pulse which will be produced by the computer once it has completed reading the proper code data.

The state of the Key Reader described thus far is known as the 'Lock-On' state. The remaining conditions of this state occur when the READ ENABLE circuitry forms a level which prohibits lower priority Readers from obtaining this 'Lock-On' state just as the READ LOCK level prohibits higher priority Readers from obtaining the 'Lock-On' state. This Key Reader will remain in the 'Lock-On' state until the computer has read the code data and generated a READ CLEAR circuitry which changes the Reader back to its reset state.

There is one other mode in which a Key Reader may operate and this is called the INTERRUPT REQUEST state. This occurs whenever another Reader of higher or lower priority is being read, or when another Reader of higher priority requests to be read. When either of these conditions exist the READ LOCK or READ ENABLE input lines will be at a level which inhibits the DATA READ decision circuitry from creating a 'Lock-On'state. When this occurs the INTERRUPT REQUEST circuitry will remain in a REQUEST state until the other stations have been read which allows the READ LOCK and READ ENABLE input lines to return to a proper level necessary for producing the 'Lock-On' state. During the INTERRUPT REQUEST state, the READ ENABLE output line delivers the proper level to all lower priority Key Readers so that they cannot be read until all higher priority Readers requesting INTERRUPT have been read."

## THE CMI SYSTEM

The software developed for this system to interact with the student as a guide through the course and maintain system records consists of the following requirements:

1. File management - control of student record file input and update, course file input, report line output

2. Time-sharing monitor for 2 terminal use (not implemented at this time)

3. Key-Reader input/out control

4. CMI control-interaction with the student that is non-course specific

5. Report file creation routines

6. Testing and scoring routines

7. Course file interpreter routines (command language)

The peripheral equipment other than key readers under control of the CMI and associated key-reader locations, if applicable are:

1. VTØ5 alphanumeric terminal Key-Reader Station #0 (Main Station)

2. Card Reader

3. DECtape units

4. Disk Storage

5. Marked document reader Key-Reader Station #1

6. Line Printer (80 column) Key-Reader Station #1

7. Computek Graphic terminal/tablet (related to item 2 under software requirements).

8. Random access slide projector Key-Reader Station #0

Other equipment and media not under computer control will be utilized at the remaining stations, incorporating such presentations as sound-slide, programmed text, microfiche, and film-strip.

1. Course Specification

The essence of the CMI system lies in the capabilities provided for the user of the system. Herein is the success or failure of the system to provide, with ease of use, the tools necessary in accomplishing the mission set forth. This input to the CMI system is known as the Course Specification file as shown in Figure 3. This file contains all the commands, dialogue and decision-making mechanisms necessary to successfully direct students through a course, record the progress, and provide the statistical and other data for the various files in the system.

The course file language is in the form of commands which are sequentially interpreted and executed by the CMI for each active student. These commands can be entered into the system as punched cards or as card-image files.

The course file has two header cards and an end-of-file card in addition to the command cards. The general format of the command card is illustrated in Figure 4.

COMMAND CARDS

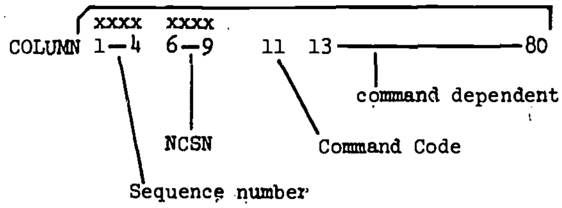


FIGURE 4 GENERAL FORMAT FOR COURSE FILE CARDS

## THE CMI SYSTEM

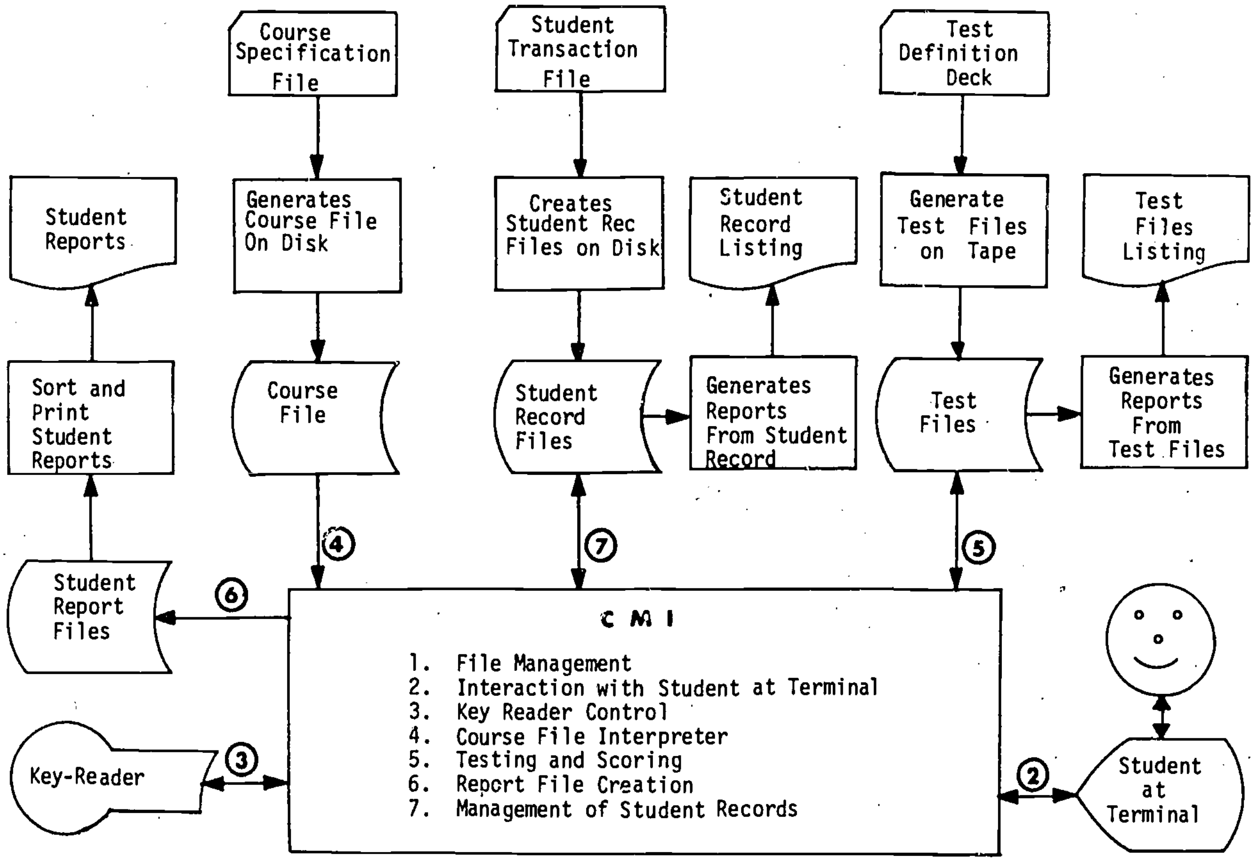


FIGURE 3

The command cards are numerically sequenced with the first card required to be ØØØ1. The maximum number of cards (commands) allowed is 1999 due to current disk space limitation. Associated with each card is a next command sequence number (NCSN) as a pointer to the next command to be executed. If this space on the card is left blank, the sequence number of next card in the deck will be used. There are twenty-three command codes composed of a single alpha character currently implemented. A table is included showing the commands and their associated mnemonics. Non-specified fields can be freely used for comments. A one-pass form of assembler is used to format the commands for a random access file on disk. Diagnostics are provided for the following error types:

Alpha in Numeric Field

Sequence Number Missing/or Repeated

Invalid Mnemonic, numeric value, and type code

2. Student Transaction

The course file is authored for a number of student users. We next need to relate to the individual student in order to be adaptive to their needs and provide the best utilization of their time and our system. The student transaction provides the means by which we have individualized the instruction.

A contiguous disk resident file of 128 words in length is generated for each student. These files contain predefined information provided by only 3 card types per student in addition to the specified course each student is entering. Type 1 card provides the student name and identification code which matches the coded plastic key designating this student. The type 2 cards provide the student's reading, mechanical ability, and general IQ scores. Type 3 card provides the level of the current course and its ID, as well as the level of the student's goal, the number and ID of previous CMI courses, and the student's completion and achievement ratios. The CMI system uses this file for active information relating to the student's progress throughout the course. Typical information available in this file is the current course number, course completion status, test identification, assigned key-reader station, and three switch fields. The three switch fields are used freely by the author for any additional information desired. An eight-word block is reserved for each of the eight lessons. Lesson start and finish date, time elapsed, media assigned, test number and score, and test scores by category are the items entered by the CMI system.

3. Test Definition

Our third and last consideration for author input to the system is the test definition file. This file is test structured but need not be used in adherence to its name. One may wish to present questions and record responses to determine the student's comprehension and serve only as a check on the validity of the material presented. The author is free to ignore this section or use it within the limits of its structure for whatever purpose he wishes to assign the file. Each test, identified by a number (0-255) is one complete file of 1024 words currently assigned to DEC-tape. Questions may be of four types, true/false, multiple choices, combination of the first two, or a constructed response of a maximum 10 character ASCII string. Six arbitrary categories are provided for each file in which one may wish to categorize the questions or test items; e.g., comprehension, general concept, computation, etc. The system will maintain additional information for each question pertaining to the total number of times asked, number of correct and incorrect responses, and the total number of true, false, A, B, C, D and E responses.

4. Information Retrieval

The information retrieval for the updated test and student records files are programs which are run when there is no student load. These reports contain the necessary identifying information from the input and are predominantly a presentation of the activities produced during the active CMI system. A third retrieval program generates the student reports from a report file that has sequentially recorded the activities of the CMI system. This latter report on the student gives us the tracking information, as well as a record of how long he spent at a station, type of media, of test score results, CMI course interpreter comments on progress, and the student's own comments or requests that he wished to make.

5. CMI Module

This is the module that controls and directs the system. The system monitors and directs students through a course of instruction. It may be well to point out here that CMI handles many students simultaneously through the use of different off-line study materials; however, it can only be executed for one course (up to 8 lessons) at a time, as presently configured.

The system communications center has been assigned to the VT05 display terminal with its associated key-reader station. All direct communications with the system takes place at this station. This becomes the initial key-in station for every student and is then assigned from here to the other stations in the system as he progresses through the course.

The system checks each key-in at the stations for legality; that is, comparison of assigned ID with the actual station ID. If the light (key-reader system) flickers and remains on, the student is accepted at the assigned station. If the light remains off, on a key in, the student should reinsert the key a second time and if the light still remains off, the student has been rejected. At this point, the student should return to the communications terminal (main station) and key in here to find out why he was rejected. The student will be directed to his assigned station if he had keyed in at the wrong station. The station may be course file dependent, but the dialogue here is CMI interpreted and directed, as are the remaining illustrations of the system's operation.

| CODE | DESCRIPTION |
|---|---|
| A | Accept an answer to printed test question on line |
| C | Compare student record item(s) and branch |
| D | Ask student to rate lesson difficulty |
| E | Exit subroutine |
| F | Set value of a student record item |
| G | GO TO |
| I | Interrogate student and wait for response |
| J | Call Subroutine |
| K | Assign student to station and check if station busy |
| L | Ask student to write comment in his report file |
| M | Score test, store and print result |
| N | Advance current lesson pointer |
| O | Off-line test to be scored at optical reader |
| P | Select and display a slide |
| Q | Ask test question and accept answer on-line |
| R | Test response and branch |
| S | Display a statement (VTØ5) |
| T | Turn On/Off slide projector |
| U | Update time and achievement ratio |
| V | Write to Line Printer |
| W | Write a comment to student report file |
| X | Student logging off system |
| Y | Add a value to student record switches |
| Z | Clear screen, home cursor |

TABLE OF COURSE FILE COMMANDS

The student is expected to complete a lesson at his assigned station and then he returns to the main station for further instructions. There are two CMI directed questions upon any students keying back in at the VT05. The first is, "Are you ready to start a new assignment?" for which he may respond with a "Yes" or an "Incomplete: and then is asked, "Are you ready to continue?" If the answer is "Yes," CMI passes control to the course file interpreter for the next sequential instruction. The other alternative for the student is to "LOGOFF" or discontinue at this time and effect the close of all files related to this student. Also before closing the files, the system will interact with the course file to provide the insertion of comments (unlimited number of lines) by the student for the record file.

A student is never rejected at the main terminal unless his student record or assigned course is not available.

The CMI course file interpreter exhibits the major capability of the system. The interpreter provides the output to the student in the form of instructions of CAI via the display terminal. It will also clear the display screen and position the cursor at the upper left hand corner. A random access slide projector can be addressed to display any one of a hundred slides.

Interrogation is a display of a 58 character line and acceptance of up to 15 character response. The question may be several lines in length. The response is compared with a specified field and branching results on logical equality to the next command's sequence number.

Comparisons of any student record item may be made with another item in the record or against a specified value. Certain values may be set during execution, such as the three switches, course completion status, or the media used. A student may be asked to rate the lesson difficulty on a scale of 1-5, and this is also output along with the question to the report file. The lesson pointer can be advanced upon completion of the lesson and also update the student's time and achievement ratio utilizing the elapsed time and test score for the completed lesson.

Test administration can be on-line at the display terminal or off-line using a marked document reader. In either case the answers are stored in an array and then scored, the results are printed on the line printer for the student and entered in his record file as well as the report file. The test questions for an on-line test may be asked at the terminal or it may be presented in hard copy form and only the question number is presented and in either case, the answer is accepted from the terminal and stored in an array for scoring.

The course file interpreter also provides communications links for the author in the form of the Fortran "GO TO" statement, subroutine's "CALL" and "RETURN" commands, and "SWITCHES." It will also assign the student to a key-reader station and determine if the station is busy. Control can be returned to the author in the event of an unexpected "LOGOFF" other than the end of the course.

When the CMI system is not in use, the blank key may be inserted to close all files and return control to the monitor. The three out-put programs may be run to obtain information and statistics of the CMI activities. The student report file is sorted by individual student and lists the activities of the student; e.g., key-in time, station, media, key-out time, lessons completed, comments, etc. The student record listing may also be run to review the updated information. Test file listings are of particular interest to the course authors. These contain the statistics on the responses to the questions asked and provide the guidelines for evaluation of the materials developed.

## AN OVERVIEW

The CMI system is only a simulation of a much larger system. Its design is to demonstrate some of the capabilities which will be a part of the AIS. Potential users as well as interested observers relate more readily to a small functional system. Course authors can develop and test the materials and media in a small-scale "total system" environment while becoming acquainted with system concepts.

We do not wish to imply that this system is totally functional and without a number of limitations. Certain limitations can be eliminated and improved performance obtained by expanding disk storage. Inherent expandability exists in the system's structure, particularly within the course file interpreter. A more costly expansion would be in time-sharing for more than the one CAI terminal which is now shared with the main CMI communications device.

The experimental system has provided insight to the many contingencies of hardware/software interfacing, hardware reliability, media selection, and presentation of course material. Transfer of this information to the design and implementation of the AIS will provide the Air Force and the educational community in general with a training system that is capable of utilizing the full potential of instructional and computer technology.

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