NASA CONTRACTOR REPORT

NASA CR-917

NASA CR-917

N68-13897	
(ACCESSION NUMBER)	(THRU)
445	1
(PAGES)	(CODE)
	08
(NASA CR OR TMX OR AD NUMBER)	(CATEGORY)

FACILITY FORM 602

GPO PRICE $ ________

CFSTI PRICE(S) $ ________

Hard copy (HC) 3.00

Microfiche (MF) ________

ff 653 July 65

COMPUTER ASSISTED INSTRUCTION

Feasibility Study

by Richard L. Balogh and Don L. Purdum

Prepared by
PHILCO-FORD CORPORATION
Houston, Texas
for Manned Spacecraft Center

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION • WASHINGTON, D. C. • JANUARY 1968

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Issued by Originator as Report PHO-TR307

Prepared under Contract NAS No. 9-1261 by
PHILCO-FORD CORPORATION
Houston, Texas

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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FOREWORD

This report was prepared by Philco Houston Operations in response to Task Order No. 030a, dated October 21, 1966, entitled "Automatic Teaching System Study" (also referred to as "Computer Assisted Instruction Feasibility Study"). The Task Order was authorized under Part II, Paragraph 2a of the Statement of Work to Supplemental Agreement No. 36 to Contract NAS 9-1261.

ACKNOWLEDGMENTS

The authors wish to acknowledge those members of the NASA/MSC's Mission Simulation Branch who were particularly helpful in completing the work described in this report. Special appreciation is extended to H. G. Miller, Chief, Mission Simulation Branch; G. M. Ferguson, Head, Flight Control Qualification Section; G. H. Cress, Flight Control Qualification Section; and D. T. Swift, Philco-Ford Corporation, TechRep Division.

The following individuals also made special contributions: Dr. E. Lyman, University of Illinois; M. Jerman, Stanford University-Walter Hays; Dr. J. Kearns, IBM, University of California at Irvine; H. Shettel, American Institute for Research; R. Wye, Philco-Ford Corporation, Communications and Electronics Division; Dr. J. Kelly, Dr. L. T. Lepine and J. Adams, Philco-Ford Corporation, TechRep Division.

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SECTION 1

INTRODUCTION

1.1 GENERAL

This report presents the results of the Computer Assisted Instruction (CAI) Feasibility Study prepared for NASA/MSC Flight Control Division, Mission Simulation Branch. It represents the findings of a 6-month study to assess the potential of using advanced training concepts for training flight controllers.

The primary objectives of this study were to:

A. Review and analyze existing CAI systems and determine their applicability to flight controller training.

B. Develop the functional requirements for an optimum CAI system for flight controller application.

C. Specify the functional requirements for an initial system and recommend a design that could function as the initial CAI system.

D. Evaluate the costs incurred by programmed instruction and determine if CAI is a cost-effective method of training NASA flight controllers.

1.2 APPROACH

For this report five major study tasks were identified: namely, (1) survey and analyze existing operational CAI systems and author languages, (2) compare existing CAI systems capabilities against flight controller training requirements, (3) specify the functional requirements for the optimum CAI system for flight controller applications and, against this background, develop the functional requirements for an initial CAI system for flight controller training, (4) specify the initial system utilization techniques, procedures and constraints, and (5) perform a CAI cost-effectiveness analysis. (Refer to Figure 1.2-1.)

The survey consisted of transmitting a detailed questionnaire concerning programmed instruction to all major colleges and universities and analyzing the results. The central processing systems, terminals, and author language for each system were analyzed.

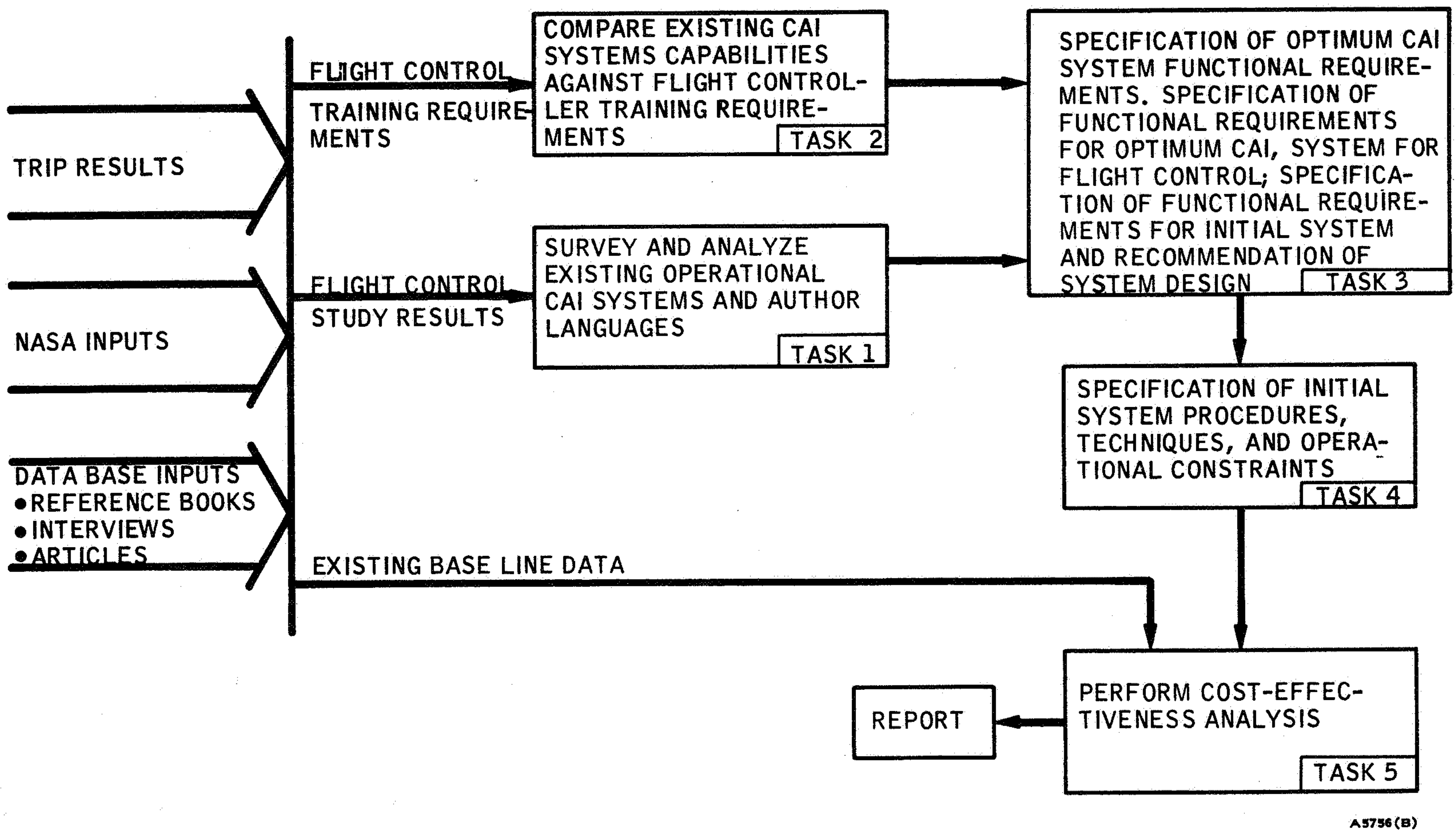

Figure 1.2-1 CAI Task Performance Flow

CAI material received from the reviewed systems was compared with the flight controller curriculum in terms of gross objectives, teaching problem similarities, relative level of curriculum complexity, course lengths, and type of presentation logic used. The characteristics of the reviewed systems were examined to determine their applicability to flight control training requirements.

Storage media requirements, user terminal requirements, author language requirements, and total systems functional requirements were specified for an optimum CAI system. Using these requirements and the results of the systems analysis, the terminal and computer functional requirements for an optimum CAI system for flight controller applications were specified.

The initial system functional requirements and recommended design were specified, and consideration was then given to existing assets which could meet the specified requirements.

A functional system design was then recommended which would meet the requirements of the initial system in the most cost-effective manner.

The costs of each instructional medium considered, i.e., conventional instruction, programmed textbooks, and CAI were investigated, and their relative effectiveness was discussed. Formulas were developed in order to arrive at the costs of each medium and to aid the reader in determining the instructional costs for any specific situation. Comparisons were made of the relative costs, time requirements, and the effectiveness of the three instructional media, and applicable trade-offs were discussed.

1.3 GUIDELINES

Prior to and during the study effort, several guidelines were specified by the NASA to establish basic task boundaries and to effect some measure of compatibility between this effort and other efforts which may be conducted by NASA/MSC and other contractors. The items that significantly governed the study activities are summarized below:

A. The curriculum task analysis was to be performed by the NASA with the results supplied to Philco Houston Operations (PHO) as required.

B. An author language and the detailed requirements for the language were not to be developed.

C. The objectives of the initial system were to provide a system which could demonstrate CAI feasibility and immediately provide the capability for limited flight controller training.

D. The study was not to reflect specific hardware design for specific equipments or systems.

E. A comprehensive survey of existing assets was not to be performed.

SECTION 2

STUDY SUMMARY

2.1 OVERVIEW OF COMPUTER ASSISTED INSTRUCTION (CAI)

Approximately twelve years ago, programmed instruction and teaching machines attracted the attention and interest of educators, school administrators, and training directors throughout the country.

The principal reason for this increased awareness was that programmed instruction had been demonstrated to be significantly more effective than conventional techniques of instruction. Often, programmed instruction can do the same teaching job in considerably less time, or can provide the student with a far greater amount of information in the same time.

Although there is something less than unanimous agreement on the principles involved in programmed instruction, the following list represents those principles which are most agreed upon:

A. The subject matter must be broken up into small units called frames. In actual practice, these frames usually vary in size from several sentences to several small paragraphs.

B. At least part of the frame should require some type of response from the student. Active participation on the part of the student is required. Generally, it is desired that the activity also demonstrate understanding of the material.

C. The student should be provided immediate feedback reinforcement. He should be told the correctness of his answer, which has the advantage of immediately reinforcing the activity or immediately correcting a misunderstanding.

D. The units should be arranged in careful sequence. Because the subject matter is broken into small increments, and the author must think carefully about the learning steps involved, the result is a much better sequence of presentation. Careful sequence also embodies the notion of shaping or gradually leading the student toward the desired goals by rewarding him for activity that more and more closely approximates those goals.

E. Programs should be aimed at specific goals. This has the desirable effect of making those involved in training evaluate their goals much more carefully and specifically.

F. Revisions should be based on student responses. Because the student's behavior can be recorded for each frame, a knowledge of his understanding of each part of the lesson can be easily obtained. Thus, if a student is making many errors on one section, the program obviously is not teaching well and must be revised. In conventional instruction an instructor often determines the final presentation, but in programming, the approach is more student-oriented.

G. The student should be free to adjust his own rate of learning. A student may work through a program rapidly or slowly. He should be completely independent of others in the class. Traditional methods such as lectures or motion pictures force every student to proceed at the same rate, which might be too fast for some and too slow for others.

These and many more learning principles are involved in programmed instruction. If it has done nothing else, the programmed instruction movement has caused educators to rethink many of their teaching procedures and to revise them accordingly.

Today, there are more students to educate and less time available in which to implement this education. Students arrive for instruction with varied and often inadequate levels of preparation. There are fewer qualified instructors for the classrooms, fewer classrooms, and everywhere there are rising costs.

New technological advances have been made as a logical and necessary extension of programmed instruction. To accommodate the rapidly increasing load imposed in the instructional system, attention has been focused on the speed and vast storage capabilities of the computer as a possible solution.

Thus, approximately 8 years ago, CAI was conceived. As with any new concept, many questions have been asked and many problems have arisen. One of the more frequently asked questions is: "What possible good can CAI bring to the pressing problems growing out of a need for quality instruction for increasingly large numbers of students?" Typical follow-on comments are: "Everyone" knows that a machine is cold, impersonal and utterly without a value system--or even common sense."

The value of CAI lies, oddly enough, in the quality that some have labeled its liability--its machine-rootedness. Because CAI rests on a computer-based system, it never gets bored, distracted, angry or impatient; it never forgets; and it can communicate as well as the human who originally programmed it to operate. CAI can use the computer's storage facilities and speed to assess individual progress and initiate and monitor remedial work as required. It can accommodate a very large number of students, each of whom appears to have exclusive access to the computer. It can perform each function faster, and with less error, than a human instructor. And, at the very heart of CAI, the control of the learning process is always vested in learning sequences created by instructional personnel. CAI permits the instructor to take on a managerial role in the instructional process. Hence, the instructor can utilize his time more productively--in individual counseling and guidance of students who require additional assistance. Thus, CAI can be used to provide a high level of instruction to many students on an individual basis at a pace determined by the student.

CAI can take many forms. At the most basic level, the interaction is limited to a relatively elementary sequence without evaluation, interpretation or variation on the part of the computer. The computer instructional material is presented via a display such as a teleprinter or cathode ray tube (CRT); the student scans the presentation, and indicates when he is ready to go on by means of a switch or pushbutton. The computer then may give further information, or it may present questions whose answers are to be recorded in a notebook or programmed textbook. Again the student notifies the computer when he is ready to proceed...and so on to the end of the lesson.

As refinement increases, the computer is used with growing subtlety and flexibility.

First the relationship between student and machine is solidified by doing away with the text or notebook. The computer then presents all instructional material and records the student's responses. At a later stage the computer actively scores the student and presents the results to him. Ultimately, as CAI approaches its full development, the computer continuously evaluates the student's responses and leads him through remedial material if he fails to demonstrate understanding of key points in the main presentation.

CAI is by no means the panacea for all the ills that afflict the learning process. With present state-of-the-art technology, there are still several types of subject matter for which it is presently unsuited, e.g., extremely dynamic data which is continually changing. But in circumstances to which it is adaptable, it can solve many problems that cannot be readily handled by conventional methods, e.g., lack of instructors, scheduling and general records keeping.

CAI is often called self-instruction because the student acquires knowledge without the intervention of a human instructor. What, then, becomes of the need for training personnel?

The role of the instructor is basically changed, but not eliminated. He must devote himself to areas where the human capabilities are unique, e.g., planning and counseling, developing remedial instruction for deficient students, and providing information as a consultant to specialists preparing new courses.

The job is changed, but the objective--to produce competent personnel who will be effective in their jobs--remains the same.

The following subsections, and subsequent paragraphs present a summary of the findings of the CAI feasibility study.

2.2.1 CAI Systems Review

Six CAI systems were reviewed in detail during the course of this study. They are:

- The PLATO System at the University of Illinois
- The Time-Sharing System (TSS) at the System Development Corporation (SDC)
- The University of California at Irvine (UCI)
- The University of California at Santa Barbara
- The Philadelphia Independent School District--Project GROW (PHILCO-FORD)
- The Stanford University projects--Brentwood and Walter Hays.

While not investigated for the purposes of this study, other CAI systems exist and are either in the final development phase or have just recently attained an operational status. Several are oriented primarily toward educational research. Examples are: IBM, Yorktown, N.Y.; Dartmouth College, Hanover, N.H.; Massachusetts Institute of Technology Project MAC; Bolt, Beranek and Newman Corporation; University of Texas; Florida State University; University of Pittsburgh; and the Westinghouse Corporation.

The reviewed systems are representative of the current activities in CAI systems development and utilization.

There are three basic design concepts by which a CAI system can be configured; viz., (1) totally centralized system--one in which the curriculum data base is managed and controlled by a central processor with user (student) terminals located adjacent to the computer or remotely located; (2) totally decentralized system--one in which the curriculum data base is assembled and transmitted to satellite computers which are remotely located. The satellite computer performs the curriculum management and control function and provides the information to terminals located adjacent to the computer. Each area can then operate as an autonomous unit; and (3) centralized curriculum control with decentralized automatic operation--one in which the curriculum data base is managed and controlled by a central processor complex with satellite computers (remotely located) completing the interface with the terminal device. It should be noted that there are numerous variations to these basic configurations. The various approaches are governed by factors of economics and operational requirements.

Five of the reviewed systems were configured as totally centralized systems and one as a centralized curriculum control with decentralized automatic operations.

Each reviewed system consisted of a general purpose computer, mass storage and a display-entry device referred to as a student terminal. Four of the systems were entirely dedicated to CAI applications while the other two were time-sharing CAI with other programs such as: scheduling, budget, and counseling programs.

Each system uses its own author language for preparing (programming) a curriculum for computer presentation. Four of these languages are considered state-of-the-art natural (English) languages; one is a modified FORTRAN (CATO) and one is a special language, a modification of FORTRAN IV, developed for on-line programming.

The student terminals in the various systems range from simple teletype devices with paper printouts to sophisticated terminals with special keyboards, light pens, computer-driven film projectors and audio tape reproducers, and CRT display surfaces.

Curriculums ranged from simple drill and practice exercises at the first grade level to engineering electronics at the college sophomore level. Based on the study, it appears that the programmed subjects have a high degree of subject matter stability.

The most significant yet disturbing aspect of CAI is that each system has apparently been designed completely oblivious to the efforts of others in the CAI field. Each system is a unique design with different operating concepts and educational philosophies. Unification of effort and standardization of equipments are not, at this time, being considered.

Detailed results of the review are presented in Paragraph 3.2.1, CAI System Design Concepts, and Paragraph 3.2.2, CAI Systems Review.

2.2.2 Survey of Programmed Instruction Utilization at Major Universities and Colleges

A survey was performed to determine the extent to which programmed instruction systems and techniques were being applied at major universities and colleges. Questionnaires were mailed to 149 various universities and colleges on 4 November 1966.

Responses were received from 56 institutions. Of those responding, 64 percent were engaged in some type of programmed instruction research. The results are as follows:

A. Thirty percent were engaged in research for programmed texts, but were not utilizing CAI techniques.

B. Thirty-four percent were involved in CAI activities.

C. Twenty-four percent utilized other programmed instruction techniques in addition to CAI.

Although a significant percentage were involved in programmed instruction to some degree, most of the reported CAI activities were in the early stages of development. Few institutions reported operational CAI systems which presented curriculum on anything but an experimental basis. Detailed results of the survey are presented in Paragraph 3.2.3, Survey of University and College Activities in Programmed Learning.

2.2.3 CAI Systems Analysis

As was previously mentioned, the systems which have been analyzed are: PLATO, SDC, Project GROW, University of California at Irvine, University of California at Santa Barbara and the Stanford projects--Brentwood and Walter Hays.

Investigations were performed on the student terminals, central processors and author languages. A summary of each analysis is presented in the following subparagraphs.

2.2.3.1 Student Terminals

Student terminals are hardware devices consisting of an entry device(s) and in several instances, display devices which are used by students and course authors to input information into the processing system and monitor curricular material generated for the user by the computer system. The remaining portion of this subparagraph summarizes the results of the student terminal investigation.

There are three system configurations for student terminals typically utilized; viz., (1) centralized--in which the terminals are clustered together and adjacent to the computer; (2) remote clustered--in which the terminals are clustered together and are remote to the computer; and (3) remote decentralized--in which individual terminals are remote from the computer.

Two types of terminals were being utilized in CAI. One type utilizes a teletype or typewriter-like keyboard which provides paper printouts of the curricular material. The other type uses a combination of special keyboard(s) and light pen devices supplemented with a visual display system; e.g., CRT, TV, and 35mm slides. None of the visual display systems have a hardcopy capability. The terminals which consist of either a teletype or typewriter-like device do, however, provide a paper copy printout as a result of the normal printing process.

Simplicity of design and operation, cost, ease of maintenance and availability are the apparent reasons for utilizing the teletype keyboards or typewriter-like devices.

Terminals, whose capabilities are limited to computer-entry and paper-copy printouts, are being utilized with simple curriculums which are presented with elementary teaching logics and strategies. This is understandable when consideration is given to the limited display capability provided the student.

Terminals with visual display capability are used to present complex graphic displays, block diagrams and textual statements which incorporate tutorial and inquiry logics with linear and branching strategies. Refer to the definitions in Appendix A.

Terminals with visual display systems were found to be configured in a central cluster, while terminals without visual display capability were generally remote from the computer. It can be concluded that the high bit rates encountered in the former method make it extremely cost-prohibitive for remote terminal application.

The visual display systems investigated were limited in the amount of characters that could be presented. All had a specific character font fixed character height and width, and a maximum repertoire of 128 characters. All had limited vector-generation capability. There is no apparent need for additional display capability for any of these systems since each system's applications are well within the system capacity. Based on the analysis, the following conclusions have been reached.

A. None of the terminals with visual displays are adaptable to other systems because of certain hardware constraints, i.e., interface equipments and display system organization, and/or the author language instructional repertoires. The terminals have each been tailored for a specific system or application.

B. Terminals are not readily expandable nor are they hardware flexible.

C. Terminals incorporating visual display capability and special keyboards are considerably more expensive than the terminals which consist of a simple teletype or typewriter-like keyboard.

D. When amortized over a 5- or 6-year period, the purchase cost of the terminal with visual display capability approaches that of the rental costs for the terminals with teletype or typewriter-like keyboards. When translating cost into capability, it is found that the visual display terminal can present more complex curriculums, operate with more involved teaching strategies, and in general provide significantly more data to the user per unit time. When consideration is given to these factors, it becomes apparent that the terminal with visual display capability (CRT or TV) is superior to the terminal with a teletype or typewriter-like keyboard.

It seems reasonable to assume that either the PLATO terminal, IBM 1510 Instructional Display terminal, the Philco-Ford Model D-20 display terminal, or the Philco-Ford SAVI terminal could provide the capability necessary for limited flight controller training.

2.2.3.2 Central Processing Systems

The central processing systems of seven CAI systems; i.e., Project GROW, University of California at Irvine, University of California at Santa Barbara, PLATO, SDC, and the Stanford projects--Brentwood and Walter Hays, were examined in the light of computer characteristics, (storage, speed, function), terminal handling capability, and author language utilization. The results are summarized in the following text.

With the exception of the Brentwood system, all the computers were general-purpose and could be classed as small-scale or medium-scale machines.

Two of the systems were time-sharing CAI with other functions including such applications as: computational programs, scheduling, counseling, testing, and grading. The remaining systems were totally dedicated to CAI. All were considered operational systems.

The two time-shared systems operate with typewriter-like keyboards rather than the more advanced visual-display terminal. This appears to be due to three factors: existing machine capabilities and limitations, the large amount of storage required for visual terminals, and the costs and difficulties encountered in transmitting high bit rate data over long distances (all the terminals are remotely located).

All systems employ the same basic storage techniques. That is, (1) data required in "real-time" is resident in main core memory, (2) bulk data, which must be retrieved during course presentation, is stored in random-access memory, such as magnetic drums, magnetic disc files or disc cartridges, and (3) historical data, e.g., performance records for each student are stored on magnetic tape.

Main memory organization and programming techniques are, for the most part, considered as proprietary information by personnel associated with the reviewed systems. Generally, each terminal is allocated a small portion of main memory for storage of curricular material and presentation logic. As the student sequences through the data, it is replaced with newer material from the random-access memory. The executive routines, I/O processing programs, real-time student record processing programs, and library storage areas consume the remaining portion of memory.

Bulk data, i.e., curricular material and presentation logic, are stored in random-access memory in 6-bit character form. The average bulk storage required per system was approximately 30 million characters.

Each system operates with a unique author language, e.g., Project GROW uses INFORM, PLATO uses CATO, University of California at Irvine uses Interpretive Coursewriter, University of California at Santa Barbara uses FORTRAN IV, Brentwood uses Coursewriter II, Walter Hays uses Teacher/Student ALGOL (TSA), and SDC uses PLANIT.

Four of the systems were in the process of redesign and will be upgraded with larger and faster computing systems. The rapid growth experienced by these systems and the diversification of applications appear to have prompted the redesigns.

Based on the analysis, the following conclusions have been reached:

A. The number and type of terminals to be serviced by the computer is a major influence on the quantity of rapid access memory required.

B. Machine speed and word size do not appear to significantly affect system operation.

C. The amount of mass storage (i.e., random access and bulk storage) is a function of the curriculum length, complexity, and presentation logic.

Refer to Subparagraph 3.2.4.2 for the detailed analysis of the central processing systems.

2.2.3.3 Author Language

Author languages are special software programs which enable course authors to enter curricular material into a central processing unit and program the sequence in which it will be presented. These languages differ primarily in terms of their intended educational purpose and the given computer on which they can be employed.

Many different author languages have been developed, e.g., INFORM, CATO, PLANIT, Coursewriter I, Coursewriter II, Interpretive Coursewriter, BASIC, AUTHOR, COMPUTEST and MENTOR. The most significant point is that, with the exception of CATO, all these languages are user-oriented rather than computer programmer oriented. This enables the author or instructor, familiar with the educational process, to program the computing system without prior knowledge of computer systems operation.

Each author language has a repertoire of alphanumeric and mnemonic codes which are used to program the computer in sequencing the curriculum to the student. Languages developed for terminals with visual display systems differ from terminals operating with a standard teletype or typewriter-like keyboards in that coordinates for data positioning must be specified and special display commands are required such as: display erase, replace, add, and overlay. Because of the additional control requirements, languages presently operating with terminals with standard teletype or typewriter-like keyboards cannot present data on a visual display system.

INFORM and Coursewriter II were selected for analysis because of their ability to control display systems and their user-oriented control repertoire.

The INFORM language initializes the computer with the curriculum and logic through the use of punched cards, while Coursewriter II can use either a punched card method, a typewriter entry, or the student/author terminal.

INFORM and Coursewriter II both provide the same basic control capability and each has a repertoire in excess of 60 instructions. Both presently operate with digital display systems.

The actual coding process, using either language , is primarily a manual operation. Both have display coordinates forms that must be utilized for constructing graphic displays and both have coding forms that must be used with the alphanumeric and mnemonic presentation codes.

Based on the analysis, the following conclusions have been reached:

A. Language repertoires are not standard and it appears that standardization will not be effected in the near future. In addition, each language is essentially tailored to the specific system with which it is associated. If CAI system development costs are to be reduced, a more versatile language or standard compiler must be developed.

B. None of the languages are natural to the extent that they resemble the English language. As a result, several weeks are required to learn the instructional codes in order that the system can be efficiently utilized. As new languages are developed, particular attention must be given the problem of language naturalness.

C. Utility programs should be developed for use with the languages in order to ensure data reliability.

D. Author languages should provide the user with a computational capability (perhaps slightly more sophisticated than BASIC).

E. The author language is one of the most important elements in the instructional system since it is the device that presents the curriculum programs to the computer, presents the particular teaching strategy to the student, and maintains student performance data. If it fails or proves inadequate, the entire system is degraded.

F. Maximum system utilization and the advancement of the educational process, using CAI, will not be fully realized until significant advancements have been made in language development.

G. Despite the above comments INFORM and Coursewriter II could be used in the flight controller training program provided certain system constraints are addressed and eliminated. The primary constraints are the type of display system to be used and the software programs that must operate with the author languages.

Refer to Subparagraph 3.2.4.3 for the detailed analysis of the author languages.

2.3.4 Comparison of CAI Systems Capabilities Relative to Flight Control Training Requirements

Six separate systems and their respective CAI curriculums have been examined with respect to their applicability to flight control training requirements. The curriculums were discussed from the standpoints of type of course, course length, type of presentation logic, preparation time, gross objectives, and complexity. Each system discussion considered terminals, central processing units, author languages, curriculum-control concept, and special techniques used in the system.

The existing flight control curriculum consists primarily of technical systems courses which encompass mathematics, science, and engineering, and are of a highly complex nature. The gross objectives are to provide a complex level of detailed conceptual and operational knowledge of network and spacecraft systems to flight control personnel.

Curriculums presented by the systems examined included mathematics, engineering, science, statistics, social sciences, education, languages, reading, and spelling. Most course materials were prepared for elementary through high school level with some at the college level.

The flight control courses vary in length from 3 to 40 class hours while the average is approximately 12 class hours. The flight control curriculum is dynamic in nature in that about one-third of each course's content changes from presentation to presentation.

In general, the examined curriculums consisted of courses much shorter than flight control courses. The course contents changed little from presentation to presentation, thus differing from the flight control curriculum.

Based on the comparison, the following conclusions have been reached:

A. The nature of these curriculums differs from flight control courses in that they do not present technical systems data at the complex level required for flight control. The objectives differ, as the curriculums examined are limited to demonstrations, practice sessions, and introductory material at a less complex level than that of the flight control curriculum.

B. Several systems utilized techniques applicable to the flight control curriculum, and each system had several components applicable for presenting the flight control curriculum via CAI.

C. The terminals of several systems had CRT display capability and were, therefore, desirable. The CPU of each system appeared to be adequate for flight control training.

D. The dynamic nature of the course content of the flight control curriculum makes a user-oriented author language desirable.

E. Four of the author languages were considered user oriented. Of these, two were capable of driving CRT displays, but none had a strong computational capability. The complex nature of the flight control curriculum makes the availability of a computational capability at the terminal desirable.

F. None of the six systems examined displayed all of the capabilities desirable for presenting the flight control curriculum.

Refer to Paragraph 3.2.5 for the detailed comparison of the systems capabilities relative to flight control training requirements.

2.2.5 Development and Specification of Optimum CAI System Functional Requirements

This paragraph summarizes the functional requirements for an optimally designed CAI system, the functional requirements for the optimum system for flight control applications, and the functional requirements for an initial CAI system for flight controller applications.

2.2.5.1 System Design Criteria for CAI Applications

The ideal characteristics that an optimum CAI system must possess were determined by outlining certain systems considerations, developing the system storage requirements, author language requirements, and user terminal requirements. These characteristics are summarized in the following Subparagraphs.

2.2.5.1.1 Total System Considerations

A. The overall system must be designed so that students and authors are not required to understand computer operation or utilization.

B. The system must have the capability of providing both group-paced and self-paced instructions.

C. The system must provide adaptive sequencing, automatic and manual hardcopy control, and the capability to restart the student at the precise point at which instruction was terminated. (Refer to the definitions in Appendix A.)

D. The system must respond to an operator-actuated signal in less than two seconds.

E. The system must be capable of processing certain student performance data in real-time and maintain student performance histories for off-line analysis.

2.2.5.1.2 Storage

Three types of storage are required for CAI. They are: rapid-access main memory, random-access memory and bulk storage. This provides for storage of the curriculums, student records and administrative materials.

The curriculums should be stored in segments which represent logical breaking points within the curriculum. Redundant storage should be provided to reduce the probability of total curriculum loss.

2.2.5.1.3 Terminals

The terminal must provide for a wide range of alphanumeric or specially coded entries to enable the student or author to assemble discrete entries or English sentences. The materials presentation medium must be a TV monitor capable of switching between computer-driven video and closed-circuit television.

2.2.5.1.4 Author Language

A. The author language must have the capability of processing English language statements from the user, as well as irrelevant or inappropriate remarks.

B. The language must be generic in structure and provide the author with the capability to write, correct and evaluate curricular material.

C. The author language must be capable of performing complex mathematical computations, processing complex student constructed responses, and performing a variety of instructions to ensure effective sequencing of curricular materials.

D. The language must have the capability to program activities other than CAI, e.g., the system must have the capability to program stimuli and responses into simulation models and process student responses to these stimuli.

2.2.5.2 Functional Requirements for the Optimum CAI System for Flight Controller Applications

The optimum CAI system for flight control applications will possess many of the ideal characteristics outlined in the preceding discussion. Examples of several characteristics not required are: audio capability, slide projection, and access to standard broadcast video. The following discussion outlines the specific functional requirements for the user terminal, computer facilities and the location of each.

2.2.5.2.1 Terminal Requirements

The total number of required terminals was determined to be a function of (1) the total number of hours that must be presented within a given time frame and (2) the number of hours that the terminal will be available for student use within that time frame. The individual parameters affecting each of these were determined and their interrelationships analyzed. From this, the following formula was derived:

$$\boxed{T_r = \frac{T_h}{T_a}}$$

Where:

T_r = Total number of terminals required

T_h = Total number of terminal hours that must be presented

T_a = Total number of hours terminals will be available

Several assumptions were made during the development of the relationship and are as follows: (1) an average student loading of 25 students per class, (2) two classes per day--each 5 hours in length, and (3) the NASA Flight Control Qualification Section could modify present scheduling constraints to increase the number of instructional hours per day.

It was necessary to consider six alternative system usage characteristics in order to develop the final systems requirements. These alternative characteristics are: (1) the current schedule should be maintained, i.e., 4 to 5 hour classes, (2) the available instruction time should be increased, while maintaining the present curriculum volume, (3) the time allocated for subject matter instruction should be increased and still maintain 8-hour terminal availability, (4) the number of instructional hours per day should be decreased, while increasing the number of terminal hours available each day, (5) the current curriculum volume should be maintained, while assuming 25 percent saving in time due to nature of programmed instruction, and (6) the instructional hours and subject hours should be decreased.

Of the six above, alternative number 2 was selected, and, based on the selection, it was concluded that 37 terminals would be required.

The display system must be capable of displaying textual information, diagrammatic information, and graphic representations. An analysis of the types of displays to be contained in the flight control curriculum indicates that the display system must provide:

A. A repertoire of 128 characters, symbols and numerals with two character sizes.

B. 1000 to 1200 displayable characters when in a textual or typewriter mode of operation.

C. Approximately 600 randomly plotted points or symbols when in the random mode of operation.

D. Approximately 20 full-length vectors and 300 to 400 randomly plotted vectors capable of extending up to a quarter length of the display surface. Continuous point vector generation is also required.

E. A mixed mode of operation in which vectors, characters and symbols are used for display construction.

A digital display system was recommended for the optimum CAI system for flight control applications since display densities approaching 1200 characters will be encountered. In addition, initial systems costs, expansion costs, and display distribution parameters appear to favor the digital display system.

Three factors influence the type of entry device(s) required; viz., complexity of input entries, input repertoire, and access times.

An examination of the flight control curriculum and the assumption that teaching strategies and presentation logic will range from simple student testing to complex student-to-computer inquiries indicates the following capability is required:

- Character entry to enable English sentence construction

- Numeric entry to enable operation with computationally oriented languages

- Symbolic inputs to enable the student to identify unique functions related to orbital mechanics, guidance or mathematics.

It was assumed that rapid entry into the computer is not a requirement in training.

The advantages and disadvantages associated with the utilization of teletype or typewriter-like keyboards, special keyboards, light pens and writing tablets were analyzed. The results were that (1) one entry device is required per terminal, and (2) a modified teletype or typewriter keyboard is required to provide the capability to construct series of mnemonic codes formed from upper and lower case letters, symbols and numerals; enter numeric data in response to a query or for computational processing; display CAI system status; provide input message correction capability and provide an extended symbolic library to include those symbols commonly used in subjects such as Orbital Mechanics and Electronics.

2.2.5.2.2 Computer Requirements

It was recommended that the computer system be fully dedicated to CAI and associated activities.

The number of computers required is a function of the curriculum control concept, curriculum complexity, number of student terminals, and diversification of application. It was concluded that the required number of machines would be determined by the type of machines which are considered during the system design phase.

There is no requirement for computer redundancy since critical functions are not being performed.

The evaluative criteria for determining main-memory storage requirements were developed and are as follows: (1) the number of terminals simultaneously in operation, (2) the size (number of computer words) of concepts or segments that must be stored for each terminal, (3) the complexity of the curriculum, (4) the complexity of the presentation logic, (5) real-time student performance storage, (6) accessibility of mass storage for handling main memory overflow, and (7) diversity of application. Based on these criteria, an estimated 95,000 to 130,000 word locations (assumed 32 bits/word) will be required.

Random-access storage is required to store a maximum of 4 subjects, provide storage for 37 terminals, and provide storage for other applications; e.g., stimulus models and administrative and student records.

The parameters affecting storage requirements were developed and are as follows: (1) number and size of concepts to be stored, (2) complexity of presentation logic, (3) diversification of application, (4) administrative capabilities, and (5) display storage. Based on the first two criteria, the following relationship was developed:

$$\boxed{C_t = C_c + C_p}$$

Where:

C_t = Total characters required to store material to be presented to user

C_c = Total characters required to store curricular material

C_p = Total characters required to store presentation logic.

C_c and C_p can also be estimated by considering the amount of CAI instructional time required. If the number of CAI instructional hours are known (IH_{CAI}), if an estimate of the number of frames that comprise an instructional hour of CAI is available (F/H), and if the average number of characters per frame can be estimated (C_a/F), the total characters required to store curricular material (C_c) can be calculated. The basic relationship is:

$$\boxed{C_c = IH_{CAI} \times F/H \times C_a/F}$$

C_p can be calculated by determining the number of CAI instructional hours (IH_{CAI}), average number of frames that comprise an hour (F/H), average number of instructions per frame (I/F), and the average number of characters per instruction (C/I). Thus:

$$C_p = IH_{CAI} \times F/H \times I/F \times C/I$$

Therefore:

$$C_t = IH_{CAI} \times F/H\ (C_a/F + I/F \times C/I)$$

The parameters affecting these variables and their interrelationships were analyzed. From this it was determined that storage must be provided for 5 million characters of curriculum and presentation logic. This would comprise 4 subjects and their concomitant presentation logic. This is a gross estimate, however, since many of the variables are dependent on the human element.

Administration and other applications will require an additional 200,000 characters.

Assuming the use of the digital display techniques recommended in the study, approximately 148,000 words (assumed 32 bits per word) of random-access storage or 370 to 444 raster storage delay lines would be required.

Standard peripherals will be required for off-line processing. Word size should be a multiple of 6 bits or 8 bits (which corresponds to standard character composition), and because of the diversification of application, i.e., gaming, CAI and computations, it is recommended that a machine(s) be selected with a memory access time of 2 microseconds <u>or less</u>.

The total random-access storage requirements for curriculum administration, display and other applications is approximately 20 million characters. This will provide for growth and inaccuracies in the assumptions made and calculations performed. Additional curriculum storage would be provided by the use of magnetic tape.

2.2.5.2.3 Special System Functional Requirements

To enable the student or author to retain certain portions of the curriculum, hardcopy capability will be required and will be controlled manually or automatically by the computer.

The author language implemented with the system must not constrain the overall system operation and must adhere to the following generic requirements: (1) must be capable of driving a digital system, (2) must be user oriented, (3) must have repertoire such that branches, questions, adaptive sequencing, etc., can be specified by the author (refer to the definitions in Appendix A), and (4) must have computational capability.

2.2.5.2.4 Computing Facilities Location

The factors which determine the location of the computing facilities for the optimum CAI system were developed and alternative locations were selected.

The locations selected for consideration and evaluation were Buildings 12, 30, 45, and 422. After weighing the considerations of space availability, adequate cooling, ease of maintenance, student and instructor accessibility, ease of installation and ease of management control, Building 45 was selected as the most desirable location.

2.2.5.2.5 Terminal Location

The terminals can be integrated into the system in a centralized configuration, remote clustered configuration, and remote decentralized configuration.

The criteria used to determine the advantages and disadvantages of each configuration were developed and are: access to equipment (instructor, student, and M&O), space requirements, maintenance, reliability, control of utilization, scheduling of equipments and personnel, permanency of installation, ease of obtaining additional instruction, and cost.

Based on these evaluative criteria, the most efficient method of integrating the terminals with the system is by means of the centralized configuration. This would require the terminals to be located in Building 45, adjacent to the computing facilities.

2.2.6 Initial System Functional Requirements

There are two basic categories of requirements for the initial system; viz., curriculum preparation and presentation characteristics, and systems hardware and software requirements.

During the development of the curriculum preparation and presentation requirements, it was recommended by the NASA Flight Control Qualification Section that 1 or 2 instructional hours of curricular material be provided with growth to 30 instructional hours. This constitutes the number of hours in the Apollo MSFN which could be programmed for CAI.

The curriculum-oriented system requirements are as follows:

- Provide the capability of presenting textual, diagrammatic and graphic displays
- Provide the capability of presenting linear, branching or combinations in the tutorial method
- Provide the capability of real-time student events processing for grading purposes

- Provide for less than two seconds response time

- Provide the capability to accept discrete entries or four-word constructed responses

- Provide for the acceptance of curricular material via punched card or through terminal control.

The hardware- and software-oriented system requirements are as follows:

- Random-access storage is required for an estimated 418,500 characters of curriculum and presentation logic

- 8 to 10 user terminals are required (this was determined by using the relationship

$$T_r = \frac{T_h}{T_a}$$

  which was developed in Subparagraph 3.2.6.2.1.

- 900 characters and symbols are required when in a typewriter or textual display mode

- The mixed mode must provide a minimum of 150 vectors and 300 to 400 characters and symbols

- A maximum of 100 characters will be dynamic and must be updated as the data changes.

- The terminal must provide at least the upper-case alphabet, standard teletype or typewriter symbol repertoire, input editing and correction, and system status instructions

- Approximately 24,000 words rapid-access main frame memory are required

- Standard peripherals are required in addition to 2 tape transports

- A memory access time of approximately 2 to 4 microseconds is required with a word size of 30 to 36 bits.

2.6.1 Initial Systems Configuration Alternatives

Two primary alternatives were developed for consideration as initial system configurations; namely, (1) utilization of equipments contained in Building 422, and (2) supplying terminal equipments to Building 45 while generating and distributing the curricular material from Building 12, 30 or 422.

With the assumption that either alternative could satisfy the system requirements, the major factors which entered into the comparison and provided the basis for the final recommendation were: cost; utilization of existing assets, and implementation and utilization schedules.

Hardware and software implementation factors were addressed, using the factors previously outlined. Based on the comparison, the most cost-effective initial system design would be to locate the entire system in Building 422.

A basic design is submitted for consideration. The major elements are:

- Univac 418 main frame (existing)
- 2 mag tapes (purchase)
- A 750,000 character drum (existing)
- 32,000-word rapid-access core (existing)
- 1 SMCVG (existing)
- 8 CRT's (existing)
- 8 ASR's (existing)

It was determined that system reconfiguration would be minor (essentially, the addition of a cable); the major difficulty would be in the area of software development and equipment scheduling.

2.3 INITIAL SYSTEMS PROCEDURES, TECHNIQUES AND OPERATIONAL CONSTRAINTS

It was assumed that the initial system recommended in the study would be implemented. An additional assumption was that the curricular material used to demonstrate feasibility would be: Introduction to Flight Control and Apollo Tracking and Trajectory.

2.3.1 Curriculum Planning and Preparation

A curriculum planning and preparation procedural system flow was developed for initial system utilization. The areas that must be addressed are: selection of the subject material, design and development of the lesson, validation and evaluation, conversion to CAI, coding, keypunching and entry into the computer for final validation and utilization.

System modifications, flight control requirements, and mission constraints were identified as the areas affecting the flight control curriculum. When selecting subject material to be programmed for CAI, the data must first be analyzed and organized by the instructor with special emphases placed on subject matter stability.

The lesson design requires a detailed specification of the observable terminal behavior required and development of criteria or tests to determine if the desired behavior has been achieved. The instructor must then construct the individual frames with consideration given to certain CAI coding functions.

The frames must be tested and thus converted to CAI. This step requires the instructor to develop the detailed teaching strategy and presentation methods. Organization, coding, and keypunching or keyboard entry of the material should be performed by technicians.

This entire programming is very time consuming. The majority of time is required for planning and testing rather than writing.

2.3.2 Programming of Material and Input to the System

In order that the instructor not be restricted by the capabilities of the system, it is recommended that display densities not exceed 1500 characters when in a typewriter mode.

Two character sizes should be available to the instructor; viz., 0.28-inch and 0.14-inch or 0.56-inch and 0.28-inch.

Initially, the instructor should have the capability to position up to 100 dynamic characters and symbols on the display surface. Display-erase capability is to be provided, but the section of the display to be erased must be specified.

Student performance data can be collected by the instructor through use of the author language codes. Basic course flow command capability such as BRANCH, DISPLAY and QUESTION will be provided to the instructor.

2.3.3 Terminal Operations

Each student must identify himself by student number and course name in order to determine whether to operate in an author or student mode.

Each terminal will have the capability to input curricular materials to the computer or respond to computer stimuli.

Student responses will be limited to simple constructed responses of 4 words or less.

2.4 COST EFFECTIVENESS ANALYSIS

Four categories are considered in any estimate of costs. There is, first of all, the basic computer hardware which must be purchased, or leased. The hardware has as an inherent cost, maintenance and spare parts (the second category). A third category can be labeled "software," and refers to all CAI-related computer programming, whether it involves the development of a CAI language or the routine programming in getting some segment of subject matter to run on a CAI system. The fourth category is instructional design and program preparation. It is the fourth category that has been considered during the study.

The factors influencing the development of the instructional system and their relationship with the total system costs were developed in this study. A comparison of the cost and effectiveness of the media was also performed.

The results are summarized in the following paragraphs.

2.4.1 Instructional System Development Procedures

The four major elements that affect the development of the instructional system are: (1) course planning, (2) curriculum preparation, (3) curriculum presentation, and (4) curriculum modification.

Each element was further broken down into its major components with the results as follows: (1) course planning encompasses specification of job requirements, performing a general training requirements analysis, and development and specification of detailed training objectives; (2) curriculum preparation encompasses the determination and specification of detailed lesson objectives, development of lesson sequences, organization and preparation of detailed instructional content, development of criterion test (refer to the definitions in Appendix A), developmental testing of materials, and testing and evaluation of the completed material; (3) curriculum presentation encompasses the presentation of curricular material and testing of students; and (4) curriculum modification encompasses altering course content due to changes in the subject material.

Based on these procedural criteria, detailed costing equations were developed for each medium and for each major element. The costing equations are presented in Table 2.4-1. Although many of the terms appear to be similar, their derivations are considerably different.

TABLE 2.4-1

SUMMARY OF COST EQUATIONS

PHASE \ MEDIUM	CONVENTIONAL INSTRUCTION	PROGRAMMED TEXT	COMPUTER ASSISTED INSTRUCTION
COURSE PLANNING	$MH_p = MH_i + MH_{typ} + OC$	$MH_p = MH_i + MH_{typ} + OC$	$MH_p = MH_i + MH_{typ} + OC$
CURRICULUM PREPARATION	$MH_{cpr} = MH_i + MH_{tech} + MH_{typ} + OC$	$MH_{cpr} = MH_i + MH_{tech} + MH_{typ} + OC$	$MH_{cpr} = MH_i + MH_{coder} + MH_{kp} + MH_{typ} + OC$
CURRICULUM PRESENTATION	$MH_{pres} = MH_i + MH_s + OC$	$MH_{pres} = MH_s + OC$	$MH_{pres} = MH_s + MH_p + MH_{es} + OC$
CURRICULUM MODIFICATION	$MH_{mod} = MH_i + MH_{tech} + MH_{typ} + OC$	$MH_{mod} = MH_i + MH_{tech} + MH_{typ} + OC$	$MH_{mod} = MH_i + MH_c + MH_{kp} + MH_{typ} + OC$

MH_p = Total Planning Manhours

MH_{cpr} = Total Preparation Manhours

MH_{pres} = Total Presentation Manhours

MH_{mod} = Total Modification Manhours

MH_i = Instructor Manhours

MH_{typ} = Typist Manhours

MH_{tech} = Technician Manhours

MH_s = Student Manhours

MH_{es} = Equipment Support Manhours

MH_{kp} = Keypuncher manhours

MH_{coder} = Coder Manhours

OC = Other Costs

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In addition to the detailed costing equations, the basic relationships affecting the cost per instructional hours, cost per student and cost per student hour were developed and are as follows:

Cost per instructional hour:

$$\text{Total Cost}_{IH} = \frac{MH_{plan} + MH_{prep} + MH_{pres} + MH_{mod} + OC}{IH}$$

$$\text{Development Cost}_{IH} = \frac{MH_{plan} + MH_{prep} + OC}{IH}$$

Cost per student:

$$\text{Total Cost}_{s} = \frac{MH_{plan} + MH_{prep} + MH_{pres} + MH_{mod} + OC}{NS}$$

Cost per student hour:

$$\text{Total Cost}_{sh} = \frac{MH_{plan} + MH_{prep} + MH_{pres} + MH_{mod} + OC}{IH \times AV_s}$$

Where: N_s = Number of students

IH = Total instructional hours

AV_s = Average student loading per curricular hour

The manhours expended for programmed instruction development are for complete packages, and therefore, are nonrecurring costs. By that, it is meant that a detailed analysis is performed and the curricular material is properly sequenced and validated and will not require revision. However, on the other hand, conventional instruction costs are definitely recurring since many of the same development procedures must be repeated preparatory to each class.

It was concluded that conventional instruction development and presentation and modification techniques, when performed with the same meticulous care as programmed instruction, would expend approximately the same time and incur approximately the same costs as programmed instruction. Thus, it appears that manhours and costs of programmed instruction are artificial and that other factors should be considered when selecting an instructional medium.

2.4.2 Media Comparison

The three instructional media, i.e., conventional instruction, programmed text, and CAI were compared in terms of their time and cost relationships and effectivity.

Development times, which are the planning and preparation times for conventional instruction, range from 7 instructor hours per class hour to 20 instructor hours per class hour. Programmed instruction development times ranged from 11 development hours per hour of instruction to 320 development hours per hour of instruction. The wide variation is attributable to the development of objectives and content organization. The stringency with which these tasks are performed accounts for the bulk of the total development time. An analysis by one university indicates that these two factors, i.e., planning and preparation consume 59 percent to 73 percent of the total effort.

All of the statistical data available relative to conventional instruction indicates that conventional instruction does not and has not adhered to the development criteria outlined. This, in fact, accounts for the wide variation between media.

Preparation of materials for CAI will require the addition of two new skills, viz., coder and keypuncher. All three media require the services of instructor(s) and typist(s).

Typical development costs for programmed instruction range between \$395 and \$3840 with an <u>accepted</u> average of approximately \$1500. No cost data was available for conventional instruction.

The time required to present a subject is a function of the curriculum complexity and the terminal behavior desired of each student.

Conventional instruction requires the expenditure of time by instructors and students; programmed text requires only the students' time expenditure, while CAI requires students, proctor(s) and equipment support personnel. Relative to equipment support, it was assumed that CAI would require one M&O technician and two computer specialists.

The comparison to be made between the media relative to presentation time is the <u>length of time required to present a subject</u> and the <u>personnel required to provide the presentation</u>. In either case, the savings realized could be expressed in terms of dollars. When each medium was compared and contrasted, the result was a percentage of time saved by one medium as compared to the others.

An average student population of 30 students was assumed in attendance at a 4-hour class. Based on manning requirements only, CAI requires an increase of 13 percent over programmed text while the conventional method requires 3 percent more than programmed text. Assuming that the total number of hours taught by the NASA Flight Control Qualification Section during 1966 (approximately 1906 instructional hours) could have been programmed, the results would have been significant. Conventional instruction would have taken approximately an additional 1900 manhours while CAI would have required 6624 manhours.

An additional savings of time occurs with programmed text and also with CAI if terminal availability is extended beyond the 8-hour work day. If each student is provided all the necessary curricular material as is the case with programmed text and CAI, it is quite probable that a large percentage of the students wlll complete the courses at home or after working hours if terminals are made available.

The second manner in which savings could occur is in a reduction in overall presentation time. Information received during the study indicates that programmed instruction reduces the presentation times by an average of 32 percent.

It was assumed that a 25 percent savings in presentation time would be a more reasonable value. Based on that assumption, the curricular material presented by the NASA Flight Control Qualification Section which could be programmed (estimated at 264 instructional hours) would result in a savings of 66 instructional hours. When multiplied by the student population, a significant savings results.

The NASA Flight Control Qualification Section presented 1906 instructional hours during 1966. Assuming that all of these hours could be programmed, 477 hours of instruction time would be saved.

Programmed text and CAI would eliminate the need for extensive travel during curriculum presentation. It was found that this would produce a significant savings in per diem and travel expenses.

The time required for curriculum modification is a function of the extent of the modification and how stringently the curriculum modification criteria are adhered to. No specific modifications times have been uncovered as a result of the study.

Effectivity was considered in terms of the proficiency and retention of material by the student as a result of training.

Extensive studies and research projects on student learning indicate that programmed instruction provides increases in achievement averaging more than 15 percent (the significant point being that the increase in achievement is frequently accompanied with a savings in presentation time).

Since an increase in student achievement is generally accompanied by an increase in development costs, the obvious questions that must be asked are, "What percentage of achievement is required?" and "How much will it cost?" These questions raise another question, viz., "What price must be paid in an attempt to avoid critical errors, improve performance, and reduce supervision?"

In the final analysis, the tradeoff is between achievement and development costs rather than achievement and time savings, since programmed instruction has demonstrated that a higher achievement can be attained along with a savings in time.

2.5 CONCLUSIONS AND RECOMMENDATIONS

Computer assisted instruction (CAI) is feasible when considered as only one resource in the instructional system. Other facets of this system must be given equal attention. Its superiority is manifested in the variety of instructional applications for which it qualifies. In light of this, it is recommended that the NASA Mission Simulation Branch maximize the benefits which can be accrued through programmed instruction techniques by integrating this new technology into the instructional system.

Existing CAI systems are not capable of supporting flight controller training requirements. Therefore, it is recommended that efforts commence for specifying the detailed requirements for the initial system and that this effort be so directed that the requirements can be utilized for the optimum system.

Available author languages do not provide the capability required for flight controller training. It is recommended that specification and development of an author language suitable for flight controller applications commence immediately. As a further recommendation, the specification of requirements should be directed toward both the initial system and optimum system design. In this manner, maximization of efforts will occur.

The single most important aspect of programmed instruction is the proper development of the curricular material. It is recommended that the NASA Mission Simulation Branch re-evaluate the scope of the training effort and then perform a comprehensive analysis of the instructional system to include: development of specific job requirements, specification of behavioral objectives and organization of course content for the entire flight controller curriculum. It is further recommended that this analysis be performed by specialists knowledgeable in the appropriate areas of human behavior with assistance from subject-matter specialists.

SECTION 3

STUDY ANALYSIS

3.1 GENERAL

This section consists of several analyses which lead to the determination of the functional requirements for a flight control computer assisted instruction (CAI) system.

Six representative CAI systems were reviewed and the operational aspects and applications of each are discussed. A survey of universities and colleges was performed to determine the application of programmed instructional techniques within the various institutions.

Eight types of student terminals and the central processors associated with seven CAI systems were examined in detail. Two author languages were examined and sample curriculums were programmed using each language. The capabilities and curriculums of each CAI system were compared with the flight control training requirements. From these analyses the CAI system functional requirements for an optimum system and initial system for flight control applications were developed.

3.2 SYSTEMS REVIEW AND ANALYSIS

This subsection presents the findings of a CAI Systems Review, University Capabilities Survey, Systems Analysis, comparison of CAI systems capabilities relative to flight control requirements, and the functional requirements for a CAI system for flight control applications.

3.2.1 CAI System Design Concepts

In general, the basic elements of a Computer Assisted Instruction System (CAI) include: the central computing facility, remote terminal equipment, and the necessary communication links. In addition to the hardware elements mentioned above, the student, the administrator, and the instructor must also be considered important system elements; however, this subsection concerns only the hardware aspects of the system.

Three basic CAI system design concepts are discussed in subsequent paragraphs. Factors of economics and operational requirements govern the approach selected.

3.2.1.1 Totally Centralized System

This approach uses a very large central processor equipped with ample core and large mass memory. All lines connect to this central facility through a message switching processor located at the center. Each console interfaces with the central processor over a high-speed (voice grade) half duplex or full duplex telephone circuit. (Refer to Figure 3.2-1.)

Obvious advantages of this approach are the absence of intermediary equipment at the student terminals and minimal handling of curricular data. Shortcomings are the complete dependence of the student on data lines to the center, data line service costs, and the need for complete terminal dependence on the center for performing every function. Alternatives for handling data from the remote terminals are depicted in Figure 3.2-2.

3.2.1.2 Totally Decentralized System

This approach uses processors at each cluster of remote terminals with a medium size processor at the center. (Refer to Figure 3.2-3.)

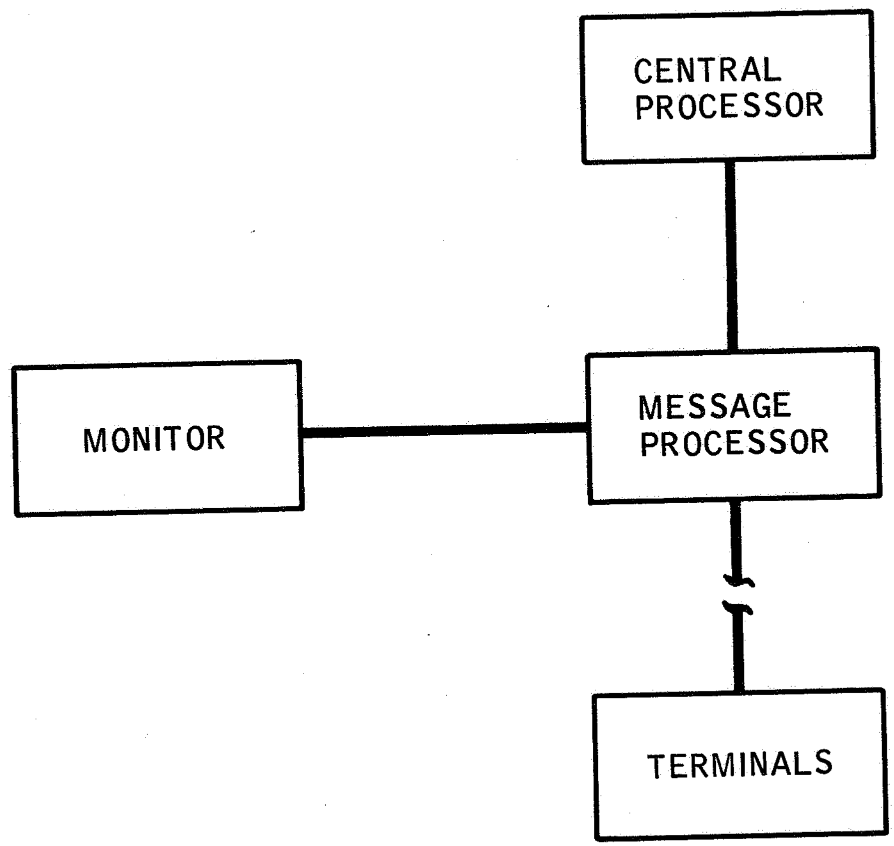

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Figure 3.2-1 Totally Centralized System Functional Block Diagram

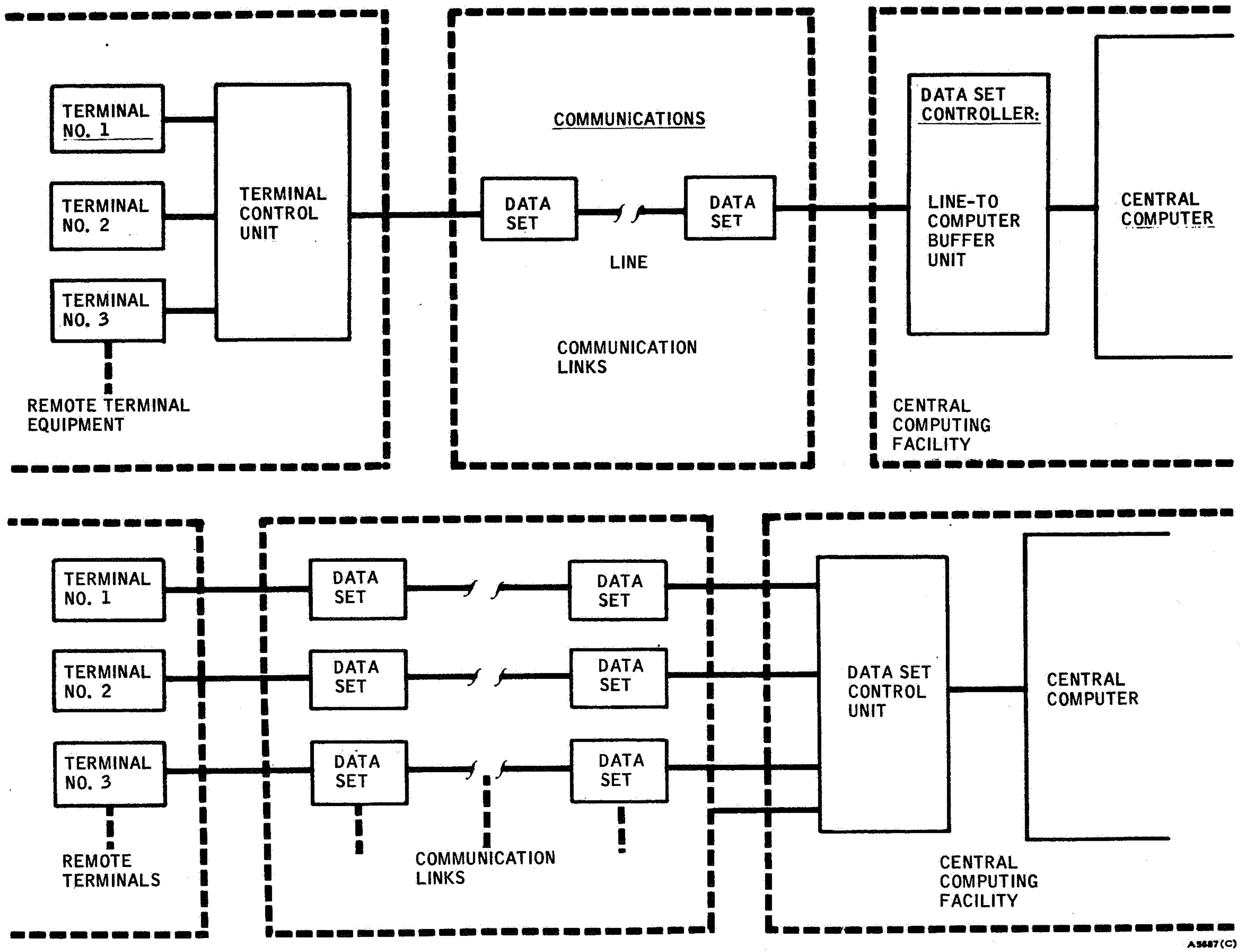

Figure 3.2-2 Alternate Configuration for Handling Curricular Material

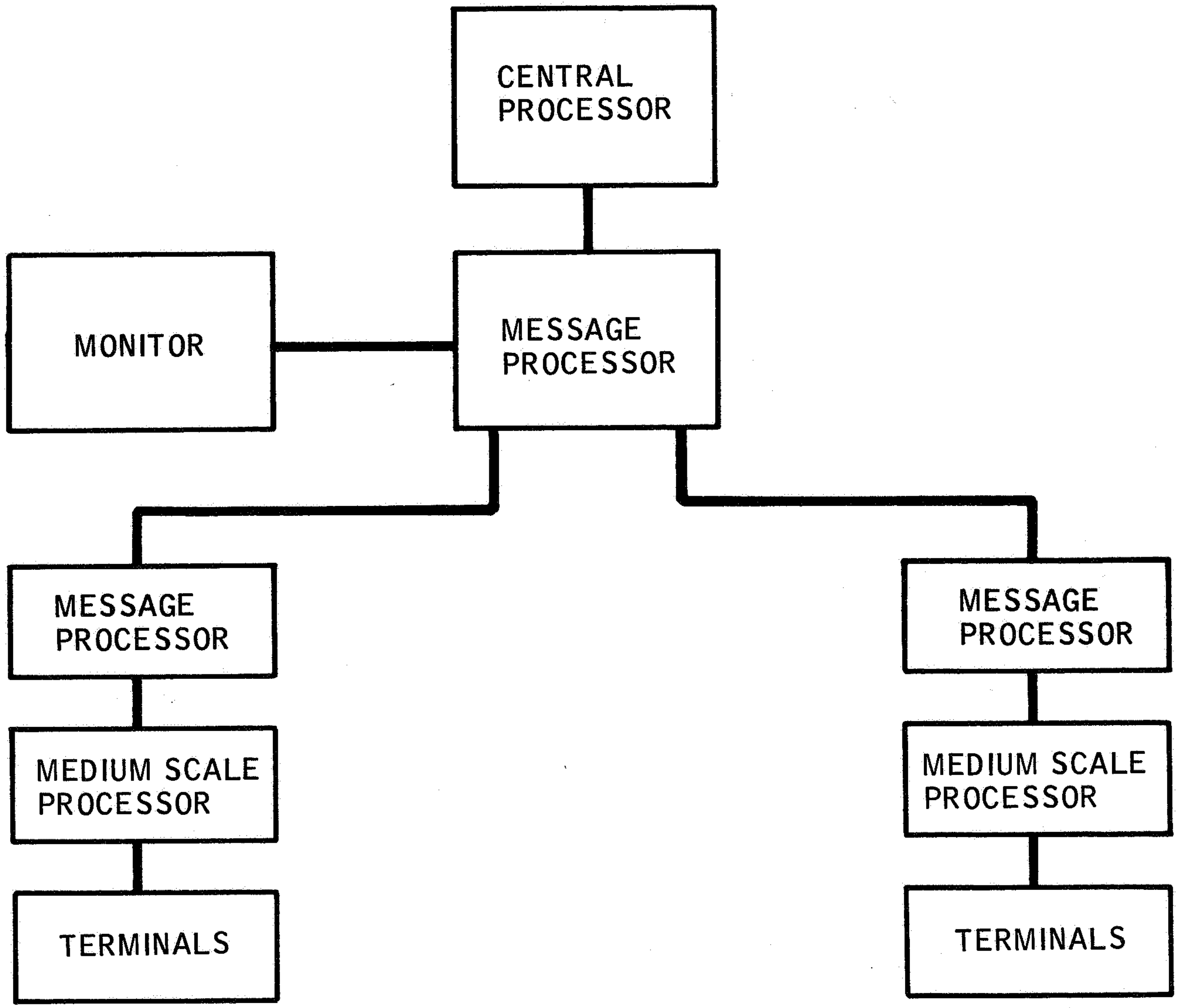

Figure 3.2-3 Totally Decentralized System Functional Block Diagram

All processing of student data is accomplished at the remote terminal site. Only large scale analyses are accomplished at the center. Thus, each area operates as an autonomous unit. This approach has the advantage of operating with a minimum of commercial data lines and permits each cluster to operate with independent control of its terminals. Disadvantages include the high initial investment cost of equipment, lack of real-time overall system control and the inefficient application of data processing techniques.

3.2.1.3 Central Curriculum Control With Decentralized Automatic Operation

This approach consists of using a large-scale central processor which handles all curricular material for all remote terminals. (Refer to Figure 3.2-4.) Located at each cluster of terminals and at the central processor area are communication switching processors which have adequate data processing capabilities to handle local processing needs. Adequate random access memory permits storage of curriculum data with real-time data retrieval capabilities. This arrangement permits a large number of student terminals to have automatic access to the central processor over a small number of data lines. It utilizes, but is not totally dependent on, the central processor for its operation within a cluster of terminals, and it permits system growth without degrading system speeds. Obvious disadvantages are initial system costs and increased maintenance costs.

3.2.2 CAI Systems Review

This paragraph is concerned with a review of the major "large-scale" CAI systems in existence in either an operational or experimental capacity.

Although other systems are involved in CAI, the systems to be described in this paragraph were chosen because they are indicative of the typical CAI system and will provide an overview of the various techniques being employed.

To provide a broader understanding of activities and applications relative to programmed learning, the results of a programmed learning oriented survey of the major universities and colleges are contained in Paragraph 3.2.3.

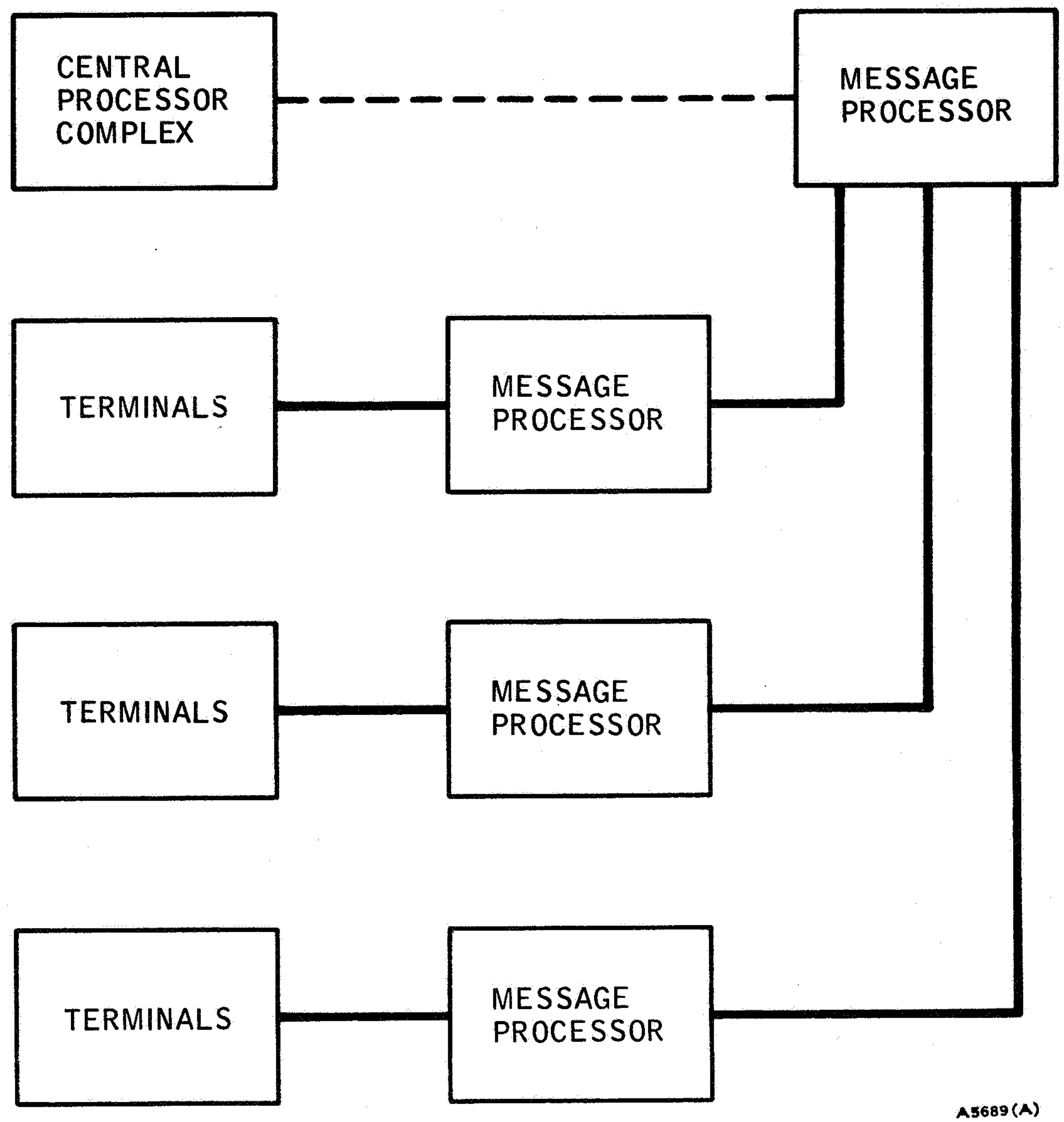

Figure 3.2-4 Central Curriculum Control with Decentralized Automatic Operation Functional Block Diagram

3.2.2.1 Operational Description

3.2.2.1.1 Programmed Logic for Automatic Teaching (PLATO)

During the past 5 years, the Coordinated Science Laboratory at the University of Illinois has developed and experimented with an automatic teaching system called PLATO.

Three successive models of PLATO have evolved, each embodying improvements indicated by the previous model. The first consisted of a single student station connected to ILLIAC, a medium-speed computer built at the University of Illinois. The second model consisted of two student terminals and was initially connected to ILLIAC and later to a Control Data Corporation (CDC) 1604 computer which serviced 10 student terminals. The current model, which is designated PLATO III and is the one to be described, has 20 student stations connected to the CDC 1604 computer.

PLATO III is a relatively sophisticated, high-speed, digitally-driven CAI system. (Designers of this system prefer Computer Based Education System (CBE.) The PLATO III system is capable of teaching 20 students simultaneously. The subject material is presented by utilizing either a tutorial logic or inquiry logic technique.

The new PLATO III tutorial logic technique, which has been written for the PLATO compiler, provides a more flexible set of rules for the instructor. The instructor may allow the student to respond with long answers. Several "help" sequences are permitted and many "judgers" are available. A "help" sequence is initiated by the student and causes the program to branch to preconstructed explanations designed to help the student. "Judgers" are special software routines which are used to "judge" the validity of an operator input, e.g., a spelling judger would display "SP" when the student makes a mistake in spelling.

The inquiry logic is designed to provide more student control and afford the opportunity to ask questions of the computer. The student's request will be received and interpreted and a reply will be made based on stored information or calculations. This logic provides, in effect, a syntax for students to use in communicating with the computer. The student directs his learning by composing his own requests. Computer responses are programmed by initializing a family tree of answers and the appropriate judgers.

At present, the PLATO III has 19 operational tutorial logic teaching programs and 8 inquiry logic teaching programs.

3.2.2.1.1.1 PLATO Hardware System

The PLATO III system consists of 20 student terminals (presently expandable to 32) and a nontime-sharing 1604 computer. (Refer to Figure 3.2-5.) Nontime-sharing means that the machine cannot be shared with others who may, for instance, be compiling or computing at the same time. PLATO III usurps the entire machine when it is operating.

The student terminal consists of a display surface and teletype typewriter. The number of usable plottable points on the display surface are 488 in the X axis and 383 in the Y axis. This provides approximately 15 rows of 32 characters per row.

Information from the computer destined for the display surface is output to a storage tube where the data can be superimposed with background data from a 122-position, 35 mm computer-controlled slide selector.

The PLATO keyset is a standard teletype typewriter (Model UK-8) which, through SHIFT and CONTROL key depressions, provide 96 unique inputs to the computer. The keyboard is the control instrument for both the student and the instructor. The system provides a mode lockout which will activate only those keys which are required for student control during the presentation of a specific subject. Each key has removable keycaps which indicate the new function assigned to that key.

The CPU is a CDC 1604 computer with a 32,000-word (48 bits/word) memory. The machine performs four major functions, namely: (1) input and output switching of information, (2) real-time processing of input data, (3) real-time control of slide storage and (4) mass storage for teaching rules, character lists and tables and student storage tubes.

3.2.2.1.1.2 PLATO Software System

The software system for PLATO consists of a modification of the basic FORTRAN language. A brief description follows. The Compiler for Automatic Teaching Operations (CATO) is a modified FORTRAN '60 compiler with additional features to accommodate the uses of PLATO in teaching operations and other experimentation. In addition to the usual FORTRAN subroutines, there are numerous PLATO system subroutines available. Additional subroutines can be added as the need arises.

With a basic knowledge of FORTRAN programming, it is relatively easy to write a complete computer program for use with the PLATO system. The user can express himself as a course author in CATO and the system will compile and get his material ready for presentation.

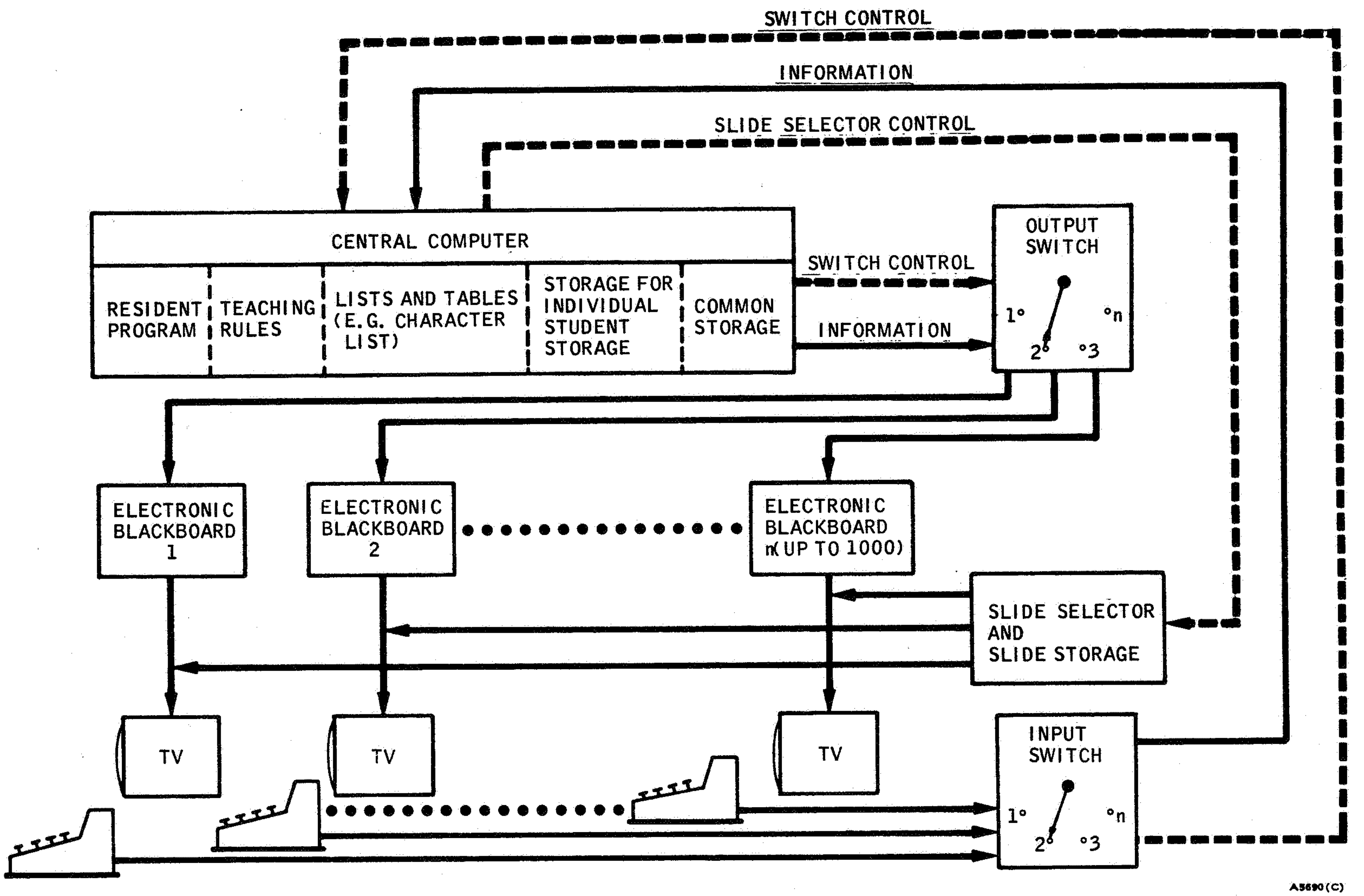

Figure 3.2-5 PLATO System Functional Block Diagram

CATO automatically provides for multiple student time-sharing of a CATO program, i.e., programming for one student provides the same facilities for all students using the program.

3.2.2.1.2 Project GROW

The Philco-Ford Corporation is developing and implementing a CAI system to be used by the Philadelphia Independent School District (PISD). The initial design will accommodate four schools: two high schools and two junior high schools. The schools involved are: Germantown, Roosevelt, Overbrook and Wanamaker; hence, the acronym GROW. As of this writing, the fourth terminal cluster has been installed and partially checked out. The system has programmed lessons stored in digital form on mass memory at the school. When the student arrives at the console, he uses the keyboard to enter the code number specifically assigned to him. The processor recognizes this information and through program control, the lesson segments are displayed. As the student responds, program control determines the correctness of the response, records the operation and, if desired, provides reinforcing or connecting information. (When the audio option is exercised, the same program control will select the proper audio segment and activate the reproduce mode.

During the presentation of the lesson, the processor maintains a record of the student's progress, permitting proper sequencing of material for each student for instructions on following days. Initially, the system will operate using the tutorial approach with linear and simple branching strategies. As more experience is gained, complex branching programs and perhaps mathematical programs will be employed.

3.2.2.1.2.1 GROW Hardware System

The system approach is that of central curriculum control with decentralized automatic operation. (Refer to Figure 3.2-6.) A large-scale central processor complex performs the curriculum development and statistical analyses. Communications switching processors are located at each school; schools are connected to the central processor by high-speed data lines.

The CPU is a Philco Model 2000-211 processor with a 32,000-word (48-bit/word) core memory.

In addition to the main frame and core, the CPU consists of tape drivers, card controller, punch and reader, flexowriter, line printer, and I/O processor/control devices. A full complement of logical and

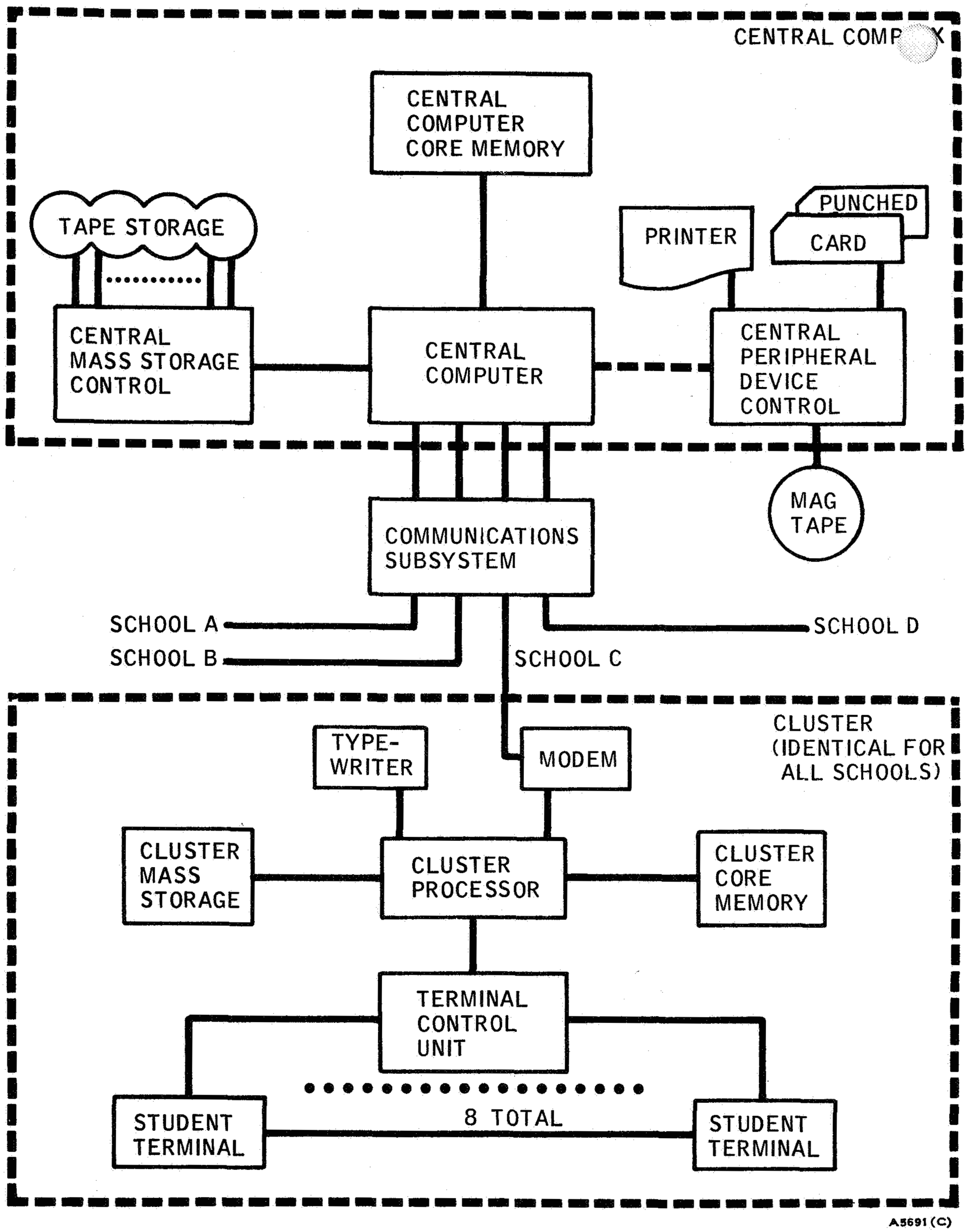

Figure 3.2-6 Project GROW System Configuration

arithmetic operations can be performed. The machine performs three major functions, namely: (1) development, generation, storage, and distribution of the curricular to the terminal clusters, (2) off-line problem solving, trends analysis, statistical functions and arithmetic functions, and (3) communicates with cluster processors to accept on-line inputs from the clusters and provide curriculum updates to the clusters.

The cluster processor is a Philco Model 102 processor with a 16,000-word (32 bits/word or 65,000 characters) core memory. In addition, a disc with a 1 million character capacity is provided. The machine performs the following major functions: (1) controls and processes terminals and typewriter input/output messages, (2) interfaces with central processor for transmission and reception of curricula or curricular related parameters, and (3) stores the curricula (including display data) and routes these data to the appropriate terminals.

Fundamental to the system are the student audio-visual interfaces (SAVI). The console comprises a CRT, light pen, keyboard device and expansibility to include audio queueing.

The principal element of the terminal is a standard all-channel Philco 12-inch television receiver with a usable display surface of 10 inches x 7.5 inches. Three types of video data can be displayed on the CRT surface, namely: processor generated images (digital video), standard VHF-UHF broadcast television and closed-circuit television. Data density for the digital video is 800 characters with no shades of gray.

A 64-character keyboard of special design is provided for student-to-processor control. Also provided is a ruggedized fiber optics light pen for additional data management.

3.2.2.1.2.2 GROW Software System

The software system for GROW utilizes a general purpose software package, curriculum generation programs, and test and diagnostic routines.

The general purpose software for the central processor consists of the following:

- Assembler - TAC
- Compiler - FORTRAN IV, COBOL, JOVIAL, MAD

- Data Handlers - REPORT, TOPS, LP, SIMSCRIPT and SORT
- Statistical Analyses - STAT/2000.

Special languages for input and output control and management control are also provided.

The curriculum generation programs consist of: (1) initial curriculum generation programs, (2) curriculum modification programs, (3) curriculum checkout programs, and (4) master curriculum file protection programs.

A. Initial Curriculum Generation Programs. These programs provide the instructor with a series of formats for use in generating the curriculum. The forms are designed so as to eliminate completely any confusion concerning how the instructor must interface with the computer. The information on the forms completed by the instructor is fed into the computer and compiled into a form acceptable to computer operations.

B. Curriculum Modification Programs. These programs provide the author with the facility to modify the curriculum by addition and/or deletion so that changes can be easily incorporated.

C. Curriculum Checkout Programs. These programs provide a means of stepping through selected portions of the curriculum to ensure proper content and flow. The instructor is provided with curriculum diagnostic reports to facilitate the detection of computer recognizable errors such as, discontinuity and endless-loop conditions.

D. Master Curriculum File Protection Programs. These programs are provided to prevent accidental destruction of compiled curriculum segments. Modification of the master file contents is controlled by a specialist.

When an authorized modification is made, the new segment is incorporated into the designated file position and any resequencing and recompiling of the file is handled automatically. In addition, all modifications of the student status file, necessitated by such sequencing, are posted automatically. Listing and reports reflecting the current status of the curricula and students are generated automatically for distribution.

3.2.2.1.3 System Development Corporation (SDC)

The SDC has developed a time-sharing system (TSS) for on-line interactive use. This system has replaced the original experimental facilities. Prior to discussing the existing system, a brief description of the original facility (CLASS) is provided.

The Computer-based Laboratory for Automation of School Systems (CLASS) facility developed out of studies investigating branching effects in programmed instruction. An earlier experimental teaching machine at SDC used a Bendix G-15 computer, a random access projector holding up to 600 35 mm slides and an electric typewriter. The CLASS facility had 20 teaching stations and 2 teacher stations on a Philco 2000 computer. Each teaching station consisted of a 2000 frame, manually operated, 35 mm film strip viewer and a multiple-choice response device including computer-controlled lights for indicating feedback. The teacher console included facilities for monitoring the materials and responses of any student, and inspecting student records on a CRT. The system was reconfigured and used regular teletypes and experimental stations attached to a time-shared Q-32V. The terminal configuration on this system included CRT display, light pen and button input, and Rand Graphic Input Tablet in addition to keyboard facility.

Originally, the SDC TSS was a product of SDC's search for a tool to support studies on ways to apply automated information processing techniques to the needs of military command and control systems. The studies culminated in the implementation of a time-shared complex of communication and digital equipment centered around an AN/FSQ-32 computer.

The early TSS had only 8 terminals. Presently, the TSS has 53 terminals serving approximately 500 authorized users. (Refer to Figure 3.2-7.)

In addition to projects sponsored by the National Science Foundation (NSF) and the activities at various institutions, the TSS has been used in an experimental robbery report retrieval system for the Los Angeles Police Department and in an information retrieval system for the VA Hospital. The system is also providing a vehicle for SDC's Salary Information Retrieval System (SIRS).

The SDC has devoted considerable effort to the design and development of a new time-sharing system for operation on an IBM system 360 computer. This will provide an increase in time-sharing capacity from 25 to 30 users to as many as 60 simultaneous users. The new TSS is presently scheduled to become operational in 1967.

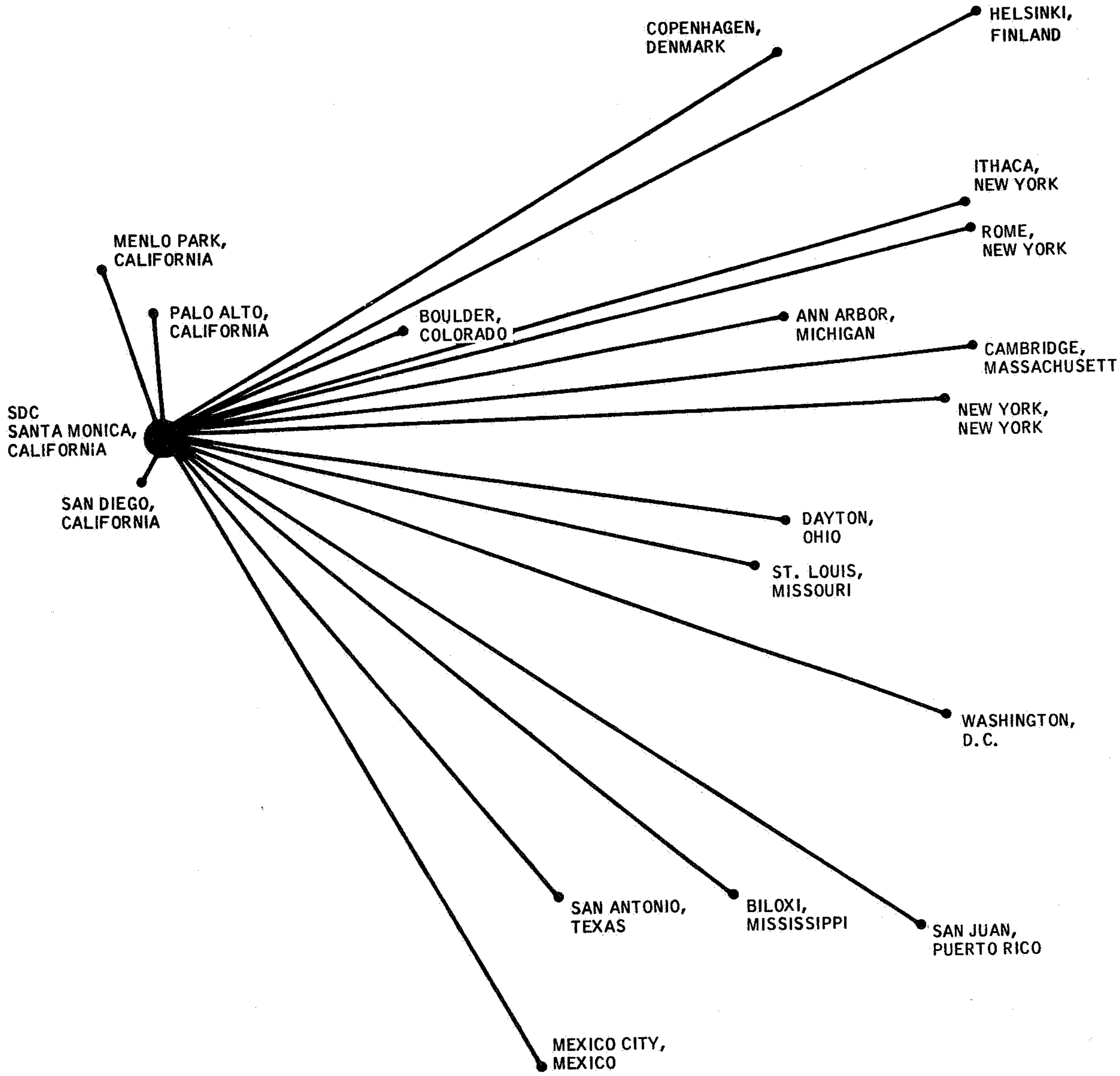

Figure 3.2-7 SDC's Time-sharing System (TSS)

The TSS provides the capability to process programs for up to 30 users without the intermediary services of an operator or programmer.

TSS users interface with the Q-32 through teletypes or other terminal devices to converse with their own programs or with the Executive program which automatically regulates scheduling and traffic in the system.

The Executive schedules requests in "round robin" fashion and allots each user a specific amount of machine time. When the time expires, the program is moved into storage and another is read into core memory for processing. A program requiring more than the specified amount of machine time must wait until the input cycles back to its position.

Terminals serve both to issue commands (inputs) to the programs and to receive responses (output).

The following paragraphs outline several TSS applications:

A. <u>On-Line Programming and Debugging</u>. With TSS, the user can write and alter programs at his terminal. Through the Executive the user has access to a number of programming aids and error-checking systems developed for use under time-sharing. One of these is TINT, a system designed with features to assist the inexperienced user in construction programs in the SDC-designed JOVIAL language. TINT is also an aid in on-line debugging.

B. <u>Data Base Systems</u>. SDC has designed a system that allows the nonprogrammer to perform complex data management functions in an on-line, time-shared mode. LUCID makes it possible for a user with little or no data processing experience to communicate with the computer in simple English. The system has the capability to organize, manipulate and perform various other operations on large collections of data, commonly called "data bases." Another SDC system, the General Purpose Display System (GPDS), permits the user to construct his own tables, graphs and charts and have them displayed pictorially on a CRT scope. GPDS utilizes data bases written in LUCID.

C. <u>Programmed Instruction</u>. The TSS is being used in the development of educational systems for on-line student instruction. The Programming Language for Interactive Teaching (PLANIT) is the author language used with the Q-32 system. The system is used to prepare either tutorial or branching instruction. The PLANIT system operates in four modes: lesson building, editing, execution and calculation. The first two allow the instructor to construct and edit lesson frames and store them in designated sequences. The execution mode allows presentation of this data to the student. The calculation mode can be used as a calculating aid by either the instructor or student.

Currently in development on the PLANIT system are (1) a 20-hour statistical inference course and (2) a counseling course.

Refer to Figure 3.2-8 for a graphic representation of the SDC TSS.

3.2.2.1.3.1 TSS Hardware System

The system approach is that of central curriculum control. The Q-32, an IBM developed machine, performs the curriculum development and statistical analyses and provides these data to remote and local users. Remote users are connected to the Q-32 via high-speed data lines. Refer to Figure 3.2-9.

The central processing unit is an AN/FSQ-32 computer with a 65,000-word (48 bits/word) core memory. An additional 16,000-word memory is provided for I/O buffering.

In addition to the main frame and core memories, the Q-32 has approximately 600,000 words of magnetic drum storage, 4 mega words of disk file, and 16 magnetic tape drives.

The PDP-1, which acts as the system I/O device controller, is an 18-bit machine with 8000 words of core. The PDP-1/Q-32 complex performs the following major functions: (1) compiling and debugging programs, (2) on-line programming using both algebraic and list processing languages, and (3) experimental CAI programs.

The terminals consist of Model 28 (6 in use) and Model 33 (22 in use) ITT teletype machines. SHIFT and CONTROL key depressions provide 96 unique inputs to the computer. The keyboard is the control instrument for both the student and instructor.

3.2.2.1.3.2 TSS Software System

The software systems for the TSS utilize several programming languages, i.e., TINT, IPL-TS JOVIAL and LISP.

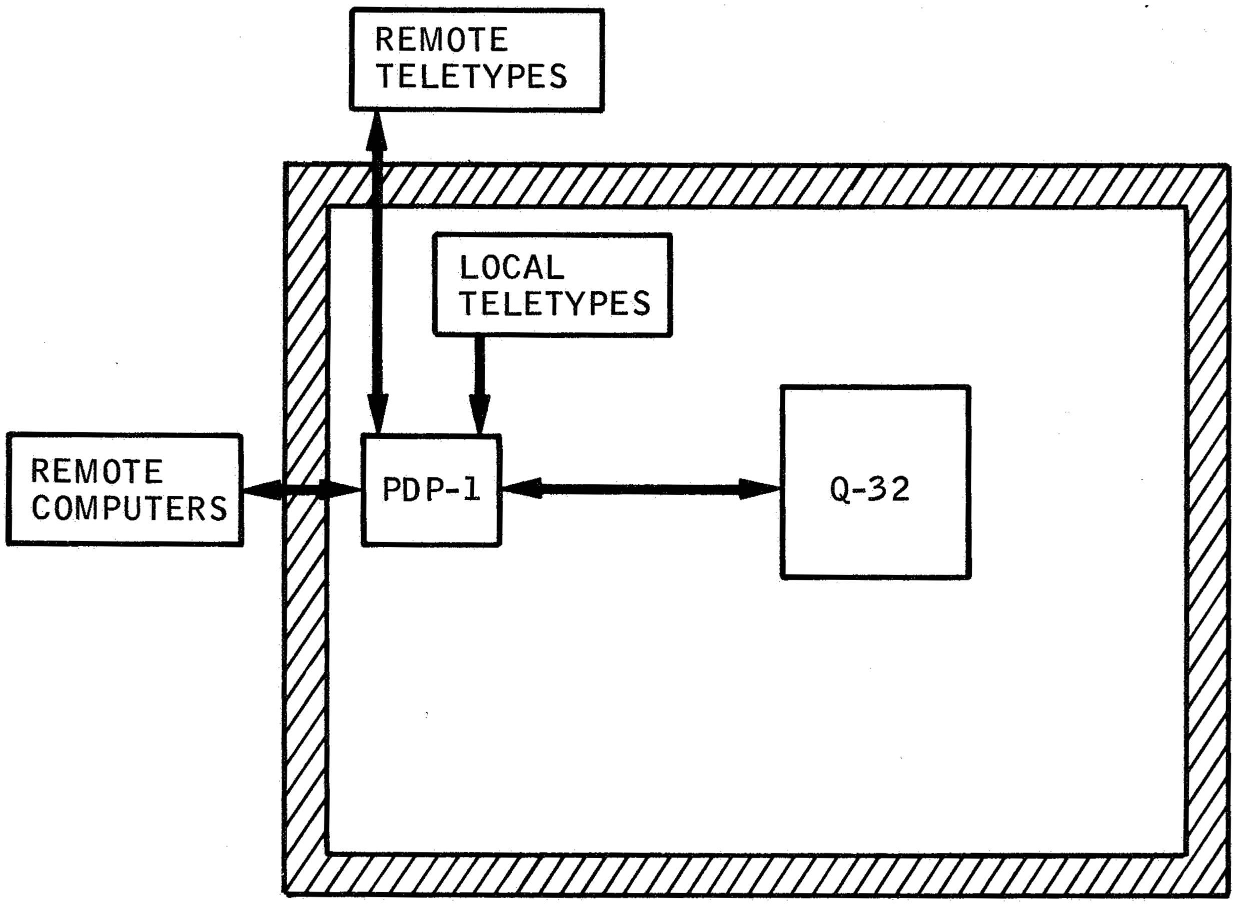

Figure 3.2-8 SDC Time-sharing System Functional Block Diagram

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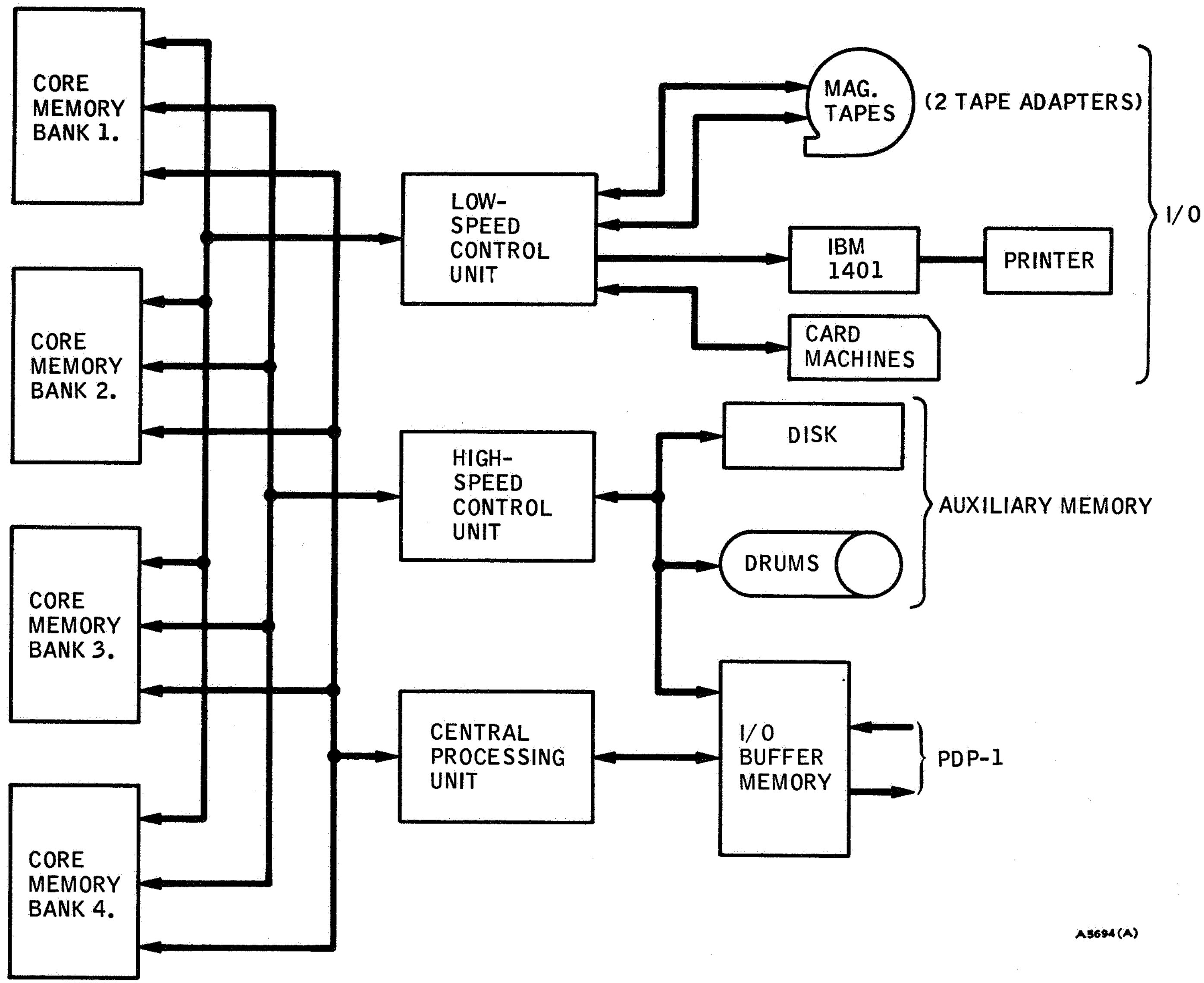

Figure 3.2-9 Q-32 Configuration Functional Block Diagram

PLANIT, however, is the programming language which allows a lesson designer to enter course content into the computer for use as a teaching device. It will allow a lesson designer (LD) to enter questions, specify answers, and specify actions to take as a function of the student's answers. The language includes statistical functions and a mathematical capability which will allow an instructor to present problems, generate sample data for those problems, and query and evaluate the student's response in terms of the samples generated and the statistical routines which operate on them.

Provision is made for decision branching, recording, and course editing.

PLANIT also provides service functions for evaluating student answers that depart from the expected response by making PHONETIC comparison, KEYWORD match, and equivalent ALGEBRAIC matching. It also allows one lesson to call on another, and any program (or subroutine) written in JOVIAL can be added to the lesson and executed at any time.

PLANIT has four modes of operation which are defined as follows:

A. EDIT Mode. This mode can only be used by the LD. It is through this mode that all lesson editing is done. The LD can print frames, delete frames, and insert frames. He can also display student's records, and retain old lessons or retrieve new lessons. This is also the mode in which PLANIT starts off. By using the appropriate command the LD can enter any of the other three modes: viz., LESSON BUILDING mode, EXECUTION mode, or the CALC mode.

B. LESSON BUILDING Mode. This mode is used to build lessons. Lessons are composed of frames; frames are composed of groups; groups are composed of lines of information such as textual material, questions, anticipated answers, actions, etc.

C. CALC Mode. This mode is designed for use by both the LD and the student and provides a powerful computing capability. Explicit arithmetic expressions can be evaluated (i.e., the indicated arithmetic is performed). Mathematical functions may be defined and evaluated. There are also a variety of "stored" functions and primitives for use in arithmetic expressions or in function definitions: e.g., FACT(N) stands for N!, ZTOP(X) stands for normal probability integral with upper limit X and lower limit at minus infinity. Matrices may be defined also and the elements of these matrices can be generated through function definition and execution. While taking a course, the student can use this mode in solving the problems presented by the lesson. The lesson designer may use this mode to define functions to be made available to the student.

D. EXECUTION Mode. This is the mode used for presenting lessons to student. Once a lesson is built, it (or parts of it) can be executed. If PLANIT is presenting lessons where the answers require computation, the user may interrupt the EXECUTION mode to enter the CALC mode in order to compute his answers. He then returns to the lesson EXECUTION mode to insert his answers and for PLANIT to judge them as correct or otherwise. Alternation between these two modes is effected by the user taking a single button action.

3.2.2.1.4 University of California at Irvine

The University of California at Irvine, California (UCI) is engaged in a joint research project with the IBM Corporation to experiment with new approaches toward the achievement of a totally integrated information system within a university or campus. Principal emphasis is given to three areas of work; viz., Instruction, Administration and Library.

The present system consists of an IBM 1410/1440 CPU functioning as a coupled system, i.e., memory to memory, 18 IBM 1050 terminals, and an appropriate mix of disk and tape units which provide mass storage for the curricula, statistical data, and scheduling information.

The project has four major objectives; viz., (1) to gain an understanding of the nature of the university information system, (2) design and implement an advanced educational application language and operating system, (3) develop application programs which take advantage of a remote terminal time-shared operating system and (4) design and implement instructional, administrative and library systems which will incorporate the experience gained from the application programs previously developed.

The CAI system instructs approximately 500 college students on an accredited basis. Remedial courses are also available to students who wish to prepare for examinations and/or review basic programming and mathematics. The courses offered are primarily linear. However, several subjects have basic intrinsic patterns interleaved with the linear program.

After presenting a new idea or concept, the computer asks the student a question. The student enters his reply and receives recognition as to the correctness of his answer. If the answer is correct, the computer proceeds to the next question or idea. If his answer is wrong, a hint is usually provided to help him make his answer, and the computer will wait for the student to answer the question a second time. Repeated hints can be provided until the student answers correctly. Since a student can answer a particular question in a number of ways, the preparation of suitable material requires careful thought on how to present the material, ask the questions and, in particular, anticipate the type and kind of replies that a student may make. The interaction between the student and the lesson material must be carefully planned in advance in order to direct the student through the subject.

The course author may provide extra help for a poor student by directing the computer to "branch" (i.e., skip ahead or back) to a remedial sequence on the basis of either the student's response to a specific question or his cumulative score over several questions. In the first case, if the student responds that 2 plus 2 equals 6, the course might be programmed to present more problems in simple addition. In the second case, a student who missed over half the questions in a certain section of the course might be reprimanded for his failure and urged to try harder.

When correctly programmed a computer is capable of accepting a constructed response. This allows one to ask "Who is the current President of the U.S.?" rather than being forced to phrase such a question as "Is it true or false that Johnson is President of the U.S.?" The computer can also keep track of the number of questions the student has missed and display this number to him at any point in the course which the author desires.

To facilitate the preparation of computer material by an author, the Interpretive Coursewriter Language has been developed and is in use at UCI. The language allows the computer to process material which has been prepared by the author according to the rules of the language. Certain situations in a course may not be handled in the most efficient manner, but the author must conform to the rules of the language to have the material processable by the computer.

3.2.2.1.4.1 UCI Hardware System

The system approach is that of central curriculum control (refer to Figure 3.2-10). The CPU consists of an IBM 1440 and 1410. The 1410 has direct access to eight of the eleven 1311-disk units, and five 7330 tape units. In addition, 100,000 characters of storage is provided on the 1410. It should be noted that presentation of course material requires that only 4000 characters of the program be resident in the 1410. A maximum of 20 different programs can be processed simultaneously. The processed curriculum is relayed to the 1440 which buffers the data and outputs the information to the 1440 Transmission Control Unit.

The student terminal is an IBM Model 1050 which is similar to the IBM electric typewriter. Proper activation of control keys provides the necessary combination of control entry for CAI development and usage.

The keys on the keyboard include character and function keys. The shift keys and the shift lock generate the up-shift code when pressed. When the shift keys are released, the down-shift code is generated.

The keyboard function keys are:

- Space
- Backspace
- Line Feed
- Tab
- Return (returns the carrier to the left and moves the paper up for the next line to be printed)
- Shift (and Shift Lock)
- Alternate Coding.

The alternate-coding key (ALTN CODING) is used with the top (numeric) row of keys. ALTN CODING does not generate a code character. Instead, while pressing and holding ALTN CODING, you can also press a key in the top row to generate the output code for a particular control function.

For example, if you press ALTN CODING and the 5 key at the same time, you generate an end-of-block (EOB) code. If the ALTN CODING key and the 0 key are depressed at the same time, a cancel code is generated. These are the only two codes needed for the CAI program. Although other control functions are available, they are not necessary.

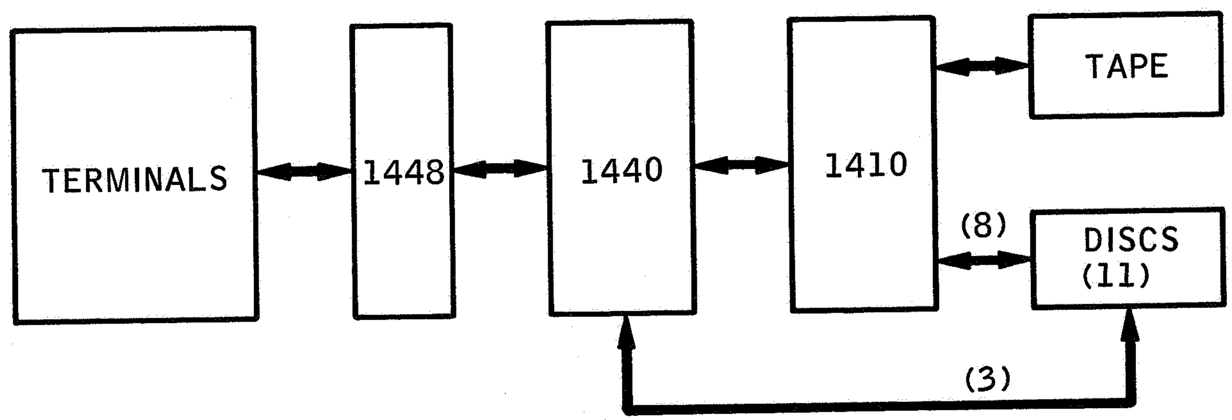

Figure 3.2-10 University of California at Irvine Time-sharing System Functional Block Diagram

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3.2.2.1.4.2 UCI Software System

The software system for the Irvine project is a modified version of the DEAN time-sharing system developed at Yorktown Heights. The modifications enable DEAN to time-share several projects unrelated to CAI.

The author language, Interpretive Coursewriter, is a modified version of the IBM coursewriter language. Three categories of control inputs are provided for the operator. A brief description of each follows:

A. Operation Codes. Operation codes are used to instruct the computer when and how to process the text statements, questions, and student responses of the course.

   There are three types (levels) of operation (OP) codes:

   1. The first type of OP codes provides control for (1) materials presentation, (2) formulation of questions, and (3) collection of several second and third level OP codes into a named group. The input coding for these commands are: present (PR), question (QU), and group (GR).

   2. The second type of OP codes is executed after a student responds to a question. The codes are used to identify correct answers, wrong answers, and unanticipated responses.

      The keyboard identification (ID) is as follows:

      - Correct answer (CA)
      - Alternate correct answers (CB)
      - Wrong answer (WA)
      - Alternate wrong answer (WB)
      - Unanticipated response (UN).

      The author may use the code UC rather than UN, in which case a message is typed out for the student. Two other codes are provided; viz., next (NX) which allows Level 3 OP codes to be processed, and function (FN) which allows the author to call in special functions.

3. The third type of OP codes provides the capability to type (TY) statements to the student and continue with the next operation. Type 3 OP codes must immediately follow a Level 1 statement or follow a successful Level 2 operation.

B. Branching. The execution of instructions by the computer generally follows a sequential approach. However, the author may desire to interrupt this pattern by directing the computer to branch or transfer to a problem name somewhere in the course. For example, if you want students who miss Question 5 in your course to go back and do Problems 4 and 5 over again, you simply put a branch operation following the WA statement.

C. Special Functions. All special functions have the OP code, FN. There are three special functions within the FN OP code; viz., keyword test (KWT), partial answer test (PAT) and snapshot (SNAP).

In early 1967, an IBM 360 Model 50 system will replace the existing system (refer to Figure 3.2-11). It is planned that this system will have 524,000 bytes of core storage, 110 line/minute printer card reader and punch units, and 4 tape units (45,000 characters, 1600 bits/inch, and 4 disk units on each of 2 disk channels). The beginning complement of remote terminals will be 40 IBM 2741 typewriter terminals connected through two IBM 2702 transmission control units.

Figure 3.2-12 is a representation of the current software organization to be employed on the System 360-Model 50. As illustrated, the Process Supervisor will initially time-share four programs, i.e., CAI, Enrollment, Irvine Symbolic Interpretive System (ISIS), and Budget Control.

3.2.2.1.5 Stanford-Brentwood CAI Laboratory

In January 1963, the Institute for Mathematical Studies in the Social Sciences began a program of research and development of computer-based instruction. The initial effort, which was funded by the Carnegie

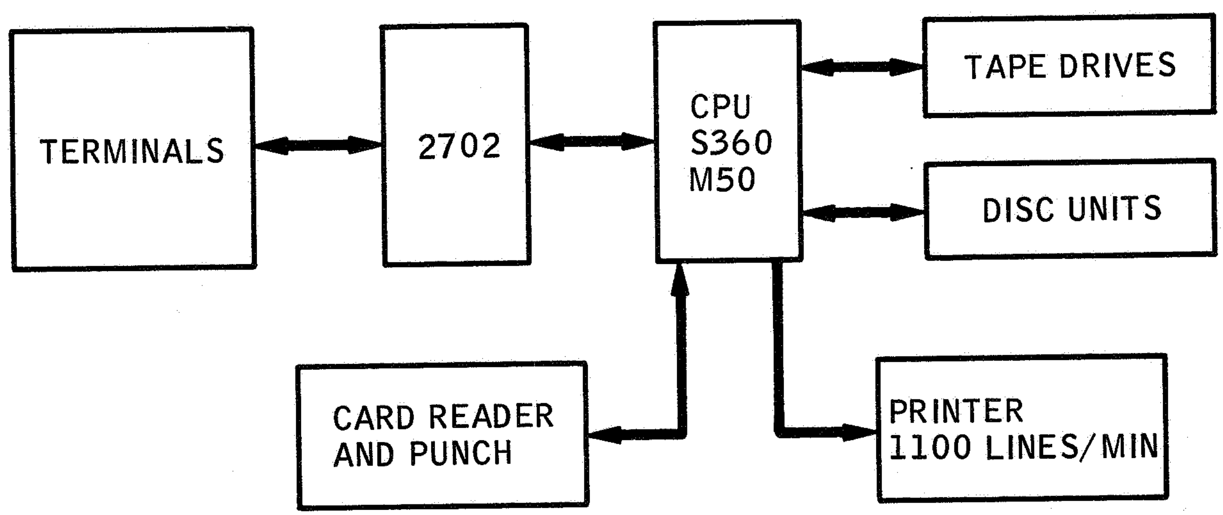

Figure 3.2-11 University of California at Irvine Proposed Time-sharing System Functional Block Diagram

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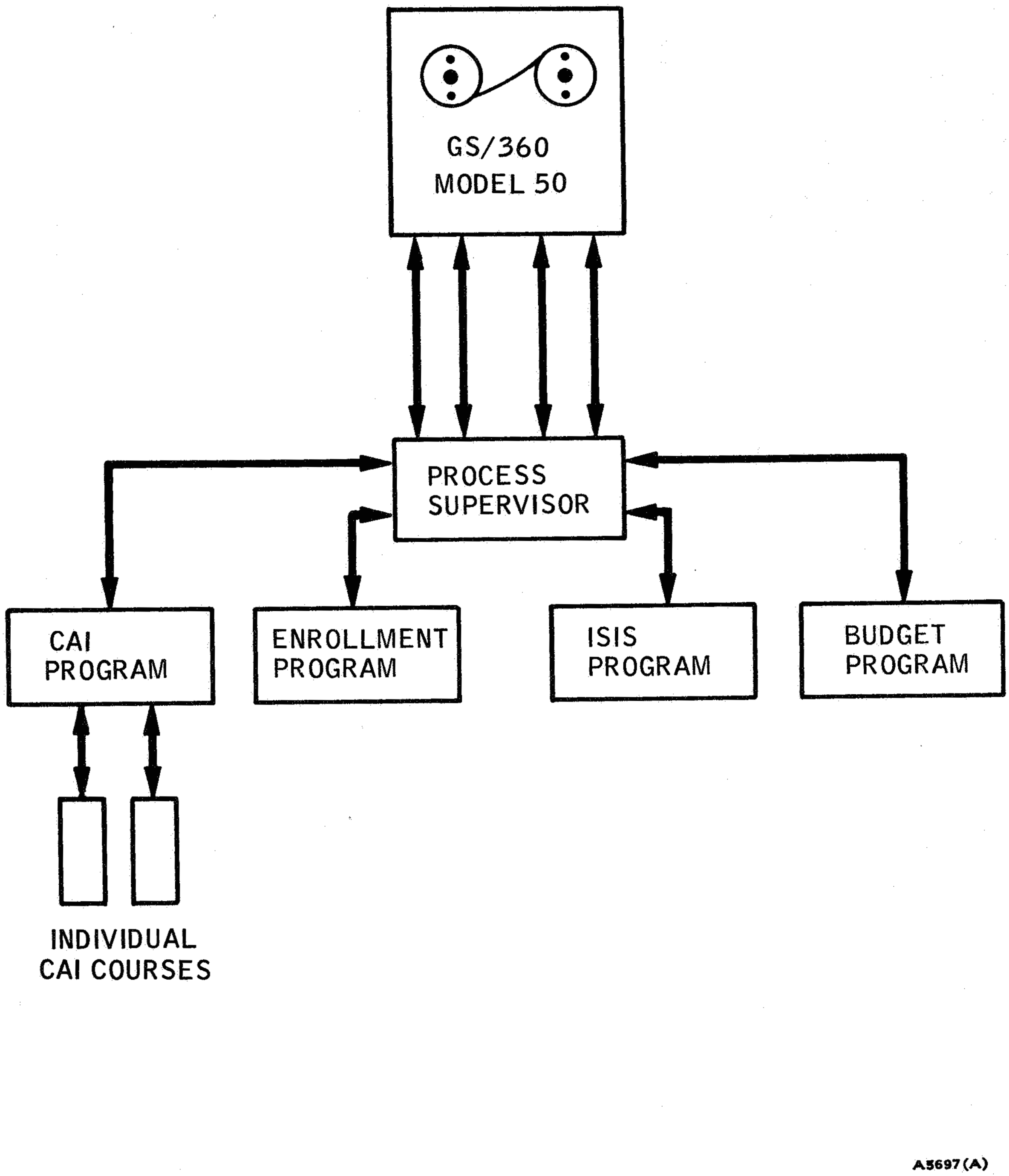

Figure 3.2-12 Hierarchy of Programs for Proposed Time-sharing Software System

Institute of New York and shortly thereafter by the National Science Foundation (NSF), led to the construction of a computer-based laboratory for learning and teaching on the University of Stanford campus. The campus laboratory has been in operation since the spring of 1964, and has conducted a program of instruction in schools nearby Stanford. This program has particularly concentrated on elementary school mathematics.

In the summer of 1964, the Institute was granted a contract by the United States Office of Education to establish a computer-based instructional laboratory at a public elementary school for the purpose of investigating computer-assisted instruction over an extended period of time.

The Stanford-Brentwood Computer-Assisted Instruction Laboratory, which is the first to be an integral part of a public school, is housed in a specially built laboratory at Brentwood Elementary School (Ravenswood City School District) in East Palo Alto, California. The laboratory is equipped with an IBM 1500 Instructional System operated by an IBM 1800 computer.

The Brentwood System is a computer-based learning laboratory with equipment capable of presenting programmed instruction to 16 students at a time. The laboratory is being used to teach mathematics and reading to elementary school children and to collect data on their learning behavior.

Presently, 100 children are participating in the project, including all of the children who are enrolled in the first grade.

The children are sent to the laboratory at regular periods each day. The children stay for a half-hour to study either reading or mathematics and, at the close of the period, return to their classrooms. Eight half-hour periods are presently scheduled each day.

The mathematics and reading instruction received is a coordinated, cooperative program utilizing both CAI and traditional classroom activities. In addition, the computer is programmed to provide printouts of each student's progress. There are five reports compiled and printed by the computer; viz., (1) daily reports listing the lessons each child did on that day, (2) weekly reports reflecting the progress of each class during that week (The weekly reports list the lessons and summarize the individual response records of each student.), (3) monthly reports providing a summary of student performance, (4) semester summaries, and (5) yearly summaries.

3.2.2.1.5.1 Design Philosophy

The system approach is that of centralized curriculum control. The CPU performs curriculum development and control and is dedicated to CAI, i.e., it is not a time-shared system.

The Brentwood system consists of a CPU, a station control, disk storage, a card reader/punch, a line printer, video storage, and instructional stations. The CPU and station control act as a link between the student and the course material stored on the interchangeable disk cartridges, audio tapes, or film. (Refer to Figure 3.2-13.)

The instructional station consists of devices for presenting course material to the student and receiving the student's responses. The presentation devices include an instructional display, a typewriter, a random access image projector, and a random access audio message device. The student input devices to the system include a keyboard, a typewriter, and a hand-held light pen.

Course material for system presentation can be prepared from instructional display, typewriter keyboards, or card punches. A 16 mm camera is used to prepare master films for the projector, and an audio magnetic tape recorder may be used to record audio material. The course is contained on one or more disk packs. Courses may be divided into segments and each segment treated separately.

3.2.2.1.5.2 Stanford-Brentwood Hardware System

The CPU is an IBM 1800 with a 32,000-word (16 bits/word) core memory. It is capable of accessing CAI course material from interchangeable disk cartridges, interpreting course statements, analyzing student responses, and controlling the instructional stations.

Disk storage within the IBM 1800 provides the necessary storage required for refreshing the 16 CRT's located on the terminals. A disk storage capacity of approximately 4000 bytes is required for each monitor.

The disk storage units provide interchangeable disk cartridges each of which has a storage capabity of 512,000 words.

Courses are placed on disk storage until ready for use. A minimum of one disk cartridge for the operating system and one disk cartridge for course material is required. The interchangeability of these disk cartridges provides additional off-line storage.

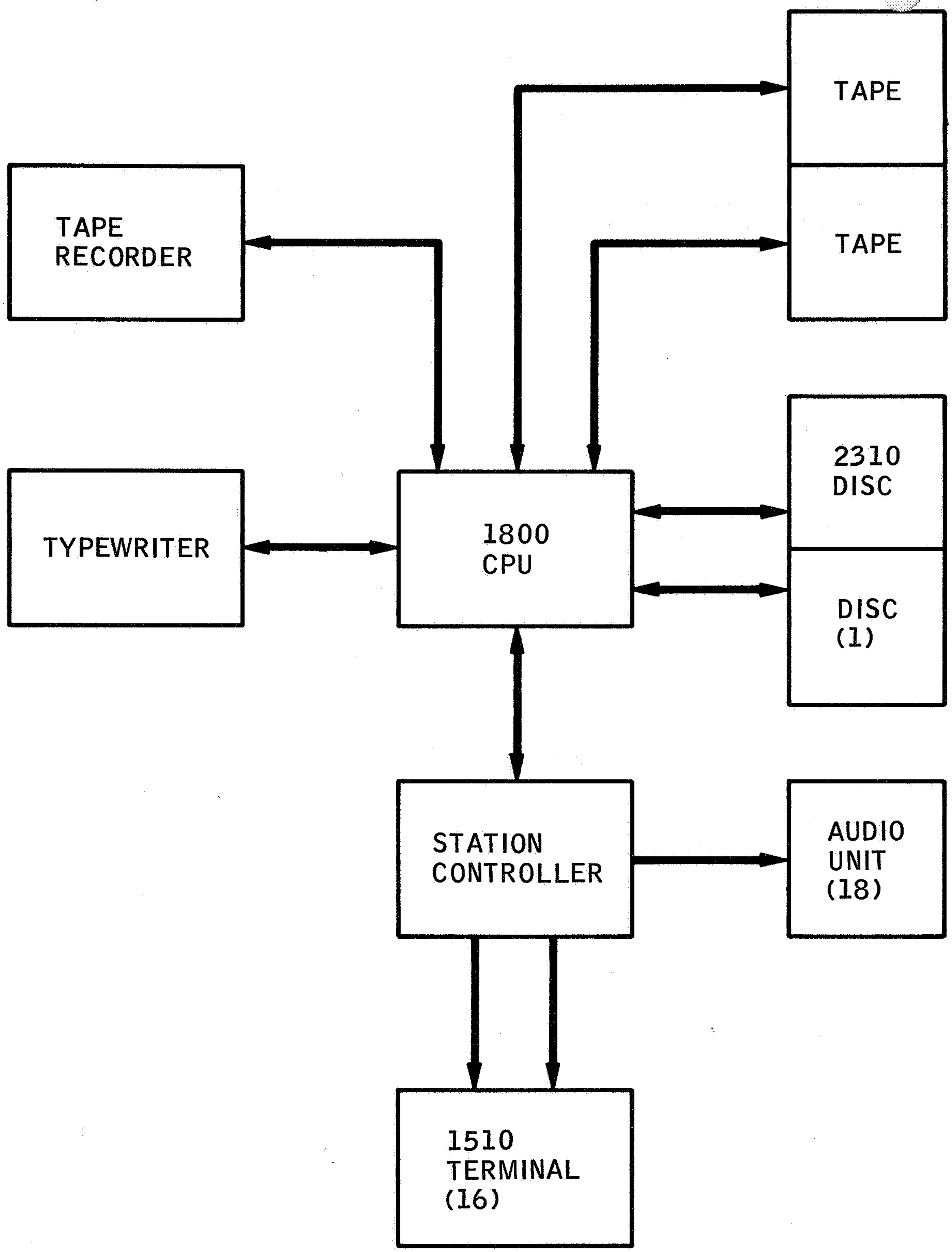

Figure 3.2-13 Brentwood System Functional Block Diagram

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The IBM 1132 Line Printer provides for output of student performance records, course listings, and any other required listings. Printing speeds are 82 lines per minute for alphabetic printing and 110 lines per minute for numeric printing. The print line is 120 positions wide.

The IBM 1442 Card Read-Punch provides card input/output for programs and data at speeds dependent on the operation being performed.

Each Brentwood System Student Terminal can be used in any one of 3 modes: author, student, or proctor. (Refer to Figure 3.2-23, Subparagraph 3.2.4.1.6, "Terminal Characteristics.") The devices available to the station are:

- 1518 Typewriter
- 1512 Image Projector
- Audio Tape Drive-Play, and Play/Record
- Light Pen (No information available).

A. <u>1510 Instructional Display with Keyboard</u>. This display contains a rectangular CRT for display of alphabetic and numeric characters or images. It is under operating system control, as directed by the course. All characters may be subscripted, such as 3_1, or superscripted, such as 3^1. Author-defined picture symbols may also be presented.

An emphasis indicator, in the form of special underlining, may be positioned and displayed on the screen to highlight selected portions of visual displays, as controlled by the course. This indicator may be stepped along the screen to emphasize words or phrases.

The 1510 keyboard permits the student to enter his response from the terminal. The student's keyed responses are displayed on the screen to emphasize words or phrases.

The 1510 keyboard permits the student to enter his response from the terminal. The student's keyed responses are displayed on the screen. A cursor symbol is used to indicate to the student where the next character on the screen will be displayed. The light pen is used by the student to respond to a question asked by an audio message, or by the displayed text, to point to a specific location on the screen. The position touched can be interpreted by the course for accuracy. As the student positions his light pen, an automatically generated brightened area on the display will indicate the location he is selecting.

B. <u>1518 Typewriter</u>. This typewriter can be used instead of, or in addition to, the 1510 instructional display. Through proper operation of control keys, 126 control functions are provided. Course material is presented to the student on the typewriter, and he can bype his responses on the typewriter keyboard for entry to the system. The student can check the accuracy of his responses by referring to this typed input.

C. <u>1512 Image Projector</u>. This projector holds a display screen (9 inches x 7 inches) on which filmed images can be projected in black and white or in color. It is a tabletop device and can be controlled by the computer. Images from a film strip can be presented in any sequence. When the cartridge is inserted into the projector, the film is automatically threaded into the projection station. Each frame is addressable, and the system selects each frame for display as directed by the course.

D. <u>Audio Tape Drive-Play, and Play/Record</u>. This device permits the student to listen to audio material and to record a recitation if requested.

The 1505 Audio Adapter contains the audio tapes and controls for audio transmission to student stations and audio recordings of student responses.

Each audio unit consists of a magnetic tape transport system, controls for remote operation by the instructional system, and manual controls for loading and unloading the tape. The tape for each audio unit is contained in a manually inserted cartridge, and is automatically threaded.

A tape can contain 2 hours of audio messages for each station, 40 minutes of which may be allocated to record student statements. Each message may be as long as 5 minutes, and the messages may be presented in any sequence. Each audio message is addressable.

3.2.2.1.5.3 Stanford-Brentwood Software System

The author language utilized in the system is Coursewriter II. Each course statement, or instruction consists of four parts: the label, the operation code, the modifier and the text. A brief description of each follows:

A. Label. The label is optional and consists of from 1 to 6 alphanumeric characters (A-Z; 0-9). It is used as an entry into the course and allows unique identification of a course statement. Within a course segment, no two instructions may have the same label. The first instruction in a course segment must be labeled. Subsequent instructions must be labeled only if they are to be reached by a branch (BR) instruction. Statements immediately following each label are sequenced automatically by the operating system.

B. Operation Code. The operation code is required in each instruction and consists of two lower case alphabetic characters which define the action to be performed on the text part of the course statement.

C. Modifier. The modifier is applicable only to certain operation codes and, when used, consists of a single alphabetic character.

D. Text. The text contains a series of arguments, of which the number, length, and contents depend on the operation code. If more than one argument is required, they are separated by special delimiter characters. If an argument preceding another argument is optional, it may be omitted by simply writing a delimiter in its place. Such an argument is then said to be "null."

Instructions of up to 123 characters in length may be entered, including the special delimiter characters but not including the label field.

The Continuation Code in Column 72 is used only with card input. When punched, it denotes that the following card is part of the present course statement. The Identification and Sequence number field in Columns 73-80 may be used for course identification and sequencing of cards or lines. Normally, this field would be punched only for card input; it is never entered when the author is entering course statements through the keyboard.

3.2.2.1.5.4 Stanford-Walter Hays CAI Project

Separate from the Brentwood System, but an integral part of the Stanford project, are the efforts being conducted at the Walter Hays Elementary School in Palo Alto, California. (Refer to Figure 3.2-14.) This school, in addition to five others, is experimenting with drill and practice exercises in mathematics, spelling, and logic. Over 800 students are provided drill and practice sessions each day. The instruction received is supplementary to the daily instruction.

Although the physical system is simple and somewhat crude, the obvious accomplishments and statistical information being gathered are most impressive. A significant point that should be made is that some students have been participating in the experiment for three years and, yet, are still highly motivated.

The schools involved in the project are:

- Grant Elementary - Cupertino, California
- Walter Hays Elementary - Palo Alto, California
- Oak Knoll Elementary - Menlo Park, California
- Clifford Elementary - Redwood City, California
- Ravenswood High School - East Palo Alto, California
- Costano Elementary - East Palo Alto, California.

Each of the schools is provided with ITT Model 33 teletypewriters. Grant has 8, Walter Hays - 9, Oak Knoll - 4, Clifford - 4, Ravenswood - 2, and Costano - 4.

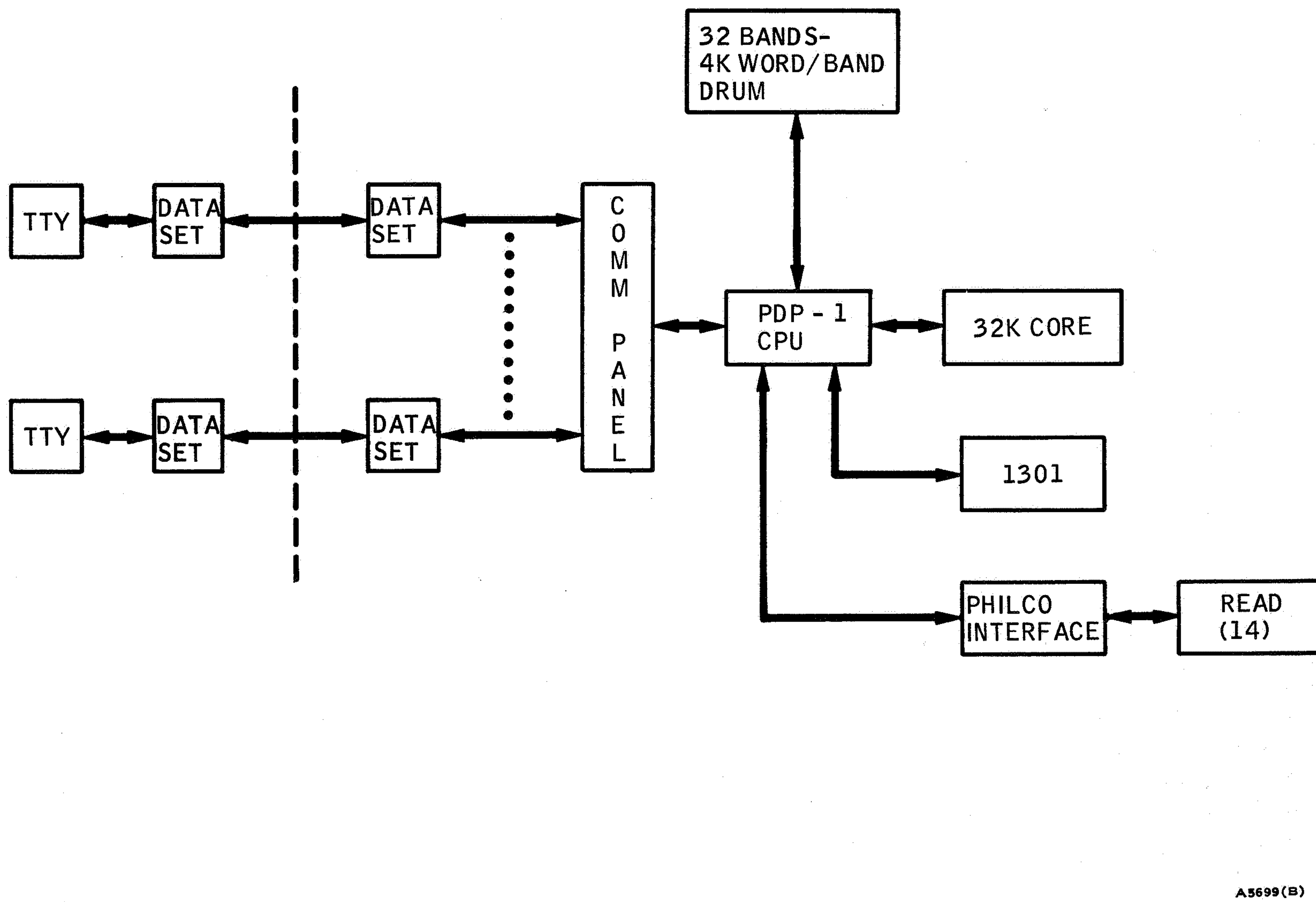

Figure 3.2-14 Walter Hays System Functional Block Diagram

The system has a total of 16 users. The first five schools are considered as one user; Costano is the second user, and the remaining 12 users are situated in the laboratory on the University of Stanford campus. The 12 users on campus are Philco READ systems used in curriculum development. Costano Elementary is considered as a separate user because it is experimenting with speech and audio.

The system concept is that of centralized curriculum control. The PDP-1, in response to control signals from various teletype machines, outputs the drill and practice exercises. Each teletype (31 active) interfaces with the CPU over individual phone lines.

The software package used for curriculum development is a modification of ALGOL. The computer program provides for adaptive sequencing on a lesson basis, i.e., a student receiving material at one level may be shifted to a higher or lower level based on performance. It is important to note that adaptive sequencing is not the same as remedial sequencing.

Figure 3.2-15 illustrates a typical lesson on addition. Referencing the first problem, the computer prints 38, +, and 7. The student must respond with the 45. The student is timed-out at approximately 15 seconds. This time frame is adjustable through initialization. Figures 3.2-16, 3.2-17, and 3.2-18 illustrate the type of statistical data being compiled and analyzed at each school, and the types of status reports submitted to the teachers.

```
PLEASE TYPE YOUR NUMBER AND NAME.
1 DEMO N. STRATION,  GRADE 1



     DRILL NUMBER C401000



THIS IS A LESSON ON ADDITION


3 8
+ 7
4 5


  5
+ 9
1 4


5 + _M_ = 99
WRONG

5 + _H_ = 99
WRONG, ANSWER IS 94

5 + ___ = 99
TIME IS UP, ANSWER IS 94


 ___ + 7 = 59
TIME IS UP

 ___ + 7 = 59
TIME IS UP, ANSWER IS 52

 ___ + 7 = 59
TIME IS UP, ANSWER IS 52


  1 2
  3 3
+ 4 8

TIME IS UP
```

Figure 3.2-15 Typical Lesson on Addition A5700(A)

```
    1 2
    3 3
  + 4 8

TIME IS UP, ANSWER IS 3

    1 2
    3 3
  + 4 8

TIME IS UP, ANSWER IS 3

    1 2
    3 3
  + 4 8
    8 3
WRONG

    1 2
    3 3
  + 4 8
      3
TIME IS UP, ANSWER IS 9

    1 2
    3 3
  + 4 8
    9 3


    5 7
  + 4 2
    1 9
WRONG

    5 7
  + 4 2
    9 9


8 + 9 = 17

4 + 3 = 7

13 + 5 = 18


    7
  + 8
    1
WRONG

    7
  + 8
  1 5
```

Figure 3.2-15 (Cont'd)

A5700(A)

```
6 + _12_ = 18

_8_ + 7 = 15

36 + 8 = _44
TIME IS UP

36 + 8 = _44

5 7
+ 8
6 5

3 + 5 = _8_

8 + 6 + 7 = _21

     END OF DRILL NUMBER C401000



19 JAN. 1967
16 PROBLEMS

              NUMBER   PERCENT

CORRECT         10        63

WRONG            3        19

TIME-OUTS        3        19

WRONG
 3
 6
10

TIME-OUTS
 4
 5
13

 290.6 SECONDS THIS LESSON.

CORRECT THIS CONCEPT, 75 PERCENT: TO DATE, 78 PERCENT.

OVERALL TIME:  0 HOURS, 55 MINUTES, 10 SECONDS.

GOOD-BYE, DEMO. PLEASE TEAR OFF ON THE DOTTED LINE.
```

A5700(A)

Figure 3.2-15 (Cont'd)

Report C: Item analysis and averages per student.

An item analysis is given which includes errors on second response (errors >1) and average time to complete the problem, including typing time. The numbers given in the correct, wrong, and time-out columns are on first responses only.

ITEM ANALYSIS OF DRILL

PROB.	CORRECT	WRONG	TIME OUTS	ERRORS >1	LATENCY
1	17/100.00	0/ 0.00	0/ 0.00	0/ 0.00	8.7
2	17/100.00	0/ 0.00	0/ 0.00	0/ 0.00	4.1
3	17/100.00	0/ 0.00	0/ 0.00	0/ 0.00	4.6
4	17/100.00	0/ 0.00	0/ 0.00	0/ 0.00	5.1
5	17/100.00	0/ 0.00	0/ 0.00	0/ 0.00	4.7
6	15/ 88.23	2/ 11.76	0/ 0.00	1/ 5.88	5.7
7	16/ 94.12	1/ 5.88	0/ 0.00	0/ 0.00	4.5
8	15/ 88.23	2/ 11.76	0/ 0.00	2/ 11.76	7.8
9	17/100.00	0/ 0.00	0/ 0.00	0/ 0.00	4.5
10	7/ 41.17	6/ 35.29	4/ 23.53	7/ 41.17	17.6
11	14/ 82.35	2/ 11.76	1/ 5.88	2/ 11.76	9.0
12	15/ 88.23	2/ 11.76	0/ 0.00	0/ 0.00	5.5
13	16/ 94.12	1/ 5.88	0/ 0.00	0/ 0.00	5.8
14	17/100.00	0/ 0.00	0/ 0.00	0/ 0.00	4.8
15	17/100.00	0/ 0.00	0/ 0.00	0/ 0.00	4.4
16	16/ 94.12	0/ 0.00	1/ 5.88	0/ 0.00	8.6
17	12/ 70.59	4/ 23.53	1/ 5.88	1/ 5.88	8.9
18	17/100.00	0/ 0.00	0/ 0.00	0/ 0.00	4.7
19	16/ 94.12	1/ 5.88	0/ 0.00	0/ 0.00	5.6
20	12/ 70.59	4/ 23.53	1/ 5.88	4/ 23.53	12.1

AVERAGES PER STUDENT

CORRECT	18.0/ 90.00
TIME OUTS	.4/ 2.00
ERRORS	1.4/ 6.99

A5701 (A)

Figure 3.2-16 Item Analysis and Averages Per Student

```
DAILY STATUS REPORT

SCHOOL:  GRANT

TEACHER:  SHIRLEY YAMASAKI

GRADE:  5

CLASS:  7

DATE:  13 JAN. 1967

TIME:   3:51  PM



THE FOLLOWING STUDENTS ARE STILL ON CONCEPT  2
AND SHOULD BE ENCOURAGED TO CATCH UP.
MILLARD ROSE
MIKE TOOLEY
CAROL HOLT



THE FOLLOWING STUDENTS DID NOT RUN TODAY:
KAI AMONDSON
PETER BERGER
JON WYATT
STEVE LOPEZ
ROBBI WAER
SHERYL MATHERS
LAURA WILLIFORD
PATRICIA WATT
KIM HOSKING
LAURA WATKINS
LISA CHUNG



YOUR CLASS IS CURRENTLY WORKING ON:
CONCEPT 2. SUBTRACTION, VERTICAL AND HORIZONTAL
           1- AND 2-DIGIT

CONCEPT 3. MIXED ADDITION AND SUBTRACTION
           3- AND 4-DIGIT
           MIX BORROW, CARRY
```

Figure 3.2-17 Typical Daily Status Report

A5702(A)

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CONCEPT 25. SPECIAL DRILLS
            ADDITION AND MULTIPLICATION


CONCEPT 26. SPECIAL DRILLS
            SUBTRACTION AND DIVISION



THE AVERAGE PERCENT CORRECT FOR:
CONCEPT   2  IS  78
CONCEPT   3  IS  74
CONCEPT  25  IS  96
CONCEPT  26  IS  96



THE FOLLOWING STUDENTS SCORED ABOVE 90 PERCENT:
MATT COBB
KAI AMONDSON
TOM RAMBACK
DANNY BLAKE
PETER BERGER
SAM HUSMANN
MILLARD ROSE
MARK RODRIGUES
LUIS LLERENA
JON WYATT
JOE DELAMANO
STEVE LOPEZ
MIKE SELF
ROBBI WAER
LISA BEAN
CAROL HOLT
SHERYL MATHERS
PATRICIA WATT
BONNIE LOCKYER
KIM HOSKING
TENLEY MITCHELL
LAURA WATKINS



THE FOLLOWING STUDENTS PERFORMANCE ON THEIR CURRENT
LESSON IS BELOW THEIR INDIVIDUAL AVERAGES:
MIKE TOOLEY
```

Figure 3.2-17 (Cont'd)

A5702(A)

STUDENT DRILL TRACE FOR CLASS 5.

123 MIKE DOYLE

DAY	PRE TEST	1	2	3	4	5	POST TEST
LEVEL		3	2	3	4	5	
PERCENT CORRECT	56	42	60	88	92	95	100
PERCENT WRONG	34	52	40	7	8	5	0
PERCENT TIMED OUT	10	5	0	5	0	0	0
ELASPED TIME	230	221	203	166	142	125	103

124 SUSAN SLADE

•
•
•

YEAR TO DATE STUDENT REVIEW TRACE FOR CLASS 5.

123 MIKE DOYLE
BLOCKS REVIEWED 5 2 7 4 3 2 3 2 3 6 1 2 1 3

124 SUSAN SLADE

•
•
•

Figure 3.2-18 Typical Student Drill and Review Trace A5703(A)

3.2.2.2 Systems Applications

This paragraph presents a summary of the curriculums which are taught by the various CAI systems reviewed. Table 3.2-1 lists each system reviewed and the application of the system. The systems application includes a notation of whether the application is experimental or operational, the subject matter taught, the grade level and course lengths, the method of instruction, the administrative uses of the system (simulation, scheduling, grading) and appropriate remarks.

Other tables, Tables 3.2-2 through 3.2-4, provide summaries of the subject matter taught by the PLATO System, summaries of CAI courses at the University of California at Irvine, and summaries of CAI materials under development at the university.

TABLE 3.2-1

SUMMARY OF SYSTEM APPLICATION

SYSTEM \ APPLICATION	EXPERIMENTAL	OPERATIONAL	SUBJECT MATTER TAUGHT	GRADE LEVEL AND HOURS	METHOD OF INSTRUCTION	SIMULATION	SCHEDULING	GRADING	REMARKS
PLATO	X	X	SEE TABLE 3.2-2	COLLEGE, 12TH GRADE, PRIMARY AND PRE-KINDERGARDEN	TUTORIAL AND INQUIRY	-	-	-	THE STAFF OT THE COORDINATED SCIENCE LABORATORY AT THE UNIVERSITY OF ILLINOIS HAS WRITTEN OVER 200 PROGRAMS USING 25 LOGICS. THE UNIVERSITY IS DEVELOPING A PLASMA DISCHARGE DISPLAY THAT WILL GREATLY REDUCE THE COST OF STUDENT TERMINALS.
GROW		X	INFORMATION NOT AVAILABLE	7TH, 8TH, 9TH, 10TH, 11TH, AND 12TH	TUTORIAL	-	X	X	THE CURRICULUM IS BEING DEVELOPED BY THE PISD AND IS EXPECTED TO RANGE FROM DRILL AND PRACTIVE AT THE LOWER GRADE LEVEL, I.E., 7TH, 8TH, AND 9TH TO COLLEGE CHEMISTRY AND OTHER COURSES OF EQUAL DIFFICULTY.
STANFORD	X	X	SETS AND NUMBERS; ARTTHMETIC DRILL; LOGIC ELEMENTARY READING; SPELLING DRILL	ELEMENTARY, 1ST, 2ND, 3RD, 4TH, 5TH, 6TH AND 7TH	DRILL AND PRACTICE TUTORIAL (LINEAR AND BRANCHING)	-	X	X	THESE COURSES INCLUDE THE BRENDWOOD SYSTEM AND WALTER HAYS, GRANT, OAK KNOLL, CLIFFORD, RAVENSWOOD, AND COSTANO.
UNIVERSITY OF CALIFORNIA AT IRVINE		X	SEE TABLE 3.2-3	COLLEGE LEVEL	TUTORIAL	-	-	X	APPROXIMATELY 500 STUDENTS ARE PARTICIPATING IN CAI AT IRVINE. THE CARNEGIE CORPORATION AND NATIONAL SCIENCE FOUNDATION HAVE GIVEN GRANTS TO UCI FOR DEVELOPMENT OF CAI MATERIALS. SEE TABLE 3.2-4.
SYSTEM DEVELOPMENT CORPORATION	X		STATISTICAL INFERENCE COURSE (EXPERIMENTAL) STUDENT COUNSELING COURSE	COLLEGE LEVEL	TUTORIAL	-	X	X	
UNIVERSITY OF CALIFORNIA AT SANTA BARBARA			INFORMATION NOT AVAILABLE						

TABLE 3.2-2

SUMMARY OF SUBJECT MATTER TAUGHT BY PLATO SYSTEM

TEACHING PROGRAMS

TUTORIAL LOGICS

1. Perimeter of Polygons (PLATO I, II, III). A simple geometry demonstration lesson on perimeters designed to illustrate all the features of the PLATO system (i.e., control keys, help sequences, judging, evaluating, etc.), updated for each new version of the PLATO system.

2. Addition of Fractions (PLATO I, III). A demonstration lesson on fractions showing the use of the PLATO keyset and improvements (PLATO III version) in the flexibility of the teaching logic.

3. Introduction to Automatic Digital Computing (PLATO II). Three lessons comprising the first week of material taught in Math 195 (UCI): I. The Word as a Number; II.A. The Biquinary Code, B. The Storage Unit; III.A. The Arithmetic Unit, B. Instruction Format, C. The Control Unit, D. Execution of Single Instructions. Data collected from student runs provided material for studying the learning ability of each student, lesson effectiveness, and data rate requirements of the PLATO system.

4. Introduction to Computer Programming (PLATO II). Seven lessons designed to teach programming for the ILLIAC computer and written with PLATO tutorial logic. Chapter titles included: I. Number Representations; II. Binary Arithmetic; III. Negative Number Representation; IV. The ILLIAC Order Code (Part 2); VII. The ILLIAC Order Code (Part 3).

5. Network Synthesis (PLATO II). Two short lessons in network synthesis for electrical engineering students demonstrating circuit diagram construction by means of the PLATO keyset and a judging routine allowing a tolerance in numerical answers and a degree of freedom in the answer form.

6. Maxwell's Equation (PLATO II). Three lessons introducing material on Maxwell's Equations to senior engineering students taking EE 355 (UCI): I. Introduction to Maxwell's Equations; II. Boundary Conditions at a Surface of Discontinuity; III. The Wave Equations in Free Space.

7. Things and Their Names (PLATO II). Two lessons in introductory secondary mathematics dealing with the subject of "Things and Their Names", designed for incoming sub-freshmen at a high school.

TABLE 3.2-2 (CONT'D)

8. CHAOS (PLATO II). An exercise on number sequences written for use with the studies on physiological correlates of mathematical discovery in which student heart rates were recorded along with the lesson responses.

9. ZOO (PLATO II). A second grade level mathematics demonstration lesson (with a zoo theme) written for primary school children visiting the PLATO project.

10. TEXT TESTER (PLATO III). A program designed to test new text-books in which text materials are reproduced on slides with student answers inserted from the keyboard. Teacher comments and lesson modification are also able to be inserted on line. TEXT TESTER has been used to present lessons in the following areas: a) Remedial Arithmetic from the University of Illinois Committee on School Mathematics 7th grade course (20 lessons); b) Politics Unit from the experimental materials of the Social Sciences Curriculum Center (12 lessons).

11. Circuit Analysis (PLATO III). Lessons written for use in a University of Illinois course for junior year electrical engineering students (Electrical Engineering 322). The course has been presented for three semesters each time in a different manner: a. Spring 1965. Twice a week in the classroom, twice a week using PLATO (18 lessons). b. Fall 1965. Once a week using PLATO, three times a week in the classroom (9 lessons). c. Spring 1966. Four times a week for a three-week period in the middle of the semester, half the class using a tutorial presentation of the material, half an inquiry approach (12 consecutive PLATO lessons, no intervening classroom work).

12. ARITH DRILL (PLATO III). Arithmetic drill sequences for low achievers from sixth and seventh grades.

13. LIBUSE (PLATO III). 14 units (28 lessons) comprising a one semester course, "An Introduction to the Use of the Library," given to non-library science majors at the University of Illinois (Library Science 195).

14. Fortran Programming (PLATO III). Ten lessons on the Fortran programming language written for students in business and commerce in which the material is presented so as to be incorporated eventually into a programmed textbook.

15. Special Demonstration (PLATO III). A program illustrating various possible functions of the keys of a PLATO keyset, written as the preface to some of the courses given on the PLATO system.

16. ARRAYS (PLATO III). Four lessons for fourth grade pupils (about one hours each) using arrays of symbols.

TABLE 3.2-2 (CONT'D)

17. SEQUENCES (PLATO III). Nine one-hour lessons on recursive definitions for high school students.

18. QUANTITIES (PLATO III). Test development and studies of quantitative aptitude in higher education students.

19. TEXT EDIT (PLATO III). (Some versions called BRAILLE). A tutorial type teaching logic that permits textual slides, questions stored in memory and plotted on the "blackboard", and student inputs from an auxiliary device (such as a BRAILLE typewriter), as well as on-line editing.

INQUIRY LOGICS

1. REPLAB (Responsive Environment Programmed Laboratory)(PLATO II and III). A lesson in scientific inquiry based on the properties of the bimetal strip in which the students inquire into the physical phenomenon in order to describe, analyze, predict, control and explain it. Important data is provided from student input for the multidimensional analysis of the inquiry process. The lesson uses an auxiliary film sequence to show the bimetal strip experiment.

2. PROOF (PLATO II and III). A program (with several versions) which enables students to compose proofs of mathematical problems in a logical manner, each solution or proof being judged only for violations in logic. The most recent version of the program allows for insertion of lemmas in the proofs. The program provides a system for collecting data on thought processes during methematical problem-solving or for preparing instructional programs in the mechanics of rigorous mathematical proof.

3. MEDICARE (PLATO II). A lesson for student nurses in the care of a patient with myocardial infarction using an auxiliary film sequence to provide the background material for the problem posed the students. Student input provided data for analysis of each student's approach to the solution of the problem.

4. ORDER (PLATO II). A timed exercise in numerical pattern recognition (more simple than CHAOS) used with the studies on physiological correlates of mathematical discovery.

5. ARCH (Archimedes) (PLATO II and III). A demonstration lesson using PLATO as a simulated laboratory in which experiments based on Archimedes' Principle can be performed such as making volume or weight measurements.

6. ALPHABAT (Alphabet Automatic Teaching) (PLATO III). A program designed for experimenting with the teaching by PLATO of the letters of the alphabet to two- and three-year old children.

TABLE 3.2-2 (CONT'D)

7. MAKING THINGS MOVE (PLATO II). An elementary science lesson based on a second grade science unit written as a demonstration for primary school children.

8. TEACHER (PLATO III). A lesson designed to demonstrate the operation of the PLATO system to non-technical persons interested in preparing lessons for PLATO.

9. Circuit Analysis (PLATO III). See Number 11c under Tutorial Logic.

RESEARCH PROGRAMS

1. TALK (PLATO III). Short program to demonstrate communication between student stations.

2. EXPERIMENT (PLATO III). A program which controls real-time on-line experiments in a secondary emission surface physics study and immediately analyzes the experimental data, displaying the desired analysis on the PLATO screen.

3. VERBOSE (PLATO III). A program making possible an elementary analysis, in real-time, of a word chain generated by a subject's free association.

4. TEXTDOPE (PLATO III). An inquiry-type logic for author use in analysis of student dope. Author can request graphs of latency or number of errors, lists of answers, or can specify other statistics in which he is interested, or sequential traces of individual student histories.

5. KEYSET 1 (PLATO III). A program to provide data for assessment of the relative efficiency of different configurations of the keys on the keyset so as to compare keyset input with input by long-hand writing.

6. CEWCODE (PLATO III). A general paired-associate learning computer program providing an almost unlimited variety of configurations for paired learning and response situations. The program has been used in studies of the use of concepts and word-meaningfulness in verbal learning.

7. CIRCLE (PLATO III). Program designed for use in the production with the PLATO system of short, animated films for a language-free test of interpersonal norms. Each film strip, or scenario, portrays an interpersonal intention composed of discrete sequences of visual events identified with abstract, theoretical components.

8. CONCEPT (PLATO III). A general concept attainment program allowing up to three logical types of concepts rules and four methods of presenting components.

TABLE 3.2-2 (CONT'D)

9. GIN-1 (PLATO III). A general program written to facilitate group interaction studies such as Inter-nation Simulation and Security-Game studies. Messages can be written, edited, read, sent and retrieved, the latter two under communication rules controlled by decision makers.

10. VRBADV (PLATO III). A program designed to test C. E. Osgood's theory of meaning by satiating components of denotated meanings, the effects of satiation being demonstrated by disturbed performance on a non-related task. The program individually administers experimental sequences and allows measurements of latencies in situations where the speed of presentation is critical.

TABLE 3.2-3

SUMMARY OF CAI COURSES AT UNIVERSITY OF CALIFORNIA AT IRVINE

CAI COURSES CURRENTLY IN USE

Introductory General Biology

"Mendel", a review of Mendeliam genetics, is being used on an optional basis by approximately 50 of the 400 Biology I students. Currently it is being expanded to include simulation of laboratory experiments.

English A

"Synrev", a syntax review, is being used by 50 students who need special help with grammar.

Introduction to Economics

"Ecin" is being used by 120 students as a required part of this class.

Introduction to Psychology

Various units of CAI materials are offered on an optional basis to the 125 students taking this course for credit.

Introduction to Communication Science

"Proceed", a CAI course used in conjunction with a syllabus entitled Introduction to Procedures and Procedure Followers, is required of the 130 students enrolled in this class.

Marine Ecology

"Fishes", a taxonomic key, will be used by the 15-20 students who take this class during the winter quarter.

COURSES AVAILABLE FOR STUDENTS TO TAKE ON THEIR OWN TIME

"Flag", a review of American history, and "Govern", a review of Americal government are available to students who wish to prepare for the exam on American history and institutions which is a requirement for graduation. Approximately 50 students have used these courses this quarter.

TABLE 3.2-3 (CONT'D)

"Alg-rev", an algebra review, and "trigl", an introduction to trigonometry, are available as remedial help for students who lack sufficient background in mathematics.

"Fortran 4", an introduction to Fortran IV, is currently available for any students or members of the staff who which to learn Fortran.

CAI COURSES IN PREPARATION

Mathematics for Social Scientists

"Math 5a" will be an integral part of this course. Expected completion: January 1, 1968. Estimated number of students: 150

Introduction to Sociology

"Soc" will be a required part of this class during the winter quarter, 1968. Estimated number of students: 125

Introduction to Geography

CAI materials are being prepared for use during the spring quarter, 1968. Estimated number of students: 100

Introduction to Political Science

CAI materials are being prepared for use during the spring quarter, 1968. Estimated number of students: 100

Introduction Ecology

CAI materials are being prepared for use during the spring quarter, 1968. Estimated number of students: 20-25

Introductory Mathematics

"Math 1a", an introduction to pre-calculus mathematics, will be used, in conjunction with this class for approximately 80 to 100 students during spring quarter, 1968.

TABLE 3.2-4

CAI MATERIALS UNDER DEVELOPMENT AT UNIVERSITY OF CALIFORNIA AT IRVINE

CARNEGIE CORPORATION GRANTS	NATIONAL SCIENCE FOUNDATION GRANTS
Psychology - Course material is being written to form a required part of Introduction to Psychology.	Analytic Geometry and Calculus (Math 2a) - This is a series of exercises for course material dealing with limits and functions.
Sociology - Course material is being written to form a required part of Introduction to Sociology.	The System of Real Numbers - Course material for Math 1a.
Trigonometry - This is an optional remedial mathematics course used by students to prepare themselves for required college mathematics courses.	Functions - Course material for Math 1a.
	Exponential and Logarithmic Functions ; Course material for Math 1a.
Political Science - Course material is being written as a required part of Introduction to Political Science.	Complex Numbers - Course material for Math 1a.
	The Theory of Equations - Course material for Math 1a.
Economics - Course material is being written as a required part of Introduction to Economics course.	Systems of Equations - Course material for Math 1a.
Geography - Course material is being written as a required part of Introduction to Geography.	Permutations, Combinations and Binomial Theorem - Course material for Math 1a.
Algebra Review - This is a review mathematics course for all social science students taken, without credit, in preparation for the Division's curriculum.	Taxonomy of Fishes - A taxonomic key of the families of true fishes has been prepared which in the process of identifying specimens will teach students how to use taxonomic principles and techniques. This material will be used by students in an upper division course this year.
	Mendelian Genetics - This is an optional course intended to prepare students for a course in human genetics.

TABLE 3.2-4 (CONT'D)

CARNEGIE CORPORATION GRANTS	NATIONAL SCIENCE FOUNDATION GRANTS
	Syntax Review - This is a review grammar course for Freshmen students taking the Subject A course. History Review - This is a review history course for use by students who are preparing for UCI's American History and Institutions Examination, a test given in lieu of a course in this subject, as required by the State of California. Introduction to Functional Areas - Several short courses are available to introduce the student to the basic principles of the punch card, the binary number system and computer programming. Introduction to JOSS - This is a CAI course used in conjunction with Information and Communication Sciences L (ICS 1). About 100 students are enrolled in this course every term. FORTRAN - This is a CAI course and manual also used in conjunction with ICS 1. In addition, this material is used in conjunction with a non-credit evening FORTRAN course for students so that they can help the faculty with research computing projects.

3.2.2.3 Software Languages Description

The following subparagraphs provide a brief description of some of the more commonly used languages for programming numerical computations, i.e., algebraic languages and list-processing languages for the processing of verbal information; i.e., author languages.

3.2.2.3.1 Algebraic Languages

A. FORTRAN. At present, Formula Translation (FORTRAN) is the most commonly used computer language for computational mode programs. It was designed by IBM in 1954 for the IBM 704, but is now available on almost every computer in the world. It is an algebraic language which describes calculations using expressions similar to those used in algebra. As with all computer languages, FORTRAN has many different "dialects," the three most widely used being FORTRAN, FORTRAN II, and FORTRAN IV. Although there is no consistency in the use of these terms, FORTRAN II usually includes the use of logical "IF" statements and complex variables.

B. ALGOL. Algorithmic Language (ALGOL) is a second generation algebraic language, succeeding FORTRAN and having a somewhat more logical structure. ALGOL is not nearly as widely used in this country as it is in Europe. There are, however, many American machines with ALGOL compilers, although these compilers often omit some of the more esoteric features of the language.

C. JOSS. The Johnniac Open Shop System (JOSS) is an algebraic language which was developed by the RAND Corporation for use at time-sharing, typewriter-like terminals. It can be used either to program or to make the terminals operate as electronic desk calculators. Because it is intended for terminal use, it is designed to provide rapid feedback of grammatical errors made by the programmer. Variations of JOSS, under slightly different names, are now available at UCI (JOSSI and ISIS), and at the University of California at Berkeley (CAI, not to be confused with computer-assisted instruction). A version called TELCOMP is available for use in the Boston area through Bolt Beranek and Newman.

D. <u>BASIC</u>. Beginners All-purpose Symbolic Instruction Code (BASIC) is an algebraic terminal language, similar in some ways to JOSS, which was designed at Dartmouth College for use on their time-shared computer system. It is also used at the General Electric Corporation (GE) and Ford Motor Company as a time-sharing language, and is available to other colleges through the use of centralized GE machines.

E. <u>QUIKTRAN</u>. QUIKTRAN is a terminal-oriented version of FORTRAN developed by IBM and available from them at terminals in certain large cities. Unlike JOSS and BASIC, it uses the full complexity of FORTRAN.

F. <u>PL/1</u>. PL/1 is a new language announced by IBM for implementation on some versions of their System 360 computer series. As of this writing, no experience is available with PL/1 compilers. The language combines the features of both an algebraic language and a symbol—or list-processing language. As an algebraic language it could be called a "third generation" language, succeeding FORTRAN and ALGOL. Because it combines algebraic and list-processing facilities, it allows complex programs which use both linguistic and computational modes.

G. <u>FORMAC</u>. FORMAC is an extension of FORTRAN IV which adds the facility for formal algebraic manipulation--including differentiation--to an existing language. Developed by IBM in 1964, it is the most widely used language of this type. Languages, like FORTRAN for example, have the facility for multiplying the expression (A-B)(A+B) if numerical values are provided. However, FORMAC can operate on the same expression obtaining the result A^2-B^2.

H. <u>JOVIAL</u>. Jules Own Version of International Algebraic Language (JOVIAL) was developed to provide a scientific capability (much like FORTRAN and ALGOL) and at the same time, provide a data handling capability much like COBOL. JOVIAL was developed by SDC around 1960. Definitely user-oriented, JOVIAL is a readable and concise programming language, utilizing self-explanatory English words and the familiar notations of algebra and logic.

3.2.2.3.2 List Processing Languages

A. COURSEWRITER. Several modifications to the Coursewriter I language have been made since its inception. They are: Coursewriter II, Interpretive Coursewriter (used at UCI); Coursewriter II (used at Brentwood), and a new more powerful language under development which is to be called Course Author Language (CAL). This language will be used with the System 360 machines.

In brief, COURSEWRITER is an interpreter language of about 12 executable instructions or operation codes and 10 manipulative commands by which an author at a terminal enters and edits text material and branching logic. The edit commands include INSERT, DELETE, and TYPE, and can reference text by line only. The computer interprets the stored instructions to present reading assignments, questions, and replies to student answers. The student types the responses he has constructed on a keyboard, and these responses are entered into the computer for comparison with alternatives previously stored by the author: the match between student answer and computer alternative determines the next computer reply. In achieving a match, the author can specify a variety of conditions for recognition of responses other than an exact match, including the presence of a portion of a given list of items, and the ignoring of trivial characters, such as space and tabulation, in the student response.

B. MENTOR. Researchers at Bolt Beranek and Newman are giving particular attention to a system in which an author-instructor can implement training and testing of complex analytic tasks, such as diagnosing medical ailments, arriving at decisions in business and management, developing military strategy, and investigating scientific problems. For this they are developing a teacher-author language called MENTOR for use in constructing conversational tutorial dialogues. The instructional program in this system is in the form of logical expressions which determine computer replies and subsequent material on the basis of whatever aspects of the student performance history the author cares to designate. Typically, the situation is established in which a problem may be solved by the gradual acquisition of information. The student makes inquiries of declarations composed from a list of acceptable terms, and the machine processes these replies according to complex conditional rules described by the author.

C. COMPUTEST. A simple, unsophisticated instructional author language has been developed at the University of California at San Francisco. The COMPUTEST language permits the construction of simple question-and-answer dialogues, including a skip-ahead form of branching. It is characterized by the ease with which a person untrained in computer programming may write sequences of material. The IBM 1620 computer with typewriter and card input/output is used. Preparation and input of instructions to the computer are by punched cards; the typewriter serves as the student station. The system includes the capability of grading the student's responses to questions.

D. CATO. The Programmed Logic for Automatic Teaching Operations (PLATO) project at the Coordinated Science Laboratory of the University of Illinois has developed a compiler language for writing teaching logics or patterns for their CDC 1604 system. It incorporates an extended FORTRAN with their own language (called CATO) for specifying the logical structure of an instructional sequence, and can accept CDC 1604 assembly language statements at any point. The programmer can prepare basic patterns (such as tutorial, inquiry, and simulation) into which any author can later insert his particular teaching material. For example, using a tutorial logic an author need write only the text, right answers, and diagnostics to obtain a computer-controller sequence of instruction; the computer has been programmed in advance to fit arbitrary text and answers into a particular type of dialogue. In another pre-programmed strategy, the author may insert any text which he wishes to evaluate; the computer has been programmed to ask questions and collect data during presentation to students according to a particular pattern. A third type of strategy being explored is simulation of laboratory or real-world situations such as international relations. To accomplish these functions, special routines have been written for judging student answers by various complex criteria, plotting graphs on student request, plotting data from an on-line physics experiment, constructing and checking statements in a mathematical proof, monitoring physiological data entered over supplementary input channels, and controlling supplementary audio or visual displays.

E. INFORM. INFORM is a language currently being developed for the Philadelphia Independent School District through joint efforts of the Philco Communications and Electronics Division and the Philco TechRep Division.

The language has control provisions for generating graphic data, tabular data, and controlling audio recording.

The author prepares the curriculum and structures each lesson in the pattern considered most suitable for that lesson. To assist in this structuring, three forms are provided: Form 1 provides for curriculum description, Form 2 provides for the specification answers and displays to be viewed by the students and, Form 3 provides the author the means of specifying graphical and character displays.

Nine operational commands are provided in the control repertoire; viz.:

- Problem Command (P)
- Display Command (D)
- Examine Command (E)
- Test Response Commands (C, W, A, T, U, X)
- Unconditional Branch Command (B)
- Conditional Branch Command (B)
- Arithmetic or Load Branch Command (B)
- Figure Command (FIG)
- Graphic Command (GRA).

F. PLANIT. The author language, PLANIT, has been developed at SDC to provide effective man/machine interaction with the PLANIT CAI system.

PLANIT allows operation in four distinct modes: LESSON BUILDING, EDITING, EXECUTION, and CALCULATION. The first two modes permit the teacher to construct and edit lesson frames in various formats and store them in designated sequences for later presentation to the student in the EXECUTION mode. The CALCULATION mode is extremely useful for mathematical subject matter and can be used as a calculation aid for the teacher to build the lesson or the student to perform the lesson.

"Concise" or "verbose" options are available which allow concise, abbreviated printouts where practicable, but also allows greater explanation upon request.

At any point in building the lesson, the instructor may use any of the four modes; thus, allowing the instructor to try out lessons and make immediate improvements on-line. Another important benefit is the teacher's ability to modify the lesson quickly and easily after presentation, on the basis of the student's responses.

Student answers that depart from the expected responses may be evaluated through key word matching, phonetic comparison, or algebraic-equivalency routines.

The student may utilize the CALCULATION mode when he comes to a lesson frame that requires computation. Although the student has access to only the EXECUTION and CALCULATION modes, the lesson designer has access to all four modes.

3.2.3 Survey of University and College Activities in Programmed Learning

This section presents the results of a survey which was made to determine the extent of programmed instruction techniques, applications, and systems being utilized at major universities and colleges in the United States. These results have been compiled from the responses to questionnaires which were mailed on 4 November 1966 to 149 universities and colleges.

Of these 149, responses were obtained from 56 institutions, giving a 38 percent rate of response. Sixty-four percent of those responding indicated that they were involved in programmed instruction research in some capacity.

Thirty percent of the respondents were engaged in the utilization of programmed textbooks, but had not advanced to experimentation with CAI.

Of the 56 respondents, 29 percent had teaching machines, (Autotutor, Min-Max, etc.) available for either demonstration or instruction. Many of these teaching devices were in the form of language laboratories or rapid reading machines.

Thirty-four percent of the institutions responding were involved in CAI activities. Ten percent were utilizing CAI but were not concerned with programmed textbooks. Twenty-four percent made use of both CAI and other forms of programmed or automated instruction.

The results show that a significant portion of those queried were engaged in some form of programmed instruction. Of those not actively engaged in the area, nearly every response indicated that the institution was seriously considering the use of CAI or programmed textbooks.

The fact that 34 percent of the respondents were working with CAI belies the experimental nature of the concept. Few of the institutions reported operational CAI systems presenting curriculum for other than experimental purposes and those that were considered operational were in the early stages of development. As a result of the developmental and experimental nature of the existing systems, very little information concerning analyses of the systems' benefits was available.

The survey results are presented on two tables which comprise three sections. Information on Table 3.2-5 is contained in A and B below; information on Table 3.2-6 is contained in C.

A. Programmed Textbooks. The institution is listed along with the subjects being taught by programmed text and the method of programming used (B-branching; L-linear; CPB-combination, primarily branching; CPL-combination, primarily linear). Comments and statistics are provided where applicable. Very little analyses are available which address student performance or instructional efficiency.

B. Teaching Machines. A brief description or listing of teaching machines at each institution is presented.

C. Computer Assisted Instruction. The following information will be found on the second table (Table 3.2-6): The number of computer systems on each campus is given along with a listing of the specific systems with the application and language utilization of each. The CAI instructional language used at each institution is listed, as are the courses taught by CAI and the operational or experimental status of each course. The name or acronym of each project and comments concerning the systems are presented where applicable.

TABLE 3.2-5

PROGRAMMED TEXTBOOKS AND TEACHING MACHINES
QUESTIONNAIRE RESULTS
(2 FEBRUARY 1967)

I. PROGRAMMED TEXTBOOKS							II. TEACHING MACHINES
INSTITUTION	SUBJECTS	METHOD OF PROGRAMMING B	L	CPB	CPL	COMMENTS AND/OR STATISTICAL ANALYSES OF STUDENT PERFORMANCE	DESCRIPTION OF SYSTEM
California Institute of Technology	Not engaged in programmed instruction research						
Baylor University	Not engaged in programmed instruction research						
University of Alabama	Not engaged in programmed instruction research						
The City College, New York	Not engaged in programmed instruction research						
Colgate University	Applied Statistics Independent Study				X X	Low % of curriculum Uses prog. text	None
North Texas State U.	Not engaged in programmed instruction research						
Indiana University	Statistics Matrix Algebra	 X	 X	X X		Low % of curriculum Uses prog. text	Audio-Visual unit with student control of "start" and "reverse" operations
Xavier University	Not engaged in programmed instruction research						
University of Miami	Law					Low % of curriculum Uses prog. text	None
University of Texas	Aux. to Statistics Ed. Psychology		X X			Low % of curriculum Uses prog. text	Not currently in operational use
Univ. of Connecticut	Statistics Comp. Programming Various other subjects	 X	X			Low % of curriculum Uses prog. text	Language lab, reading labs, education courses - technology
Texas A&M Univ.	Calculus		X			Low % of curriculum Uses prog. text	"Autotutor" - Industrial Ed. CCTV System (CATE)

TABLE 3.2-5 (CONT'D)

I. PROGRAMMED TEXTBOOKS							II. TEACHING MACHINES
INSTITUTION	SUBJECTS	METHOD OF PROGRAMMING				COMMENTS AND/OR STATISTICAL ANALYSES OF STUDENT PERFORMANCE	DESCRIPTION OF SYSTEM
		B	L	CPB	CPL		
Rice University	Not engaged in programmed instruction research						
USN Postgraduate School	Accounting		X			Indications of unsatisfactory results	None
Concordia Teachers College	Music Theory		X			Low % of curriculum Uses prog. text	Min-Max II, TMI - Grolier mechanical device to teach statistics
Bowling Green Univ.	Various subjects		X			Low % of curriculum Uses prog. text	Speed reading machine
U. S. Military Academy	Remedial English Grammar				X	Low % of curriculum Uses prog. text	"Autotutor" - map reading
Vanderbilt University	Not engaged in programmed instruction research						
Bradley University	Not engaged in programmed instruction research						
Lincoln University	Not engaged in programmed instruction research						
Univ. of Toledo	Business Statistics					Low % of curriculum Uses prog. text	None
Fordham University	Not engaged in programmed instruction research						
Drexel Institute of Tech.	Not engaged in programmed instruction research						
Univ. of Maryland	Writing Objectives for Instruction Elem. Statistics	X	X			Low % of curriculum Uses prog. text	None

TABLE 3.2-5 (CONT'D)

INSTITUTION	I. PROGRAMMED TEXTBOOKS: SUBJECTS	METHOD OF PROGRAMMING: B	L	CPB	CPL	COMMENTS AND/OR STATISTICAL ANALYSES OF STUDENT PERFORMANCE	II. TEACHING MACHINES: DESCRIPTION OF SYSTEM
Univ. of Missouri	Various experimental programs					Low % of curriculum Uses prog. text	8 mm film loops for training
Univ. of South Dakota	Not engaged in programmed instruction research						
Clarkson C. of Tech.	Not engaged in programmed instruction research						
University of Idaho	Not engaged in programmed instruction research						
Central Washington State College	Algebra Foreign Languages Psychology					Low % of curriculum Uses prog. text	Primarily for demo. and training, secondarily for instruction - TMI Groiler (4 ea.) Foranger (6 ea.), Didak (3 ea.) Autotutor (1 ea.)
Univ. of Delaware	None						Autotutor (English, Statistics)
Princeton University	Not engaged in programmed instruction research						
UCLA	Various subjects and methods						None
Clemson University	Not engaged in programmed instruction research						
Univ. of Tennessee	English Various others		X			Low % of curriculum Uses prog. text	None
U. of West Virginia	Mathematics			X		Low % of curriculum Uses prog. text	None
MIT	No programmed text or teaching machine research (See CAI)						
Univ. of Florida	No programmed text or teaching machine research (See CAI)						

TABLE 3.2-5 (CONT'D)

I. PROGRAMMED TEXTBOOKS							II. TEACHING MACHINES
INSTITUTION	SUBJECTS	METHOD OF PROGRAMMING				COMMENTS AND/OR STATISTICAL ANALYSES OF STUDENT PERFORMANCE	DESCRIPTION OF SYSTEM
		B	L	CPB	CPL		
Calif. State College of Long Beach	Evaluation in Ed.	X				Low % of curriculum	Autotutor - electronics
	Statistics		X			Uses prog. text	Video-sonic - mechanics
	Evaluation in Secondary Education	X					Both for demo.
U. of North Dakota	Computer Sci.			X		Low % of curriculum	None
	Statistics			X		Uses prog. text	
University of Utah	Reading Ed. Psychology Statistics					Low % of curriculum Uses prog. text	None
University of Georgia	Various subjects		X			Low % of curriculum Uses prog. text	None
University of Oregon	Not engaged in programmed instruction research						
South Dakota State U.	English					Low % of curriculum Uses prog. text	Language lab
U. of Texas at El Paso	Education Mathematics					Low % of curriculum Uses prog. text	Video taped lectures and CCTV
Louisiana State Univ.	Not engaged in programmed instruction research						
Univ. of Colorado	Business Administration	X				Low % of curriculum	None
	English		X			Uses prog. text	
	A-V Equip. Opr.		X				
Georgia Inst. of Tech.	Not engaged in programmed instruction research						
Texas Christian Univ.	Statistics Ed. Psychology					Low % of curriculum Uses prog. text	None

TABLE 3.2-5 (CONT'D)

I. PROGRAMMED TEXTBOOKS							II. TEACHING MACHINES
INSTITUTION	SUBJECTS	METHOD OF PROGRAMMING				COMMENTS AND/OR STATISTICAL ANALYSES OF STUDENT PERFORMANCE	DESCRIPTION OF SYSTEM
		B	L	CPB	CPL		
Purdue University	Chemical Engineering Ed. Psychology Statistics					Low % of curriculum Uses prog. text	Min-Max III (40) Rapid-Raters (100)
Univ. of Oklahoma	Elem. Algebra Groups		 X	X		Low % of curriculum Uses prog. text	None
Boston University	No specific data given						
Los Angeles State Col.	Various					Experimental only	Experimental only: Autotutor, Language Master, Min-Max, Concepto-Graph, Mast, Deveraux, Memo-Tutor, NAK-7, Auto-Score, Billerette
Illinois Teachers Col.	Programmed Instr. Mathematics English Grammar		 X X		X	Low % of curriculum Uses prog. text	Min-Max Modified Skinner device
Oklahoma State Univ.	No programmed text or teaching machine research						
Temple University	Math Health Physical Education		X X X			Low % of curriculum Uses prog. text	None
Univ. of So. Calif.	No programmed text or teaching machine research						

TABLE 3.2-6

COMPUTER ASSISTED INSTRUCTION
QUESTIONNAIRE RESULTS
(2 FEBRUARY 1967)

III. COMPUTER ASSISTED INSTRUCTION

INSTITUTION	NO. OF COMP. SYS.	SPECIFIC SYSTEMS	APPLICATION	LANG.	INSTRUCTIONAL LANG. USED	SUBJECTS TAUGHT	OPR	EXP	NAME OF PROJECT	COMMENTS
California Inst. of Technology	---	----	----	---	----	----	-	-	---	Note 1
Baylor University	---	----	----	---	----	----	-	-	---	Note 1
University of Alabama	---	----	----	---	----	----	-	-	---	Note 1
The City College, New York	---	----	----	---	----	----	-	-	---	Note 1
Colgate University	1	IBM 1620	Stu. Sched.	FORTRAN II	----	----	-	-	---	Note 1
North Texas State Univ.	---	----	----	---	----	----	-	-	---	Note 1
Indiana University	7	IBM 7040	Data Red.	FORTRAN		Matrix Algebra		X		
		CDC 3600	Data Red.	FORTRAN		Statistics		X		
			Info. Ret.	FORTRAN		FORTRAN IV		X		
			Simulation	FORTRAN, SIMSCRIPT, COMIT II	COURSE-WRITER					
			Cur. Dev.	Various						
		IBM 1460	Stu. Sched.	FORTRAN						
			Grading	FORTRAN						
			Cur. Dev.	Various						
			CAI	Various						
		CDC 6-15	Data Red.	FORTRAN						
		IBM 1800	Stimulus-Control	FORTRAN Machine						
		IBM 360/30	----	---						
Xavier University	---	----	----	---	----	----	-	-	---	Note 1
University of Miami	---	----	----	---	----	----	-	-	---	Note 1

TABLE 3.2-6 (CONT'D)

III. COMPUTER ASSISTED INSTRUCTION										
INSTITUTION	NO. OF COMP. SYS.	SPECIFIC SYSTEMS	APPLICATION	LANG.	INSTRUCTIONAL LANG. USED	SUBJECTS TAUGHT	OPR	EXP	NAME OF PROJECT	COMMENTS
University of Texas	10	IBM 360/30 CDC 6600 IBM 1401, 1440 IBM 1500	Stu. Sched. Grading Info. Ret Cur. Dev., CAI	Various CWI & II APL	Course-writer I&II APL	Chemistry Statistics German Psychology Mathematics		X X X X X		
Univ. of Connecticut	5	IBM 7040 IBM 1401 IBM 7094 (MIT) IBM 1620 IBM 1410 PDP 5	Simulation Stu. Sched. Grading CAI	FORTRAN FORTRAN CTSS, FORTRAN	Course-writer	Variety of courses (CTSS - MIT Remote)				
Texas A&M University		Various in addition to Data Processing Center							CATE	Note 1
Rice University	---	----	----	---	----	----	-	-	---	Note 1
USN Postgraduate School	2	IBM 1401 CDC 1604	Simulation Info. Ret. Research	FORTRAN FORTRAN ALGOL		Mathematics		X		Exp. abandoned
Concordia Teachers Col.	1	IBM 1401	Grading	FORTRAN						
Bowling Green Univ.	---	----	----	---	----	----	-	-	---	Note 1

TABLE 3.2-6 (CONT'D)

III. COMPUTER ASSISTED INSTRUCTION										
INSTITUTION	NO. OF COMP. SYS.	SPECIFIC SYSTEMS	APPLICATION	LANG.	INSTRUC-TIONAL LANG. USED	SUBJECTS TAUGHT	OPR	EXP	NAME OF PROJECT	COMMENTS
U. S. Military Academy	1	(3) GE-225 (1) Datanet 30	Data Red., Simulation, Stu. Sched, Grading, Comp. Instr., Scientific Problem Solving, Concordance prep.	FORTRAN GAP B. P.	CADETRON (a dialect of FORTRAN)	Civil Engr.		X	CADETS	
Vanderbilt University	---	----	----	---	----	----	-	-	---	Note 1
Bradley University	---	----	----	---	----	----	-	-	---	Note 1
Lincoln University	---	----	----	---	----	----	-	-	---	Note 1
University of Toledo	1	----	Not for CAI							
Fordham University	---	----	----	---	----	----	-	-	---	Note 1
Drexel Institute of Technology	---	----	----	---	----	----	-	-	---	Note 1
Univ. of Maryland	---	----	----	---	----	----	-	-	---	Note 1
University of Missouri	5	IBM 7040 IBM 1620 IBM 1410 IBM 360/40 IBM 360/30 IBM 360/20	Research Geology Medical Engineering Data Proc. Data Proc.							

TABLE 3.2-6 (CONT'D)

III. COMPUTER ASSISTED INSTRUCTION

INSTITUTION	NO. OF COMP. SYS.	SPECIFIC SYSTEMS	APPLICATION	LANG.	INSTRUCTIONAL LANG. USED	SUBJECTS TAUGHT	OPR	EXP	NAME OF PROJECT	COMMENTS
Univ. of South Dakota	---	-----	----	---	----	----	-	-	---	Note 1
Clarkson C. of Tech.	---	-----	----	---	----	----	-	-	---	Note 1
University of Idaho	---	-----	----	---	----	----	-	-	---	Note 1
Central Washington State College	1	IBM 1620	Stu. Sched. Grading	FORTRAN	----	----	-	-	---	Note 1
Univ. of Delaware		IBM 7094 IBM 1401 IBM 1620 SDS 9300	Stu. Sched. CAI Financial Admissions	FAP/ FORTRAN CW	Course-writer	Mathematics Mythology		X X	Ed Tech	
Princeton University	---	-----	----	---	----	----	-	-	---	Note 1
UCLA	5	UNIVAC 1108 IBM 360 IBM 7044-7094 IBM 1410 IBM 1620 1794 + (2) 1401	Data Red. Info. Ret. Simulation CAI Instr. at Programming Scientific	COBOL FORTRAN, Sym-script GPSS CW Mach. Lang., FORTRAN FORTRAN	Course-writer	In the development stage				
Clemson University	---	-----	----	---	----	----	-	-	---	Note 1
Univ. of Tennessee	---	-----	----	---	----	----	-	-	---	Note 1

TABLE 3.2-6 (CONT'D)

III. COMPUTER ASSISTED INSTRUCTION										
INSTITUTION	NO. OF COMP. SYS.	SPECIFIC SYSTEMS	APPLICATION	LANG.	INSTRUCTIONAL LANG. USED	SUBJECTS TAUGHT	OPR	EXP	NAME OF PROJECT	COMMENTS
Univ. of West Virginia	2	IBM 1401	Info. Ret. Stu. Record	Auto-coder FORTRAN COBOL						
		IBM 7040	Info. Ret. Stu. Record Simulation Stu. Sched. Grading Cur. Dev. CAI	Auto-coder FORTRAN COBOL						
MIT		PDP-7	Simulation	FORTRAN		Simulations & Displays, Tutoring via TTY			ELIZA	
		IBM 7094	CAI	MAD-SLIP						
University of Florida	3	IBM 1401	Info. Ret. CAI	CW II	Course-writer II	Statistics		X		
Calif. State Col. of Long Beach	2	UNIVAC 1107	Data Red. Info. Ret. Stu. Sched. Grade Re-port	FORTRAN						Note 1
		IBM 1620	Data Red. Info. Ret.	FORTRAN						
Univ. of North Dakota	1	IBM 360/30	CAI	FORTRAN		Engineering				
University of Utah	2	UNIVAC 1108 1108 & PDP-8	Data Red. Comp. Graphics	FORTRAN Assem. Lang.						Note 1
		IBM 7044	Simulation Stu. Sched. Grading	Simscript COBOL FORTRAN						

TABLE 3.2-6 (CONT'D)

III. COMPUTER ASSISTED INSTRUCTION

INSTITUTION	NO. OF COMP. SYS.	SPECIFIC SYSTEMS	APPLICATION	LANG.	INSTRUCTIONAL LANG. USED	SUBJECTS TAUGHT	OPR	EXP	NAME OF PROJECT	COMMENTS
University of Georgia	2	IBM 7094 IBM 1401 IBM 1620	Info. Ret. Simulation CAI Stu. Sched. Grading	FORTRAN Belfap FORTRAN	Belfap					
University of Oregon	---	----	----	---	----	-----	-	-	---	Note 1
So. Dakota State Univ.	---	----	----	---	----	-----	-	-	---	Note 1
U. of Texas at El Paso	---	----	----	---	----	-----	-	-	---	Note 1
Louisiana State Univ.	---	----	----	---	----	-----	-	-	---	Note 1
Univ. of Colorado	---	----	----	---	----	-----	-	-	---	Note 1
Georgia Inst. of Tech.	1	Burroughs 5500	Info. Ret. Stu. Sched. Grading	Algol						Note 1
Texas Christian Univ.	2	IBM 1401 IBM 1620 Remote Term. to U. of Tex. IBM 1440	CAI		Coursewriter I & II					
Purdue University	2 (CAI)	IBM 1401 TRW 530	CAI CAI	CW CW	Coursewriter	Mathematics Home Ec. Speech Russian Statistics		X X	CAI-PURDUE	

TABLE 3.2-6 (CONT'D)

III. COMPUTER ASSISTED INSTRUCTION										
INSTITUTION	NO. OF COMP. SYS.	SPECIFIC SYSTEMS	APPLICATION	LANG.	INSTRUC-TIONAL LANG. USED	SUBJECTS TAUGHT	OPR	EXP	NAME OF PROJECT	COMMENTS
Univ. of Oklahoma	13	(2) CDC - 615 (2) IBM -1620 (2) IBM -1401 IBM -1410 IBM -1710 OSAGE	Data Red., Info. Ret., Simulation, Grading, Cur. Dev., CAI, Comp. Lang. Dev., Num. Analyses	Various	Coursewriter I & II	Mathematics Comp. Prog. Medicine Lab. Theory	X X X X			
Boston University	No specific data given									
Los Angeles State Col.	---	----	---	---	----	-----	-	-	---	Note 1
Illinois Teachers Col.	---	----	---	---	----	-----	-	-	---	Note 1
Oklahoma State Univ.	---	----	---	---	----	Botany	X			
Temple University	1	----	Info. Ret. CAI							
Univ. of So. Calif.	6	IBM 1401 Honeywell 200, 400, & 800 IBM 1620 Q-32 (at SDC)	CAI	PLANIT		Statistics		X	PLANIT (SDC)	

Note 1: Not engaged in CAI research

3.2.4 CAI Systems Analysis

This paragraph outlines the significant points and conclusions that were developed as a result of three different analyses. The system's elements analyzed were: User terminals, computer central processors, and author languages.

The terminals analyzed were those associated with Project GROW, the PLATO system, SDC, University of California at Irvine, University of California at Santa Barbara, and the Brentwood and Walter Hays system. In addition, the Philco-Ford Corporation's, Philco Houston Operations' Model D-20 was discussed because of its several unique qualities which are directly applicable to CAI.

The computing systems analyzed were those associated with the seven systems previously mentioned. Insufficient information was provided by the University of California, Santa Barbara, to make a comprehensive evaluation.

The author languages analyzed were coursewriter II and INFORM. These were selected for analysis since they were the only two that are user-oriented and capable of controlling visual display systems.

The analysis is presented in the following subparagraphs.

3.2.4.1 Terminals

3.2.4.1.1 General

Terminals are hardware devices used by students and course authors to input information into the computer processing system and monitor curricular material generated for the user by the computer system. The terminals presently utilized in CAI systems range from simple teletype machines to sophisticated display systems equipped with light pens, random access audio tape reproducers, and specially designed entry devices.

3.2.4.1.2 Configurations

Three basic system configurations for terminals are utilized and will be addressed in this report as centralized, remote clustered, and remote decentralized. In the centralized configuration, the terminal devices are located in the same room or functional area adjacent to the computing facilities.

In the remote clustered configuration, the terminal devices are located in the same functional area; however, the computing facilities are physically removed and require phone lines or line amplifiers to distribute the signals to the users.

The remote decentralized configuration is the same as the remote clustered configuration, except that only one terminal is involved at each location. Of the seven systems reviewed, four had adjacent cluster terminals, two had remote clustered terminals, and one had a remote decentralized configuration. It is significant to note that all participants indicated that their long-range plans considered the use of a remote clustered configuration, the obvious advantage here being that an increased student population can be reached with a resultant decrease in CAI costs per student.

Eight terminals were analyzed to determine the following characteristics: input control, display capability, terminal flexibility, and expansibility. Two of the terminals analyzed, although not associated with the systems reviewed, have incorporated into their designs certain characteristics that are worth noting in the analysis. A summary of these characteristics is presented in Table 3.2-7.

3.2.4.1.3 Display Medium

Three of the eight terminals examined have no visual display capability other than a paper copy printout of generated information. Of these three, two were presenting simple drill and practice exercises and elementary facts and concepts. The third was presenting a course in statistical inference. It seems reasonable to conclude that this type of terminal is best suited for those subjects which require a minimum of display data for student interpretation and comprehension.

Of the remaining terminals, three employ a digital/television (D/TV) display system and two utilize an analog display system (stroke writer). All are limited in the amount of characters (data density) that can be presented; all have a specific character font and fixed character height and width. The maximum repertoire is 128 characters. All have limited vector generation capability. It is important to note that these systems do not generate vectors in the conventional manner; i.e., specifying a start point with a given slope and length, or specifying a start and end point. Rather, vector generation is accomplished on a character basis; i.e., within a given dot matrix used to construct a character, there exists a finite number of combinations of dots which will produce vectors in a variety of angles and positions within the matrix.

TABLE 3.2-7

SUMMARY OF TERMINAL CHARACTERISTICS

SYSTEM \ PARAMETER	TELE-TYPE	TYPE-WRITER	LIGHT PEN	DISPLAYABLE CHARACTERS	CHARACTER REPERTOIRE	COST	CENTRAL-IZED	REMOTE CLUSTERED	REMOTE DECEN-TRALIZED
PROJECT GROW		YES (1) PER TER-MINAL	YES (1) PER TER-MINAL	800 CHARACTERS 20 ROWS OF 40 CHARACTERS/ROW	97 CHARACTERS AND 15 CONTROL FUNCTIONS			X	
PLATO	YES (1) PER TER-MINAL			APPROXIMATELY 15 ROWS OF 32 CHARACTERS/ROW	96 CHARACTERS AND CONTROL FUNCTIONS		X		
SDC	YES (1) PER TER-MINAL				STANDARD TTY CHARACTER REPERTOIRE				X
UNIVERSITY OF CALIFORNIA AT IRVINE		YES (1) PER TER-MINAL			106 CHARACTERS AND CONTROL FUNCTIONS		X		
UNIVERSITY OF CALIFORNIA AT SANTA BARBARA				APPROXIMATELY 500 CHARACTERS 20 ROWS OF 25 CHARACTERS/ROW	UPPER CASE ALPHA-BET AND NUMERALS 0 THRU 9. OTHER CONTROL FUNCTIONS AND VECTOR GENER-ATION PROVIDE 520 FUNCTIONAL ENTRIES AND 22 CONTROL FUNCTIONS.	$5000 PLUS COST OF CRT SCOPE	X		
BRENTWOOD		YES (1) PER TER-MINAL	YES (1) PER TER-MINAL	640 CHARACTERS 16 ROWS OF 40 CHARACTERS/ROW	128 CHARACTERS		X		
WALTER HAYS	YES (1) PER TER-MINAL				STANDARD TTY CHARACTER REPERTOIRE			X	
PHILCO MODEL D-20		YES (1) PER TER-MINAL		768 CHARACTERS 24 ROWS OF 32 CHARACTERS/ROW	56 CHARACTERS, SYMBOLS AND CON-TROL FUNCTIONS EXPANDABLE TO 64	$\approx$ 8000		NOT APPLICABLE	

3.2.4.1.4 Entry Devices

Four types of data entry devices were utilized; viz., teletype keyboards, typewriter keyboards, special keyboards, and light pens.

Only one terminal used a special keyboard (experiments were being conducted in on-line programming). Seven used a teletype or typewriter keyboard, and of these seven, two used a light pen as a supplemental control entry to the computer. The keyboard entry devices are used to construct messages or multiple-letter inputs while the light pen is restricted to discrete control entry. None of the terminals have the capability to generate a signal which controls hardcopying equipment.

3.2.4.1.5 Conclusions

This subparagraph outlines the most readily apparent conclusions that can be formulated from the foregoing analysis.

A. None of the terminals have built-in expansibility with the possible exception of the Philco SAVI unit and this applies only to audio.

B. None of the terminals are adaptable to other systems. As previously mentioned, this is due to certain hardware constraints; i.e., interface equipments and display system organization, and the author language instructional repertoire. It appears that terminals, like author languages, have been personalized for a specific system or application.

C. None of the systems are utilizing the light pens most impressive feature; viz., data management. Nor are they utilizing the capability to construct displays such as graphics and schematics. It should be noted that to utilize these capabilities would require sophisticated software packages whose costs may not be offset by their effectiveness when directed toward specific student populations.

D. Teletype and typewriter keyboard terminals are used in remote cluster or remote single configurations while keyboard plus visual display terminals are used in adjacent cluster configurations. This is influenced by the bit rates, update requirements, reliability, and cost. It is much simpler and more cost-effective to drive a teletype or typewriter keyboard terminal over a 60 words per minute (wpm) or 100 wpm TTY line than it is visual display over a high quality voice grade circuit or other relatively high bit rate line.

E. The typewriter keyboard apparently has become an integral part of the terminal unit. The primary factor influencing this fact is that of cost. Typewriter keyboards can be rented for a comparatively modest cost when considering the costs incurred in designing special keyboards or modification of existing keyboards.

F. Although it is an accepted fact that typewriter keyboards are not the most effective or efficient device for student use, no one has as yet offered a solution or even a reasonable suggestion as to its replacement.

When appraising the curriculum and the terminal devices, it is reasonable to conclude that these types of devices are adequate for present applications and will suffice for applications in the immediate future (18 - 24 months). However, the technologies being developed in the area of curriculum design will rapidly antiquate this type of entry device. A more versatile device must be designed which can fully utilize the capabilities of the computing system.

G. When consideration is given to vector generation capability, methods of presenting textual data, desirability of graphics generation, and display update characteristics it becomes apparent that the keyboard plus visuals terminal is superior to the keyboard only terminal. Refer to Table 3.2-8. This is manifested when considering that all new systems being designed have visual display capability and all the systems undergoing modification or planning modifications will be incorporating visual display capability.

H. Terminals incorporating visual display capability are considerably more expensive; however, when amortized over a 5 or 6 year period the monthly cost of the terminal with visual display capability approaches that of rental for the keyboard-only terminal. When translating cost into capability it is found that the visual display terminal can present more

TABLE 3.2-8

KEYBOARD ENTRY DEVICES

PARAMETER	KEYBOARD ENTRY DEVICE ONLY	KEYBOARD AND LIGHT PEN PLUS VISUALS
1. VECTOR GENERATION CAPABILITY	NO	YES - LIMITED TO BLOCK DIAGRAMS AND RELATIVELY SIMPLE GRAPHICS
2. PRESENTATION OF TEXTUAL DATA	YES - IN A TYPEWRITER MODE ONLY	YES - RANDOM PLACEMENT OF CHARACTERS OR TYPEWRITER MODE
3. PRESENTATION OF GRAPHIC DATA	NO	YES
4. GRAPHICS CONSTRUCTION FROM ENTRY DEVICE	NO	NO
5. MESSAGE CONSTRUCTION CAPABILITY	YES - NO APPARENT LIMITATION ON NUMBER OF INPUT CHARACTERS PER MESSAGE	YES - PRESENTLY LIMITED TO 128 CHARACTERS PER MESSAGE
6. DISCRETE ENTRY CAPABILITY	YES	YES
7. HARDCOPY GENERATION CAPABILITY	YES - INHERENT IN SYSTEM	YES
8. INPUT ERROR CORRECTION CAPABILITY	YES	YES
9. INSTANTANEOUS DISPLAY UPDATE	NO - UPDATED APPROX IS CHARACTERS PER SECOND	YES
10. DYNAMIC UPDATE OF EXISTING CHARACTERS	NO	YES
11. CHANGEABLE FONTS	YES - IN SOME CASES THIS IS IMPRACTICAL	NO - UNLESS EXTENSIVE PROGRAMMING MODIFICATIONS ARE INCORPORATED
12. CHANGEABLE DATA DENSITIES	NO	NO - UNLESS EXTENSIVE PROGRAMMING MODIFICATIONS ARE INCORPORATED AND VISUAL DISPLAY MODIFIED

complex curriculums, operate with more involved teaching strategies, and in general provide significantly more data to the user per unit time. And, perhaps most important, the computer is freed from simply being a page turner or frame reproducer and is enabled to provide complex curricular material in a variety of modes.

I. With consideration given to certain system aspects of CAI, the capabilities of three of the terminals could be used in flight controller applications; viz., IBM 1510 instructional system, SAVI, and PHO Model D-20.

3.2.4.1.6 Terminal Characteristics

As previously mentioned, the selection and development of hardware equipment for CAI systems is determined by the following criteria: adaptability, flexibility, expansibility, reliability, availability, and cost.

Adaptability is essentially a measure of how easily a terminal can be utilized with a variety of systems. As an example, a teletype terminal is not readily adaptable to a system that utilizes a visual CRT display device. However, assuming the instructional repertoire of the author language used with the teletype system can control a terminal with CRT capability, the terminal with visual display capability can easily be adapted to the teletype environment.

Flexibility is an attribute which is determined by the number of functions a terminal can perform in any given configuration and is a function of software initialization and hardware configuration. Expansibility is a feature which determines the additional capability (hardware addition) that can be provided to a terminal.

Basic hardware constraints; i.e., coding, line rates, interfaces and terminal configuration, and the characteristics of the author language utilized eliminate the characteristic of adaptability and is therefore not discussed.

Reliability figures are not available and terminal availability figures are of no significance in this analysis, and are, therefore, not discussed. The following tables and figures discuss each terminal in terms of the preceding characteristics.

UNIVERSITY OF CALIFORNIA

AT

IRVINE, CALIFORNIA

TABLE 3.2-9

IBM MODEL 1052 PRINTER-KEYBOARD

COST	SIZE	INPUT CONTROL	DISPLAY	TERMINAL FLEXIBILITY	TERMINAL EXPANSIBILITY
KEYBOARD ≈ \$65/MO RENTAL DATA SET RENTAL ≈ \$35/MO 1051 CONTROL UNIT ≈ \$75 - \$145/MO RENTAL		THE 1052 KEYBOARD IS ONE OF THE MODULAR COMPONENTS OF THE 1050 DATA COMMUNICATION SYSTEM. REFER TO FIGURE 3.2-20. TWO TYPES OF KEYS ARE PROVIDED: CHARACTER AND FUNCTION KEYS. TWO TYPES OF CODES ARE PROVIDED: UP-SHIFT CODES AND DOWN-SHIFT CODES. THE KEYBOARD FUNCTION KEYS AVAILABLE ARE: SPACE, BACKSPACE, LINE FEED, TAB, ALTERNATE CODING, RETURN AND SHIFT. THE <u>ALTN CODING</u> KEY DOES NOT GENERATE A CODE, RATHER IT ENABLES THE ALTERNATE FUNCTIONS LISTED ABOVE THE NUMERIC KEYS, TO BE IDENTIFIED TO THE COMPUTER. SIX OF THE FUNCTION KEYS DO NOT PRINT-OUT; VIZ., SPACE, LINE FEED, BACKSPACE, TAB, RETURN AND SHIFT. THIS IS IMPORTANT WHEN CONSIDERING THAT THE CHARACTER LIMIT PER BLOCK OF PRINT IS 150 CHARACTERS. A MAXIMUM OF 22 CHARACTERS (INCLUDING UP-SHIFTS, DOWN-SHIFTS, ETC.) ARE ALLOWED FOR STUDENT OR AUTHOR ID. EVERY COMPLETED INPUT MUST BE FOLLOWED BY AN EOB. ONCE THE EOB HAS BEEN ENTERED, THE LINE OF TYPE CANNOT BE ERASED. MECHANICAL INTERLOCK PREVENTS DEPRESSION OF MORE THAN ONE KEY AT A TIME. REFER TO FIGURE 3.2-21. THIS ILLUSTRATES THE SETTING OF CONTROL SWITCHES ADDITIONAL TO THE KEYBOARD SWITCHES. 106 CONTROL INPUTS ARE PROVIDED FROM THE KEYBOARD. TRANSMISSION RATE IS NOMINALLY 14.8 CHARACTERS/SECOND	PRINTED HARDCOPY KEYBOARD CODING DOES NOT PROVIDE FOR CONTROL OF CRT DISPLAYS.	THE 1052 PRINTER-KEYBOARD (PK) REQUIRES THE 1051 CONTROL FOR EFFECTIVE OPERATION. THE SYSTEM IS MODULAR IN THAT A PRINTER, PAPER TAPE READER, PAPER TAPE PUNCH, CARD READER AND CARD PUNCH CAN BE ADDED TO THE 1051 CONTROL UNIT AND CAN OPERATE WITH THE PK IN SEVERAL MODES. IN ADDITION, THE PRINTING ELEMENT (SIMILAR TO THE IBM SELECTRIC TYPEWRITER) CAN BE REPLACED TO PROVIDE ALTERNATE CHARACTER ARRANGEMENTS AND FONTS. EACH CONTROL UNIT IS CAPABLE OF DRIVING TWO MACHINE-READABLE INPUTS AND TWO MACHINE-READABLE OUTPUTS. 102 CHARACTERS, NUMERALS AND CONTROL FUNCTIONS ARE PROVIDED BY THE PK. IN ADDITION, 11 CONTROL FUNCTIONS ARE PROVIDED FOR PRINT AND PUNCH CONTROL, ETC.	NONE. IT SHOULD BE NOTED, HOWEVER, THAT ADDITIONAL TERMINALS AND CONTROL UNITS CAN BE PURCHASED OR RENTED.

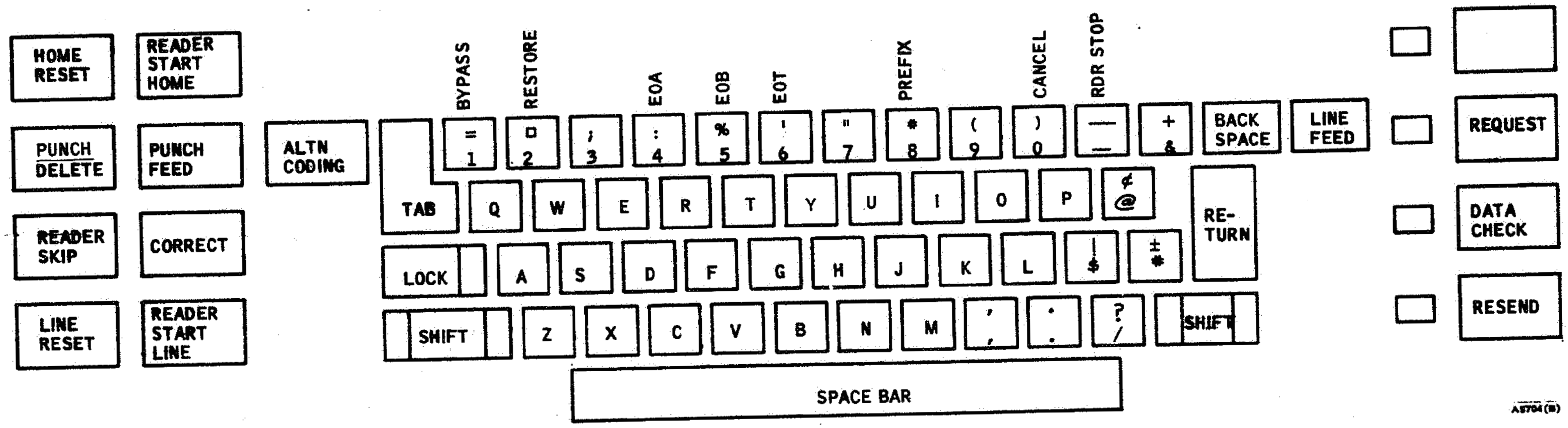
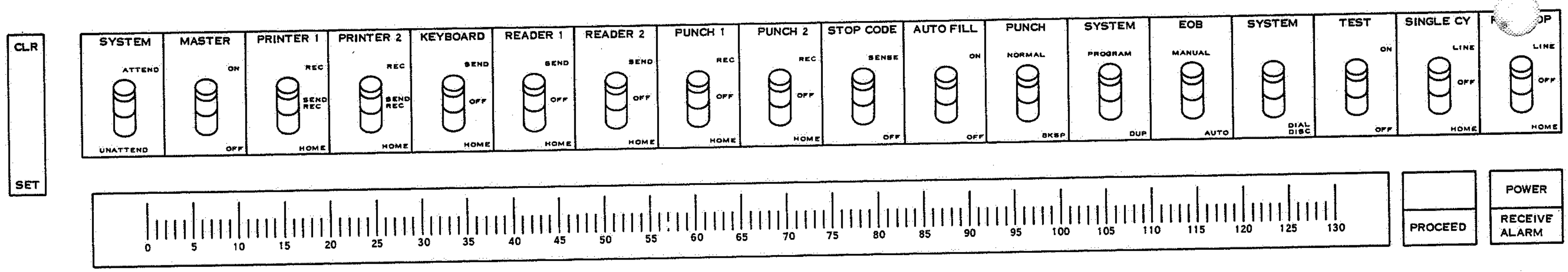


Figure 3.2-19 IBM Model 1052 Keyboard



FRONT PANEL SWITCHES

SWITCH NAME	POSITION
SYSTEM*	ATTEND (UP)
MASTER	OFF (DOWN)
PRINTER 1*	SEND/REC (MIDDLE)
PRINTER 2	HOME (DOWN)
KEYBOARD*	SEND (UP)
READER 1	OFF
READER 2	OFF
PUNCH 1	OFF
PUNCH 2	OFF
STOP CODE	OFF
AUTO FILL	OFF
PUNCH	NORMAL
SYSTEM	PROGRAM
EOB	MANUAL (UP)
SYSTEM*	(UP)
TEST*	OFF (DOWN)
SINGLE CY	OFF
RDR STOP	OFF

*THE MINIMAL SET OF SWITCHES REQUIRED FOR CAI

A5706 (C)

Figure 3.2-20 Front Panel Switches on the IBM Model 1052 Printer Keyboard

UNIVERSITY OF CALIFORNIA

AT

SANTA BARBARA, CALIFORNIA

TABLE 3.2-10

BOLT, BERANEK AND NEWMAN (BBN) TELEPUTER

COST	SIZE	INPUT CONTROL	DISPLAY	TERMINAL FLEXIBILITY	TERMINAL EXPANSIBILITY
TELEPUTER $5000 TELEPUTER CONTROL UNIT. STANDARD MODEL $25,000 IMPROVED MODEL $40,000 DATA SET CONTROLLER UNIT $10,000 - $20,000	DESK-MOUNTED CONSOLE: 72" IN LENGTH, 48" IN HEIGHT, 36" IN DEPTH. TELEPUTER CONTROL UNIT: 55" IN HEIGHT, 25" IN DEPTH, 23" IN WIDTH.	THE TERMINAL DEVICE CONSISTS OF A DOUBLE KEYBOARD, ONE FOR FUNCTION OPERATORS AND ONE FOR OPERANDS (REFER TO FIGURE 3.2-21). TYPICAL OPERATOR BUTTONS ARE SQRT (SQUARE ROOT), MAX (FIND MAXIMUM VALUE), AND THE LIKE. OPERANDS ARE REPRESENTED BY ALPHANUMERIC SYMBOLS, WHICH MAY BE EITHER CONSTANT OR ARBITRARY FUNCTIONS. THE OPERATOR PORTION OF THE KEYBOARD CONTAINS 26 OPERATORS WHICH CAN PROVIDE A MAXIMUM OF 260 UNIQUE INPUTS BY DEPRESSING THE SEMANTIC LEVEL OPERATOR KEYS. ELEVEN ADDITIONAL KEYS ARE PROVIDED FOR CONTROL. THIS OPERAND PORTION OF THE KEYBOARD PROVIDES 26 OPERAND KEYS WHICH CAN PROVIDE A MAXIMUM OF 260 UNIQUE INPUTS (STORAGE LOCATION ADDRESSES). ELEVEN ADDITIONAL KEYS ARE PROVIDED FOR CONTROL. OPTIMUM SYSTEM OPERATION IS WITH A 2400 BPS LINK; HOWEVER, 2000 BPS TELEPHONE CIRCUITS CAN BE USED.	THE DISPLAY IS A STANDARD TEKTRONIX STORAGE OSCILLOSCOPE TYPE 564. EACH SCOPE HAS A TYPE 2A60 VERTICAL AND HORIZONTAL PLUG-IN AMPLIFIER. THE CRT IS A 5-INCH MEDIUM PERSISTANCY, GREEN PHOSPHOR WHICH CAN DISPLAY ALPHANUMERIC CHARACTERS AND VECTOR DATA. CHARACTERS ARE WRITTEN AT AN APPROXIMATE RATE OF 25 CHARACTERS PER SECOND. APPROXIMATELY 20 ROWS CAN BE ACCOMMODATED, 25 CHARACTERS/ROW.	SEVERAL AREAS OF FLEXIBILITY AND CAPABILITY EXIST. THE INSTRUCTOR CAN DISPLAY WHAT HE IS DOING ON EACH OF THE STUDENT TERMINALS. STUDENT TERMINALS OPERATE INDEPENDENTLY, BUT THE INSTRUCTOR CAN MONITOR DATA ON ANY TERMINAL. THE STUDENT CAN SWITCH HIS DISPLAY TO THE INSTRUCTOR MODE AND DISPLAY HIS WORK TO THE REST OF THE CLASS ON THEIR TERMINALS. NINE CLASSIFICATIONS OF OPERATOR LEVELS ARE AVAILABLE TO THE USER; VIZ., SINGLE NUMBERS, REAL FUNCTIONS OR REAL VECTORS, COMPLEX FUNCTIONS OR COMPLEX VECTORS, REAL MATRICES, COMPLEX MATRICES, STATISTICAL PROGRAMS AND EDITING PROGRAMS. THE TERMINAL CAN BE USED BY EITHER A STUDENT OR AN INSTRUCTOR WITH ONLY AN ID CODE REQUIRED. IT CAN BE USED FOR PURE ON-LINE PROGRAMMING, TO LIMITED ACTIVITIES IN CAI. KEYBOARD FUNCTIONS CAN BE MODIFIED BY SIMPLY REINITIALIZING TO THE COMPUTING SYSTEM. AS NOTED EARLIER EARLIER, 520 UNIQUE INPUTS AND 52 CONTROL INPUTS ARE PROVIDED. THE TERMINAL IS RATHER BULKY, AND DUE TO THIS FACTOR, PLUS THE ABUNDANCE OF CABLING, THE TERMINAL IS CONSIDERED TO BE A PERMANENT STRUCTURE.	THE KEYBOARD CANNOT BE EXPANDED BECAUSE OF MECHANICAL CONSTRAINTS. THE STANDARD MODEL CONTROL UNIT CAN CONTROL A MAXIMUM OF 16 TELEPUTER TERMINALS. THE IMPROVED MODEL CAN CONTROL UP TO 32 TERMINALS. IN ADDITION TO THE OSCILLOSCOPE DISPLAYS OF THE TELEPUTER TERMINAL, HARD-COPY OUTPUTS OF EITHER ALPHANUMERIC OR GRAPHICAL DATA CAN BE OBTAINED BY ATTACHING THE APPROPRIATE DEVICES TO THE TELEPUTER CONTROL UNIT. ALPHANUMERIC DATA IS PROVIDED ON THE MODEL 33 TELETYPE AND GRAPHICAL DATA ON THE X-Y PLOTTER. A GRAFACON TABLET CAN BE USED TO GENERATE INPUT DATA IF MINOR MODIFICATIONS ARE MADE TO THE CONTROL UNIT.

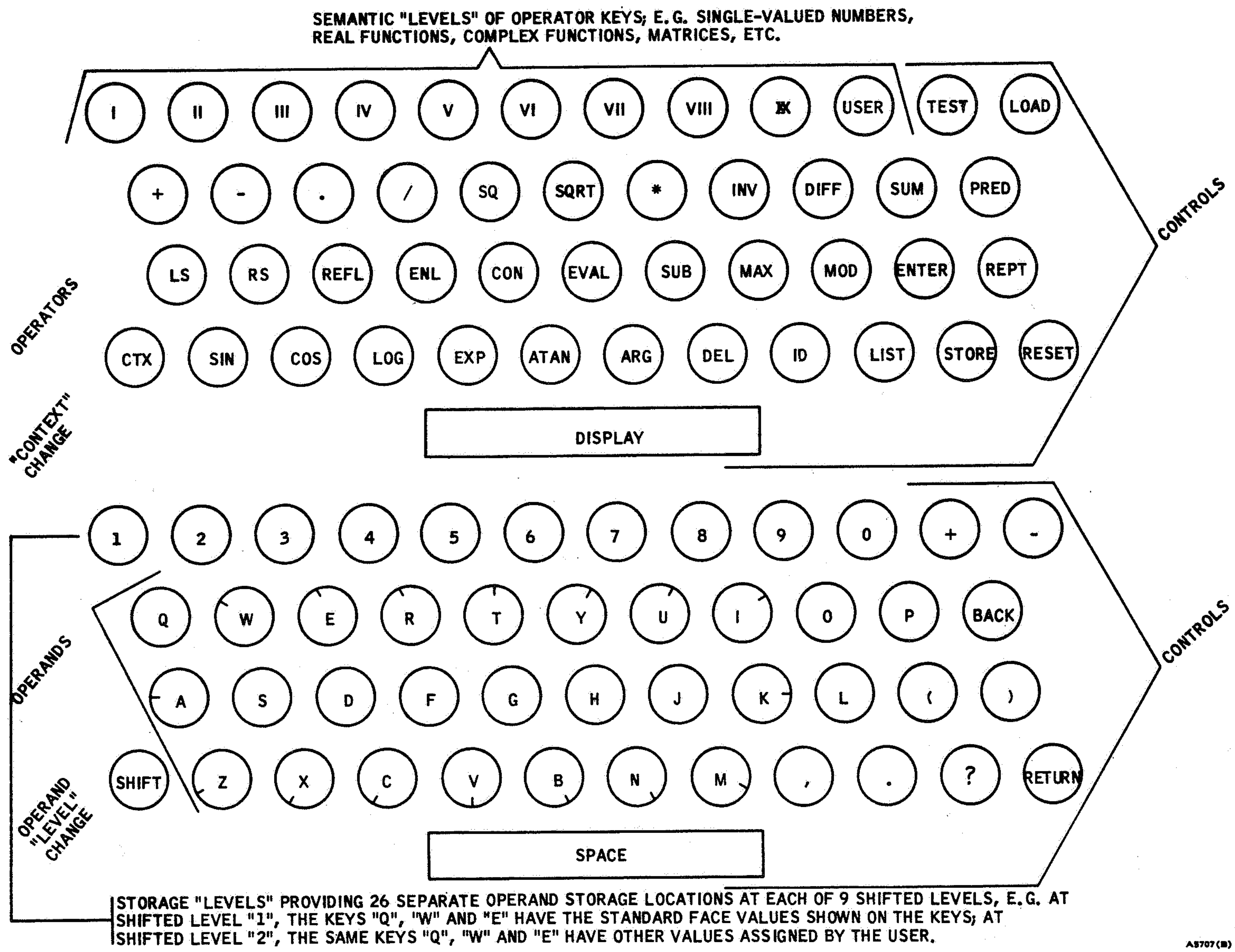


Figure 3.2-21 Bolt, Beranek and Newman (BBN) Teleputer Keyboard

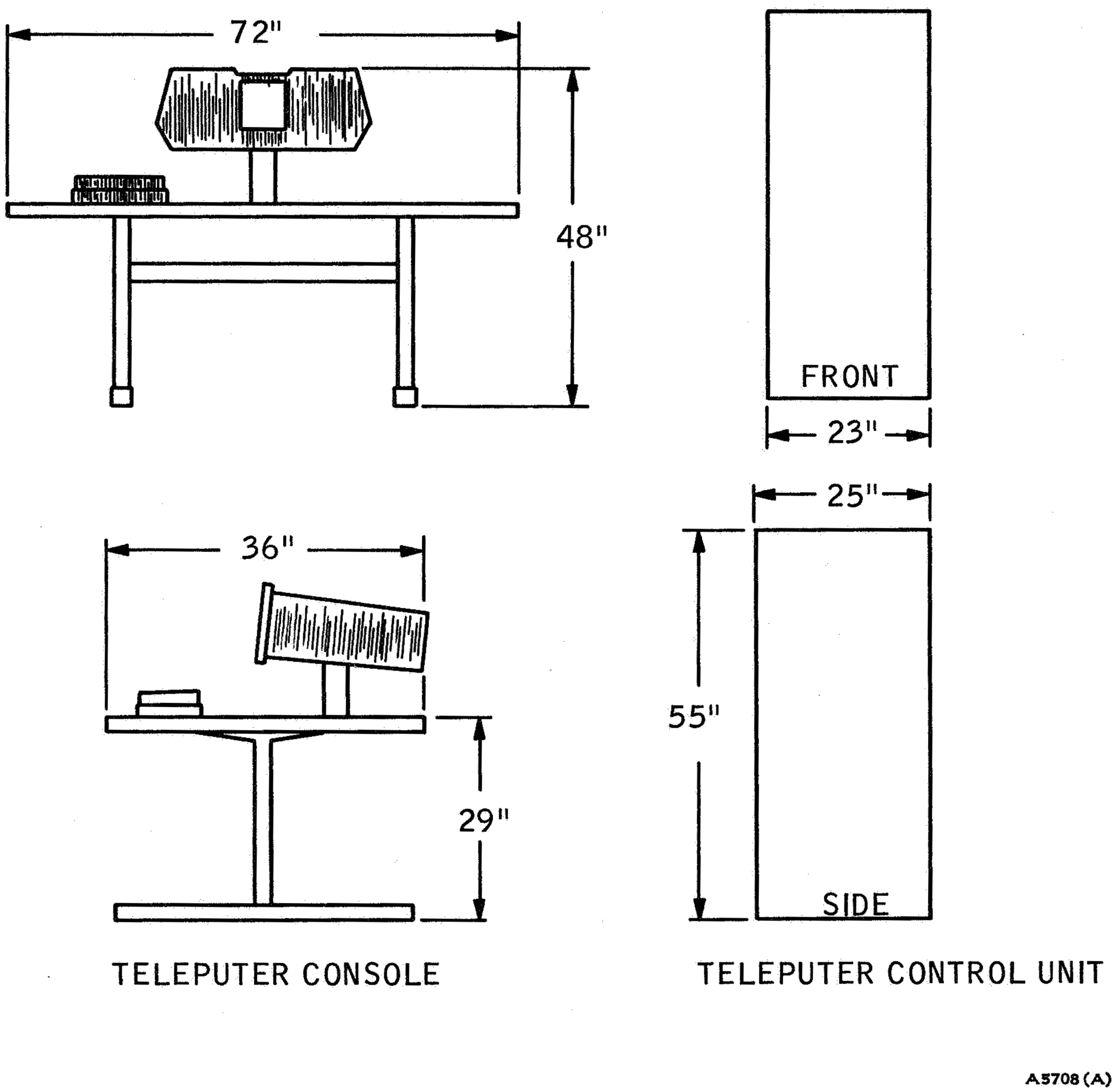


Figure 3.2-22 Bolt, Beranek and Newman (BBN) Teleputer Console and Control Unit Diagram

STANFORD PROJECT

BRENTWOOD SYSTEM

PALO ALTO, CALIFORNIA

TABLE 3.2-11

IBM 1500 SYSTEM (BRENTWOOD)

COST	COST	INPUT CONTROL	DISPLAY	TERMINAL FLEXIBILITY	TERMINAL EXPANSIBILITY
NOT AVAILABLE BECAUSE SYSTEM IS CONSIDERED EXPERIMENTAL.	NOT AVAILABLE	THE 1500 SYSTEM TERMINALS INSTALLED AT THE BRENTWOOD ELEMENTARY SCHOOL CAN BE USED IN ANY ONE OF THREE MODES: AUTHOR, STUDENT, OR PROCTOR. EACH TERMINAL IS EQUIPPED IN THE FOLLOWING MANNER: 1510 DISPLAY WITH KEYBOARD, 1512 IMAGE PROJECTOR, AUDIO TAPE DRIVE PLAY, AND PLAY/RECORD, AND LIGHT PEN. THE TYPEWRITER KEYBOARD (REFER TO FIGURE 3.2-23) CONTAINS 44 DATA KEYS AND PROVIDES 88 DATA CHARACTERS (44 UPPER CASE AND 44 LOWER CASE). THE ALTERNATE CODING KEY PROVIDES THE CAPABILITY TO ENTER AN ADDITIONAL 38 DATA CHARACTERS. IN ADDITION, 14 FUNCTION KEY CODES ARE AVAILABLE. (REFER TO FIGURE 3.2-24 AND TABLE 3.2-12). INSTRUCTIONS OF UP TO 123 CHARACTERS IN LENGTH MAY BE ENTERED INTO THE COMPUTER. MORE LENGTHY STATEMENTS ARE ACCOMMODATED BY DEPRESSING THE "CONTINUATION" KEY. WHEN TYPING TEXT FOR DISPLAY ON THE VIDEO SYSTEM, LINE LENGTH IS RESTRICTED TO 40 CHARACTERS. THE CONTINUATION FUNCTION IS PROVIDED. A LIGHT PEN (MANUFACTURER UNKNOWN) IS ALSO USED TO INPUT CONTROL INFORMATION TO THE COMPUTER. TABLE 3.2-13 ILLUSTRATES THE INPUT KEYBOARD CHARACTER CODES.	THE 1510 INSTRUCTIONAL DISPLAY CONTAINS A RECTANGULAR CRT FOR DISPLAY OF ALPHABETIC AND NUMERIC CHARACTERS AND LIMITED VECTORS. THE SYSTEM CAN DISPLAY A MAXIMUM OF 16 ROWS OF 40 CHARACTERS PER ROW, FOR A TOTAL OF 640 CHARACTERS. THESE ARE SELECTABLE FROM A TOTAL OF 128 DISPLAYABLE CHARACTERS. IT SHOULD BE NOTED THAT CHARACTER FONTS CAN BE MODIFIED BY REINITIALIZING THE CPU. THE 1512 IMAGE PROJECTOR HOLDS A DISPLAY SCREEN (9" X 7") ON WHICH FILMED IMAGES CAN BE PROJECTED IN BLACK OR WHITE OR IN COLOR. THE PROJECTOR UTILIZES A SELF-THREADING CARTRIDGE AND CAN STORE 1000 16 MM FILM STRIPS, EACH OF WHICH IS INDIVIDUALLY ADDRESSABLE BY THE COMPUTER FOR RANDOM ACCESS OPERATION.	THE SYSTEM IS SOFTWARE FLEXIBLE, I.E., THE KEYBOARD, LIGHT PEN, AND PROJECTOR CAN ASSUME DIFFERENT FUNCTIONS SIMPLY BY REINITIALIZING THE INPUT DEVICES. THE STATION CONTROL UNIT PROVIDES CONTROL FOR A MAXIMUM OF 32 INSTRUCTIONAL STATIONS. AS MENTIONED PREVIOUSLY, A TERMINAL MAY BE USED IN THE AUTHOR MODE DURING WHICH TIME HE CAN OPERATE ON ANY COURSE SEGMENT, EXAMINE STATEMENTS, MODIFY STATEMENTS, INSERT ADDITIONAL STATEMENTS, RELOCATE STATEMENTS, DELETE STATEMENTS, INSERT NEW STATEMENTS, EXECUTE A SECTION OF THE COURSE AND EVALUATE COURSE EFFECTIVITY. OPERATING IN THE STUDENT MODE, THE TERMINAL PROVIDES INDEPENDENT COURSE OPERATION, RESPONDS TO PROBLEMS AND QUESTIONS, AND REQUESTS FOR ASSISTANCE. IN THE PROCTOR MODE, THE TERMINAL PROVIDES CONTROL OVER OTHER INSTRUCTION STATIONS, AND ANY DEALING WITH THE STUDENT, THE AUTHOR, AND THE CONTROL SYSTEM.	THE 1510 IS A DESK-SIZE COMPACT TERMINAL THAT IS NOT OF A MODULAR DESIGN. ADDITIONAL EQUIPMENTS CANNOT BE EASILY ADDED-ON.

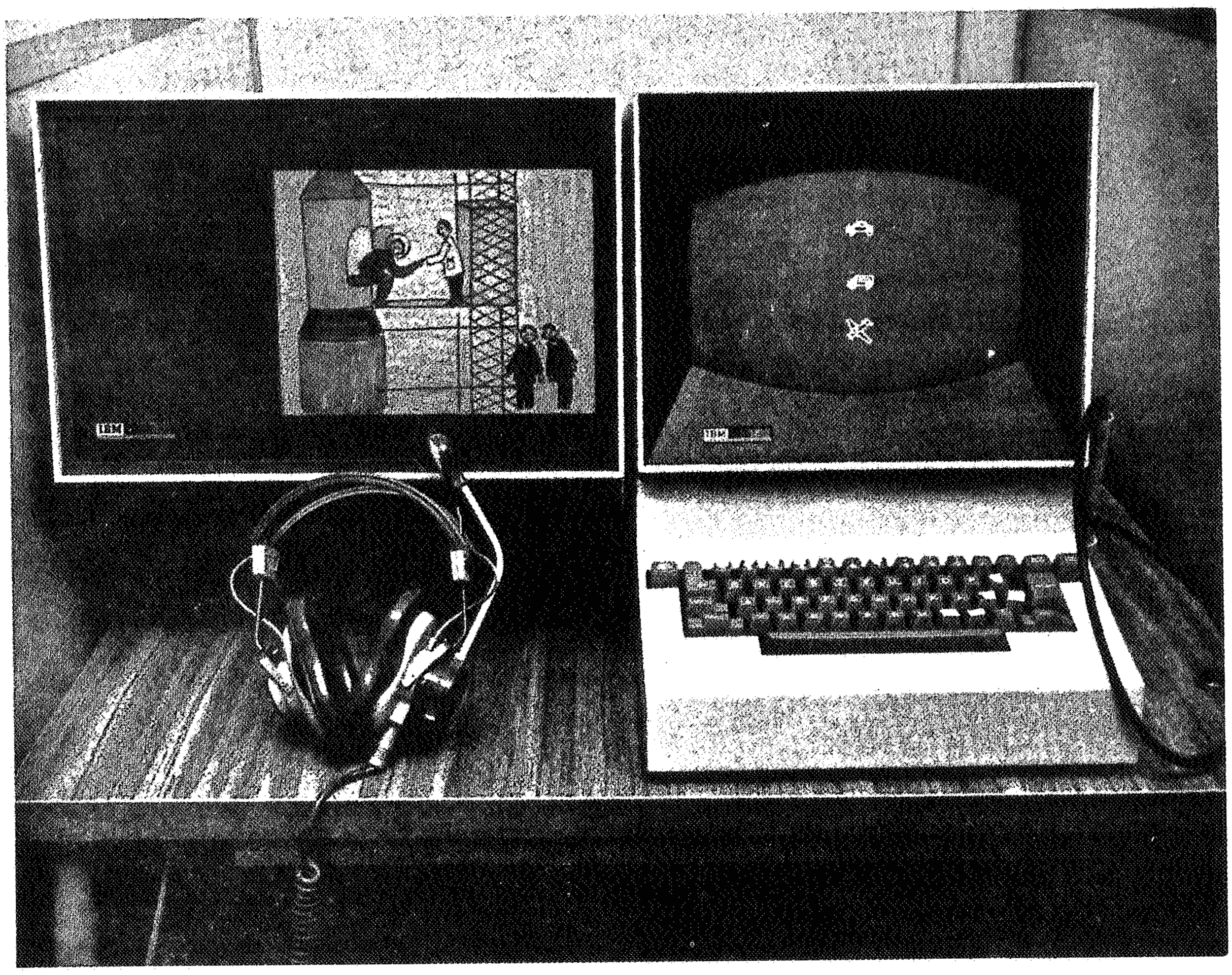


Figure 3.2-23 Stanford-Brentwood System Student Terminal

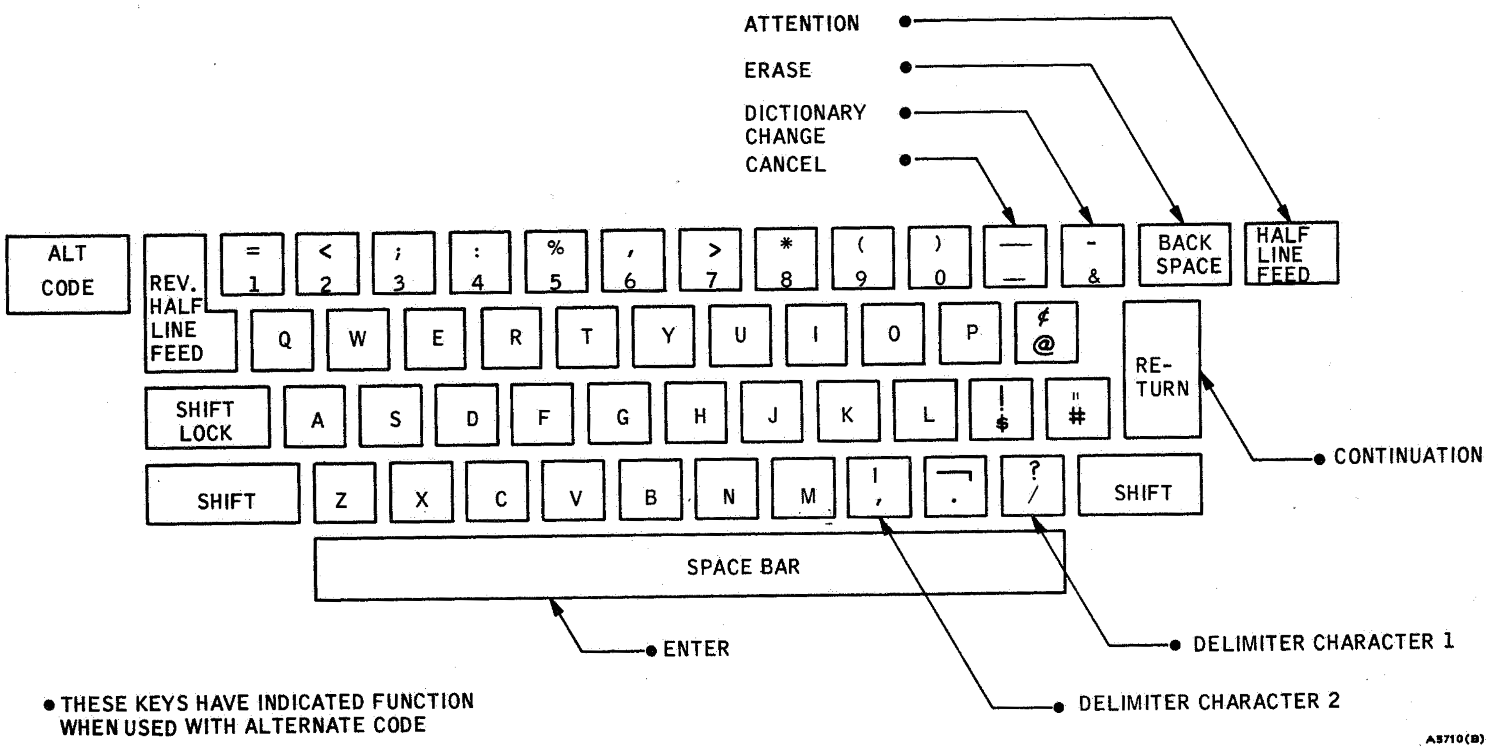


Figure 3.2-24 1510 Keyboard Arrangement

TABLE 3.2-12

SYSTEM CONTROL FUNCTION KEYS

FUNCTION	KEY USED WITH ALTERNATE CODING	DESCRIPTION
ATTENTION	HALF-LINE FEED	PROVIDES A MEANS OF ENTERING ATTENTION STATUS, WHICH STOPS STATION OPERATION
ENTER	SPACE BAR	WHEN STATION IS IN ATTENTION STATUS, USED TO RESUME STATION OPERATION. WHEN STATION NOT IN ATTENTION STATUS, USED TO END AUTHOR CONSTRUCTED COURSE STATEMENTS OR TO END STUDENT CONSTRUCTED RESPONSES.
ERASE	BACKSPACE	DELETES THE LAST CHARACTER FROM THE INPUT/OUTPUT AREA IN CORE STORAGE.
CANCEL	-(DASH)	DELETES ALL INPUT FROM THE INPUT/OUTPUT AREA THAT HAS BEEN KEYED SINCE THE LAST ENTER FUNCTION.
CONTINUATION	RETURN	PERMITS THE AUTHOR TO ENTER THE NEXT CHARACTER AT THE LEFT MARGIN OF THE NEXT LINE. NO RETURN (CARRIAGE) CHARACTER IS GENERATED.
DICTIONARY CHANGE	& (AMPERSAND)	PERMITS THE SELECTION OF A NEW DICTIONARY OF INSTRUCTIONAL DISPLAY CHARACTERS. ENTERING OF THE DICTIONARY CHANGE FUNCTION MUST BE FOLLOWED BY A CHARACTER KEY DEPRESSION TO SPECIFY THE NEW DICTIONARY.
DELIMITER 1 DELIMITER 2	/ (SLANT) , (COMMA)	PERMITS SEPARATION OF ARGUMENTS IN THE TEXT OF COURSE INSTRUCTIONS.

TABLE 3.2-13

IBM 1500 INSTRUCTIONAL SYSTEM CHARACTER CODES

KEYBOARD ENTRY	INSTRUCTIONAL DISPLAY OR FUNCTION PERFORMED	TYPEWRITER BALL	CHARACTER STREAM
SHIFT UP a - z	UPPER ALPHABETIC	A-Z	A-Z
a - z	LOWER ALPHABETIC	a-z	a-z
0 - 9	NUMERIC	0-9	0-9
,	,	,	,
.	.	.	.
/	/	/	/
S	S	S	S
#	#	#	#
@	@	@	+
&	&	&	&
_	_	_	_
SHIFT UP 1	=	=	=
SHIFT UP 2	<	<	<
SHIFT UP 3	;	;	;
SHIFT UP 4	:	:	:
SHIFT UP 5	%	%	%
SHIFT UP 6	'	'	'
SHIFT UP 7	>	>	
SHIFT UP 8	*	*	*
SHIFT UP 9	(	(	(
SHIFT UP 0	)	)	)

TABLE 3.2-13 (CONT'D)

<table>
<tr><th>KEYBOARD ENTRY</th><th>INSTRUCTIONAL DISPLAY OR FUNCTION PERFORMED</th><th>TYPEWRITER BALL</th><th>CHARACTER STREAM</th></tr>
<tr><td>SHIFT UP -</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>SHIFT UP &</td><td>+</td><td>+</td><td>-</td></tr>
<tr><td>SHIFT UP @</td><td>¢</td><td>¢</td><td>¢</td></tr>
<tr><td>SHIFT UP $</td><td>!</td><td>!</td><td>!</td></tr>
<tr><td>SHIFT UP #</td><td>"</td><td>"</td><td>"</td></tr>
<tr><td>SHIFT UP '</td><td>|</td><td>|</td><td>|</td></tr>
<tr><td>SHIFT UP .</td><td>¬</td><td>¬</td><td>¬</td></tr>
<tr><td>SHIFT UP /</td><td>?</td><td>?</td><td>?</td></tr>
<tr><td>SPACE</td><td>SPACE</td><td></td><td>SPACE</td></tr>
<tr><td>CARRIER RETURN</td><td>CARRIER RETURN</td><td></td><td>CARRIER RETURN</td></tr>
<tr><td>SHIFT UP</td><td>SHIFT UP</td><td></td><td></td></tr>
<tr><td>SHIFT DOWN</td><td>SHIFT DOWN</td><td></td><td></td></tr>
<tr><td>BACKSPACE</td><td>BACKSPACE</td><td></td><td>BACKSPACE</td></tr>
<tr><td>HALF LINE FEED</td><td>HALF LINE FEED</td><td></td><td>HALF LINE FEED</td></tr>
<tr><td>REVERSE HALF LINE FEED</td><td>REVERSE HALF LINE FEED</td><td></td><td>REVERSE HALF LINE FEED</td></tr>
<tr><td>ALTERNATE CODE &</td><td>DICTIONARY CHANGE</td><td></td><td>DICTIONARY CHANGE</td></tr>
<tr><td>ALTERNATE CODE</td><td></td><td></td><td></td></tr>
<tr><td>ALTERNATE CODE SPACE</td><td>ENTER</td><td></td><td>ENTER</td></tr>
</table>

PHILADELPHIA INDEPENDENT SCHOOL DISTRICT

PROJECT GROW

PHILADELPHIA, PENNSYLVANIA

TABLE 3.2-14

PHILCO STUDENT AUDIO-VISUAL INTERFACE (SAVI)

COST	SIZE	INPUT CONTROL	DISPLAY	TERMINAL FLEXIBILITY	TERMINAL EXPANSIBILITY
NOT AVAILABLE	APPROXI-MATELY 14" HEIGHT, 14-1/2" WIDTH, 22-23" DEPTH	THE STUDENT TERMINAL CAN BE USED IN ONLY ONE MODE OF OPERATION, NAMELY, STUDENT MODE. COMMUNICATION WITH THE COMPUTER IS VIA THE KEYBOARD AND LIGHT PEN. THE KEYBOARD PROVIDES FOR 52 CHARACTERS (26 UPPER AND 26 LOWER), 23 SPECIAL CHARACTERS, 22 NUMERALS AND SYMBOLS, AND 15 SPECIAL FUNC-TIONS. THIS PROVIDES A TOTAL OF 97 CHARACTERS, SYMBOLS AND NUMERALS, AND 15 CONTROL FUNC-TIONS. (REFER TO FIG-URES 3.2-26 AND 3.2-27.) THE LIGHT PEN IS A RUGGEDIZED INSTRUMENT UTILIZING FIBER OPTICS TECHNIQUES. THE LIGHT PEN IS ACTIVATED BY TOUCHING THE FACE OF THE SCREEN WITH THE TIP OF THE PEN. THE PRO-GRAM WILL NOT PERMIT WRITING OR DRAWING. FIVE MAJOR CATEGORIES OF STUDENT RESPONSES ARE PERMISSIBLE; SINGLE ENTRY KEYBOARD RESPONSES, MULTIPLE ENTRY KEYBOARD RESPONSES, FREE FORM RESPONSES OF UP TO 100 CHARACTERS, SINGLE LIGHT-PEN RESPONSES AND MULTIPLE LIGHT-PEN RESPONSES.	THE DISPLAY IS A STAND-ARD ALL-CHANNEL 12-INCH TELEVISION RECEIVER. THE USEFUL DIMENSIONS ARE 10 INCHES IN WIDTH BY 7.5 INCHES IN HEIGHT. THE OPERATING MODES ARE: PROCESSOR GENERATED IMAGES, STANDARD VHF-UHF BROADCAST TV AND CCTV. THE DISPLAY IS CAPABLE OF PRESENTING 20 ROWS OF 40 CHARACTERS PER ROW FOR A TOTAL OF 800 ALPHABETIC AND/OR NUMERIC CHARACTERS. FOR DISPLAY OF GRAPHICS, THE DISPLAY SURFACE IS CON-SIDERED TO CONSIST OF 25 SECTORS (32 CHARACTER DISPLAY CAPABILITY PER SECTOR). EACH CHAR-ACTER IS CONSTRUCTED BY SELECTING COORDINATES FROM AN 8 X 12 DOT MATRIX. THE TERMINAL CAN DISPLAY THE FOLLOW-ING INFORMATION: LOWER CASE ALPHABETIC CHAR-ACTERS, INITIAL CAPITAL WITH LOWER CASE ALPHA-BETIC CHARACTERS, ALL CAPITAL ALPHABETIC CHAR-ACTERS, NUMBERS OR NUMBERS AND LETTERS, NUMERIC EQUATIONS, SUPER-SCRIPTS, SUPER-SCRIPT EQUATIONS, SUB-SCRIPTS AND SUB-SCRIPT EQUATIONS, PARENTHESIZED EQUATIONS, ALGEBRAIC FRACTIONS, GRAPHIC DIS-PLAYS, COMPOSITE GRAPHICS, UNDERLINE NOTATION, AND BLUNT LINE NOTATION.	THE SYSTEM SOFTWARE IS HIGHLY FLEXIBLE, I.E., THE KEYBOARD AND LIGHT PEN CAN BE INITIALIZED TO ASSUME DIFFERENT FUNCTIONS. BROADCAST TV, CCTV, AND DIGITAL VIDEO CAN BE DISPLAYED. THE TERMINAL CAN BE USED BY EITHER STUDENT OR IN-STRUCTOR.	THE SAVI CAN BE EXPANDED TO INCLUDE AUDIO. THE TERMINAL DESIGN IS SUCH THAT ADDITIONAL EQUIP-MENTS; E.G., TYPEWRITERS, MONITORS, ETC., COULD BE ADDED WITH A MINIMUM OF EFFORT.

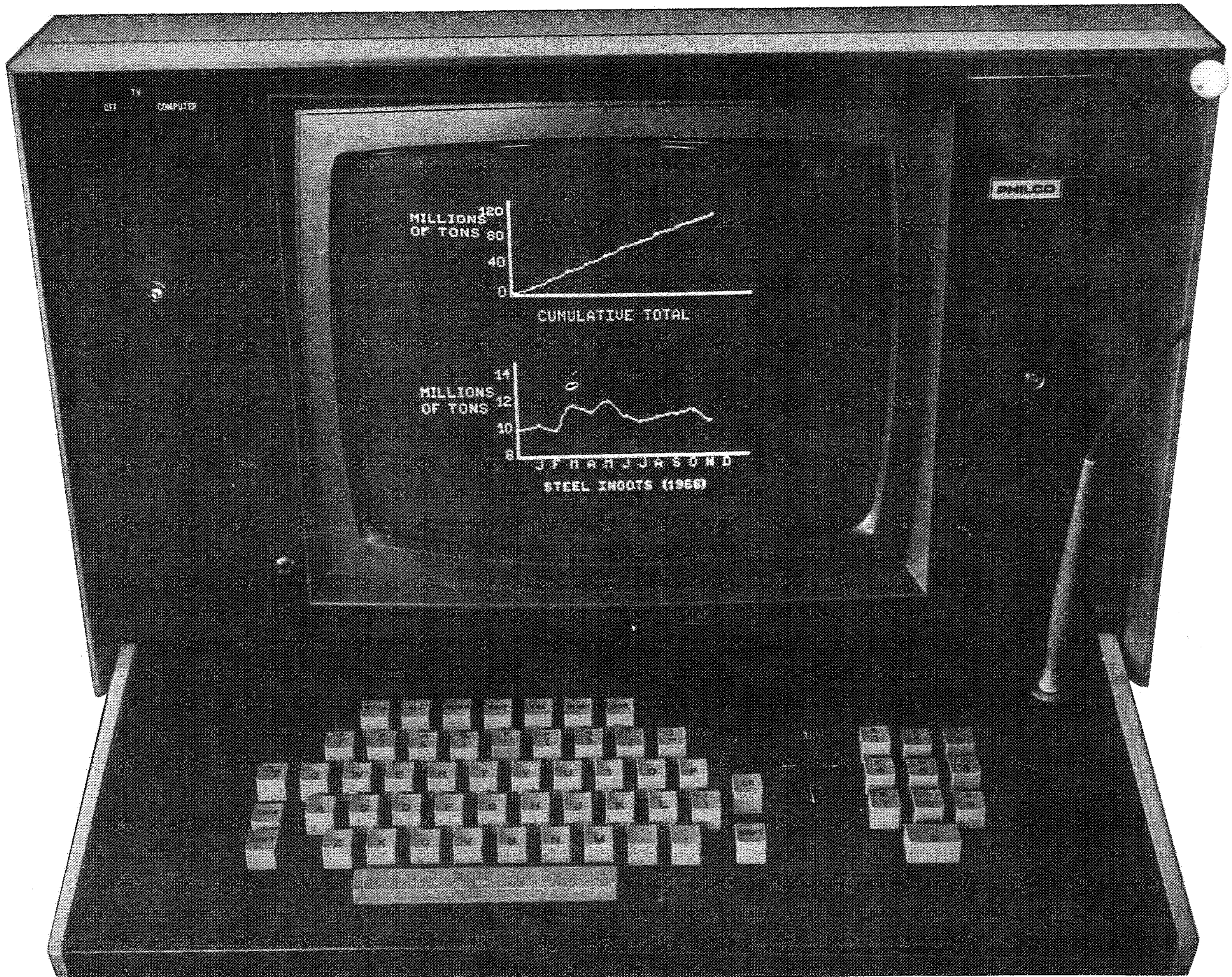
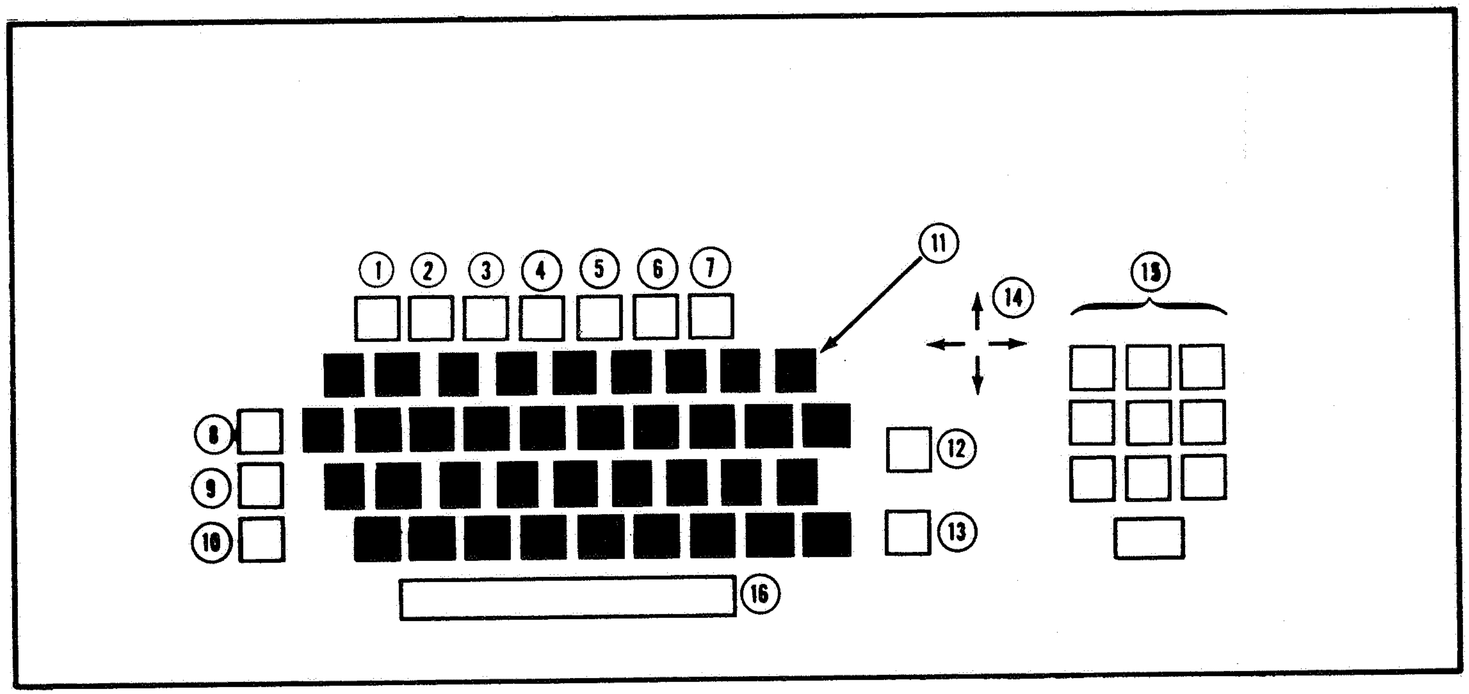


Figure 3.2-25 Philco SAVI



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DESCRIPTION

1 ATTENTION
2 REPEAT LAST FRAME
3 CLEAR SCREEN
4 DICTIONARY CHANGE
5 DELETE CHARACTER
6 INSERT CHARACTER
7 END OF RESPONSE
8 TAB LEFT
TAB RIGHT
9 SHIFT LOCK
10 SHIFT UPPER, SHIFT LOWER
11 ALPHABETIC (UPPER AND LOWER CASE) AND SPECIAL CHARACTERS
12 LINE RETURN
13 SHIFT UPPER, SHIFT LOWER
14 CURSOR KEYS
15 NUMERIC AND MATHEMATICAL
16 SPACE BAR

Figure 3.2-26 SAVI Student Terminal Keyboard Functions

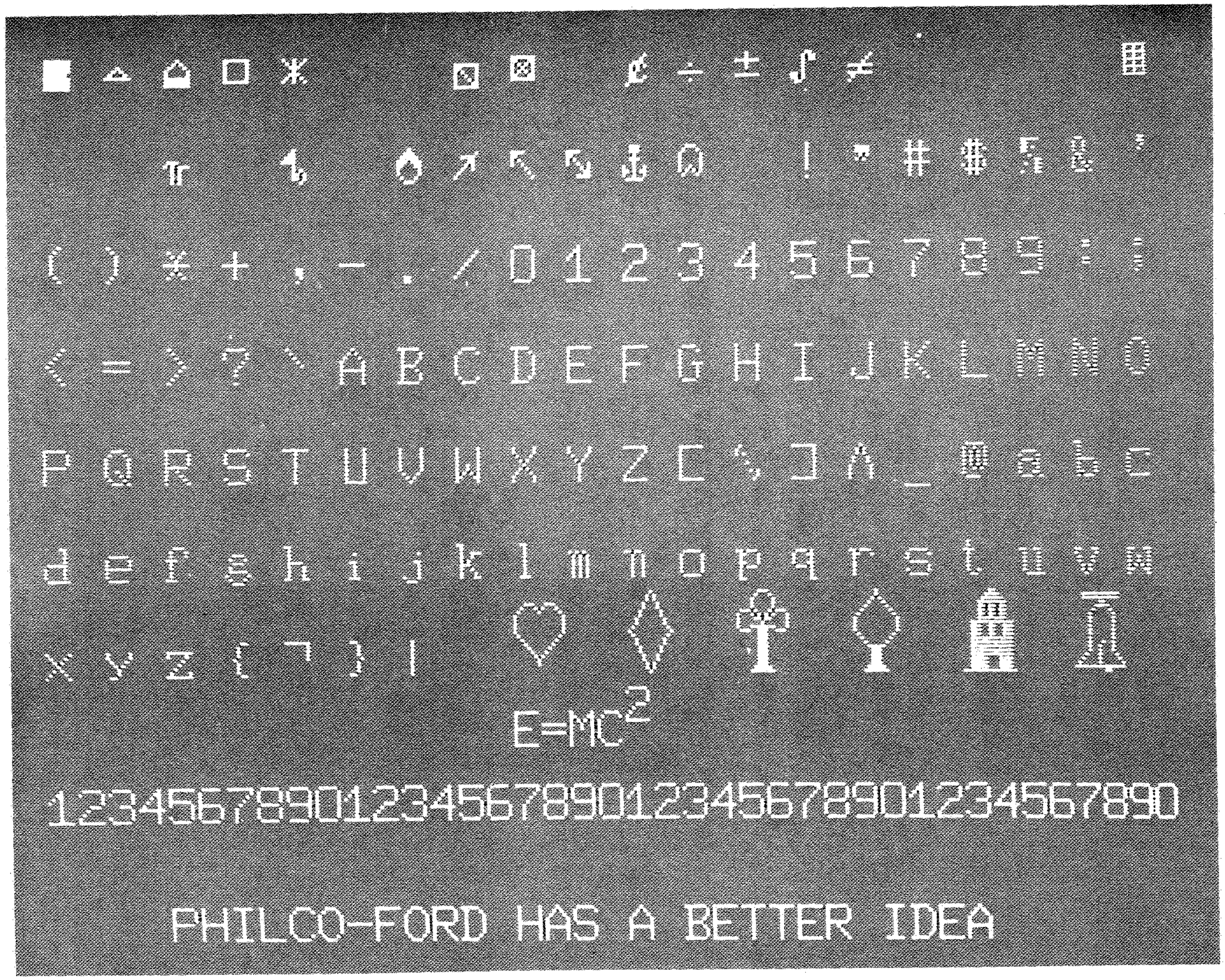


Figure 3.2-27 Alphabetic, Numeric and Special Characters

NOT ASSOCIATED WITH SYSTEMS REVIEWED

TABLE 3.2-15

PHO ALPHANUMERIC COLOR DISPLAY UNIT MODEL D-20

COST	SIZE	INPUT CONTROL	DISPLAY	TERMINAL FLEXIBILITY	TERMINAL EXPANSIBILITY
APPROXIMATELY $8,000	DESK-TOP UNIT: 14" HEIGHT, 14-1/2" WIDTH, 27" DEPTH (WITH KEYBOARD) CONSOLE-MOUNTED UNIT: DISPLAY UNIT: 14" HEIGHT, 19" WIDTH, 14" DEPTH KEYBOARD UNIT: 7" HEIGHT, 19" WIDTH, 4-1/2" DEPTH MOUNT 10^o FROM HORIZONTAL.	REFER TO FIGURE 3.2-28. THE KEYBOARD IS A MODIFIED VERSION OF A STANDARD TYPEWRITER. THE ALPHABET AND STANDARD SYMBOLS ARE ISOLATED FROM THE TEN NUMERIC CHARACTERS. DATA TO BE ENTERED VIA THE TYPEWRITER-TYPE KEYBOARD IS IMMEDIATELY DISPLAYED AND MAY BE USED TO COMPOSE AN ORIGINAL DISPLAY OR MODIFY AN EXISTING DISPLAY. THE KEYBOARD PROVIDES FOR 26 ALPHABETIC CHARACTERS, 10 NUMERIC CHARACTERS, 12 SYMBOLS, 1 SPACE, 1 CURSOR, AND 6 CONTROL FUNCTIONS. INPUT IS TYPEWRITER SEQUENTIAL. THE 6 KEYBOARD-ASSOCIATED CONTROLS ARE AS FOLLOWS: SKIP KEY WHICH ADVANCES THE CURSOR ONE CHARACTER POSITION; BACK SPACE KEY WHICH REPOSITIONS THE CURSOR TO THE PRECEDING CHARACTER POSITION; CARRIAGE RETURN DOWN KEY WHICH REPOSITIONS THE CURSOR TO THE FIRST CHARACTER POSITION AT THE FOLLOWING LINE; CARRIAGE RETURN UP KEY WHICH REPOSITIONS THE CURSOR TO THE FIRST CHARACTER POSITION OF THE PRECEDING LINE; TRANS-UNIT SWITCH WHICH INITIATES TRANSMISSION OR THE DISPLAYED MESSAGE; AND COLOR SELECTION SWITCHES WHICH SELECT THE DISPLAY COLOR OF THE KEYBOARD DATA BEING ENTERED.	THE DISPLAY PORTION OF THE MODEL D-20 CONSISTS OF A COLOR 525 LINE MONITOR WITH A USABLE VIEWING SURFACE OF 6" X 8". A TOTAL OF 768 CHARACTERS CAN BE RECEIVED, AT RATES UP TO 75 CHARACTERS PER SECOND (8 BITS PER CHARACTER), AND DISPLAYED IN 24 ROWS OF 32 CHARACTERS PER ROW. EACH DISPLAYED CHARACTER IS CONSTRUCTED FROM A 5" X 7" DOT MATRIX WITH A SEPARATION OF .09" HORIZONTAL BY .07" VERTICAL. CHARACTER HEIGHT IS .17" AND CHARACTER WIDTH IS .16". COLORS AVAILABLE ARE: RED, BLUE, GREEN, OR WHITE. REFER TO FIGURE 3.2-29 FOR CHARACTER REPERTOIRE. THE DISPLAY PORTION HAS THE FOLLOWING CONTROLS: BRIGHTNESS, CONTRAST, AND DISPLAY ERASE WHICH ERASES THE COMPLETE DISPLAY AND THE COMPLETE CONTENTS OF THE DISPLAY MEMORY, RESET SWITCH WHICH RESTORES ALL INTERNAL LOGIC TO A PRESCRIBED STARTING POSITION. ON-LINE/KEYBOARD ENABLE SWITCH: THE ON-LINE POSITION IS USED TO INDICATE TO THE DATA TRANSMISSION SYSTEM A CONDITION OF READINESS TO ACCEPT DATA. WHILE THE KEYBOARD ENABLE POSITION INHIBITS ACCEPTANCE OF DATA FROM THE TRANSMISSION SYSTEM AND CONDITIONS THE DISPLAY UNIT FOR ACCEPTANCE OF DATA FROM THE ALPHANUMERIC KEYBOARD.	THE TERMINAL IS ADAPTABLE TO MODIFICATION OF SOFTWARE PACKAGES. IN ADDITION, THE TERMINAL CAN EITHER BE DESK-MOUNTED OR RACK-MOUNTED. THE STUDENT OR INSTRUCTOR CAN COMPOSE DISPLAYS AND INPUT THE ENTIRE DISPLAY INTO THE PROCESSOR. THE UNIT CAN PROVIDE SYNCHRONIZATION TO AN ADDITIONAL COLOR MONITOR. THE STANDARD BELL INTERFACE CAN BE REPLACED WITH A DIRECT COMPUTER I/O INTERFACE. THE CHARACTER REPERTOIRE CAN BE EXPANDED TO 64.	THE TERMINAL CAN BE MODIFIED TO DISPLAY CCTV. A MULTIPLEX UNIT IS AVAILABLE TO DRIVE UP TO FOUR D-20 UNITS THROUGH THE SAME I/O INTERFACE. ADDRESSING IS PROVIDED TO MAINTAIN DATA PRIVACY.

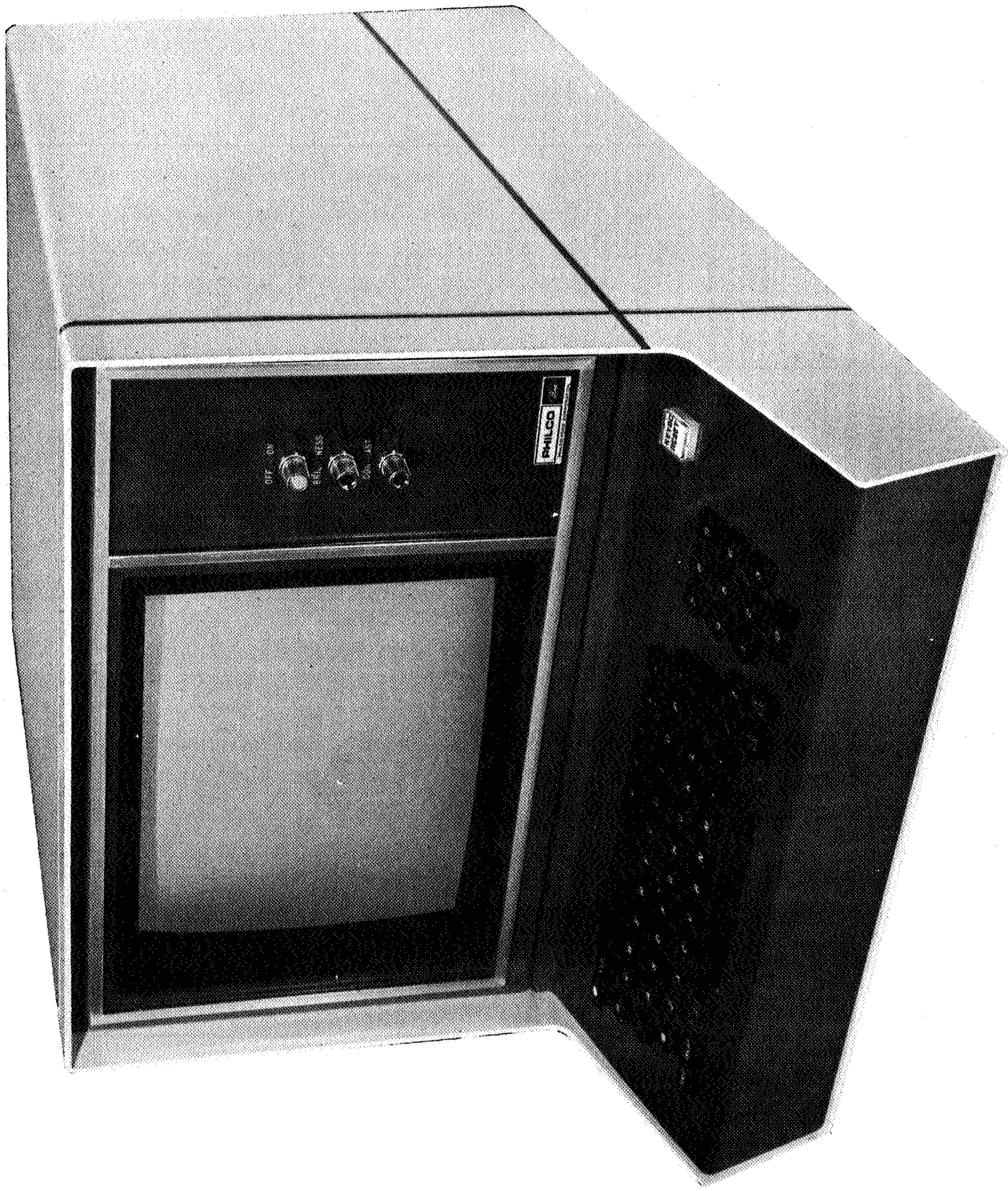


Figure 3.2-28 Philco Alphanumeric Color Display Unit, Model D-20

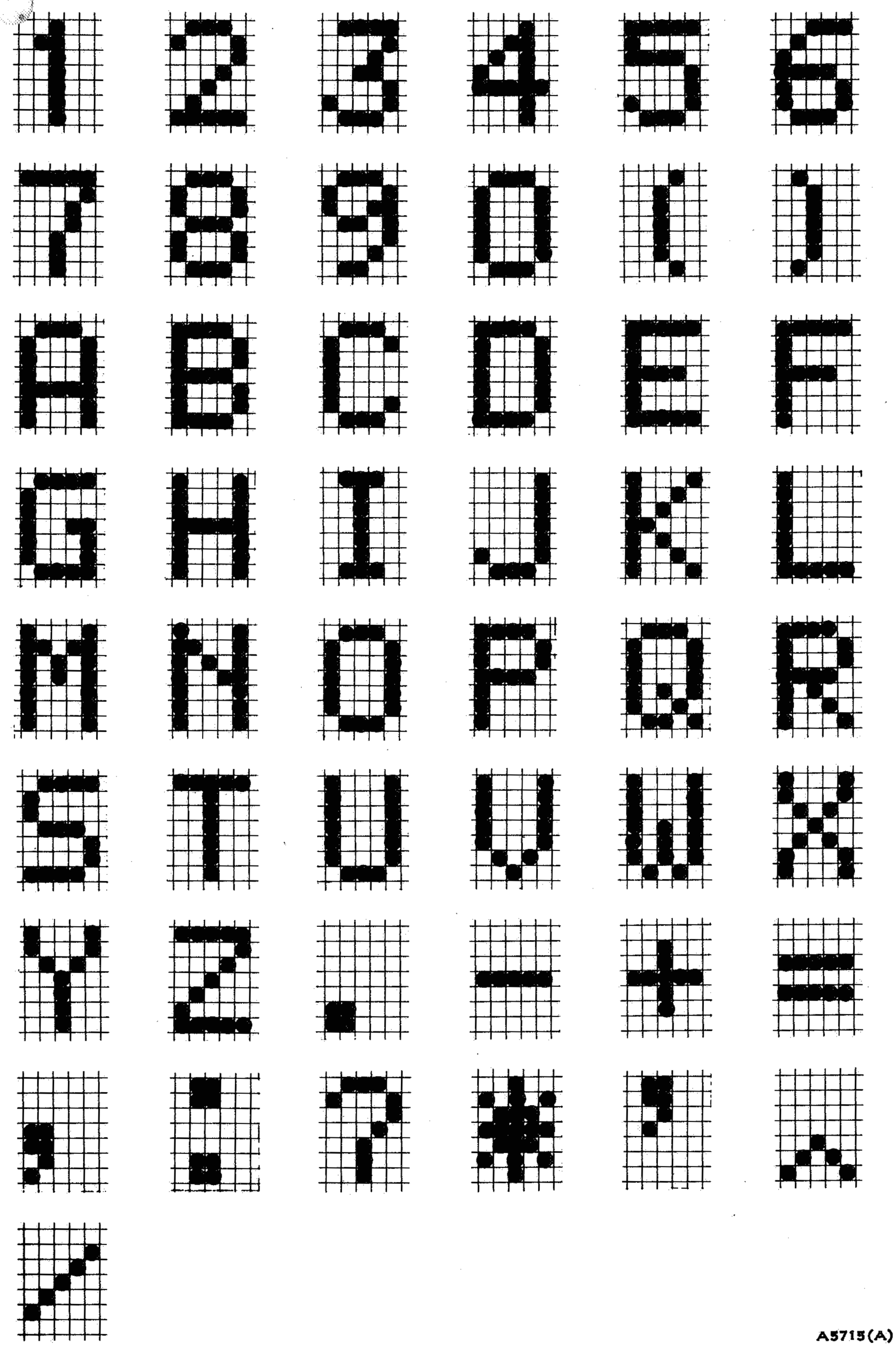


Figure 3.2-29 Character Repertoire

UNIVERSITY OF ILLINOIS

COORDINATED SCIENCE LABORATORIES

PLATO SYSTEM

URBANA, ILLINOIS

TABLE 3.2-16

PLATO SYSTEM STUDENT TERMINAL

COST	SIZE	INPUT CONTROL	DISPLAY	TERMINAL FLEXIBILITY	TERMINAL EXPANSIBILITY
TTY TERMINAL $135/MO. TV MONITOR, CHASSIS, AND HANGAR $320 TOTAL TERMINAL COST (INCL. STORAGE) APPROXIMATELY $4000	APPROXIMATELY 10-1/2" HEIGHT, 16-1/4" WIDTH, 6-1/2" DEPTH FOR KEYBOARD DESK SET TV MONITOR APPROXIMATELY 8" DIAGONAL SCREEN SIZE	THE TERMINAL CAN BE USED FOR STUDENT OR INSTRUCTOR USE. COMMUNICATION WITH THE COMPUTER IS BY WAY OF A UK-801 (ATT) TELETYPE KEYBOARD. EACH KEY HAS REMOVABLE KEYCAPS WHICH ALLOW DIFFERENT FUNCTIONS TO BE ASSIGNED KEYS. THROUGH SHIFT AND CONTROL KEY DEPRESSIONS, A TOTAL OF 96 DISCRETE INPUTS MAY BE MADE FROM THE KEYBOARD. A MODE LOCKOUT OPTION ALLOWS ACTIVATION OF ONLY THOSE KEYS REQUIRED FOR STUDENT CONTROL OF ANY SPECIFIC SUBJECT. REFER TO FIGURE 3.2-31 FOR THE KEYBOARD LAYOUT. THE SPEED OF THE UK-801 UNIT IS 100 WORDS PER MINUTE.	THE DISPLAY SURFACE IS A CONRAC TELEVISION MONITOR, TYPE CNB, WITH AN 8" SCREEN. DATA OUTPUT FROM THE COMPUTER IS ROUTED TO A RAYTHEON STORAGE TUBE WHERE IT MAY BE SUPERIMPOSED UPON BACKGROUND SLIDES BEFORE CRT PRESENTATION. THE DISPLAY SURFACE HAS 488 PLOTTABLE POINTS IN THE X-AXIS AND 383 IN THE Y-AXIS. THIS IS APPROXIMATELY 15 ROWS OF 32 CHARACTERS PER ROW. BACKGROUND SLIDES ARE PROVIDED BY A 122 POSITION, 35 MM COMPUTER CONTROLLED SLIDE PROJECTOR.	THE TERMINAL CAN BE USED FOR INSTRUCTOR OR STUDENT INPUTS AND ALLOWS GREAT FLEXIBILITY OF FUNCTIONS AVAILABLE. EACH KEY, WHEN USED IN CONJUNCTION WITH THE CONTROL AND SHIFT KEYS, OUTPUTS UP TO FOUR NUMBER CODES. CHANGING KEYCAPS AND REDEFINING THE KEY OUTPUT CODE ALLOWS THE KEYS TO PERFORM ANY FUNCTION APPLICABLE TO THE PARTICULAR SUBJECT.	OTHER THAN POSSIBLE EXPANSION TO UTILIZE AUDIO TECHNIQUES, THE TERMINAL DOES NOT EASILY ADAPT TO ADDITIONAL I/O DEVICES.

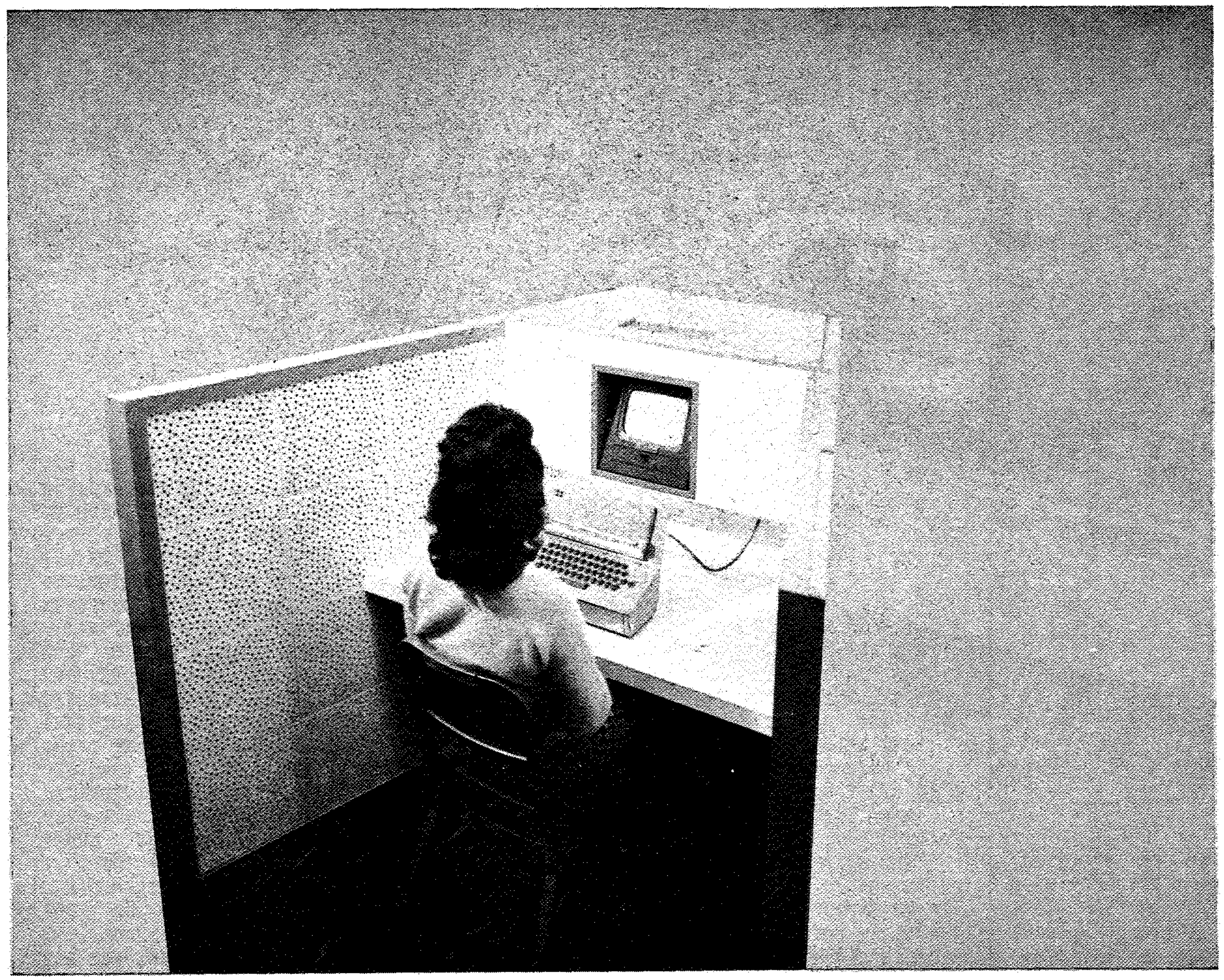
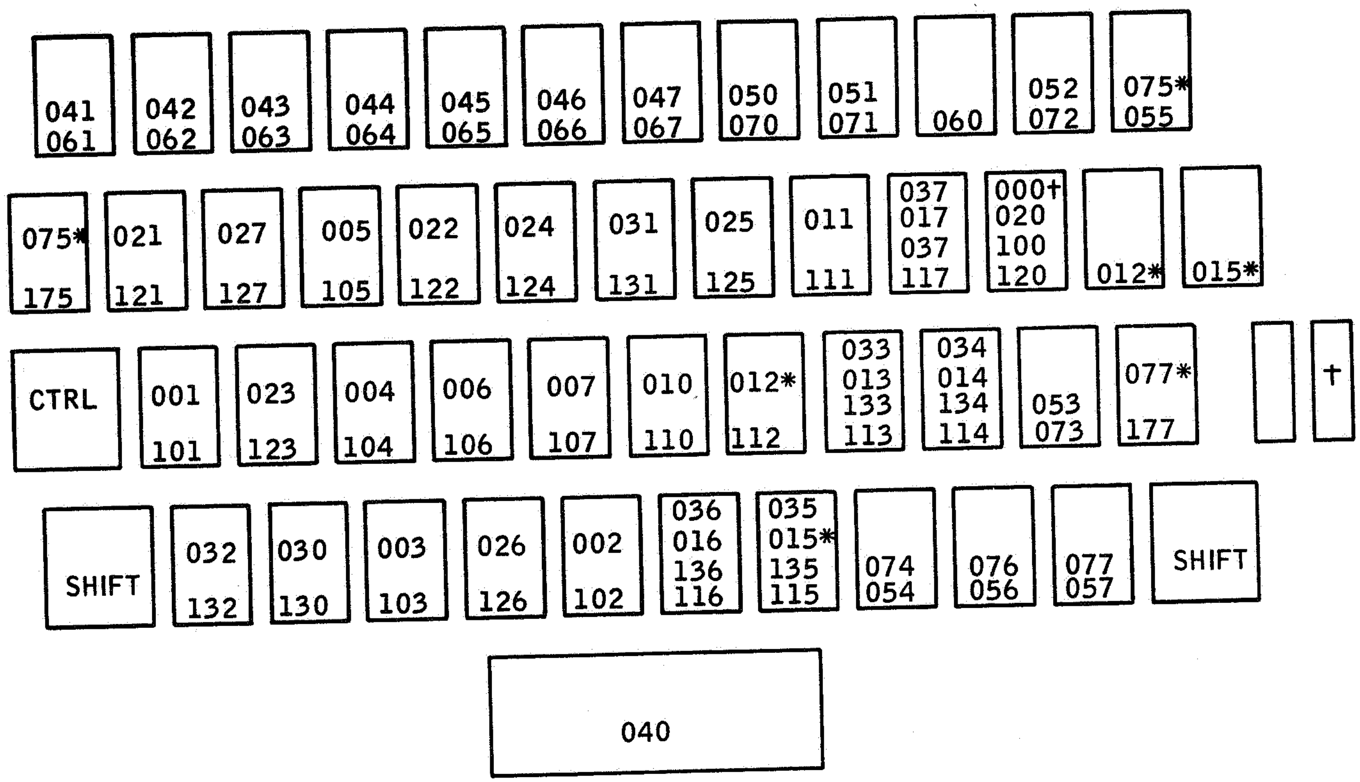


Figure 3.2-30 PLATO System Student Terminal



*DUPLICATIONS: 012 - CTRL AND NORMAL
015 - CTRL AND NORMAL
075 - CTRL AND SHIFT
077 - CTRL AND SHIFT

† INPUT OF ALL KEYS WHEN BREAK KEY IS DEPRESSED

CTRL AND SHIFT CTRL SHIFT NORMAL

- GUIDE TO NUMBERING SCHEME AS A FUNCTION OF NUMBER POSITION ON EACH KEY

A5717(B)

Figure 3.2-31 PLATO Teletype Keyset

STANFORD PROJECT

WALTER HAYS SYSTEM

PALO ALTO, CALIFORNIA

AND

SYSTEM DEVELOPMENT CORPORATION

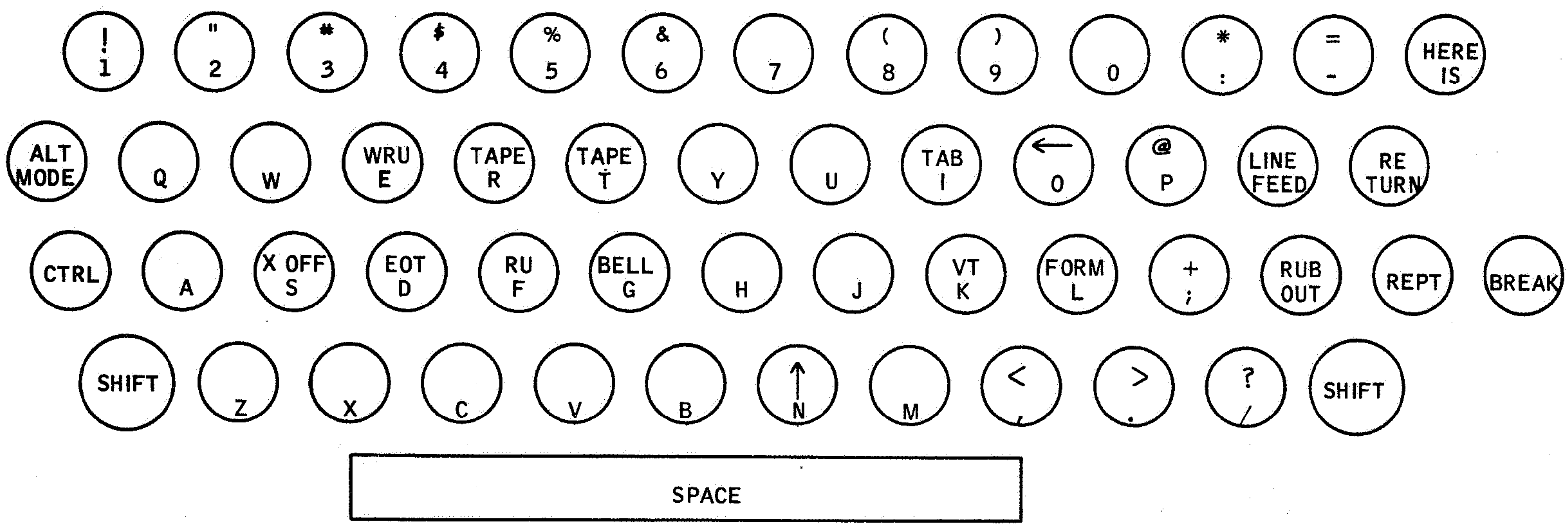
TIME SHARING SYSTEM

SANTA MONICA, CALIFORNIA

MODELS 33 AND 35 TELETYPEWRITERS

COST	SIZE	INPUT CONTROL	DISPLAY	TERMINAL FLEXIBILITY	TERMINAL EXPANSIBILITY
APPROXIMATELY $125/MO.	NOT AVAILABLE	INPUT IS MADE BY WAY OF A KEYBOARD WHICH IS SIMILAR TO A TYPEWRITER. THERE ARE FOUR ROWS OF KEYS FOR TYPING WHICH ALLOW NUMERALS, CAPITAL LETTERS, AND SPECIAL SYMBOLS TO BE PRESENTED. KEYS ARE ALSO PROVIDED FOR NON-PRINTING FUNCTIONS. REFER TO FIGURE 3.2-32 FOR THE MODEL 33 KEYBOARD ARRANGEMENT AND TO FIGURE 3.2-33 FOR THE MODEL 35 KEYBOARD ARRANGEMENTS.	DISPLAY IS LIMITED TO PRINTOUTS OF ALPHANUMERIC CHARACTERS AND 21 SPECIAL SYMBOLS. OTHER SPECIAL, NON-PRINTED FUNCTIONS ARE AVAILABLE. LETTERS OF THE ALPHABET ARE PRINTED IN CAPITAL LETTERS ONLY. THE TERMINAL IS CAPABLE OF A SPEED OF 100 WORDS PER MINUTE.	TERMINAL FLEXIBILITY IS LIMITED AS NO MODIFICA- CAN BE MADE EXCEPT TO CHANGE THE TYPE BALL AND KEYS TO ALLOW PRINTOUT OF NEW CHARACTERS.	THE CAPABILITY DOES NOT EXIST TO ADD ADDITIONAL I/O MEDIA WITH THE EXCEPTION OF PAPER PUNCHED TAPE.

*EXCEPT FOR OUTWARD APPEARANCE THE MODEL 33 AND MODEL 35 TELETYPEWRITERS ARE QUITE SIMILAR. THE FUNCTIONS WHICH CONCERN US ARE SO SIMILAR THAT THEY WILL BE DISCUSSED AS ONE MACHINE.



A5718(B)

Figure 3.2-32 No. 33 Keyboard Arrangement

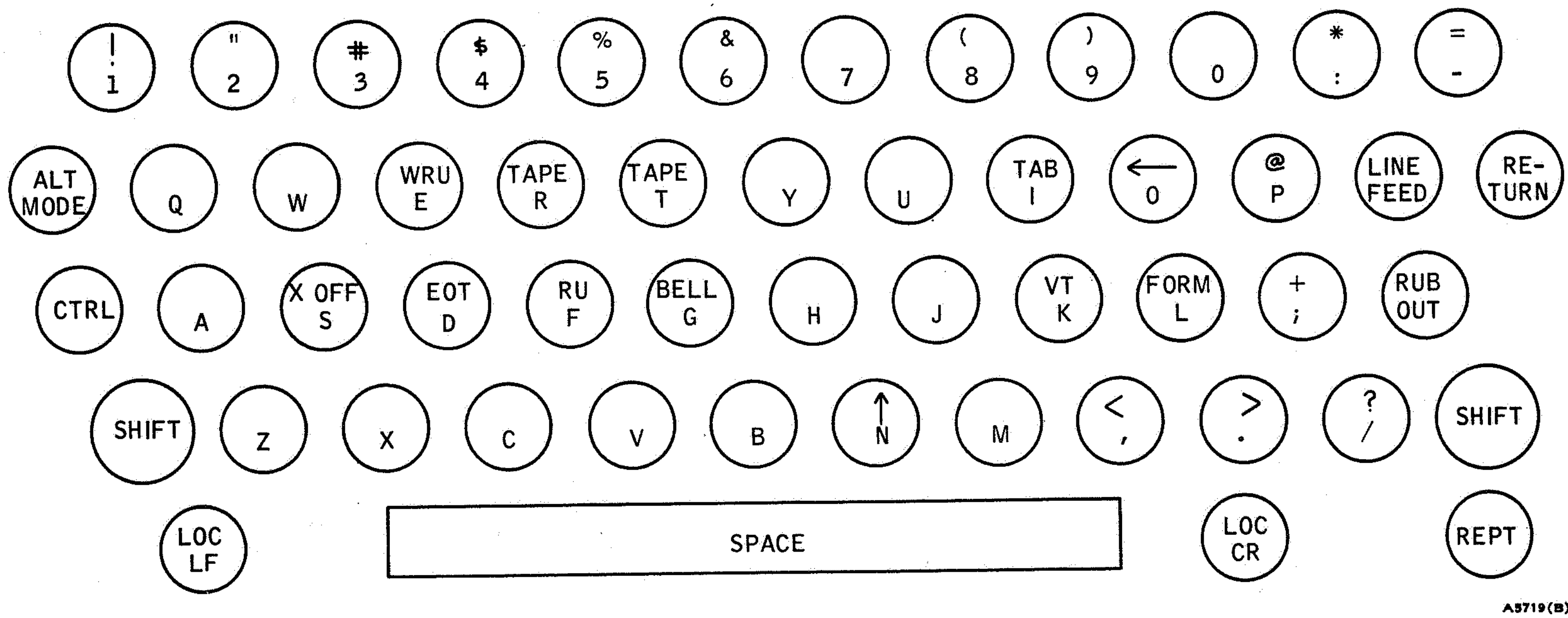


Figure 3.2-33 No. 35 Keyboard Arrangement

3.2.4.2 Central Processing Systems

3.2.4.2.1 General

This section presents the characteristics of the central processing system associated with the CAI systems reviewed. This analysis is not intended to be used as a guide for selecting a specific CAI system, but rather to provide additional insight into the peculiarities of CAI central processing systems, their basic characteristics, their commonalities, and the factors that significantly influence the system's operation.

Detailed information concerning each system examined is presented in Table 3.2-18, Central Processing System Characteristics, and is organized as follows:

A. Type. Dedicated (D) or time-shared (T), special (S) or general purpose (G)

B. Main Storage. Primary core storage capability of system

C. Word Length. In bits

D. Speed. Memory access cycle time

E. I/O Channels. Quantity

F. Secondary Storage. Quantity and type of secondary storage

G. I/O Devices. Typewriter, printer, card reader, and card punch (type and quantity)

H. Languages. Names of languages used in system for CAI or related functions

I. Terminal. Type and capabilities of terminals

J. Number of Users. Number of terminal stations being utilized for CAI

K. Storage Requirements. Main core required for CAI operations.

Of the seven systems examined, five were dedicated to CAI and two were time-shared systems. Six systems were made up of general purpose computers

TABLE 3.2-18

CENTRAL PROCESSING SYSTEM CHARACTERISTICS

CAI SYSTEM	TYPE	MAIN STORAGE	WORD LENGTH	SPEED	I/O CHANNELS	SECONDARY STORAGE	TYPEWRITER	PRINTER	CARD READER	CARD PUNCH	LANGUAGES	TERMINAL	NUMBER OF USERS	STORAGE REQUIRE-MENTS	REMARKS
PROJECT GROW PHILCO MODEL 2000-211	D G	32,000 WORDS	48 BITS	4 μSEC	2	10 TAPES 20 MILLION CHARACTERS PER TAPE	1	1 900 LINES/ MINUTE	1 2000/ MINUTE	1 100/ MINUTE	TAC, FORTRAN II, COBOL, JOVIAL, MAD, INFORM	NONE	4 MODEL 02 PROCESSORS	576 WORDS ARE ALLOTED FOR EACH TERMINAL PATH (320 WORDS FOR CURRICULUM AND 256 FOR INTER-PRETER). 6-8 WORDS PER TER-MINAL FOR TERMINAL INPUTS	HAS FIXED AND FLOATING PT. OPERATION PERMITTING VALUES IN THE RANGE OF 10^{-616} TO 10^{+616}. 225 INSTRUCTIONS ARE AVAIL-ABLE
PHILCO/MODEL 102	G	16,000 WORDS	32 BITS	2 μSEC	16	1 DISC 1 MILLION CHARACTERS	1	-	-	-	SHAL-A, UTIL-ITY SYSTEM, SORT AND INFORM	SAVI TERM-INAL CON-SISTING OF CRT LIGHT PEN TYPE-WRITER	EACH MODEL 102 DRIVES 8 SAVI'S EXPANDABLE TO 1024 TYPEWRITERS AND 100 VISUAL DIS-PLAYS	CLUSTER PROCESSOR CORE NOT ALLOT-ABLE TO INDIVIDUAL TERMINALS. 2560 WORDS - EXECUTE AND I/O 1792 WORDS - COMMON WORKING POOL 2400 WORDS - IMAGE BUFFER 640 WORDS - HARDWARE I/O 768 WORDS - SYMBOL FILE 128 WORDS - KEYBOARD MAP	I/O IS EXPANDABLE TO SEVERAL HUNDRED. I/O RATE IS 100,000 CHAR-ACTERS PER SECOND. 129 INSTRUCTIONS ARE AVAIL-ABLE
UNIVERSITY OF ILLINOIS	D G	32,000 WORDS	48 BITS	4.8 μSEC	32	MAGNETIC TAPE TWO DISC UNITS	1	1	1	1	FORTRAN '60 AND CATO	SPECIAL TERMINAL CONSIST-ING OF: CRT, TELETYPE-WRITER, SLIDE PROJECTOR	20 TERMINALS EXPANDABLE TO 32	APPROXIMATELY 50 WORDS OF CURRIC-ULUM RESIDENT IN CORE PER TERMINAL, 12 TO 20 WORDS I/O PER TERMINAL TOTAL OF 4000 WORDS FOR OPERATING PROGRAM TOTAL OF 5000 WORDS RESIDENT FOR FORTRAN, CATO, OTHER LANGUAGES	
UNIVERSITY OF CALIFORNIA AT IRVINE	T													1440 - TOTAL OF 16,000 CHARACTERS (8 BIT CHARACTERS) APPROXIMATELY: 7,300 CODING 1,700 QUEUES FOR DISC DRIVES 500 LINE CONTROL FIELDS FOR TERMINALS 4,680 (150 CHARACTERS/TERMINAL) MESSAGE BUFFER, TERMINAL STATUS 2,000 BI-LINE DUMP PROGRESS FOR DRUM DUMP	
IBM MODEL 1440	G	16,000 CHAR-ACTERS	VARI-ABLE	11.5 μSEC	2	3 DISCS 6 MILLION CHARACTERS	1	1 VARI-ABLE SPEED	1	1	COURSEWRITER	IBM 1050	18 MODEL 1050 TERMINALS	1410 - TOTAL 100,000 CHARACTERS (8-BIT CHARACTERS) APPROXIMATELY: 21,000 PROGRAM MONITOR 8,400 (400 CHARACTERS/TERMINAL)	
IBM MODEL 1410	G	100,000 CHAR-ACTERS	VARI-ABLE	4.5 μSEC		5 TAPES 8 DISCS	-	-	-	-	JOSSI ISIS	-	-	14,000 SEGMENT AREAS FOR PROGRAMS 5,000 INTERPRETER 8,000 RESIDENT TABLES, DISC TABLES, RESTART PROGRAM 37,000 ISIS OVERLAY, CONSTANTS, TABLES (CAI WILL UTILIZE APPROXIMATELY 2700 CHARACTERS PER TERMINAL WHILE ISIS UTILIZES APPROXIMATELY 3600 CHARACTERS PER TERMINAL.)	

TABLE 3.2-18 (CONT'D)

CAI SYSTEM	TYPE	MAIN STORAGE	WORD LENGTH	SPEED	I/O CHANNELS	SECONDARY STORAGE	TYPEWRITER	PRINTER	CARD READER	CARD PUNCH	LANGUAGES	TERMINAL	NUMBER OF USERS	STORAGE REQUIRE-MENTS	REMARKS
UNIVERSITY OF CALIFORNIA AT SANTA BARBARA	D														
IBM SYSTEM 360/ MODEL 50	G	64,000 WORDS	32 BITS	2 μSEC		CORE. 2 MILLION BYTES 8 DISKS 58 MILLION BYTES	1	1 1100 LINE/ MINUTE	1 1000 CARDS PER MINUTE	1 300 CARDS PER MINUTE	FORTRAN IV	BBN TERM-INALS, IBM 1050 TERM-INALS	20 BBN TERMI-NALS	NOT AVAILABLE	
STANFORD/ BRENTWOOD SYSTEM	D													32 WORDS PER TERMINAL FOR STATUS AREA. 49-99 WORD BUFFER FOR STUDENT RECORDS. 640 WORD BUFFER FOR CIRRIC-ULUM. 96 BUFFER AREAS OF 32 WORDS EACH FOR TEXT AND COMMANDS. INTERPRETER COURSEWTITER ASSEMBLER I/O MONITORS FUNCTION OR DICTIONARY AREAS OVERLAY AREAS } THESE AREAS BRING TOTAL MAIN CORE STORAGE TO 32,000 WORDS	
1800	S	32,000 WORDS	16 BITS	2 μSEC	9	7 DISCS 512,000 WORDS PER DISC. MAGNETIC TAPES	1	1	1 400 CARDS/ MINUTE	1 160 COLUMNS PER SECOND	COURSEWRITER	IBM 1510 TERMINALS CONSIST-ING OF: CRT, LIGHT PEN, TYPE-WRITER, AUDIO, & SLIDES			
STANFORD/ WALTER HAYS	D	32,000 WORDS	-	-	16		1	1	1	1	PAS- PROGRAM ASSEMBLY LNG. TSA-TEACHER/ STUDENT ALGOL	-TTY 33, PHILCO READ SYSTEMS CONSISTING OF: CRT, KEYBOARD		32,000 MAIN CORE TOTAL 12,000 IS ALLOCATED TO USER PROGRAMS (USER PROGRAMS ARE READ IN FROM A DRUM; IF THE 12,000 IN CORE IS EXCEEDED, DRUM TRACKS MAY BE USED FOR ADDITIONAL STORAGE) 20,000 ASSIGNED FOR TIME SHARING SYSTEM 16,000 FOR ACTUAL PROGRAM (2000 FOR SYSTEM INTERPRETER) 4000 FOR READ CONSOLE DISPLAY BUFFER	
PDP-1	G					56 MILLION CHARACTER DRUM					LISP, GO-GO, ALGOL				
SYSTEM DEVELOPMENT CORPORATION	T			2 μSEC										APPROXIMATELY 43,000 WORDS REQUIRED FOR EACH USER: 24,000 FOR PLANIT 6,000 FOR STUDENT RECORDS 14,000 FOR CURRICULUM FORMAT THE ENTIRE CURRICULUM IS PRESENTLY IN CORE FOR EACH USER. (IN ITS IBM 360 CONFIGURATION WHICH WILL BE OPERATIONAL LATE IN 1967, PLANIT WILL REQUIRE BETWEEN 8000 AND 15,000 WORDS PER USER. ONLY 5% OF THE CURRICULUM WILL BE RESIDENT AT ANY GIVEN TIME.)	
AN FSQ-32	G	68,000 WORDS +16,000 I/O	48 BITS		-	DRUM-600,000 WORDS	1	1	1	1	TINT, IRLT JOVIAL, LISP, PLANIT	TTY MODEL 28, MODEL 33			
PDP-1	G														

and one was a special purpose CAI computer. The systems have main core capabilities ranging from approximately 30,000 to 8,000 words with a wide range of word lengths (from 16 to 48 bits).

The number of I/O channels ranged from 2 to 32 depending upon the needs of the system. Machine speed or memory access times ranged from 2 to 5 microseconds. Each system has a typewriter, printer, card reader, and card punch capability for peripheral I/O.

Each of the systems control between 16 and 32 terminals at present. All seven systems have the capability of controlling a keyboard for student entry of information. In conjunction with keyboard input, three systems output curriculum on printers; one system outputs to a CRT; one displays information through a CRT and slide projector; one outputs to a CRT and, in addition, accepts inputs from light pens; and another controls output by printer, CRT, slide projector, and audio while accepting inputs from the keyboard and light pen. The I/O handling capabilities of the various systems are presented in Table 3.2-19.

3.2.4.2.2 Primary and Secondary Storage

In each system the core storage is almost fully utilized for CAI with the exception of the two time-shared systems, UCI and SDC. These systems allocate core to other operations; however, in the SDC system the major portion of memory is allocated for CAI. Areas in core are allocated for the operating program (interpreter, assembler, dictionary areas, time-sharing system monitor), while specific areas are allocated to each terminal for I/O, display buffering, terminal status, and curriculum. In six systems, only a small portion of the curriculum is resident in core at any given time; the curriculum is read from a disc, a frame or concept at a time and placed in core. Upon completion of the presentation of that frame or concept, the curriculum core section (approximately 300 words per terminal) is replaced by the next frame or concept from the disc. This process continues as the student is sequenced through the curriculum.

The exception (i.e., SDC) reads all its curriculum into core at once, thereby, requiring 43 thousand words for each user. This is a purely experimental system and this mode of operation will be changed when it becomes operational. With the available figures, it appears that a CAI system driving 25 to 30 terminals will need from 32 to 36 thousand words of main core, with secondary storage requirements contingent upon the volume of curriculum.

Each system utilizes secondary storage of some nature for curriculum storage and storage of student records and responses. Drum, disk, and magnetic tape are used in varying quantities depending upon

TABLE 3.2-19

I/O HANDLING CAPABILITIES

SYSTEM	KEYBOARD	PRINTOUT	LIGHT PEN	CRT	SLIDES	AUDIO	NO. OF TERMINALS
BRENTWOOD	X	X	X	X	X	X	16
WALTER HAYS	X	X					31
PLANIT	X	X					28
GROW	X		X	X			32
PLATO	X			X	X		20
UCI	X	X					18
SANTA BAR.	X			X			20

the particular requirements of each system. The curriculum may be stored on disc or drum and read into main core in small portions. One source indicates that 6 to 7 hours of course material can be stored on one 512,000-word disc. Disc or drum may also be used as an extension of main core for real-time operating program storage. Tape is generally used as a backup storage for curriculum and may store such items as student responses and records that do not require real-time processing.

Meaningful data to determine core requirements are difficult to obtain because of differences in programming techniques, I/O processing techniques, presentation logic, curriculum complexity, author languages, terminal capabilities, student records and administrative processing requirements, and use of random access auxiliary storage. Another difficulty has been variations in the definition of terminology. For these reasons there are a wide range of core storage figures for what seem to be similar tasks. With this in mind, the present information allows only gross estimates of core storage requirements for a system of any given capability.

3.2.4.2.3 Author Languages

Author languages fall into two distinct categories - those developed for use by the instructor (user-oriented) and those that require a programmer (technical specialist-oriented) to code the curricular material to be presented. Coursewriter II, INFORM, and PLANIT are examples of user or author-oriented languages. Programmer-oriented languages are CATO, FORTRAN, and the Program Assembly Language (PAS). Of the seven systems reviewed, four utilize a strictly author-oriented language (GROW, UCI, Brentwood, and SDC), while three used only a programmer-oriented language (PLATO, University of California at Santa Barbara, and Walter Hays).

3.2.4.2.4 Conclusions

It appears that the governing factors in determining the main core requirements are the number and type of terminals to be controlled; the complexity of the curriculum (matching to be performed, alternative answers, branching loops, computations to be performed, and complexity of information to be presented); the author language (number of operations, nearness of language to machine code, presentation logic, and display generation capability); and the administrative functions to be performed (student response processing, student record processing, grading, scheduling).

Word length and memory-access time do not appear to be governing factors in system utilization, but fall within the range of 16 to 48-bit word length, and 2 to 5 microseconds memory access time.

The central systems examined are self-contained and centrally located to facilitate scheduling, maintenance and supervision, and access by management. The only system that deviates in part from this is the GROW system, which has remote processors for each cluster of terminals, but still subscribes to self-containment of the central system.

From the analysis of the 7 CAI systems, it appears that the processing systems for Project GROW, Brentwood, and PLATO could be utilized in an initial flight controller CAI system. However, the diversification of application in which the optimum system for flight control training will be engaged, eliminates the possible use of these systems for an optimum CAI system.

3.2.4.3 Author Languages

3.2.4.3.1 General

Author languages are special languages used by individuals for preparation of curricular materials for CAI and differ, primarily, in terms of their intended educational purpose and the given computer system on which they can be employed.

Of the six major systems reviewed, four utilized author languages unique to their specific application, while the remaining two used specially modified versions of a common language.

Additional system research and surveys indicate that, in nearly every case, a different language or at least a language with internally unique modifications is being employed. This is manifested by the list of author languages that have been developed since the birth of CAI approximately 8 years ago. For example: Coursewriter I, Coursewriter II, Interpretive Coursewriter, Course Author Language, INFORM, CATO, PLANIT, AUTHOR, COMPUTEST, MENTOR, and to a lesser degree, LISP, TELECOMP, and THOR are indicative of the variety of languages used for preparation of curriculums for various applications of CAI.

This indicates that standardization of languages, systems, and techniques is not a criterion for the design of instructional systems. Perhaps most important is the indication that CAI languages must be further developed before the full and complete utilization of a CAI system can be realized.

There are two major areas that must be considered in the evaluation of author languages; viz., efficient computer usage and human factors considerations.

A. Efficient Computer Usage. Efficient computer usage is determined by the power, generality, and reliability of the given software package.

1. Power can be thought of in terms of conceptual efficiency and economic efficiency. In general, power can be related to the execution speed and the capacity of the system; i.e., instruction repertoire, storage facilities, and data access times.

   a. Conceptual efficiency is the amount of coding the author must input to perform certain computer tasks, such as, presenting a line of text, updating a counter, examining a register or generating a graphic display. In addition, conceptual efficiency depends on the ease with which one can undertake sophisticated tasks, such as decision making based on student performance (branching and adaptive sequencing). It should be noted that no measure has been established to determine the degree of conceptual efficiency.

   b. Economic efficiency is the amount of code that is processed by the computer in unit time; e.g., the amount of code executed by the computer in a given time for such functions as generating and displaying a graphic display, generating and displaying a line of text, or performing routines necessary to analyze student performance.

2. Generality is the degree to which a language can prove useful in a wide range of instructional applications. It is also a measure of the ease with which a language can be used with different systems.

3. Reliability is the degree to which the language facilitates the detection and prevention of logical and notational errors. The language assembler should detect errors and facilitate communication with the programmers so corrections will be efficiently performed.

B. Human Factors Considerations. The second major criterion by which CAI languages must be evaluated is the human factors consideration.

1. The time necessary to learn the language well enough to use it efficiently is an important consideration. This is a function of the naturalness of the language; i.e., its proximity to English. It should be noted that the educational background and technical maturity of the individual(s) using the language will influence the learning time.

2. A second important consideration is the degree to which the language allows easy and efficient editing and debugging procedures.

All existing CAI languages are capable of providing some useful contribution to further CAI developments. However, no author language exists that possesses all the evaluative attributes outlined in the preceding text. Finally, consideration should be given to the standardization of author languages or the development of a "universal" compiler which would allow the use of a standard author language on many systems. A detailed summary is presented in Paragraph 3.2.4.3.5.

3.2.4.3.2 Analysis

Based on the following generic set of evaluation procedures, two author languages have been selected for analysis. In the selection, two basic questions were asked; namely, (a) will the language be required to operate in conjunction with and control of a CRT display system? and, (b) will the curriculum be prepared and entered into the computer by non-computer programmers?

An answer in the affirmative to question (a) eliminated all but three of the languages. The language would be required to operate with and control CRT's, and all but three languages lacked that capability. The three capable of operating with and controlling CRT's are: CATO, IBM's Coursewriter, and Philco's INFORM. An answer in the affirmative to question (b) eliminated CATO. The curriculum would be prepared and entered into the computer by a non-computer programmer, and CATO, as mentioned earlier, is a modified FORTRAN '60 compiler with special modifications which requires the talents of a computer programmer specialist.

The two acceptable author languages, Coursewriter II and INFORM, are discussed in the following paragraphs. Although Coursewriter II and INFORM meet the criteria of the generic evaluation procedures, it should be noted that neither language possesses the capability to execute mathematical computations more advanced than simple arithmetic.

3.2.4.3.3 INFORM

The language used with Philco-Ford's Project GROW is referred to as the INFORM author language and the teacher who uses it, the author. Using INFORM, the information included in the curriculum and the material to be presented to the student is described on forms and subsequently punched on cards. The computer processes and stores this course information and, as directed by the author, displays it to the SAVI.

The flow of information through the system is illustrated in Figure 3.2-34.

3.2.4.3.3.1 Forms

To communicate with the CAI computer system, the author must write a series of author language instructions on specially designed forms. The computer is capable of accepting these instructions written in precisely specified formats on the forms.

To facilitate the preparation of subject matter and instructions in author language, three CAI forms, designated 01, 02, and 03 are available. Each of these forms has a specific purpose and is to be used to provide special types of information to the computer. As shown in Figures 3.2-35, 3.2-36 and 3.2-37, the forms have titled and pre-numbered groups of columns or fields to assist the author in their usage.

The forms contain fields used by the author to describe a series of instructions (commands) to the computer system. Special features of the commands are called parameters, and may also be specified on the form. The author identifies or names a section of the course material with "label". Other fields on the forms permit "remarks" and "card sequence numbers", which can be added by the author for reference purposes, but are not processed by the computer.

The forms are divided into vertical columns, numbered 1 to 80, corresponding to the columns on the punched cards. The forms provide the information to be punched, column for column; these cards are subsequently processed by the computer to produce the desired program and curriculum data. The fixed nature of the forms and the requirement that the author write the

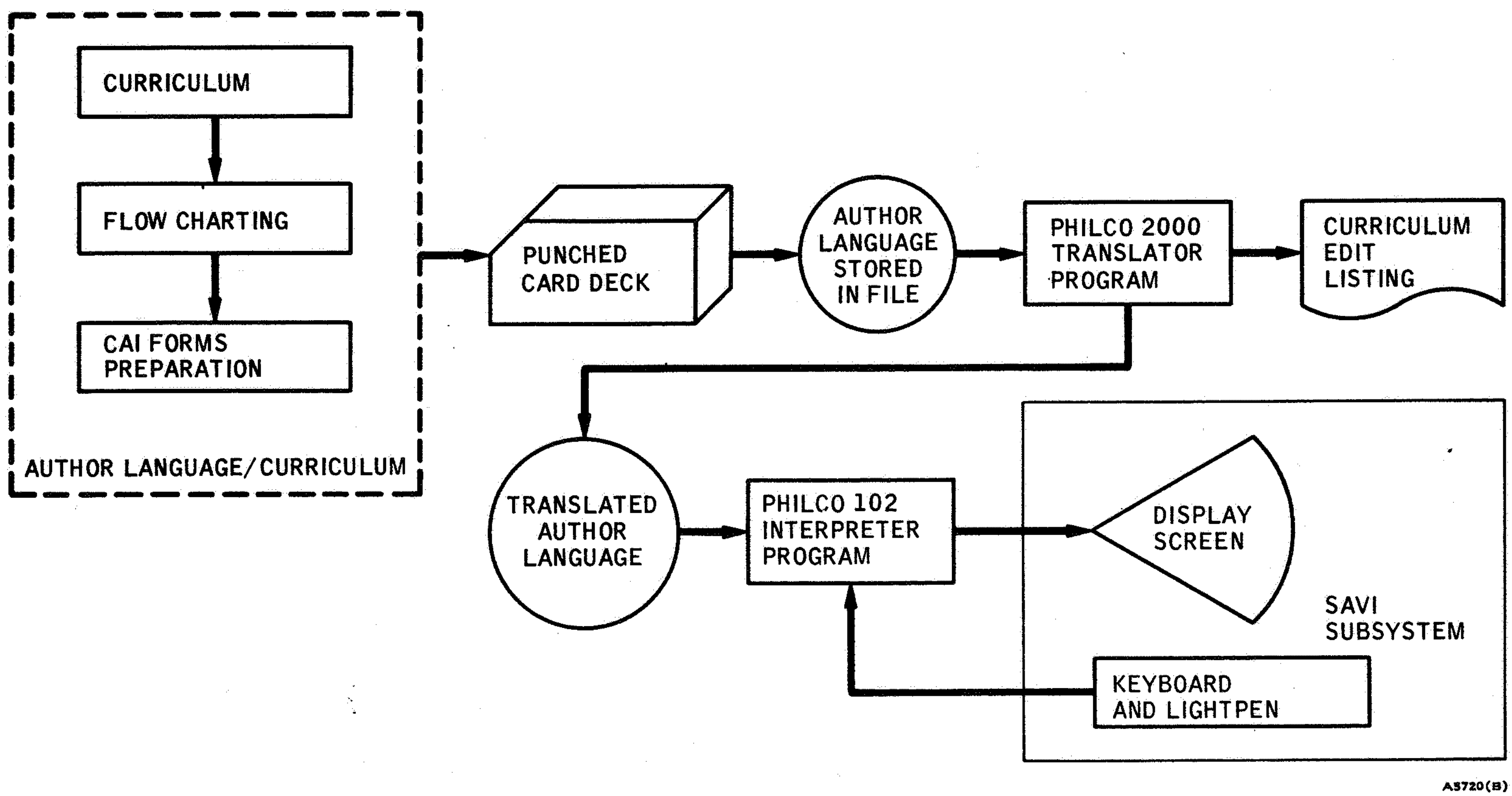
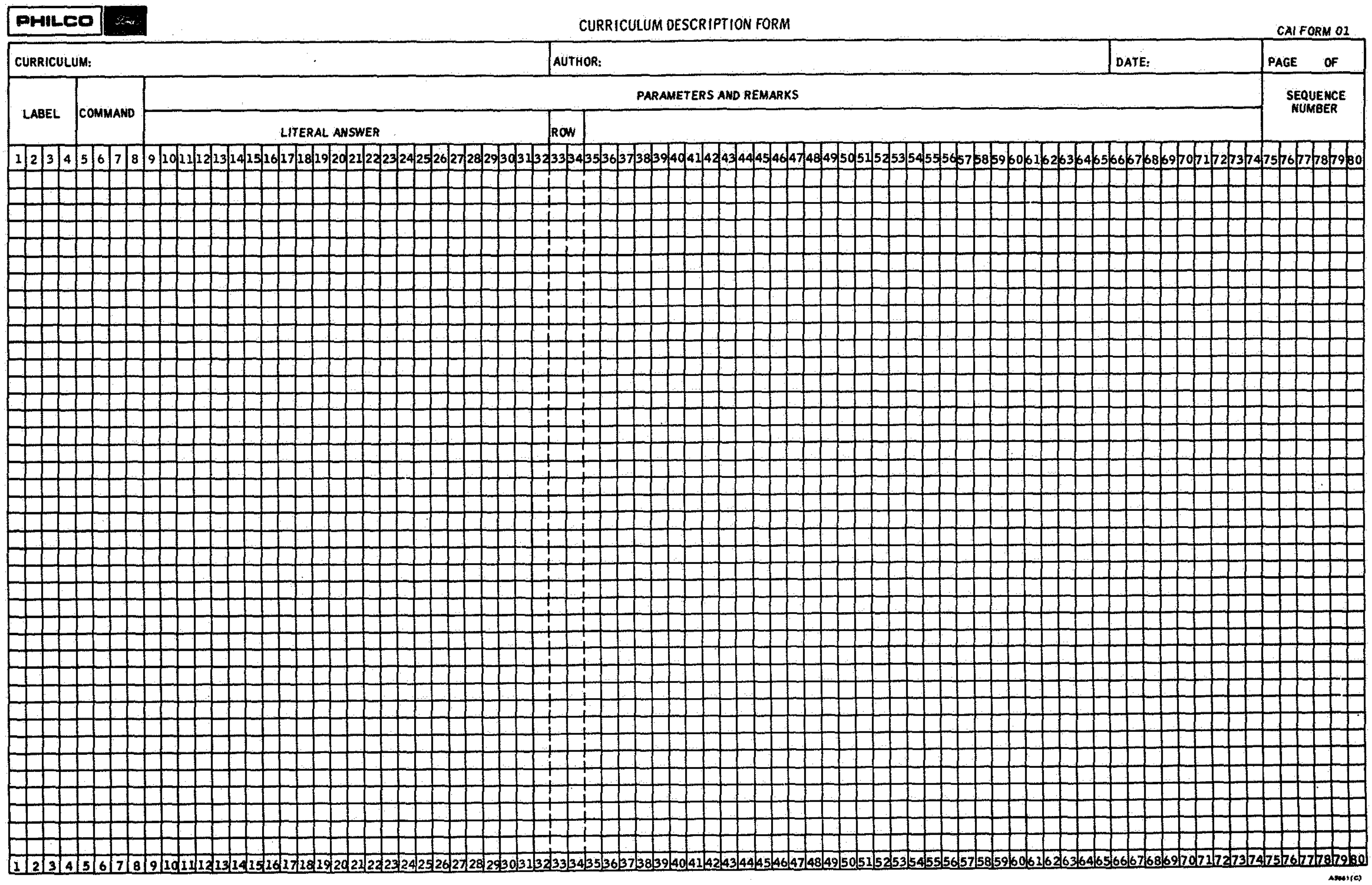


Figure 3.2-34 Curriculum Flow


PHILCO

CURRICULUM DESCRIPTION FORM

CAI FORM 01

CURRICULUM: | AUTHOR: | DATE: | PAGE OF

LABEL | COMMAND | PARAMETERS AND REMARKS | SEQUENCE NUMBER

LITERAL ANSWER | ROW

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

Figure 3.2-35 Curriculum Description Form (CAI Form 01)

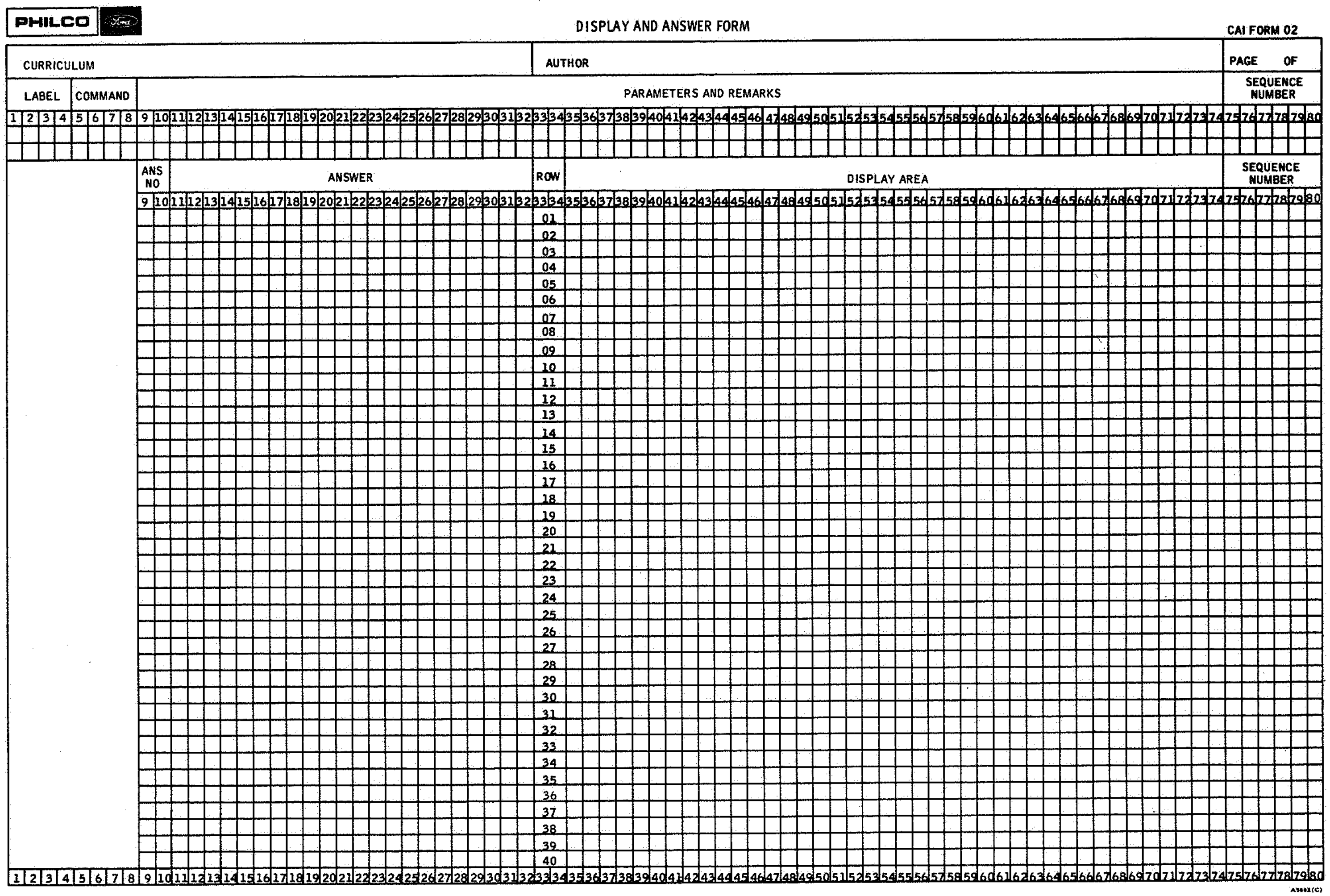
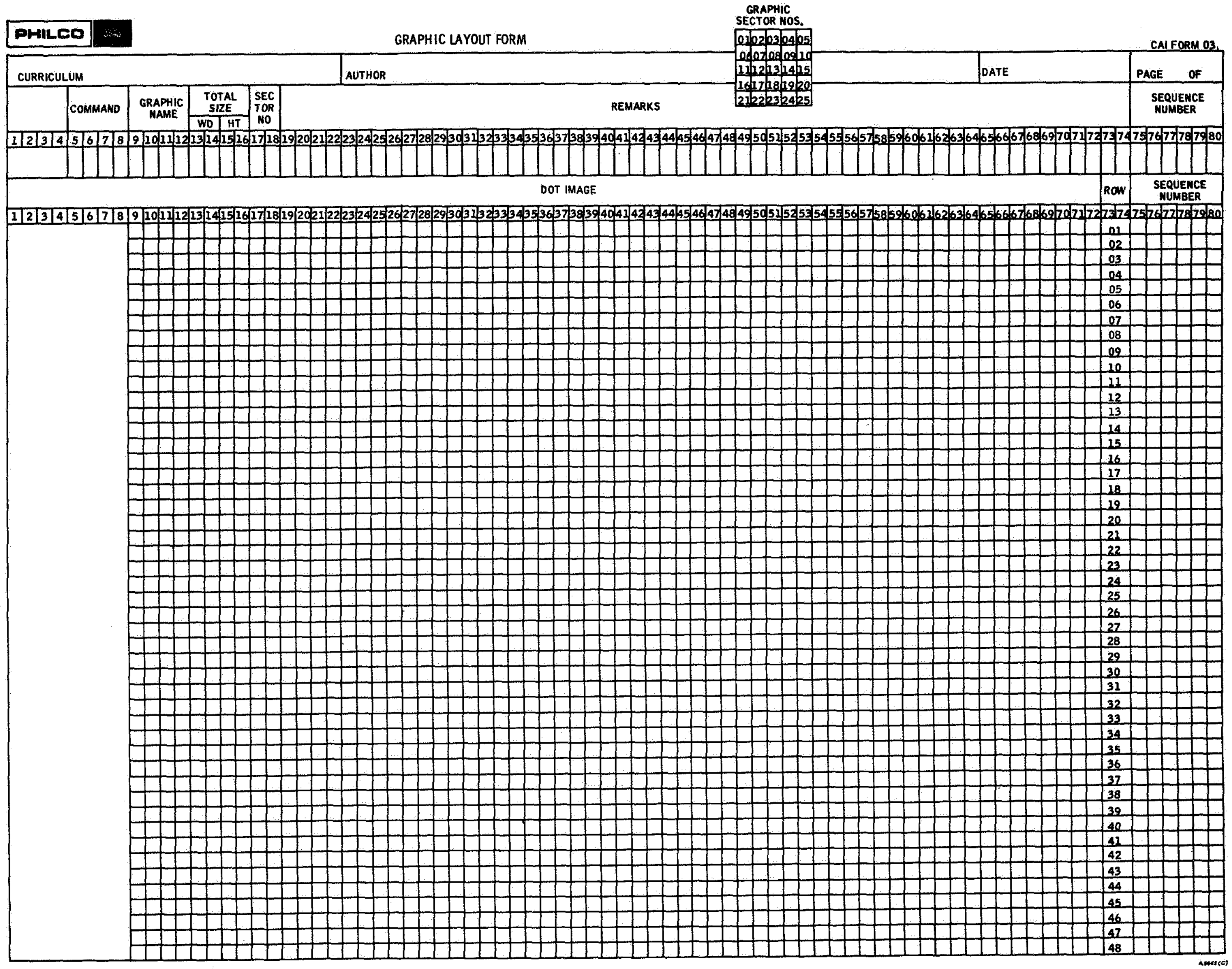


Figure 3.2-36 Display and Answer Form (CAI Form 02)



PHILCO

GRAPHIC LAYOUT FORM

GRAPHIC SECTOR NOS.

01	02	03	04	05
06	07	08	09	10
11	12	13	14	15
16	17	18	19	20
21	22	23	24	25

CAI FORM 03

CURRICULUM

AUTHOR

DATE

PAGE OF

COMMAND

GRAPHIC NAME

TOTAL SIZE

WD

HT

SEC TOR NO

REMARKS

SEQUENCE NUMBER

DOT IMAGE

ROW

SEQUENCE NUMBER

Figure 3.2-37 Graphic Layout Form (CAI Form 03) information on the forms, according to specific rules, enables the computer and its programs to properly interpret and process that information.

A. <u>FORM 01</u>. The author normally uses Form 01 to specify the desired procedural steps in his curriculum. These steps are specified by writing commands or instructions for the computer to interpret and perform; essentially, they enable the author to specify the following operations:

- Display information on the SAVI screen
- Ask questions of the student
- Examine the student's response for several different answers
- Branch a student forward or backward to a particular point of instruction within the subject, to a remedial area, or to an enrichment segment
- Establish a point in the lesson where a student should begin the lesson in his next session.

Form 01 contains the following fields:

COLUMNS	FIELD	FUNCTION
1 - 4	Label	Name or number identification
5 - 8	Command	Instruction name
9 - 74	Parameters and Remarks	Special features of the commands and authors comments (optional)
75 - 80	Sequence Number	Card sequence number (optional)

Columns 9 to 74 may also be used to describe literal display information, as follows:

COLUMNS	FIELD	FUNCTION
9 - 32	Literal Answer	Contains actual answers specified by the author

COLUMNS	FIELD	FUNCTION
33 - 34	Row	The half-line row number (01-40) where the data is to appear on the screen
35 - 74	Literal Display Area	The actual display information prepared by the author

B. FORM 02. Form 02 provides a means for the author to specify the actual information to be displayed on the screen and the layout of that information (data). The author identifies this data on Form 02 as a figure, and assigns it a number, which may be used to call it for display at any desired point or points in the curriculum procedures. Answers to displayed questions can also be specified with their associated figure and answer numbers.

The two lines at the top of the form provide the author with the fields necessary to specify commands and associated data as in Form 01.

On the remaining columns of the form, display and answer information may be described as follows:

COLUMNS	FIELD	FUNCTION
9 - 10	Answer Number	A number assigned to a specific answer expected by an associated display
11 - 32	Answer	The actual answer expected
33 - 34	Row	The half-line row number (01 - 40) where data is to appear on the screen
35 - 74	Display Area	The actual display prepared by the author
75 - 80	Sequence Number	Card sequence number (optional)

C. FORM 03. Form 03 enables the author to construct desired graphic displays, such as pictures or illustrations. The author identifies this display by a name which may be used to identify it for subsequent presentation during the lesson.

This form contains the following fields at the top of the form:

COLUMNS	FIELD	FUNCTION
5 - 8	Command	Pre-printed GRA for Graphic
9 - 12	Graphic Name	A name assigned by the author for this graphic
13 - 16	Total Size (WD/HT)	Total size of the graphic in relation to character size (WD/HT, width and height)
17 - 18	Sector Number	Position number, as shown in the chart at the top of the form (01 - 25)
19 - 74	Remarks	Author's comments (optional)
75 - 80	Sequence Number	Card sequence number (optional)

The actual graphic illustration is drawn on the dot layout area (columns 9 - 72). Row numbers are pre-printed on the form. The dot layout area is divided into 8 horizontal character positions (width) by 4 vertical character positions (height).

3.2.4.3.3.2 Commands

There are four categories of commands available to the author; viz., Procedural commands, Figure (FIG) command, Graphic (GRA) command, and Special (MACRO) commands.

Eleven procedural commands are available to the author, namely:

COMMAND	DERIVATION	MEANING
D	Display	display data on SAVI screen
Q	Question	display a question(s) on SAVI screen and request student response
E	Examine	examine student response
C	Correct	These commands are used in conjunction with the E command
W	Wrong	
A	Anticipated	
T	Time-up	
U	Unrecognized	
X	Inclusive	
B	Branch	branch or go to a point specified
P	Problem	restart a student at a specific point after being interrupted

The Figure command available to the author is:

COMMAND	DERIVATION	PURPOSE
FIG	FIGure	The figure command is used to specify that the information on the display portion of the form is to be referenced within the course flow as a figure.

The graphic command available to the author is:

COMMAND	DERIVATION	MEANING
GRA	GRAphic	The graphic command is used to define graphics larger than the normal character size for subsequent call-up by a procedural command

Five special commands are available to the author. They are:

COMMAND	DERIVATION	PURPOSE
DEFM	DEFine Macro	This command is used to identify a group of commands so that it may be referenced by Macro name throughout the curriculum
ENDM	END Macro	Identifies the end of a macro
DEFS	DEFine Segment	Identifies the start of a course segment
ENDS	END Segment	Identifies the end of a course segment
REM	REMarks	Permits author to "write" remarks to himself throughout the curriculum.

3.2.4.3.3.3 Labels

Each command must be identified with a major label or minor label. The major label is used to identify complete problem or concept units within a curriculum or to identify logical breaking points within a lesson. The minor label is subordinate to the major label and identifies points within the given major label.

3.2.4.3.3.4 Parameters

Each Procedural command, in addition to labels, may have parameters which the author must specify. Parameters provide additional or qualifying information about a command. There are 10 parameters associated with the procedural commands. They are: Figure Reference Number, Screen Effect, Clock Value, 1st Operand, 2nd Operand, Branch Reference, (2nd level) Figure Reference Number, Interpretation Mode, Answer Number, and Iteration Number.

There are five parameters associated with the Figure command; viz., Figure Number, Segment, Graphic Delimiter, Answer Delimiter, and Cursor Delimiter.

3.2.4.3.3.5 Special Information Symbols

There are 10 special values, 11 special symbols, 6 delimiter symbols, 6 delimiter modification symbols, and 2 keyboard convention symbols. A breakdown of the symbols is illustrated in Table 3.2-20.

Collectively, the special values (R, A, I, O and E) determine what effect the information to be displayed is to have on the information already on the SAVI display. The L specifies that the information following the display command is the actual information to be displayed. The S specifies that the display area or Form 02 has more than one segment to be called up during the course of instruction. KWN, ULE, and the omission of both are used with the Examine command and check the student's response.

The special symbols /LT....../NE/ specify the types of conditions that must be satisfied prior to branching from one area to another. The special symbols "=" ... "/" specify the type of operation to be performed prior to branching to another area.

The delimiter symbols are used to designate the limits of parameters given with a command or the limits of a specific area on the display screen. The delimiter modification symbols are used to override the established delimiters and redefine them as some other character.

The keyboard convention symbols are self explanatory.

3.2.4.3.3.6 Counters, Switches and Return Registers

In addition to commands, parameters, and special values and symbols, the author is provided with counters, switches, and return registers.

There are 32 counters available for author use and are identified as C1 through C32. They are used primarily for scoring. They permit the author to determine, for example, the number of right or wrong responses the student makes by counting them as the student goes through the curriculum, and later checking the contents of the counter. The author,

TABLE 3.2-20

SPECIAL VALUES AND SYMBOLS

SPECIAL VALUES		SPECIAL SYMBOLS		DELIMITER SYMBOLS		DELIMITER MODIFICATION SYMBOLS		KEYBOARD CONVENTION SYMBOLS	
SYMBOL	INTERPRETATION	SYMBOL	INTERPRETATION	SYMBOL	INTERPRETATION	SYMBOL	INTERPRETATION	SYMBOL	INTERPRETATION
L	LITERAL	/LT/	LESS THAN	'	DISTINGUISHES THE CHARACTERS GRA FROM DISPLAYABLE ALPHABETIC CHARACTERS.	G (SYMBOL)	GRAPHIC DELIMITER REDEFINED IN CLOSED PARENTHESES.	*	KEYBOARD ANSWER LIMITED TO 100 CHARACTERS.
R	REPLACE	/GT/	GREATER THAN						
A	ADD	/LE/	LESS THAN OR EQUAL TO	* #	INDICATES THAT A RESPONSE FROM EITHER THE KEYBOARD (*) OR LIGHTPEN (#) IS FORTHCOMING. THIS ALSO IDENTIFIES THE AREA OF THE DISPLAY SURFACE WHERE A RESPONSE WILL BE MADE	I (SYMBOL)	IGNORE DELIMITER REDEFINED IN CLOSED PARENTHESES.	* *	KEYBOARD ANSWER LIMITED TO THE NUMBER OF COLUMNS COVERED BY THE ASTERISKS.
I	INSERT								
O	OVERLAY	/GE/	GREATER THAN OR EQUAL TO			O (SYMBOL)	OR DELIMITER REDEFINED IN CLOSED PARENTHESES.		
E	ERASE	/EQ/	EQUAL TO	? @ *	USE IN INTERPRETATING STUDENT RESPONSE; "?" MEANS IGNORE CHARACTER IN SAME RELATIVE POSITION; "*" MEANS TWO OR MORE ANSWERS MAY BE POSSIBLE; AND "@" IS USED TO CONNECT SEVERAL WORDS.				
OMISSION OF SYMBOL	EXACT EQUIVALENCE	/NE/	NOT EQUAL			A (SYMBOL)	AND DELIMITER REDEFINED IN CLOSED PARENTHESES.		
KWN	KEY WORD NON-ORDERED	=	EQUALITY						
ULE	UPPER AND LOWER CASE LETTERS EQUIVALENT	+	ADD			K (SYMBOL)	KEYBOARD DELIMITER REDEFINED IN CLOSED PARENTHESES.		
		-	SUBTRACT						
S	SEGMENT	*	MULTIPLY			L (SYMBOL)	LIGHTPEN DELIMITER REDEFINED IN CLOSED PARENTHESES.		
		/	DIVIDE						

using the B command for arithmetic and load operations, can increment or decrement the counters by any designated number. This capability allows the author to assign different scores to different answers and to attain a final score for the student.

There are also 32 switches available for author use and are identified as S1 through S32. A switch is used to determine if the student has gone through a particular program path. The switch is used to determine whether or not the student has gone through the path once. If the author is concerned with how many times the student has gone through a particular path, a counter should be used.

There are 8 return registers available for author use and are identified as R1 through R8. The return registers enable the author to return to a particular point within his curriculum from a subroutine. (A subroutine is a group of commands for performing a particular function. If the author needs that function more than once or twice within his curriculum he could give it a subroutine name and write the name when he needs the function rather than writing out the individual commands each time.) The return register is loaded with the label of the return point. The same register would be specified for a sub-routine, but would be loaded with different values, so the return would be to the proper place.

3.2.4.3.3.7 INFORM Hierarchy of Command Repertoire

Figure 3.2-38 illustrates the hierarchy of the command repertoire and associated parameters, values and symbols. To understand the use of this figure, refer to the Conditional Branch command. This type of branch command has 3 parameters that must be described; viz., the branch reference, the first operand, and the second operand. The value of the branch reference is either a major label or minor label or one of the return registers. The first and second operands in this command are both identified as either a counter, switch, or signed number.

It should be noted that both operands can be counters or switches or a signed number or a combination, e.g., the first operand is a switch and the second operand is a counter. To define the interaction of these 2 operands, 6 symbols are required; viz., /LT/, /GT/, /LE/, /GE/, /EQ/, /NE/. As an example: branch to the branch reference when the first operand (which is a counter switch or register) is LT or GT or LE or GE or EQ or NE the second operand (a counter, switch, or register).

Refer to Table 3.2-21 for a summary of the INFORM language. Figures 3.2-39 through 3.2-48 present an example of how the INFORM author language is utilized and the unusual operations involved. The explanation is as follows: A very simple concept is to be programmed into the computer; viz., the basic idea of telemetry flow through the MSFN and the MCC-H.

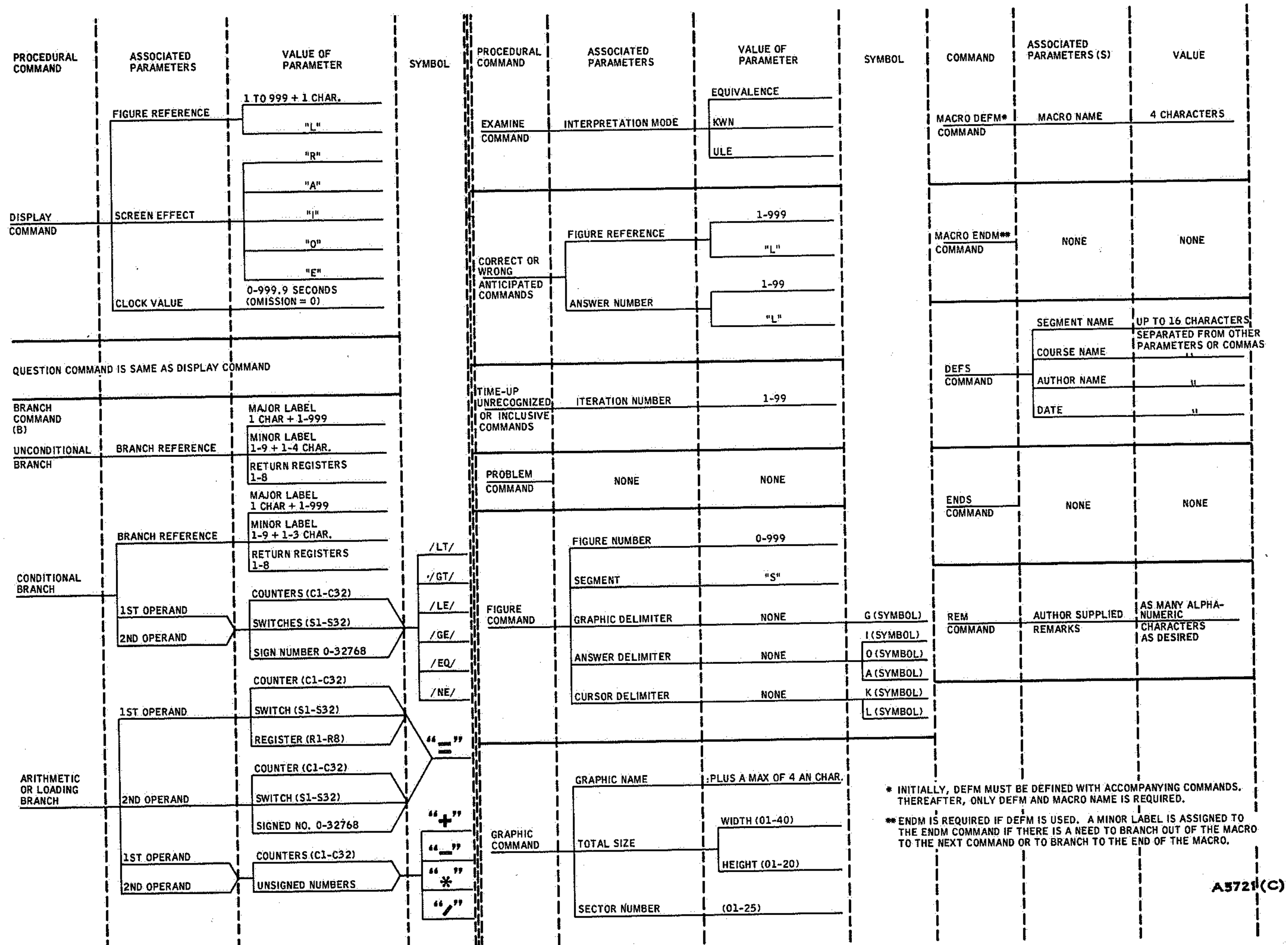


Figure 3.2-38 INFORM Hierarchy of Command Repertoire

TABLE 3.2-21

SUMMARY OF COMMAND REPERTOIRE

PROCEDURAL COMMANDS	PARAMETERS	SPECIAL VALUES	SPECIAL SYMBOLS	DELIMITER MODIFIERS
D	FIGURE REFERENCE	L	/LT/	G (SYMBOL)
Q	SCREEN EFFECT	R	/GT/	I (SYMBOL)
E	CLOCK VALUE	A	/LE/	O (SYMBOL)
C	1ST OPERAND	I	/GE/	A (SYMBOL)
W	2ND OPERAND	O	/EQ/	K (SYMBOL)
A	BRANCH REFERENCE	E	/NE/	L (SYMBOL)
T	INTERPRETATION	KWN	=	
U	ANSWER NUMBER	ULE	+	
X	INTERATION NUMBER	OMISSION	-	
B	FIGURE REFERENCE		*	
P	(2ND LEVEL)		/	
FIGURE CMD FIG	FIGURE NUMBER, SEGMENT, GRAPHIC DELIMITER, ANSWER DELIMITER, CURSOR DELIMITER	S	SEE DELIMITER MODIFIERS	
GRAPHIC CMD GRA	GRAPHIC NAME TOTAL SIZE SECTOR NUMBER	: PLUS 4 CHAR. 01 - 40 01 - 20 01 - 25		

SPECIAL CMDS	PARAMETERS
DEFM	MACRO NAME
ENDM	SEGMENT NAME
DEFS	COURSE NAME
ENDS	AUTHOR NAME
REM	DATE
	AUTHOR COMMENTS

DELIMITERS
:
*
#
?
@
*

OTHER SYMBOLS
*
* *
,
C (COUNTER)
R (REGISTER)
S (SWITCH)

MAJOR LABEL
MINOR LABEL

Figure 3.2-39 outlines the teaching strategy employed and how the concept could be flow charted. T001 is a major label starting point. GRA TLM1 is the graphic code for the block diagram to be presented to the student. FIG 1, FIG 2, FIG 3, FIG 4, FIG 5 and FIG 6 indicate the characters that comprise the 6 figures that will be presented during the instructional sequence. Note that FIG 3 appears twice since it is a segmented display. The one's and two's enclosed in circles are minor labels to which a branch can be made. The "E" enclosed in the diamond signifies the student is to be examined. T002 is another major label to which the program will branch upon the successful completion of the examination. The two counters are set to maintain accurate records of student performance.

Figure 3.2-40 is the coded sequence of the concept to be presented. Notice in the "Literal Display Area" that the author has used English text to describe the sentences to be displayed. In the Literal Answer portion of the form, the coded information indicates the function to be performed, e.g., D1, A means display FIG 1 and add it to the display surface. The FIG 1 to be displayed is described in total in Figure 3.2-41.

Upon examination, it is observed that the coded command GRA:TLM1 (illustrated in Figure 3.2-40) will cause the block diagram of the telemetry system (depicted in Figure 3.2-47) to be displayed to the student. Figure 3.2-48 (11 pages) illustrates how the Graphic Layout Form must be completed in order to prepare the display for the keypunch operator. Similarly, D1, A; D2, R; Q3A, R; D3B, A, 5; D4, R; Q5, R, 1S.0 and D6, R as illustrated in Figure 3.2-41 will cause the information depicted in that figure and Figures 3.2-42 through 3.2-46 to be presented to the student.

The remaining coded commands, i.e, B, X, E and P are used to sequence in remedial information and examine student responses.

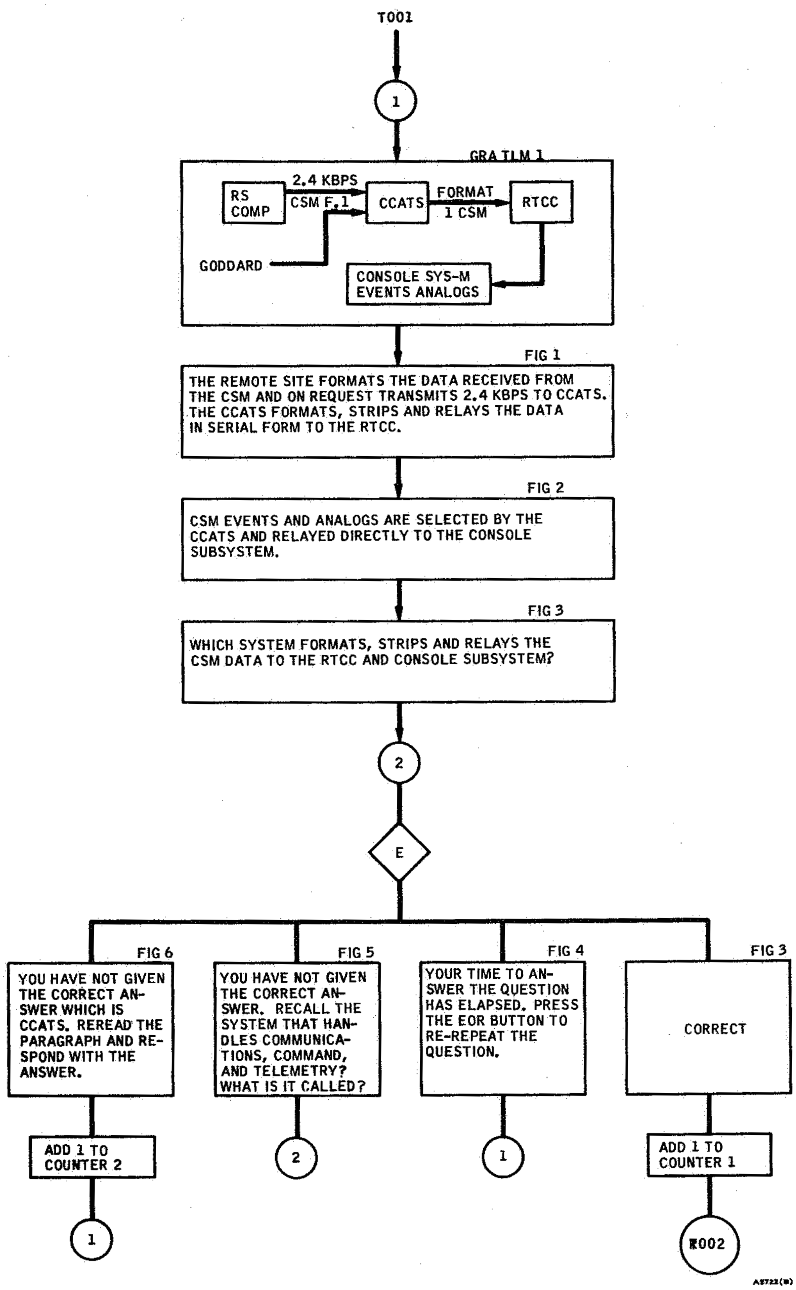


Figure 3.2-39 Flow Diagram of MSFN Telemetry Flow Concept for CAI Using INFORM

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CURRICULUM DESCRIPTION FORM

CAI FORM 01

CURRICULUM:	AUTHOR:	DATE:	PAGE 1 OF 1

LABEL	COMMAND	LITERAL ANSWER	ROW	PARAMETERS AND REMARKS	SEQUENCE NUMBER
T001	P			ESTABLISH RESTART POINT	
1	GRA	:TLM1		DISPLAY BLOCK DIAGRAM OF TLM FLOW	
	D	1,A		DISPLAY PARAGRAPH (THE REMOTE SITE...)	
	D	2,R		DISPLAY PARAGRAPH (THE CSM EVENTS...)	
	GRA	:TLM,.5		DISPLAY BLOCK DIAGRAM OF TLM FLOW	
	Q	3A,R		QUESTION (WHICH SYSTEM...)	
2	E	ULE		EXAMINE RESPONSE	
	C	3,1		IF CORRECT (CCATS OR CCAT)	
	D	3B,A,5		DISPLAY (CORRECT)	
	B	T002,C01+1		BRANCH TO T002	
	T			IF TIME UP	
	D	4,R		DISPLAY (YOUR TIME...)	
	B	1		BRANCH TO MINOR LABEL 1	
	X	1		IF ANSWER NOT RECOGINIZED 1ST TIME	
	Q	5,R,15.0		REWORD QUESTION	
	B	2		BRANCH TO MINOR LABEL 2	
	X			IF ANSWER AGAIN NOT RECOGNIZED	
	D	G,R		DISPLAY (WRONG) GIVE CORRECT ANSWER	
	B	1,C02 1		BRANCH TO MINOR LABEL 1,ADD 1 TO C02	
T002					

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Figure 3.2-40 Curriculum Description Form for Presentation of MSFN Telemetry Concept

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DISPLAY AND ANSWER FORM

CAI FORM 02

CURRICULUM	AUTHOR	PAGE 1 OF 6

LABEL	COMMAND	PARAMETERS AND REMARKS	SEQUENCE NUMBER
T001	FIG	1	

ANS NO	ANSWER	ROW	DISPLAY AREA	SEQUENCE NUMBER
		26	STUDY THE BLOCK DIAGRAM DISPLAYED	
		28	ABOVE. THE REMOTE SITE FORMATS THE	
		30	DATA RECEIVED FROM THE GSM AND ON REQ-	
		32	UEST TRANSMITS DATA AT A 2.4 KBPS RATE	
		34	TO CCATS. THE CCATS FORMATS, STRIPS AND	
		36	RELAYS THE DATA IN SERIAL FORM TO THE	
		38	RTCC	

Figure 3.2-41 Display and Answer Form for Curricular Material, FIG 1 Command

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DISPLAY AND ANSWER FORM

CAI FORM 02

CURRICULUM	AUTHOR	PAGE 2 OF 6

LABEL	COMMAND	PARAMETERS AND REMARKS	SEQUENCE NUMBER
T001	FIG	2	

ANS NO	ANSWER	ROW	DISPLAY AREA	SEQUENCE NUMBER
		01		
		02		
		03		
		04		
		05		
		06		
		07		
		08		
		09		
		10		
		11		
		12		
		13		
		14		
		15		
		16		
		17		
		18		
		19		
		20		
		21		
		22		
		23		
		24		
		25		
		26	CSM EVENTS AND ANALOGS ARE SELECTED BY	
		27		
		28	THE CCATS AND RELAYED DIRECTLY TO THE	
		29		
		30	CONSOLE SUBSYSTEM.	
		31		
		32		
		33		
		34		
		35		
		36		
		37		
		38		
		39		
		40		

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Figure 3.2-42 Display and Answer Form for Curricular Material, FIG 2 Command

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DISPLAY AND ANSWER FORM

CAI FORM 02

CURRICULUM	AUTHOR	PAGE 3 OF 6

LABEL	COMMAND	PARAMETERS AND REMARKS	SEQUENCE NUMBER
T001	FIG	3,S	

ANS NO	ANSWER	ROW	DISPLAY AREA	SEQUENCE NUMBER
		01		
1	CCATS*CCAT	02		
		03		
		04		
		05		
		06		
		07		
		08		
		09		
		10		
		11		
		12		
		13		
		14		
		15		
		16		
		17		
		18		
		19		
		20		
		21		
		22		
		23		
		24		
		25	A W	
		26	A WHICH SYSTEM FORMATS, STRIPS, AND RELAYS	
		27	A CSM	
		28	A THE CSM DATA TO THE CONSOLE SUBSYSTEM?	
		29		
		30		
		31		
		32	A T	
		33	A TYPE THE CORRECT ANSWER.	
		34		
		35	A * *	
		36		
		37		
		38	B CORRECT	
		39	B CORRECT	
		40		

Figure 3.2-43 Display and Answer Form for Curricular Material, FIG 3,S Command

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DISPLAY AND ANSWER FORM

CAI FORM 02

CURRICULUM	AUTHOR	PAGE 4 OF 6

LABEL	COMMAND	PARAMETERS AND REMARKS	SEQUENCE NUMBER
T001	FIG	4	

ANS NO	ANSWER	ROW	DISPLAY AREA	SEQUENCE NUMBER
		01		
		02		
		03		
		04		
		05		
		06		
		07		
		08		
		09		
		10		
		11	YOUR TIME TO ANSWER THE QUESTION	
		12		
		13	HAS ELAPSED. PRESS THE FOR BUTTON	
		14		
		15	TO REPEAT THE QUESTION.	
		16		
		17		
		18		
		19		
		20		
		21		
		22		
		23		
		24		
		25		
		26		
		27		
		28		
		29		
		30		
		31		
		32		
		33		
		34		
		35		
		36		
		37		
		38		
		39		
		40		

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Figure 3.2-44 Display and Answer Form for Curricular Material, FIG 4 Command

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DISPLAY AND ANSWER FORM

CAI FORM 02

CURRICULUM

AUTHOR

PAGE 5 OF 6

LABEL	COMMAND	PARAMETERS AND REMARKS	SEQUENCE NUMBER
T001	FIG	5	

ANS NO	ANSWER	ROW	DISPLAY AREA	SEQUENCE NUMBER
		09		
		10	YOU HAVE NOT GIVEN THE CORRECT ANSWER.	
		13		
		14	RECALL THE SYSTEM THAT HANDLES	
		16		
		17	COMMUNICATIONS, COMMAND AND TELEMETRY	
		20		
		21	WHAT IS IT CALLED?	
		23	* *	

Figure 3.2-45 Display and Answer Form for Curricular Material, FIG 5 Command

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DISPLAY AND ANSWER FORM

CAI FORM 02

CURRICULUM	AUTHOR	PAGE 6 OF 6

LABEL	COMMAND	PARAMETERS AND REMARKS	SEQUENCE NUMBER
T001	FIG	6	

ANS NO	ANSWER	ROW	DISPLAY AREA	SEQUENCE NUMBER
		01		
		02		
		03		
		04		
		05		
		06		
		07		
		08		
		09		
		10		
		11		
		12		
		13		
		14	YOU HAVE NOT GIVEN THE CORRECT ANSWER	
		15		
		16	WHICH IS	
		17		
		18	CCATS	
		19		
		20		
		21		
		22		
		23	REREAD THE PARAGRPH AND RESPOND WITH	
		24		
		25	THE ANSWER.	
		26		
		27		
		28		
		29		
		30		
		31		
		32		
		33		
		34		
		35		
		36		
		37		
		38		
		39		
		40		

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Figure 3.2-46 Display and Answer Form for Curricular Material, FIG 6 Command

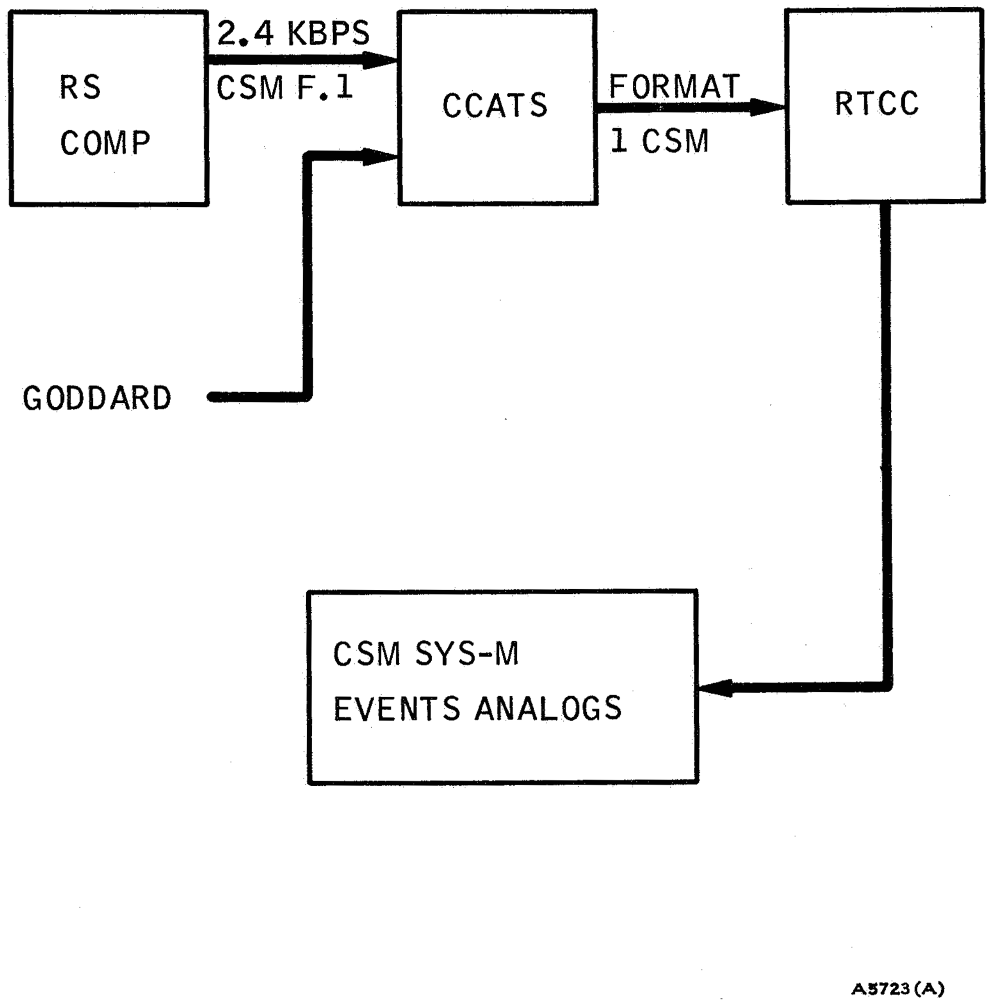

Figure 3.2-47 MSFN/MCC-H Telemetry Flow Functional Block Diagram

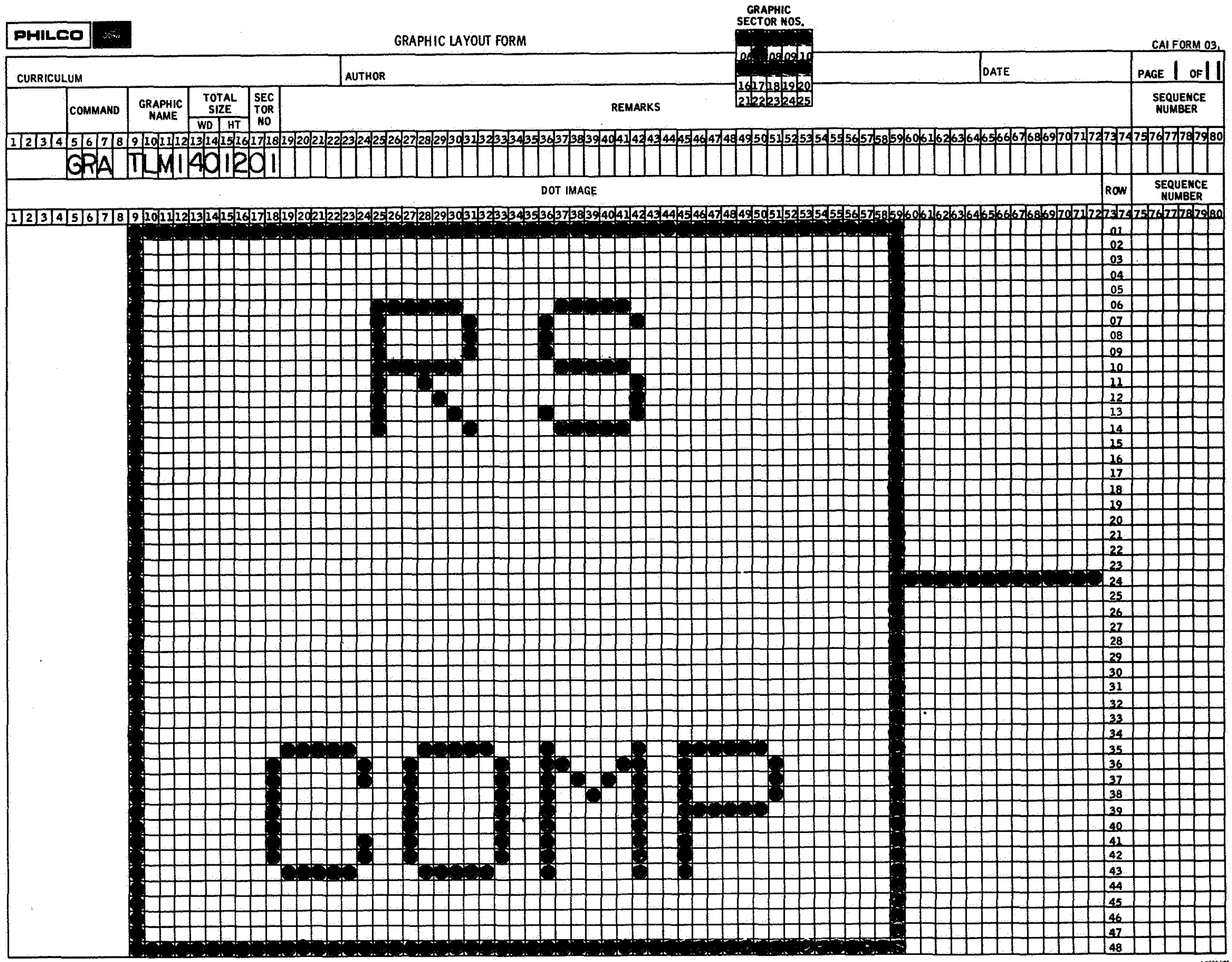

Figure 3.2-48 Graphic Layout Form Illustrating Development of MSFN/MCC-H Telemetry Flow Block Diagram

PHILCO

GRAPHIC LAYOUT FORM

CAI FORM 03

CURRICULUM	AUTHOR	GRAPHIC SECTOR NOS.	DATE	PAGE 2 OF 11
		01 02 03 04 05 / 06 07 08 09 10 / 11 12 13 14 15 / 16 17 18 19 20 / 21 22 23 24 25		

COMMAND	GRAPHIC NAME	TOTAL SIZE WD	TOTAL SIZE HT	SEC TOR NO	REMARKS	SEQUENCE NUMBER
GRA	TLM1	40	12	04		

DOT IMAGE

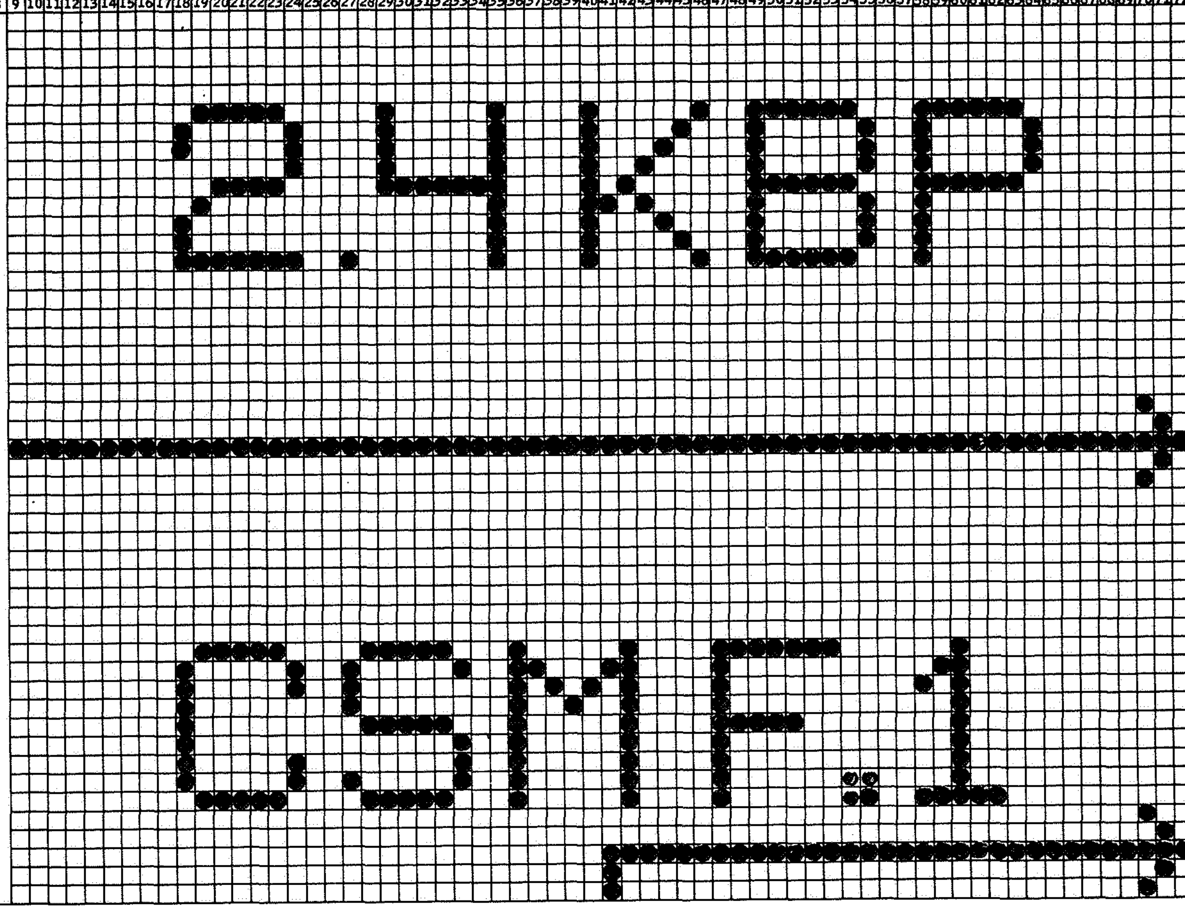

Figure 3.2-48 (Cont'd)

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GRAPHIC LAYOUT FORM

GRAPHIC SECTOR NOS.

01	02	03	04	05
06	07	08	09	10
11	12	13	14	15
16	17	18	19	20
21	22	23	24	25

CAI FORM 03

CURRICULUM | AUTHOR | DATE | PAGE 3 OF 11

COMMAND	GRAPHIC NAME	TOTAL SIZE WD	TOTAL SIZE HT	SEC TOR NO	REMARKS	SEQUENCE NUMBER
GRA	TLM1	40	12	03		

DOT IMAGE — ROW — SEQUENCE NUMBER

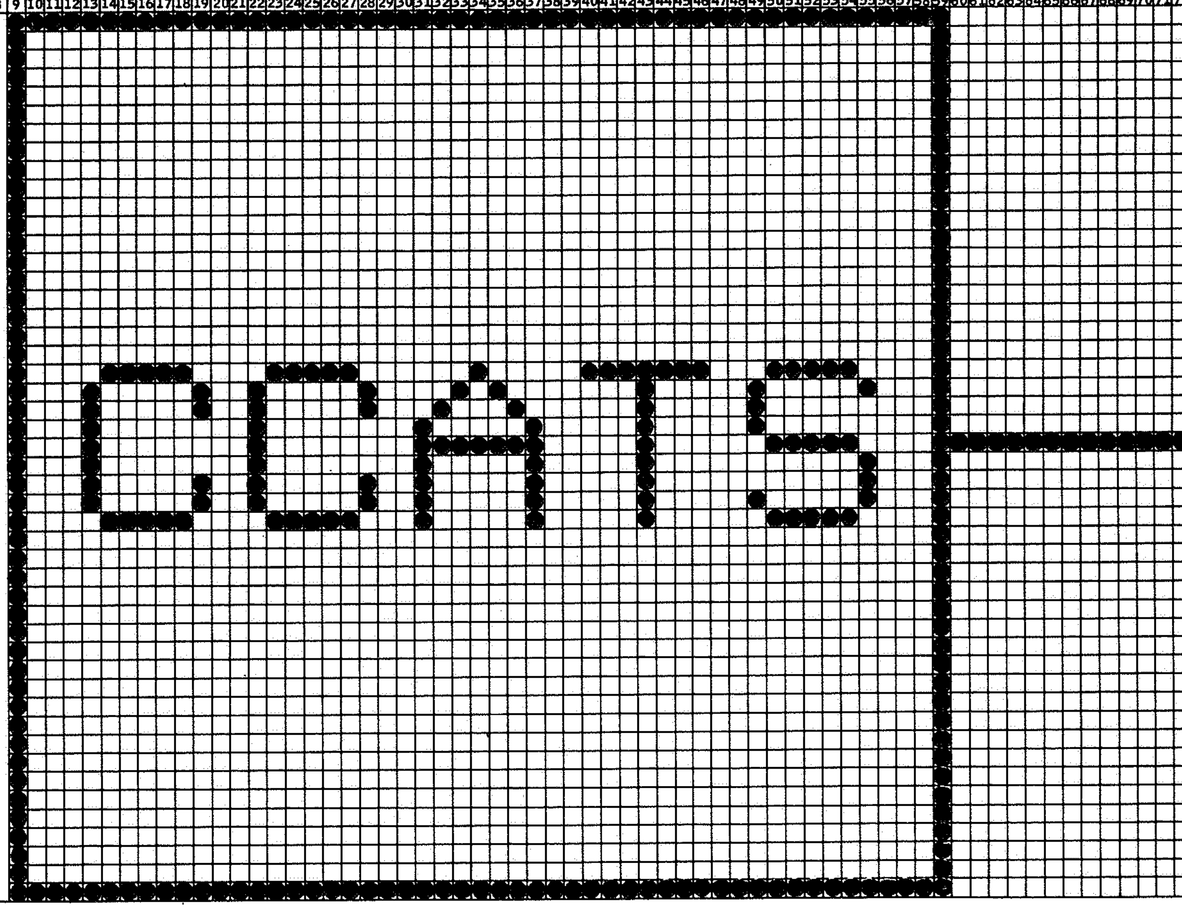

Figure 3.2-48 (Cont'd)

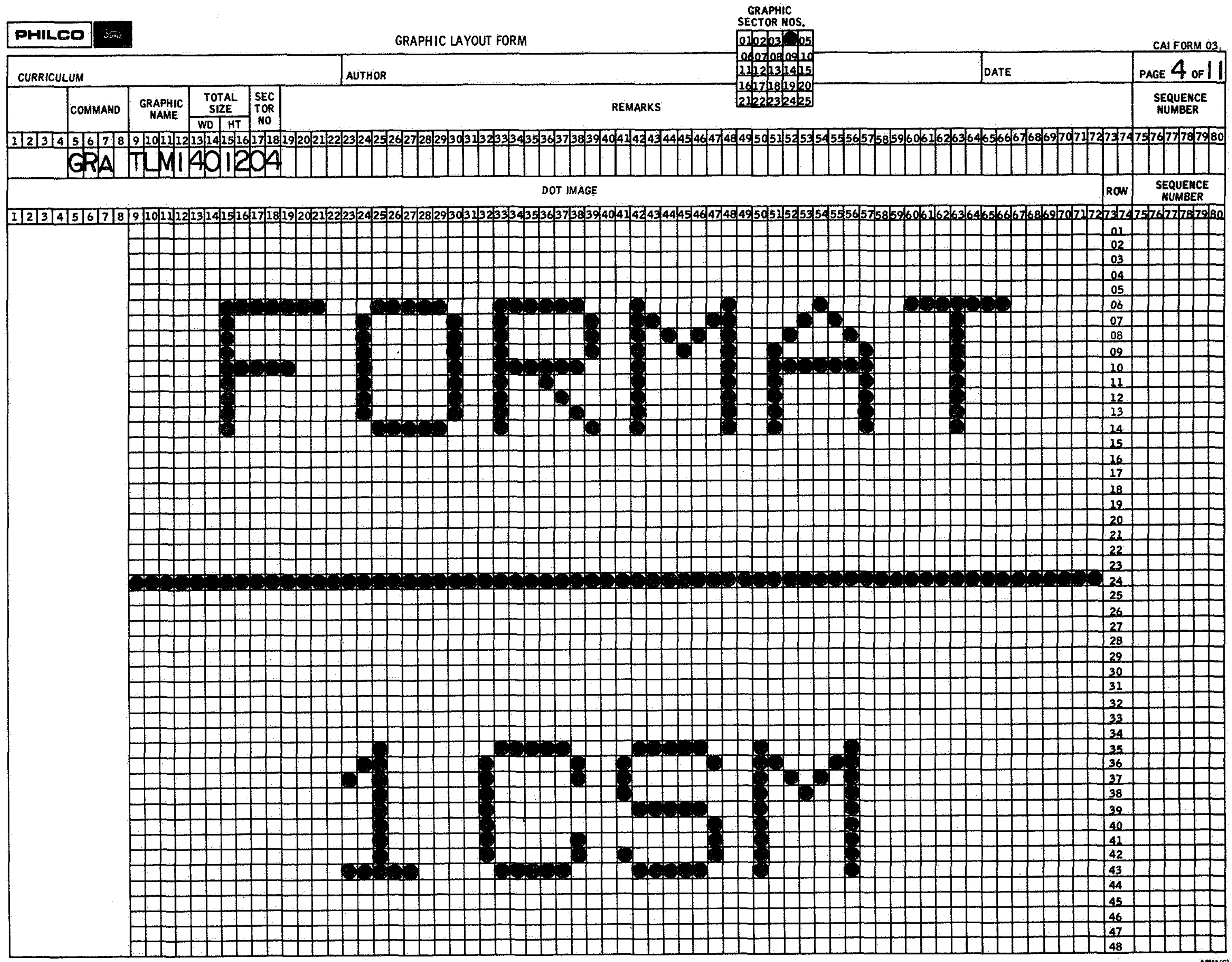

Figure 3.2-48 (Cont'd)

PHILCO

GRAPHIC LAYOUT FORM

GRAPHIC SECTOR NOS.

01	02	03	04	05
06	07	08	09	10
11	12	13	14	15
16	17	18	19	20
21	22	23	24	25

CAI FORM 03

CURRICULUM	AUTHOR	DATE	PAGE 5 OF 11

COMMAND	GRAPHIC NAME	TOTAL SIZE WD	TOTAL SIZE HT	SEC TOR NO	REMARKS	SEQUENCE NUMBER
GRA	TLM1	40	12	05		

DOT IMAGE

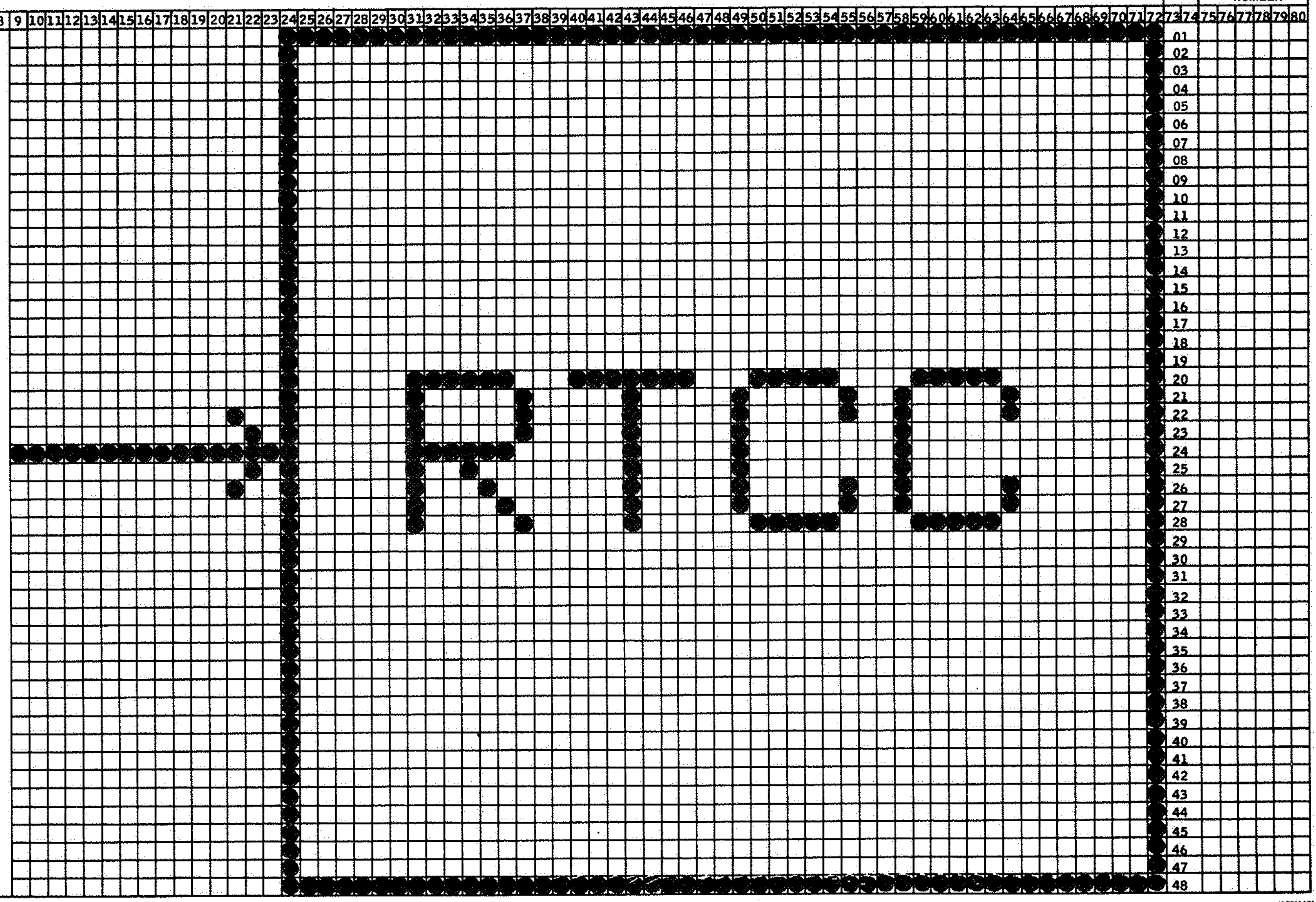

Figure 3.2-48 (Cont'd)

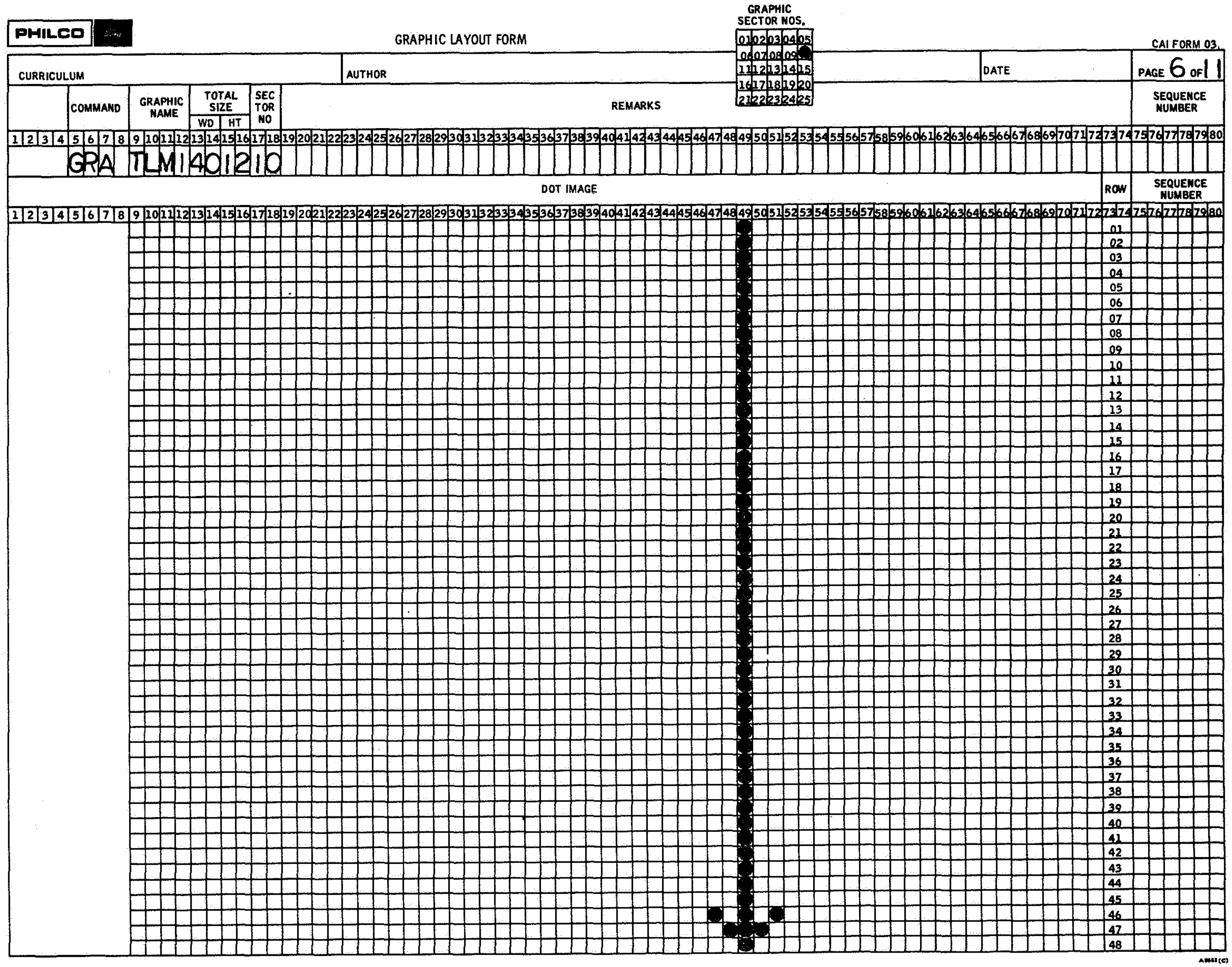

Figure 3.2-48 (Cont'd)

PHILCO

GRAPHIC LAYOUT FORM

GRAPHIC SECTOR NOS.

01	02	03	04	05
06	07	08	09	10
11	12	13	14	●
16	17	18	19	20
21	22	23	24	25

CAI FORM 03.

CURRICULUM	AUTHOR	DATE	PAGE 7 OF 11

	COMMAND	GRAPHIC NAME	TOTAL SIZE WD	TOTAL SIZE HT	SEC TOR NO	REMARKS	SEQUENCE NUMBER
	GRA	TLM1	40	12	15		

DOT IMAGE

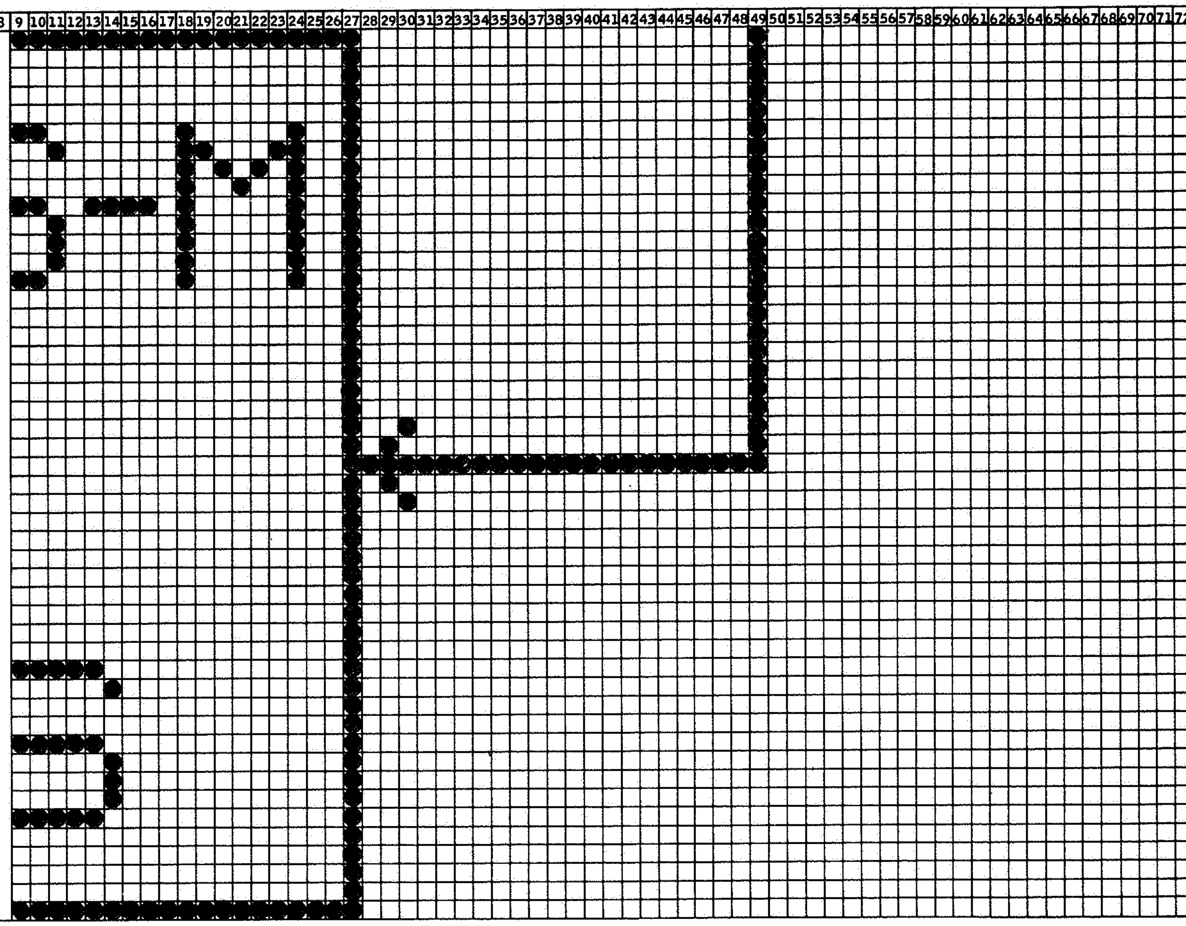

Figure 3.2-48 (Cont'd)

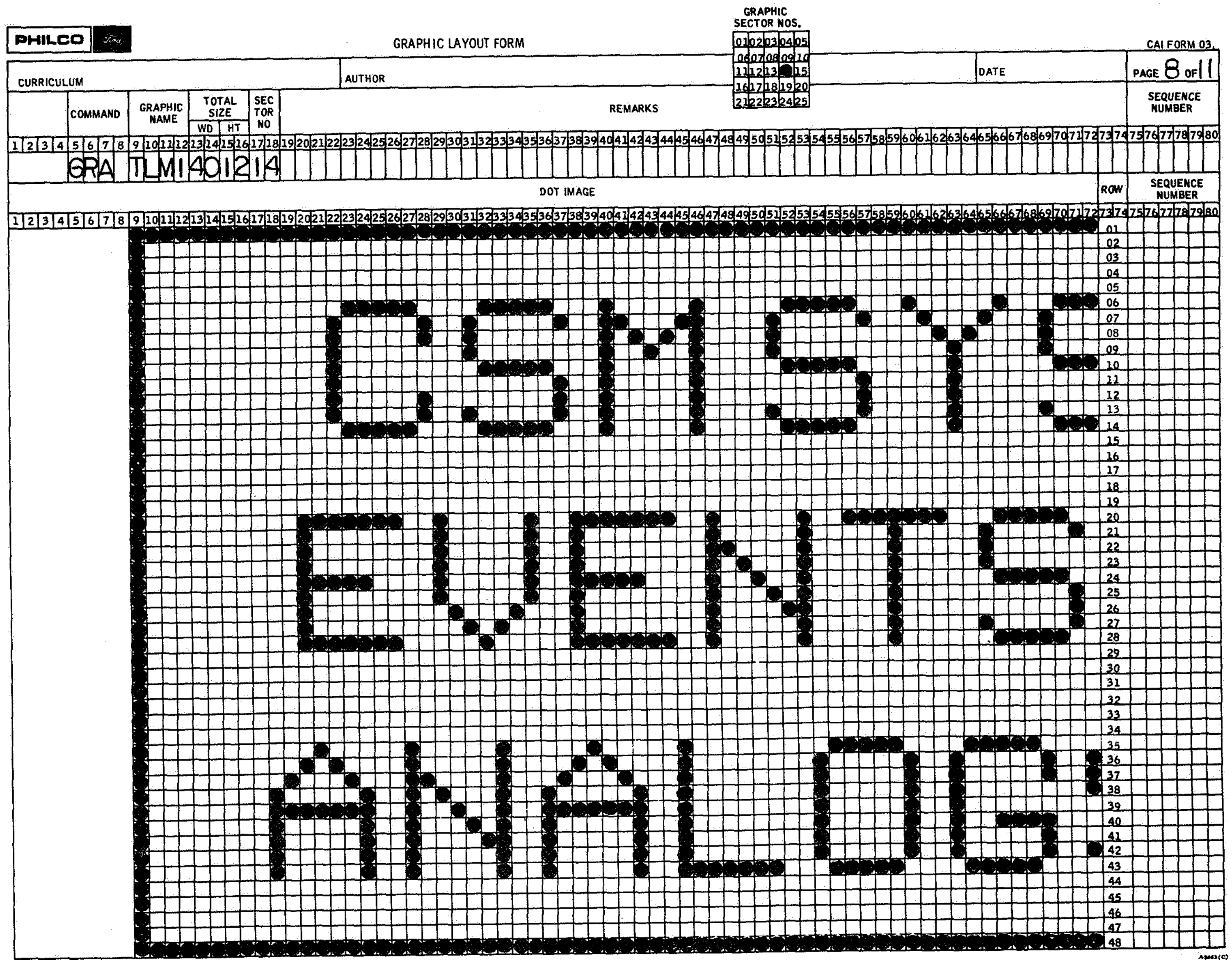

Figure 3.2-48 (Cont'd)

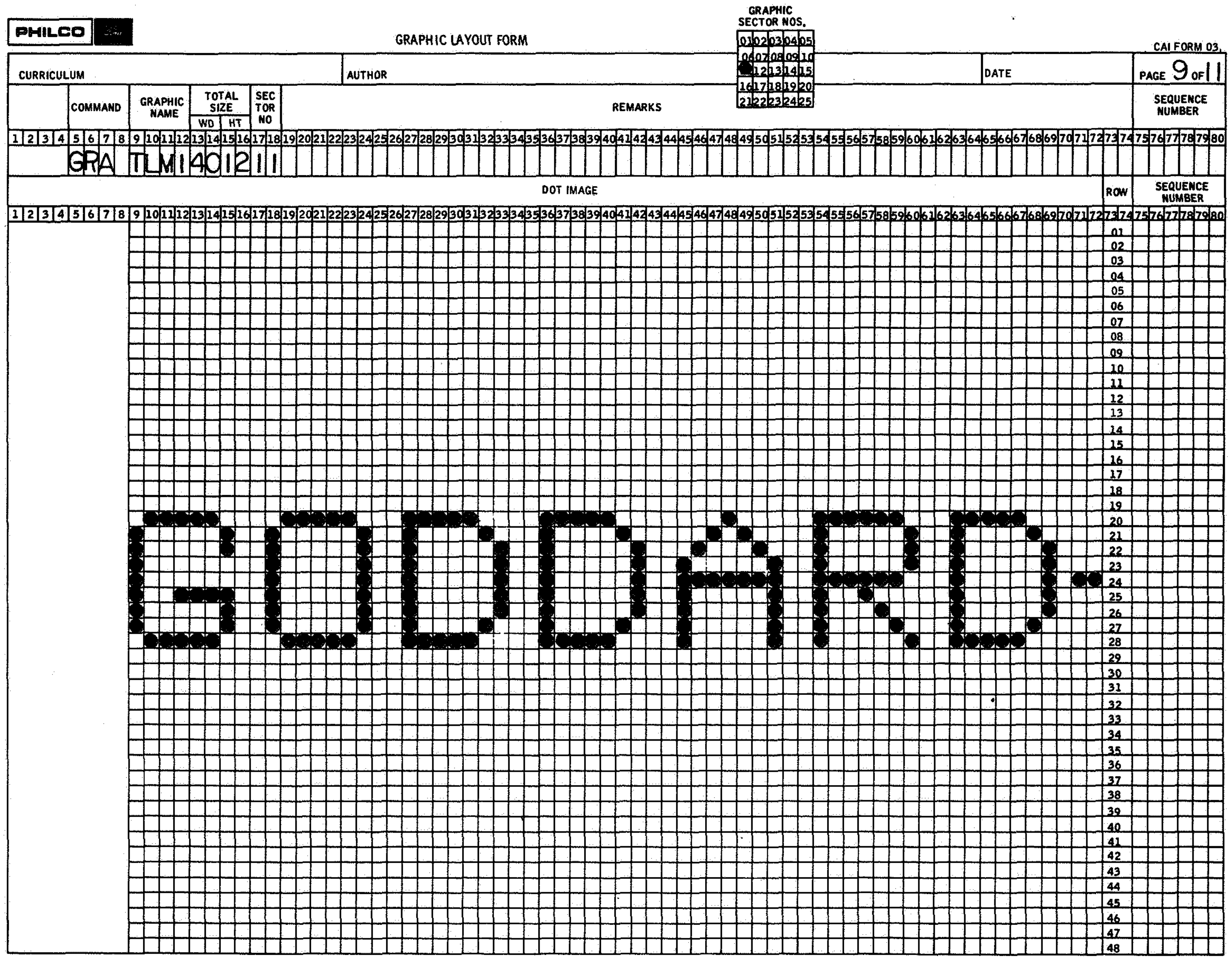

Figure 3.2-48 (Cont'd)

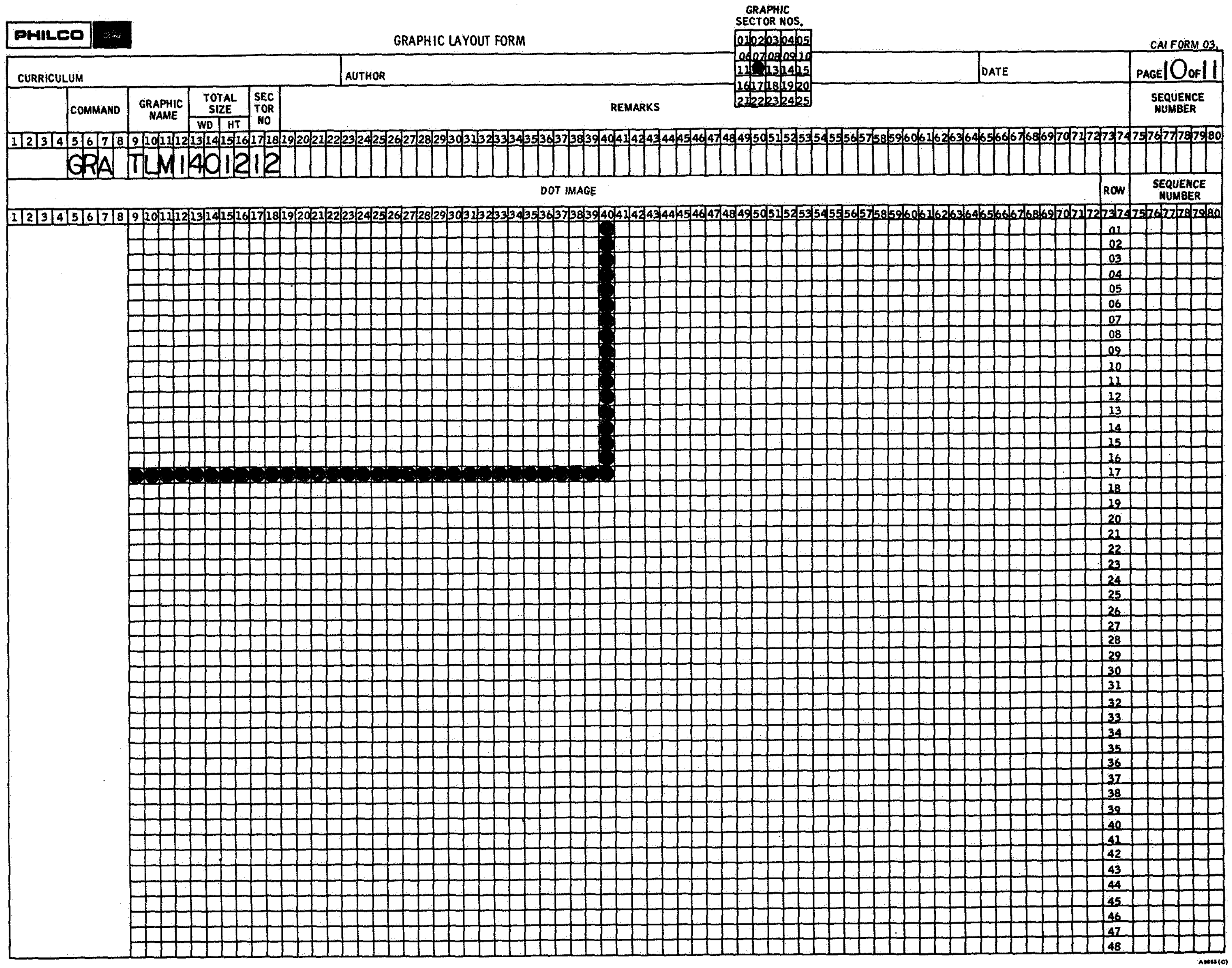

Figure 3.2-48 (Cont'd)

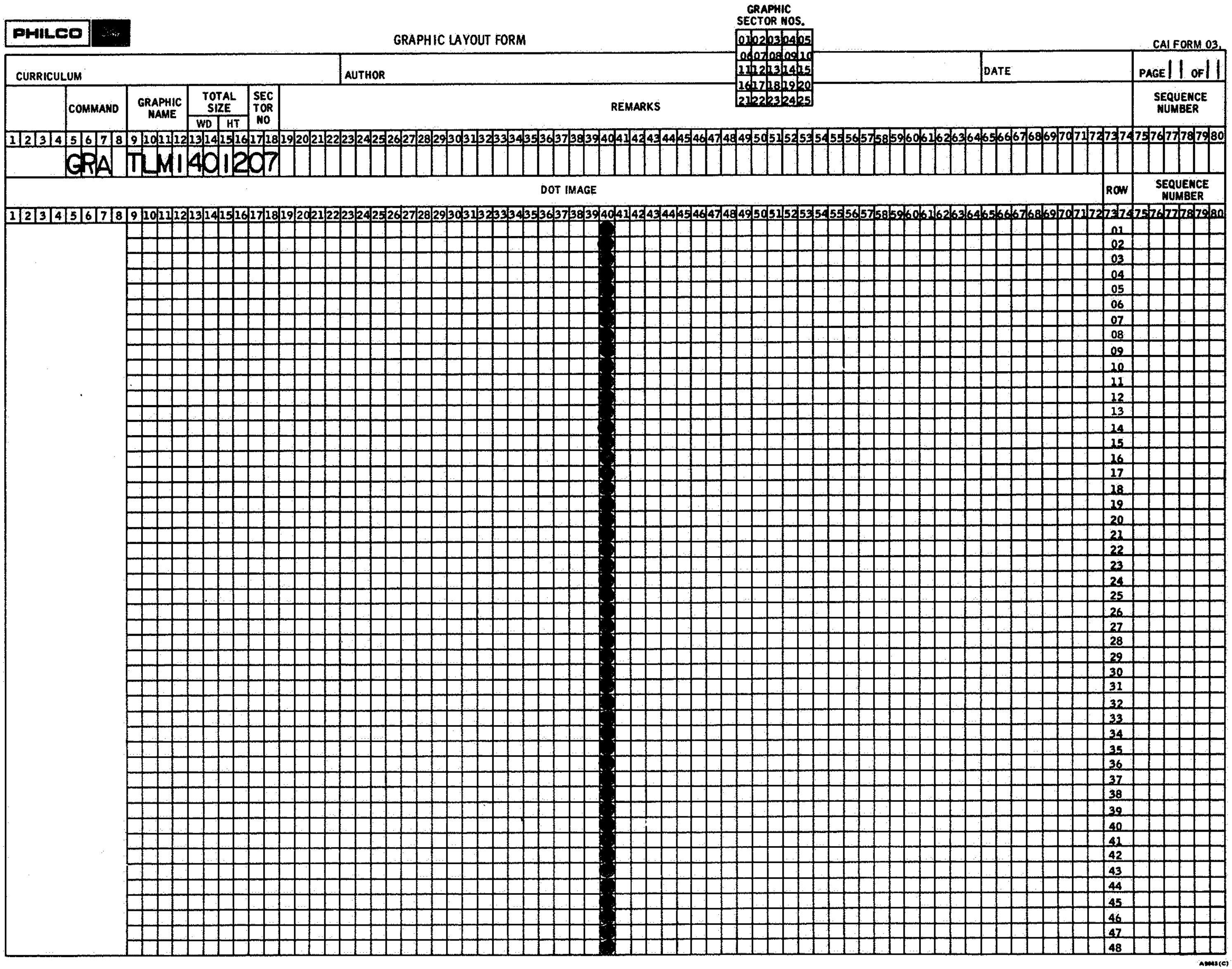

Figure 3.2-48 (Cont'd)

3.2.4.3.4 Coursewriter II

The Coursewriter II language developed by IBM is designed for operation with a typewriter and either an instructional display or a punched card system.

3.2.4.3.4.1 Forms

To facilitate the preparation of subject matter, two forms are provided. One, the Coursewriter II Instruction Sheet, is provided for the author to use in formatting statements. (Refer to Figure 3.2-49.) These statements can then be directly translated into the computer via the typewriter, instructional display system, or card punch/read equipment.

The Coursewriter II Instruction Sheet is divided into 80 vertical columns corresponding to the columns on a punched card. Columns 1 through 6 are provided for the label. The label is optional and consists of from 1 to 6 alphanumeric characters (A-Z, 0-9). It is used as an entry into the course and allows unique identification of a course statement. Within a course segment, no two instructions may have the same label. The first instruction must be labeled. Subsequent instructions must be labeled only if they are to be reached by a branch instruction. Statements immediately following each label are sequenced automatically by the computer.

Columns 7 and 8 are reserved for the operations code which consists of two lower case alphabetic characters which define the action to be performed on the text part of the course statement. Column 9 is reserved for the modifier which is a single alphabetic character used to modify certain operations code. Column 10 is blank. Columns 11 through 70 are used for textual information. Column 71 is blank. Column 72 is reserved for identifying the continuation code and is used only with card input. When punched, it denotes that the following card is part of the present course statement. Columns 73 through 80 are used by the author for course identification and card sequencing.

Textual information, appearing in columns 11 through 70, contains a series of arguments which vary in number, length and contents, and which are dependent on the particular operations code. Instructions of up to 123 characters in length may be entered. This includes the special delimiter characters, "/" and ",".

Information to be displayed on the IBM 1510 display system must be in correct format in core storage for proper translation and transfer to be effected. This necessitates the use of the Instructional Display Planning Guide. Refer to Figure 3.2-50. The guide is divided into 40

IBM

COURSE NAME ____________________

AUTHOR'S NAME ____________________

IBM 1500 OPERATING SYSTEM, COMPUTER-ASSISTED INSTRUCTION

COURSEWRITER II INSTRUCTION SHEET

DATE ____________

PAGE NO. ______ OF ______

LABEL	OP CODE	MOD.	BLANK	TEXT	BLANK	C. CODE	I. D. AND SEQUENCE NUMBER
1 6	7 8	9	10	11 16 21 26 31 36 41 46 51 56 61 66 70	71	72	73 80

Figure 3.2-49 Coursewriter II Instruction Sheet

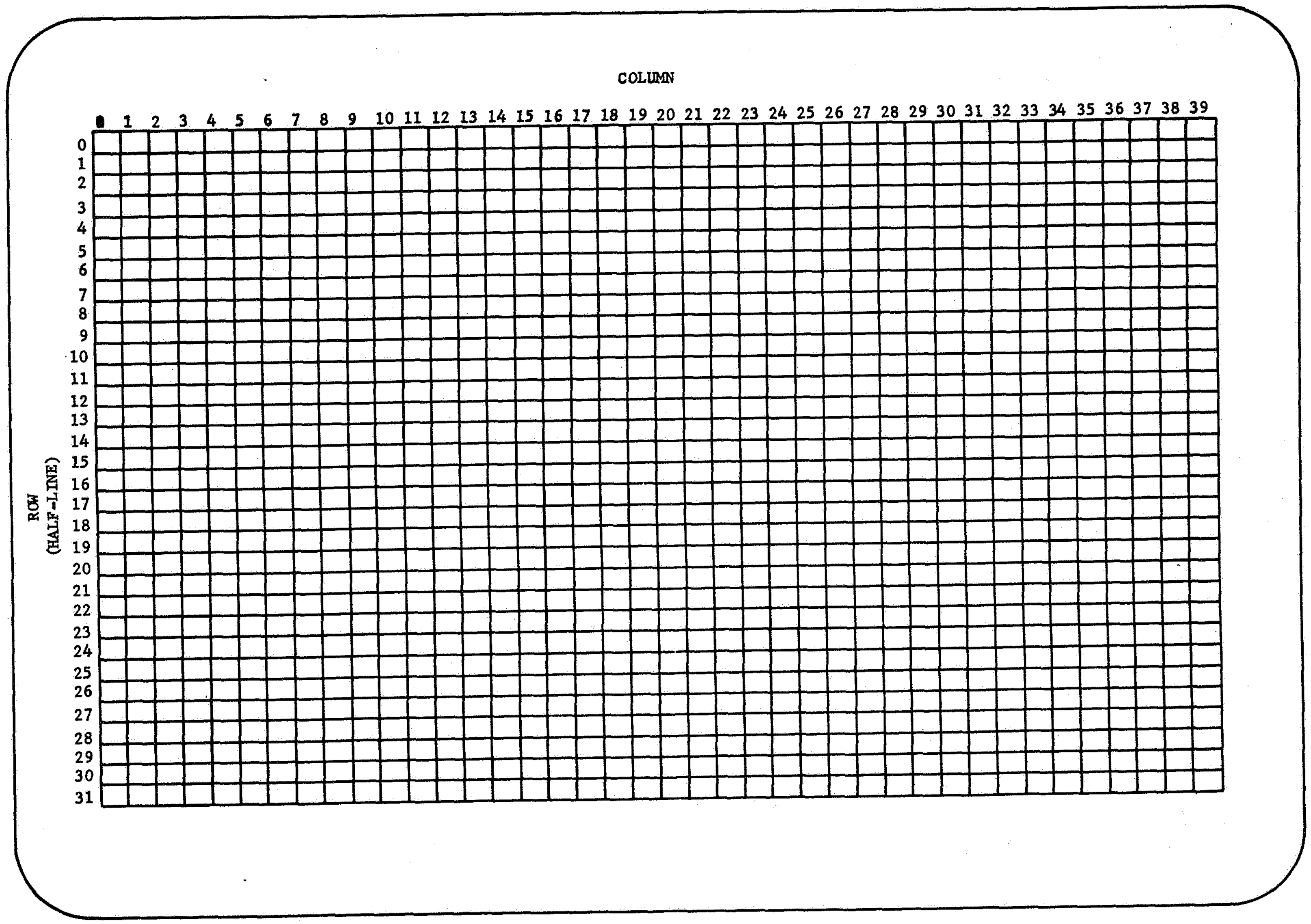

Figure 3.2-50 IBM 1510 Instructional Display Planning Guide

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columns (0-39) and 32 half-rows (16 character rows) capable of accurately positioning 640 (16 x 40) characters. For ease in developing graphics, the guide is divided into display sectors, each of which consists of 2 columns and 6 half-rows. Thus, 100 display sectors are available for use in constructing graphic displays. This will be discussed in more detail in subsequent paragraphs.

3.2.4.3.4.2 Command Instructions

Three categories of instructions are available to the author; viz., Major Instructions, Minor Instructions, and MACRO Instructions. Major instructions are used by the author to control course flow in accordance with student responses. Minor instructions are used by the author to control data presented to the display system and to manage the contents of registers, counters, buffers and switches available for use in controlling the course flow. MACRO instructions are used to develop and call up standard routines frequently used during the presentation of course material.

Ten Procedural commands (major instructions) are available to the author, namely:

COMMAND	DERIVATION	MEANING
ea	End of Answer or End of problem	Allows a set of minor instructions to be reached only through a branch instruction.
pr	PRoblem	Identifies the start of a problem.
aa	Anticipated Answer	Identifies answers which are to be compared with student responses.
ab	Synonymous anticipated answer	
ca	Correct Answer	
cb	Synonymous correct answer	
wa	Wrong Answer	
wb	Synonymous wrong answer	
un	UNrecognizable answer	Indicates action to be taken in the event the students response does not match the preceding correct or wrong answer sets.

COMMAND	DERIVATION	MEANING
nx	No match or no time out execute	Provides for execution of following minor instructions in the event of a mismatch on a previously executed ca or wa set.

Twenty minor instructions are available to the author, viz.,

COMMAND	DERIVATION	MEANING
ep	Enter and Process	Requests that a student response be made.
ec	Enter and Continue	Same as ep instruction except several entries are allowed.
ty	TYpe	Causes text to be printed on typewriter.
dt	Display Text	Causes text to be displayed on the display surface.
dg	Display Graphics	Causes graphics to be displayed on the display surface.
pm	Proctor Message	Causes message to be printed on typewriter or instructional surface.
dl	Display emphasis Line	Causes an underline to be displayed on a number of positions on a single row of the display surface.
de	Erase Instructional Display	Causes a selected number of consecutive rows on the display surface to be erased.
au	AUdio	Causes sections of audio tape to be selected.
fp	Film Position	Causes film projector to either open or close.
pa	PAuse	Causes the amount of time designeted to elapse prior to executing the next instruction.

COMMAND	DERIVATION	MEANING
ad	ADd	Causes the contents of a counter or a number to be added to a counter.
sb	SuBtract	Causes the contents of a counter or a number to be subtracted from a counter.
mp	Multiply	Causes the contents of a counter or a number to be multiplied by the contents of a counter, the result appearing in the latter counter.
dv	Divide	Causes the contents of a counter to be divided by the contents of another counter or number and to replace the contents of the counter with the result.
ld	Load	Causes the contents of a counter, number, text, state of switch or buffer to be loaded into and replace the contents of a counter, switch or buffer.
br	BRanch	Causes conditional or unconditional branches.
tr	TRansfer	Causes an unconditional branch to transfer control to the first instruction in another course or to a label within the course or to a restart point.
lr	Load return Register	Causes label associated with instruction to be loaded into a return register.
fn	Special function	Causes entry into specially coded routines.

Three MACRO instructions are available to the author; viz.,

COMMAND	DERIVATION	MEANING
cm	Call Macro	Causes the macro to be extracted from the system for use.
ma	MAcro	Used to begin the construction of a macro. (This is not executed.)
em	End Macro	Used to signify the end of a macro.

Associated with the major instructions are 4 unique modifiers and 6 unique mnemonic codes.

MODIFIERS	MNEMONICS
blank	ii , nn_2
r	bn , cc
p	nn_1
blank	rr

Associated with the minor instructions are 11 unique modifiers and 19 unique mnemonic codes.

MODIFIERS	MNEMONICS	
blank	rr_1	ffff
i	cc_1	cnn
p	rr_2	nnnnn
blank	cc_2	x
i	tttt	snn
p	mm	rnn
r	iiiii	
blank	ggg	prn
o	sssss	re
1	t	
blank	eeeee	

In addition, 8 special mnemonics are provided. They are:

- 1 - less than
- le - less than or equal to
- e - equal to
- ne - not equal to
- ge - greater than or equal to
- g - greater than
- 0 (zero) - reset (off)
- 1 (one) - set (on)

These are coded "xx" in the mnemonic table, Table 3.2-22. Two delimiters are provided for separating arguments "/" and ",". One "don't care" character "*" is provided for use with the answer set. Two parameter indicator symbols are provided for use with MACRO instructions. They are: "$" and "#". The author also has available 30 16-bit counters, 32 switches, 6 return registers and 6 response buffers for use in scoring, monitoring student responses, and data management.

For a summary of major, minor, mnemonic, and special instructions, and symbols, refer to Table 3.2-22.

3.2.4.3.4.3 Coursewriter II Hierarchy of Command Repertoire

Figure 3.2-51 is an illustration of the command hierarchy. To understand the use of this figure, refer to the ec and ep commands. Since both are essentially the same, only the ep command will be discussed. The command has three modifiers (blank, i, and p) which are used to modify the meaning of the ep command; e.g., a "blank" assumes the input device is the same one used by the student when signed on, and that a transfer erase mode will automatically erase data to the right and left of the students input area; and "i" specifies that the student answer is to be inserted within one or more lines of text on the instructional display; a "p" indicates the student input device is to emanate from the light pen.

The text associated with the "blank" or "i" modifier is: rr_1, cc_1 / nn_1 rr_2 / nn_2, cc_2 / tttt/mm/iiiiii/text. The code fields, i.e., rr_1, cc_1, etc., define the starting X-Y coordinate, the number of rows and

TABLE 3.2-22

SUMMARY OF COURSEWRITER II OPERATION CODES

MAJOR INSTRUCTIONS

OPERATION CODE	MODIFIER	TEXT - (*SEE NOTE REGARDING DELIMITERS)
PROBLEM		
	blank - no restart	none
	r - restart	
ea	none	none
ANSWER		
aa,ab	blank - keyboard input	ans.$_1$/ans.$_2$/--.ans.$_n$/ii
ca,cb		bn/ii
wa,wb	p -light pen input	nn_1,rr,nn_2cc/.../ii
un	none	ii
nx	none	none

MINOR INSTRUCTIONS

INPUT		
Keyboard or Light Pen		
ec,ep	blank - sign-on device transfer erase	rr_1,cc_1/nn_1,rr_2/nn_2,cc_2/tttt/mm/iiiiii
	i - insert	
	p - light pen	tttt/iiiiii
OUTPUT		
Typewriter		
ty	none	Text
Instructional Display or Typewriter		
dt	blank - sign-on device transfer erase	rr_1,cc_1/nn_1,rr_2/nn_2,Text or bn
pm	i - insert	
Instructional Display		
dg	none	rr,cc/ggg_1,---ggg_n
dl	none	rr,cc/nn
de	none	rr/nn
Audio		
au	p - play	
	r - record	sssss,t/eeeee
	blank - position audio	
Film	0 - shutter closed	ffff
fp	1 - shutter open	
	blank - assumes shutter closed	
TIMER		
pa	none	tttt
ARITHMETIC		
ad,sb,mp,dv	none	cnn/cnn
		nnnnn/cnn
ld	none	cnn/cnn
		nnnnn/cnn
		x/snn
		Text/bn
		bn/bn
LOGIC		
br	none	Label or rrn
		Label or rrn/cnn/xx/cnn or nnnnn
		Label or rnn/snn/x
		prn
		re
tr	none	Course segment number/Label
lr	none	Label/rrn
SPECIAL		
fn	none	Function name/Text

MACRO INSTRUCTIONS

cm	none	Macro name/parameter, parameter,---parameter
ma	none	Macro name/parameter indicator
em	none	none

MNEMONIC	MEANING
bn	Response buffer identification
cc	Column position on display
cnn	Counter
eeeee	Ending address on audio tape
ffff	Projector frame number
ggg	Graphic number
ii	Identifier (2 characters maximum)
iiiiii	Identifier (10 characters maximum)
Label	Self-explanatory
mm	Maximum permitted length of entry
nn	Number of rows or columns on display
nnnnn	Number (may be signed)
rr	Row position on display
rrn	Return register identification
snn	Switch identification
sssss	Starting address on audio tape
t	Audio track
tttt	Time (tenths of seconds)
Text	Self-explanatory
x	State of switch
xx	Relation between counters or between a counter and a number
alternate code/	Delimiter character 1
alternate code,	Delimiter character 2

NOTE 1: There are two delimiters:

Delimiter 1 is alternate code /

Delimiter 2 is alternate code ,

NOTE 2: There are three "don't care" characters:

*

$

#

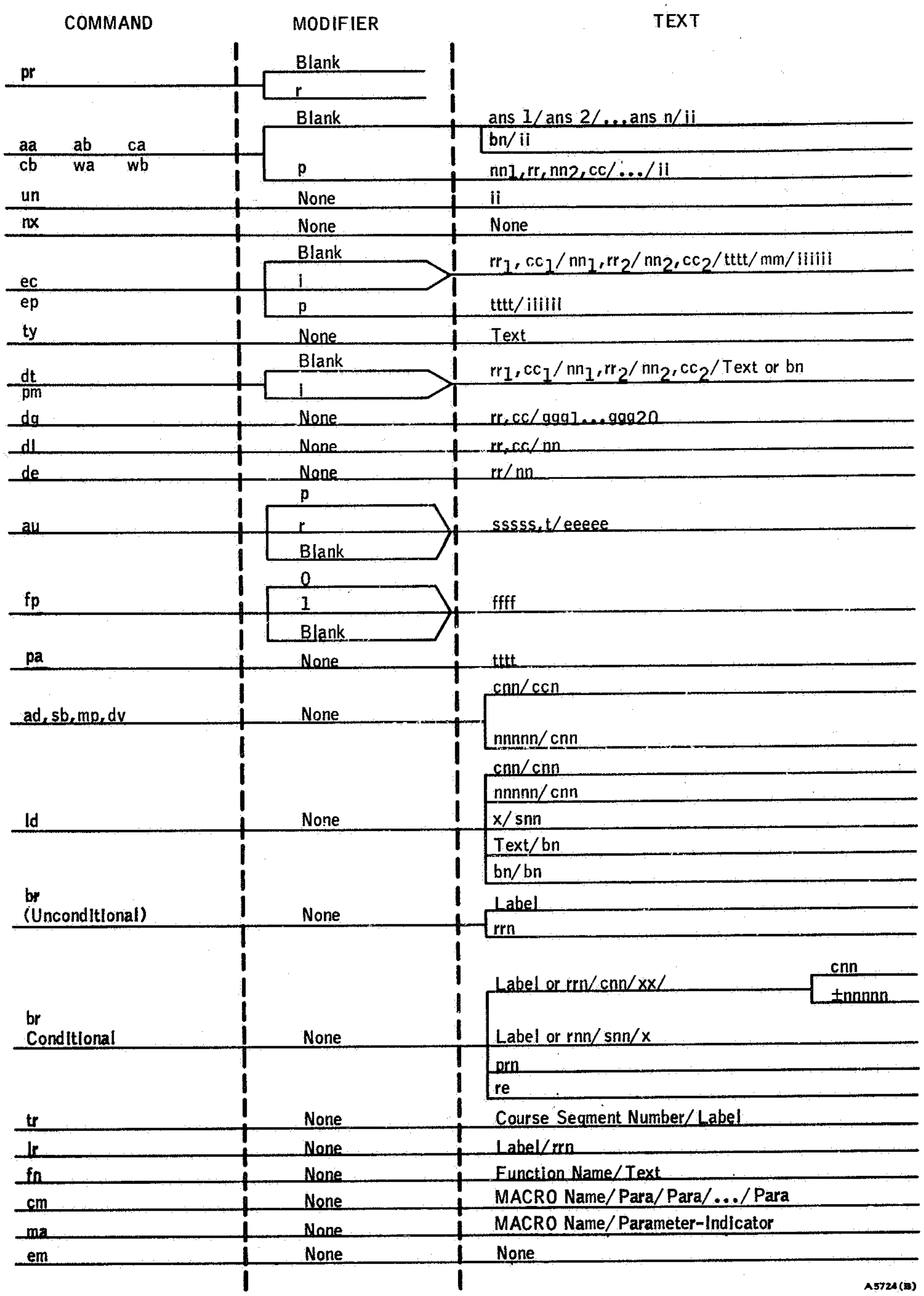

Figure 3.2-51 Coursewriter II Heirarchy of Command Repertoire

columns the information is to cover, the location of the cursor coordinates, the time (tttt) allowed for the student to complete his response, the maximum number of characters stored for the student entry and the student identifier for maintaining performance records.

3.2.4.3.4.4 Developing the Instructional Sequence

Figure 3.2-52 through Figure 3.2-57 are examples of the logic flow diagram, instructional sequence and graphic display forms that must be prepared by the author in the development of an instructional sequence. It should be noted that, the instructional sequence coded is identical to the material coded with the INFORM language. This will enable the reader to compare and contrast the two methods of preparation.

It is important to note, that in the development of the logic flow (Figure 3.2-52) and coded sequences (Figure 3.2-53) difficulty was encountered in interpreting the information and instructions contained in IBM Reference Manual Form CAI-4036-1. Therefore, certain instructional sequences may vary from the required sequence, but nonetheless provide the degree of accuracy necessary to illustrate the coding process.

Figures 3.2-54 through 3.2-56 illustrate the basic procedures to follow in constructing a graphic display.

The first step is to accurately outline the required graphic display; in this paradigm it is a block diagram. (Refer to Figure 3.2-54.) Note that three character rows remain on which the text can be displayed. As previously noted, the display surface is divided into 100 sectors, each sector consisting of 2 columns and 6 half-rows.

Represented in Figure 3.2-55 are 20 sectors of the display surface. These are used to construct the basic graphic display outlined in Figure 3.2-54. Figure 3.2-56 (5 pages) illustrates the use of this form. Note the correlation between these figures and Figure 3.2-54. It should be noted, that preparation of these forms is not necessary, but provides the author with a record and logical construction of the material to be presented.

Figure 3.2-57 (10 pages) represents the first 20 sectors on the display surface. This is a detailed translation of the graphic requirements. These figures are a detailed expansion of Figure 3.2-56. To complete the graphic display (to the extent that it could be entered into the computer), four additional sets of sectors would have to be developed in order to translate the information on the latter 4 pages of Figure 3.2-56 into a form meaningful to a computer programmer.

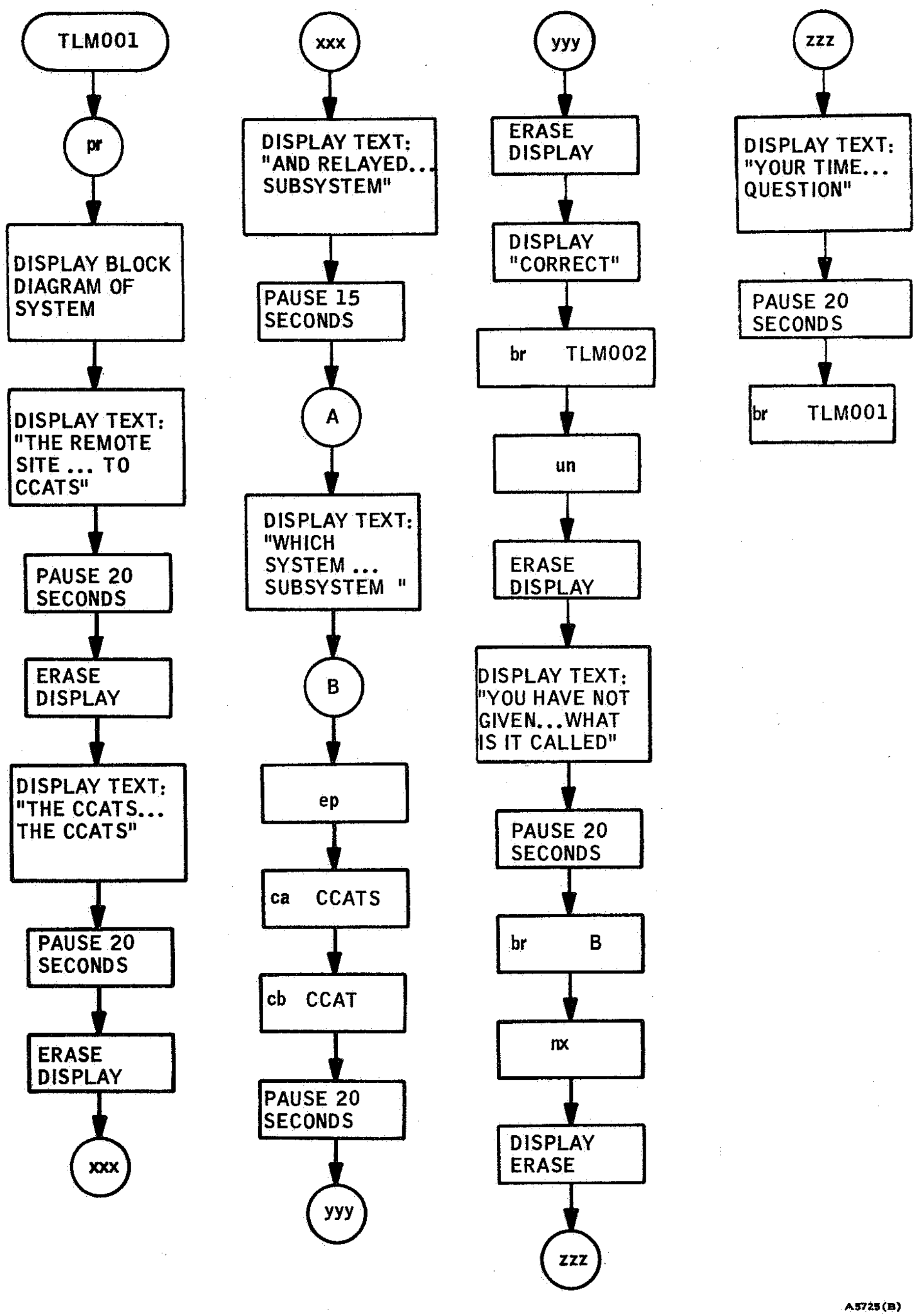

Figure 3.2-52 Flow Diagram of MSFN Telemetry Flow Concept for CAI Using Coursewriter II

LABEL	OP CODE	MODIFIER	BLANK		BLANK	CONT CODE	ID AND SEQ. NO.
TLM001	Pr	r					
	dg			0.0/0.1.2.3.4.5.6.7.8.9.10.11.12.13.14.15.16.17.18.19			
	dg			6.0/20.21.22.23.24.25.26.27.28.29.30.31.32.33.36.37.38.39			
	dg			12.0/40.41.42.43.44.45.46.51.52.53.54.55.56.58			
	dg			18.0/71.72.73.74.75.76.77.78			
	dg			24.0/91.92.93.94.95.96			
	dt			26.1/6.26/38.1/THE REMOTE SITE FORMATS THE DATA RECEIVED			
				FROM THE CSM AND ON REQUEST TRANSMITS 2.4KBPS TO CCATS.			
	pa			200			
	de			26/6			
	dt			26.1/6.26/38.1/THE CCATS FORMATS, STRIPS AND RELAYS THE DATA			
				IN SERIAL FORM TO THE RTCC. CSM EVENTS AND ANALOGS ARE			
				SELECTED BY THE CCATS			
	pa			200			
	de			26/6			

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Figure 3.2-53 Coding Requirements for Presentation of MSFN Telemetry Concept

LABEL	OP CODE	MODIFIER	BLANK		BLANK	CONT CODE	ID AND SEQ NO.
	dt			AND RELAYED DIRECTLY TO THE CONSOLE SUBSYSTEM			
	pa			150			
	de			26/6			
A	dt			WHICH SYSTEM FORMATS, STRIPS, AND RELAYS THE CSM DATA TO THE			
				RTCC AND CONSOLE SUBSYSTEM?			
B	ep			31,16/2,30/5,16/600///			
	ca			CCATS			
	cb			CCAT			
	pa			200			
	de			26/6			
	dt			28,14/2,28/7,14/CORRECT			
	br			TLM002			
	un			01			
	de			26/6			
	dt			2621/6,26/38,1/YOU HAVE NOT GIVEN THE CORRECT ANSWER. RECALL			

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Figure 3.2-53 (Cont'd)

LABEL	OP CODE	MODIFIER	BLANK		BLANK	CONT CODE	ID AND SEQ NO
				THE SYSTEM THAT HANDLES COMMUNICATIONS, COMMAND AND TELEME			
				TRY? WHAT IS IT CALLED?			
	pa			200			
	de			26,6			
	pa			200			
	br			B			
	nx						
	de			26,6			
	dt			26,1/6,26/38,1/ YOUR TIME TO ANSWER THE QUESTION HAS ELAPSED			
				DEPRESS THE ENTER BUTTON TO REPEAT TH QUESTION.			
	Pa			200			
	br			TLM001			

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Figure 3.2-53 (Cont'd)

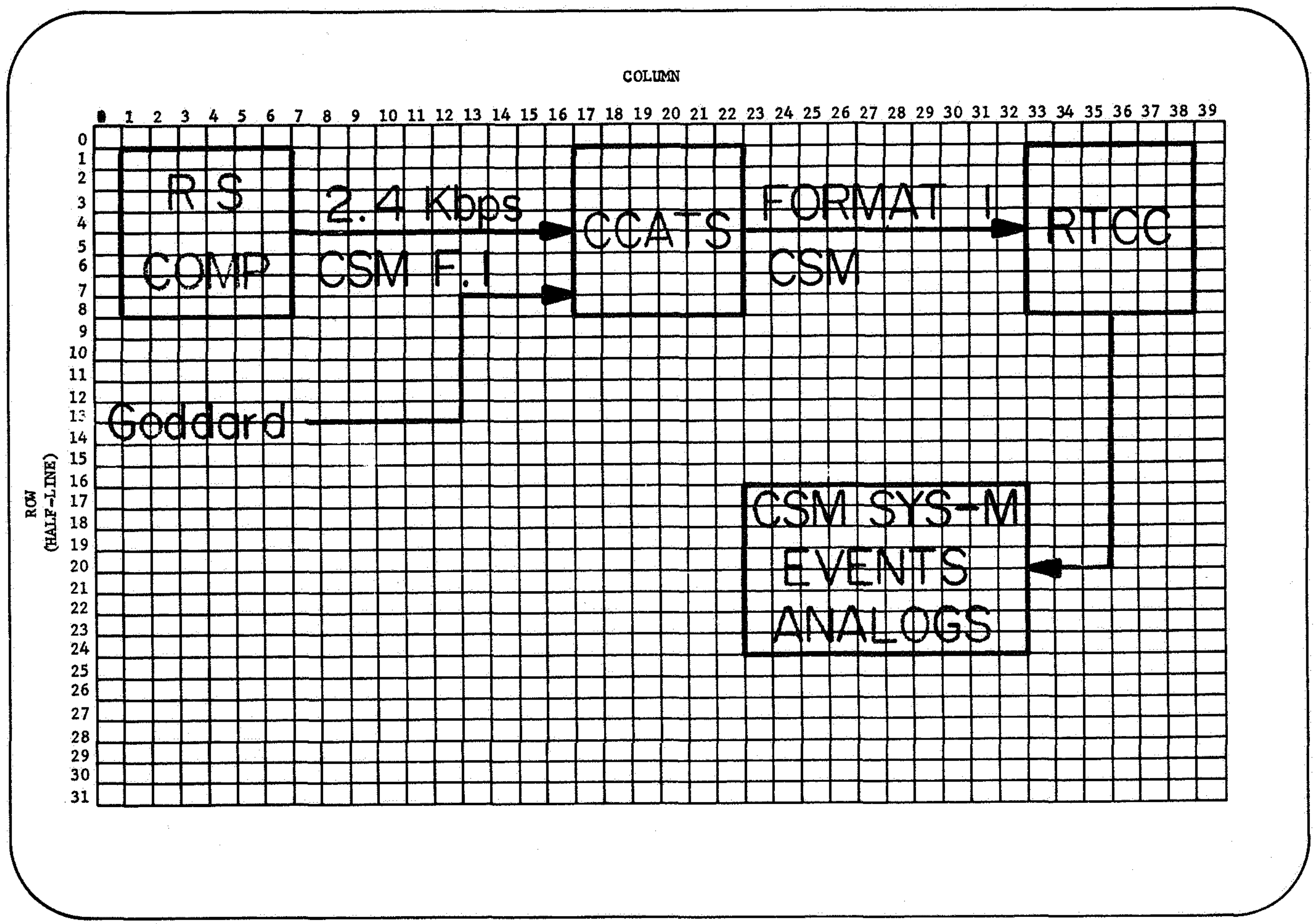

Figure 3.2-54 IBM 1510 Instructional Display Planning Guide Illustrating Relative Position of MSFN/MCC-H Block Diagram

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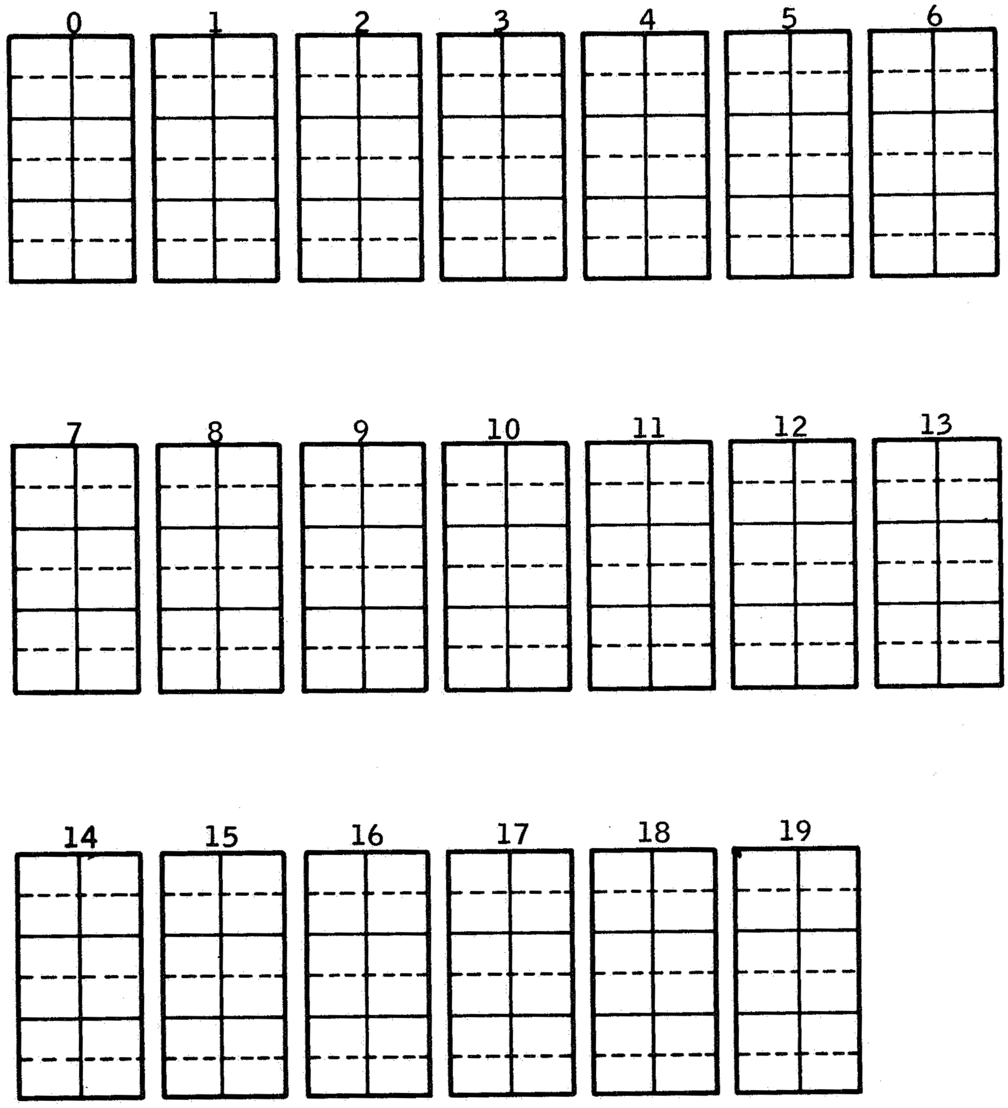
SECTOR NO.__________ AUTHOR NAME: __________

ggg NO. __________ GRAPHIC NAME: __________

rr NO. __________ DATE: __________

cc NO. __________



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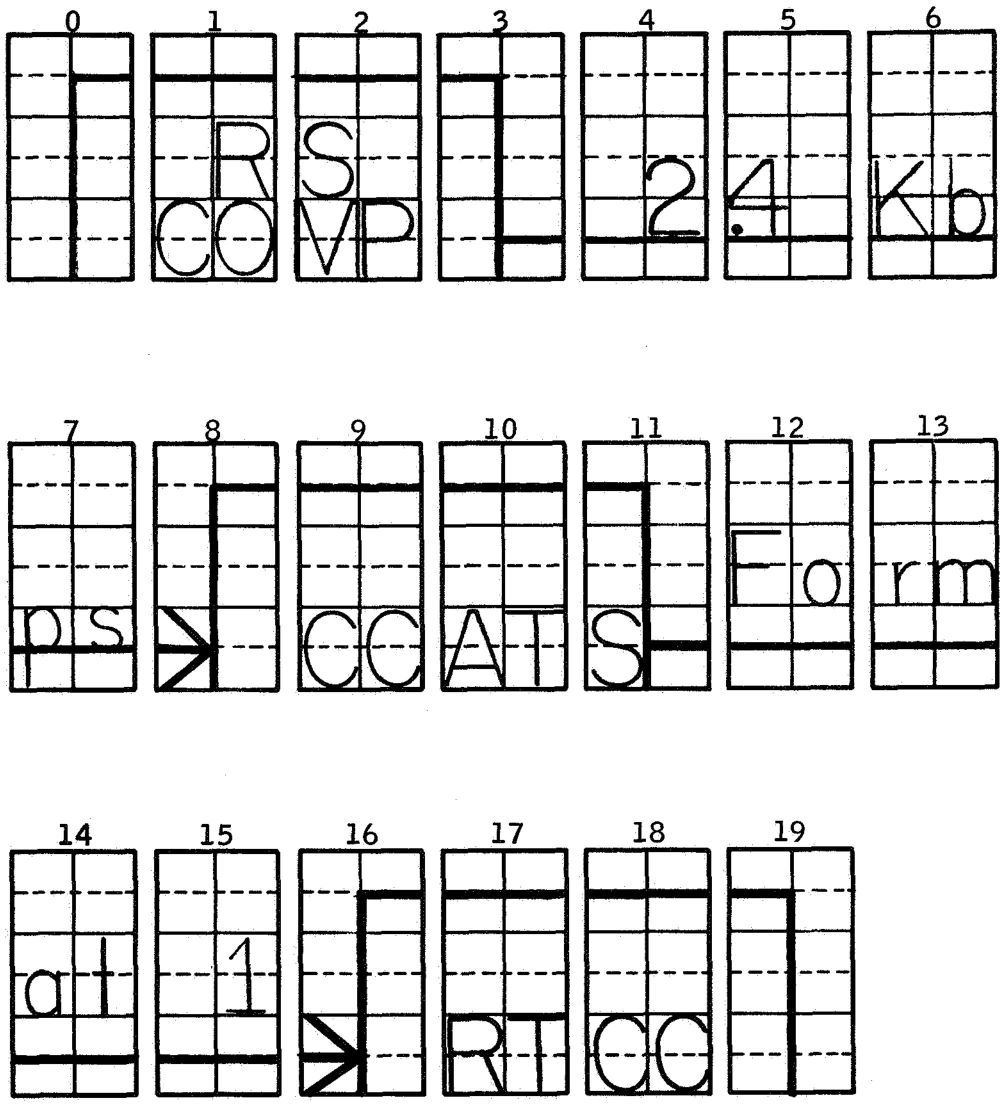
THIS FORM WAS DEVELOPED BY PHO TO ASSIST IN ANALYZING THE PROCEDURES AN AUTHOR MUST PERFORM IN PREPARING CAI MATERIALS.

Figure 3.2-55 Typical Planning Guide for Use with Coursewriter II

SECTOR NO.	0-19	AUTHOR NAME:	PHO
ggg NO.		GRAPHIC NAME:	TLM 1
rr NO.	0	DATE:	6/1/67
cc NO.	0		



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THIS FORM WAS DEVELOPED BY PHO TO ASSIST IN ANALYZING THE PROCEDURES AN AUTHOR MUST PERFORM IN PREPARING CAI MATERIALS.

Figure 3.2-56 Detailed Planning and Coding Guides for Construction of MSFN/MCC-H Block Diagram Display

SECTOR NO.	20-37	AUTHOR NAME:	PHO
ggg NO.		GRAPHIC NAME:	TLM 1
rr NO.	rr6	DATE:	6/1/67
cc NO.	0		

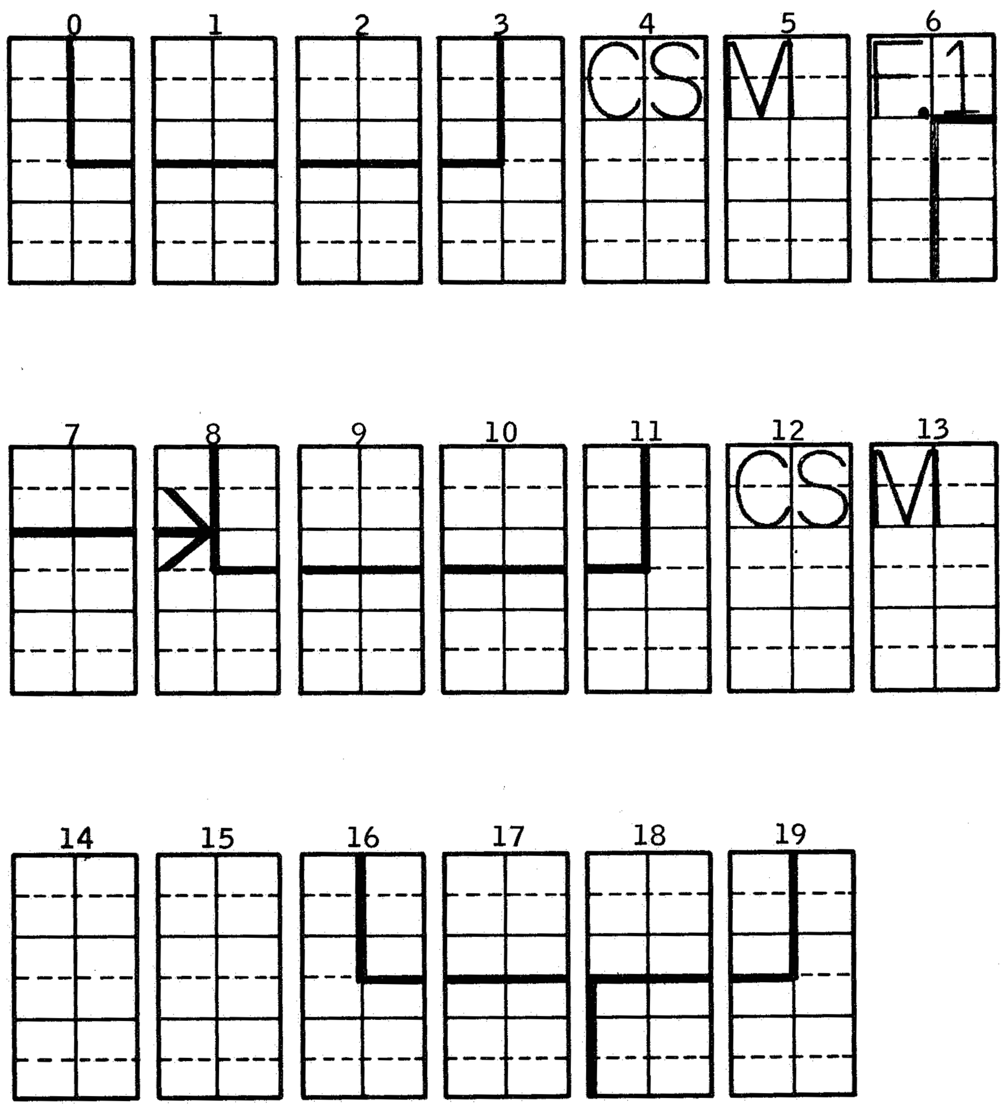

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Figure 3.2-56 (Cont'd)

SECTOR NO. 40-59

ggg NO.

rr NO. 12

cc NO. 0

AUTHOR NAME: PHO

GRAPHIC NAME: TLM 1

DATE: 6/1/67

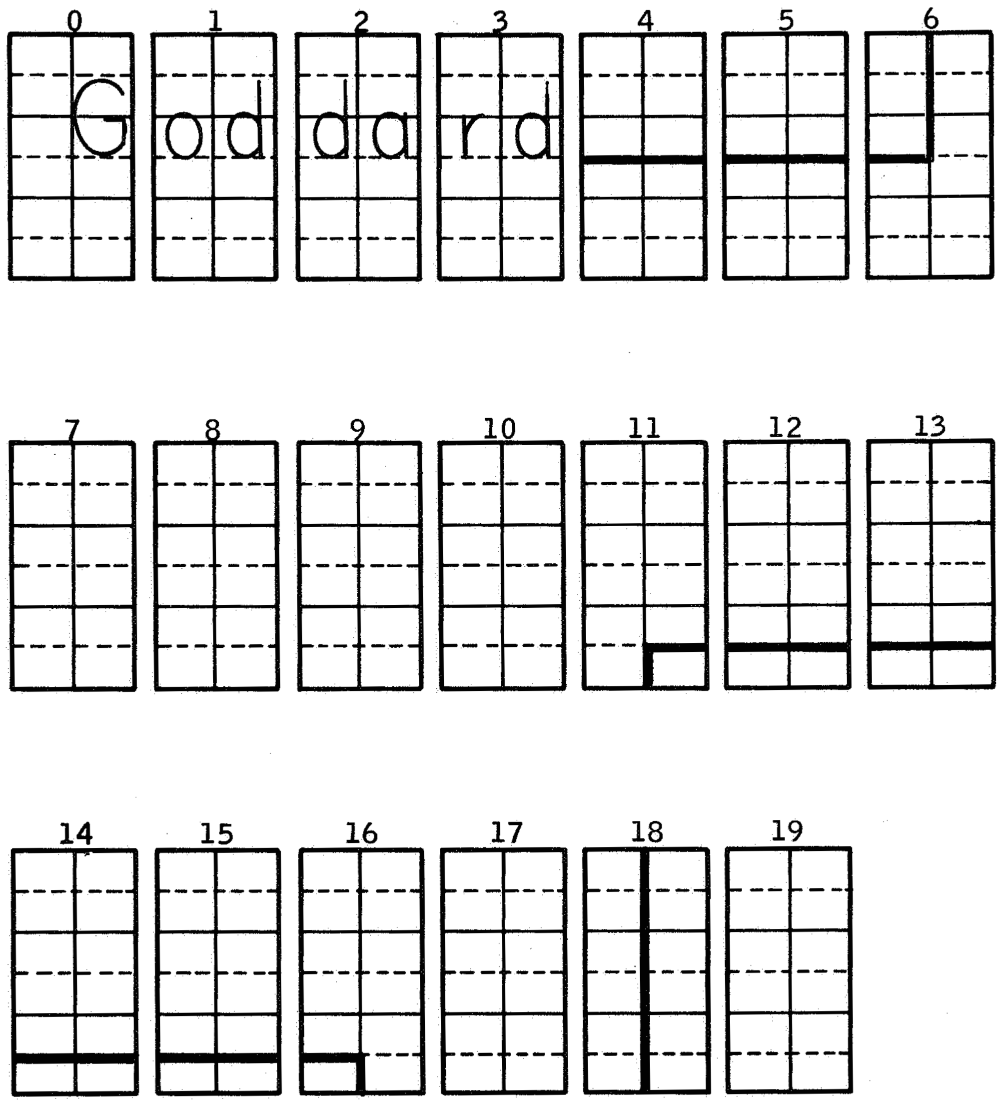

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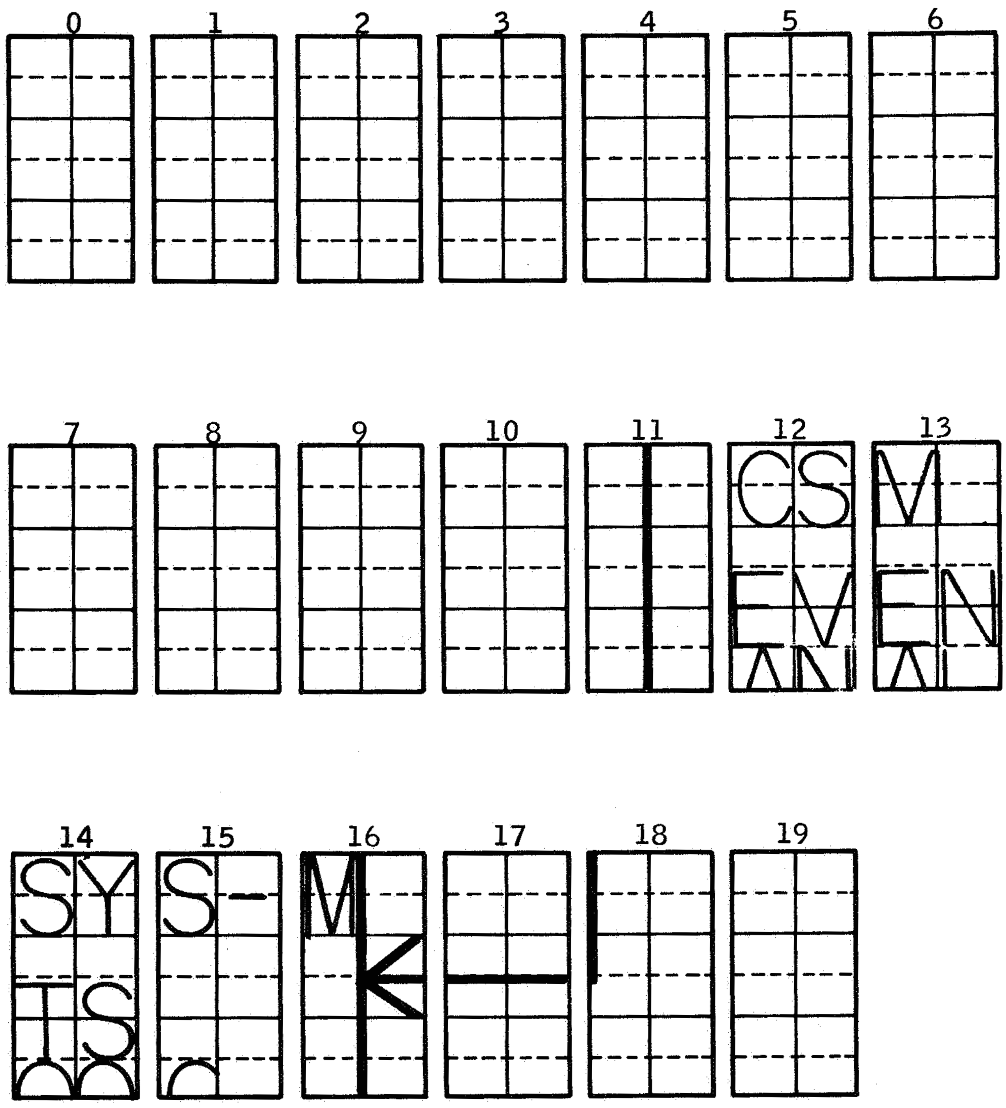
Figure 3.2-56 (Cont'd)

SECTOR NO. 60-79 AUTHOR NAME: PHO

ggg NO. GRAPHIC NAME: TLM 1

rr NO. 18 DATE: 6/1/67

cc NO. 0



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THIS FORM WAS DEVELOPED BY PHO TO ASSIST IN ANALYZING THE PROCEDURES AN AUTHOR MUST PERFORM IN PREPARING CAI MATERIALS.

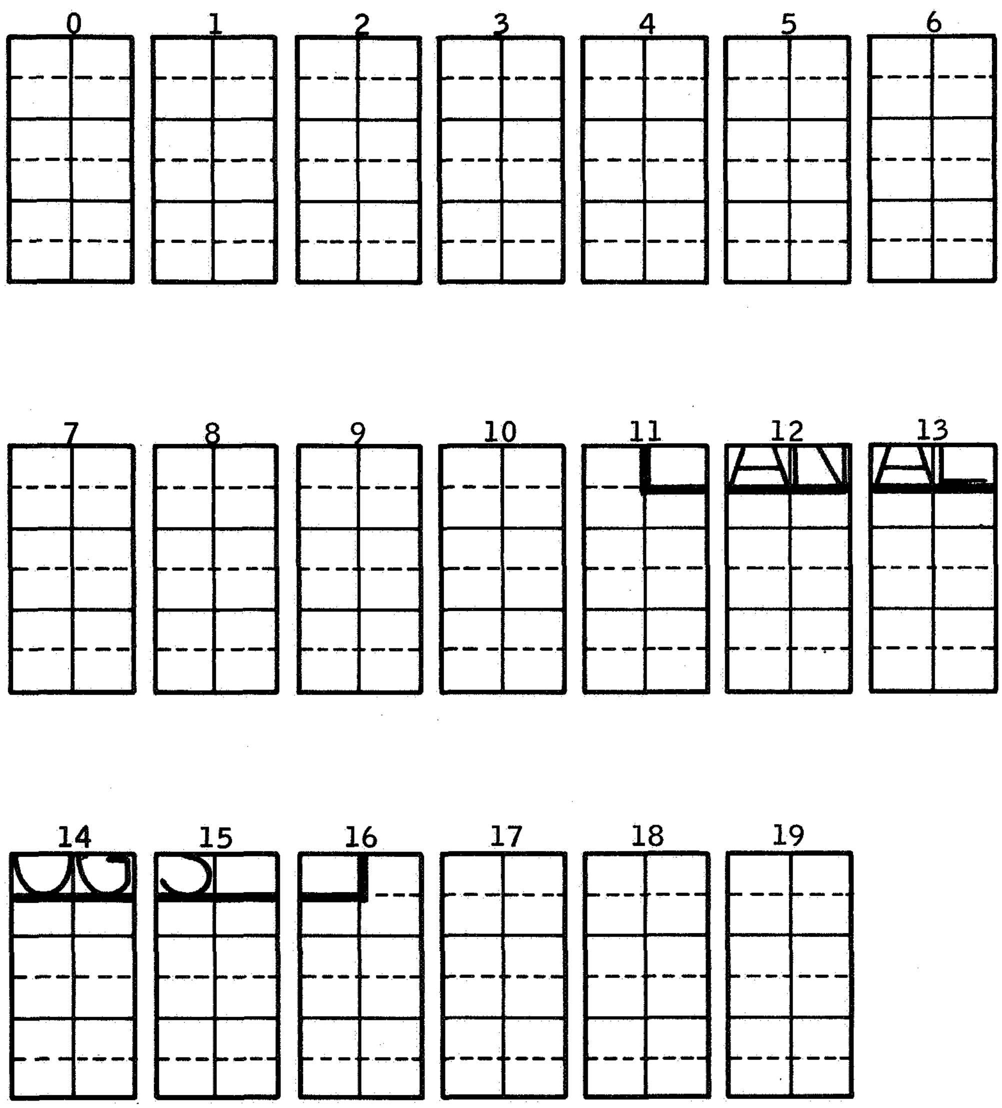
Figure 3.2-56 (Cont'd)

SECTOR NO. 80-99 AUTHOR NAME: PHO

ggg NO. GRAPHIC NAME: TLM 1

rr NO. 24 DATE: 6/1/67

cc NO. 0



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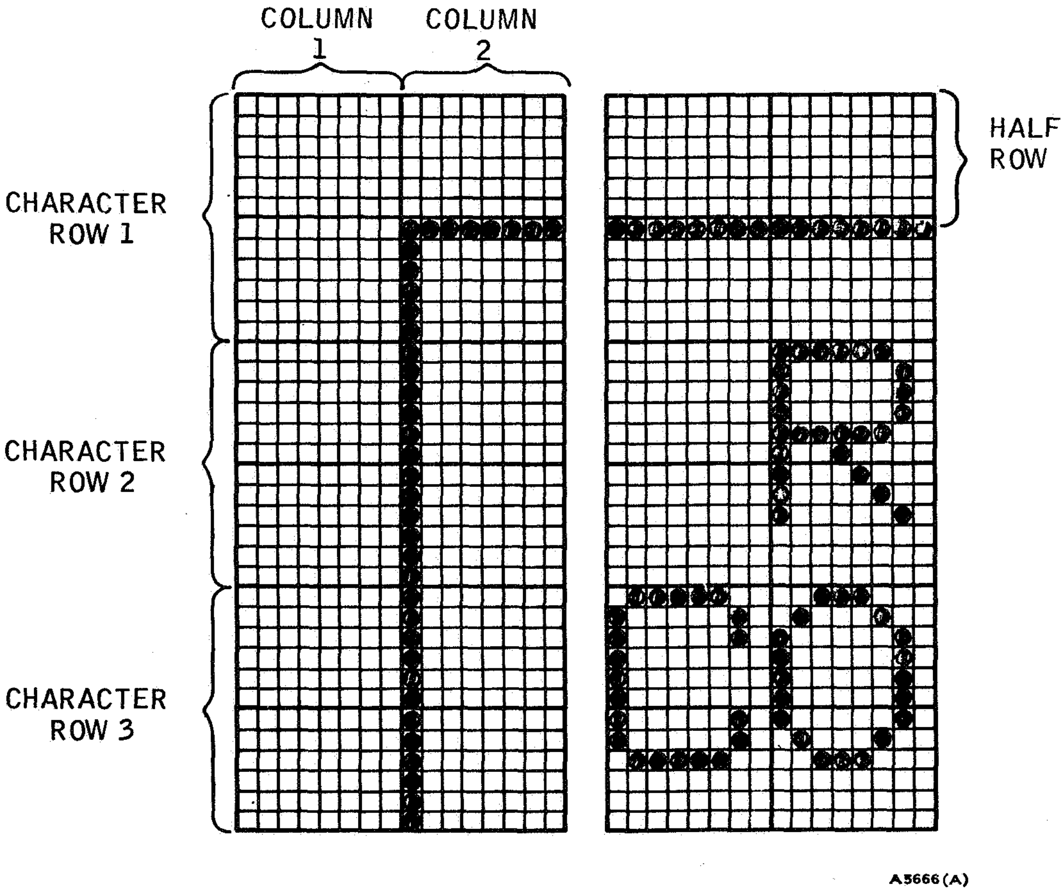
THIS FORM WAS DEVELOPED BY PHO TO ASSIST IN ANALYZING THE PROCEDURES AN AUTHOR MUST PERFORM IN PREPARING CAI MATERIALS.

Figure 3.2-56 (Cont'd)

SECTOR NO. 0 & 1

rr NO. ______

cc NO. ______



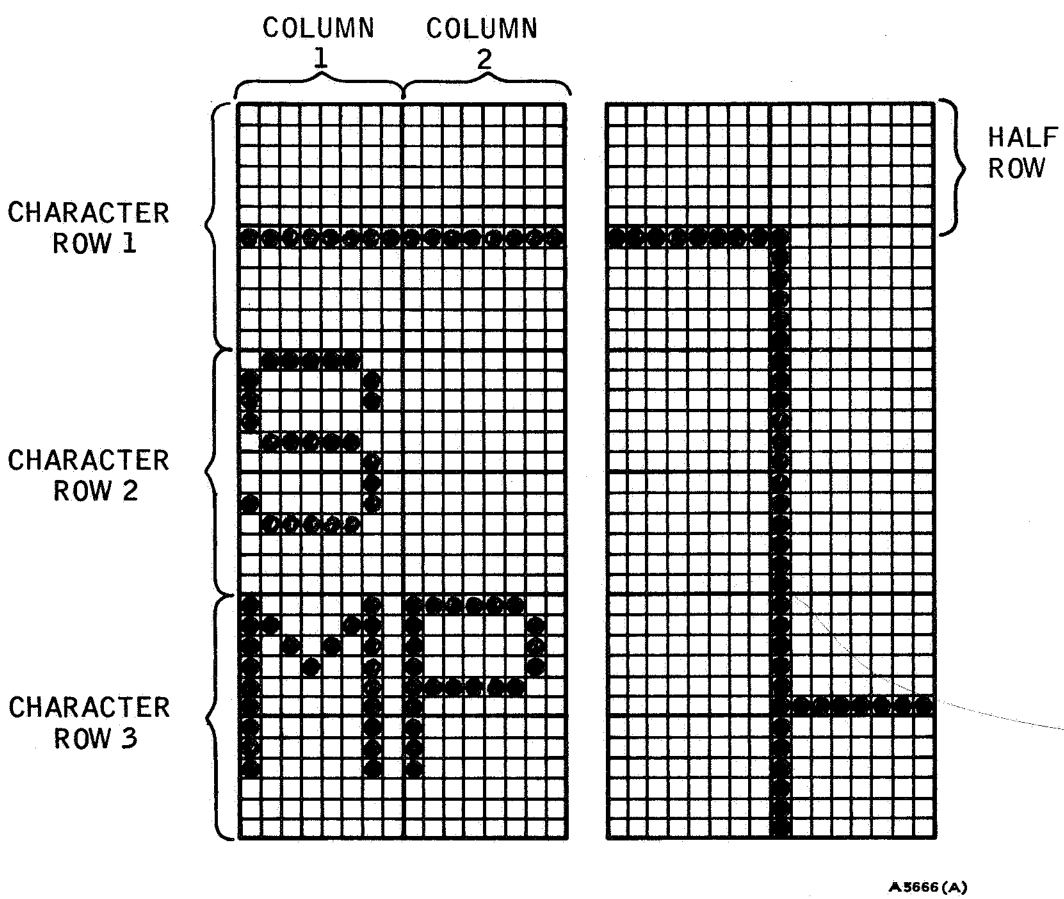
THIS FORM WAS DEVELOPED BY PHO TO ASSIST IN ANALYZING THE PROCEDURES AN AUTHOR MUST PERFORM IN PREPARING CAI MATERIALS AND TO DEMONSTRATE THE MECHANICS INVOLVED IN PREPARING GRAPHIC DISPLAYS

Figure 3.2-57 Detailed Translation of Graphic Requirements (Sectors 0 - 20) for Construction of MSFN/MCC-H Block Diagram Display

SECTOR NO. 2 & 3

rr NO. ____________

cc NO. ____________



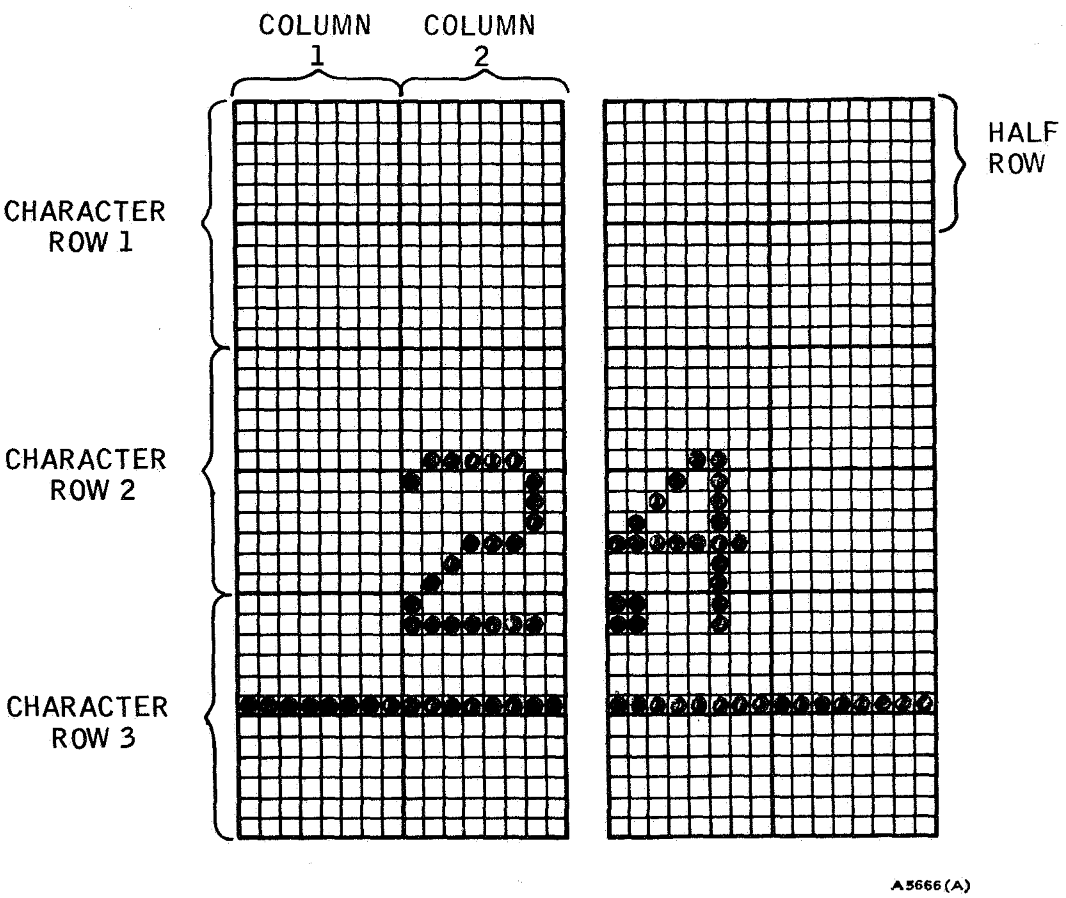
THIS FORM WAS DEVELOPED BY PHO TO ASSIST IN ANALYZING THE PROCEDURES AN AUTHOR MUST PERFORM IN PREPARING CAI MATERIALS AND TO DEMONSTRATE THE MECHANICS INVOLVED IN PREPARING GRAPHIC DISPLAYS

Figure 3.2-57 (Cont'd)

SECTOR NO. 4 & 5

rr NO. ______

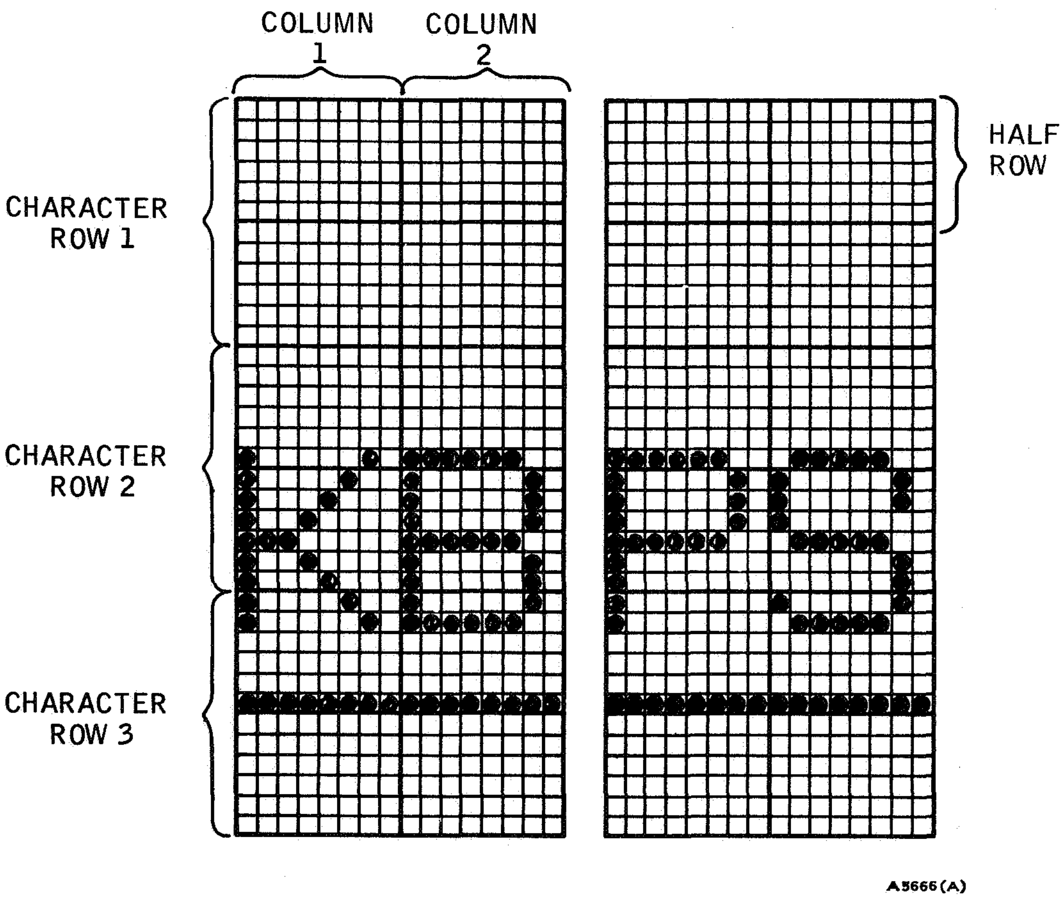
cc NO. ______



THIS FORM WAS DEVELOPED BY PHO TO ASSIST IN ANALYZING THE PROCEDURES AN AUTHOR MUST PERFORM IN PREPARING CAI MATERIALS AND TO DEMONSTRATE THE MECHANICS INVOLVED IN PREPARING GRAPHIC DISPLAYS

Figure 3.2-57 (Cont'd)

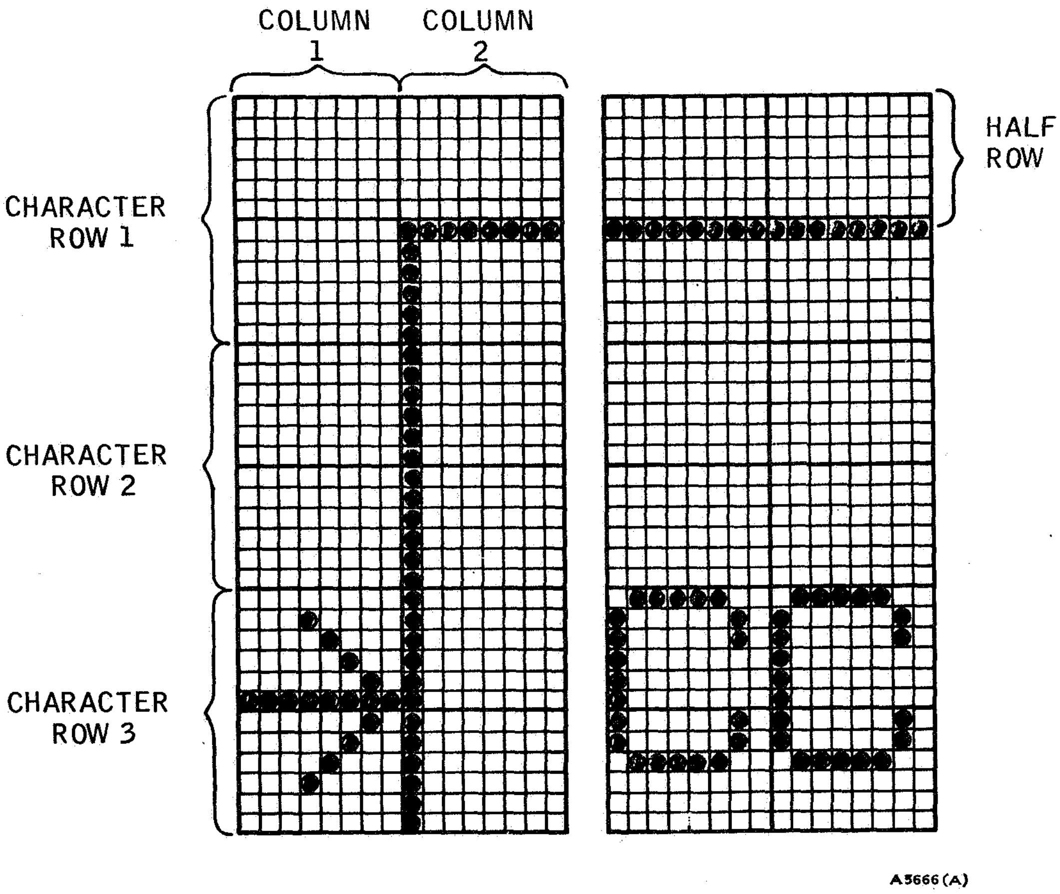
SECTOR NO. 6 & 7
rr NO. ________
cc NO. ________



THIS FORM WAS DEVELOPED BY PHO TO ASSIST IN ANALYZING THE PROCEDURES AN AUTHOR MUST PERFORM IN PREPARING CAI MATERIALS AND TO DEMONSTRATE THE MECHANICS INVOLVED IN PREPARING GRAPHIC DISPLAYS

Figure 3.2-57 (Cont'd)

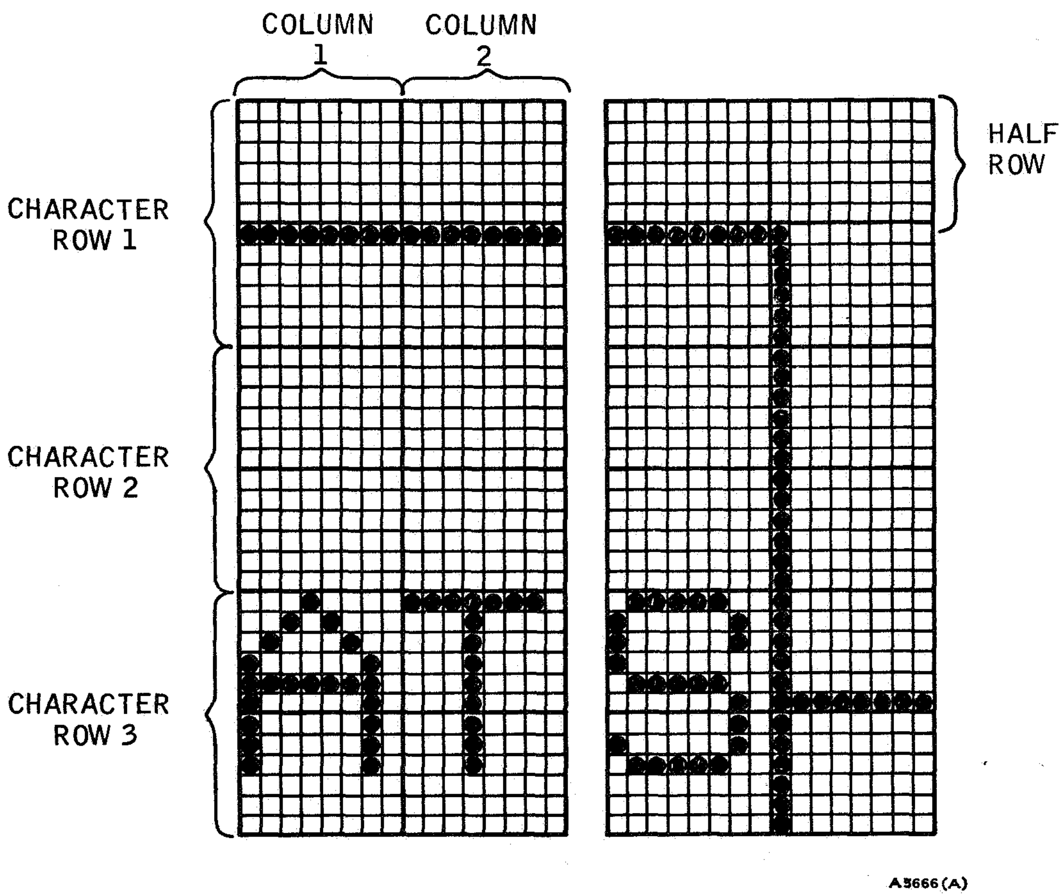
SECTOR NO. 8 & 9
rr NO. ____
cc NO. ____



THIS FORM WAS DEVELOPED BY PHO TO ASSIST IN ANALYZING THE PROCEDURES AN AUTHOR MUST PERFORM IN PREPARING CAI MATERIALS AND TO DEMONSTRATE THE MECHANICS INVOLVED IN PREPARING GRAPHIC DISPLAYS

Figure 3.2-57 (Cont'd)

SECTOR NO. 10 & 11
rr NO. ________
cc NO. ________



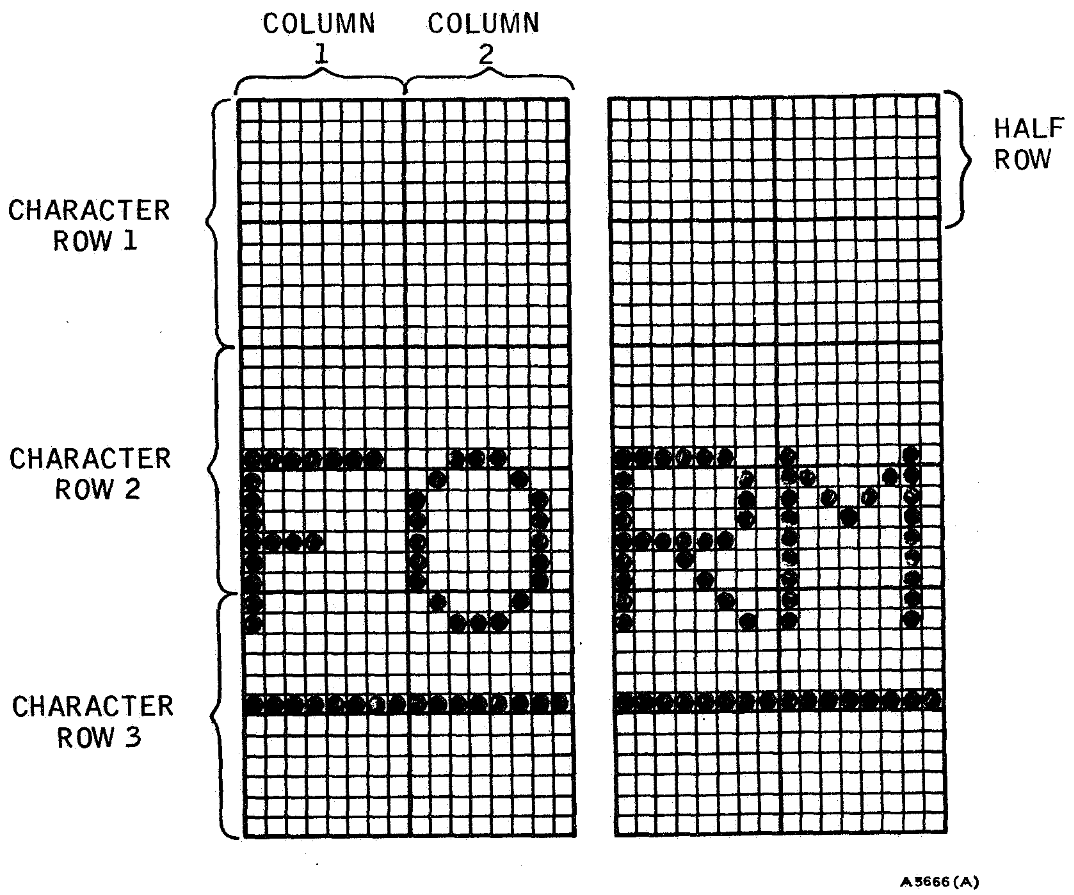
THIS FORM WAS DEVELOPED BY PHO TO ASSIST IN ANALYZING THE PROCEDURES AN AUTHOR MUST PERFORM IN PREPARING CAI MATERIALS AND TO DEMONSTRATE THE MECHANICS INVOLVED IN PREPARING GRAPHIC DISPLAYS

Figure 3.2-57 (Cont'd)

SECTOR NO. 12 & 13

rr NO. ________

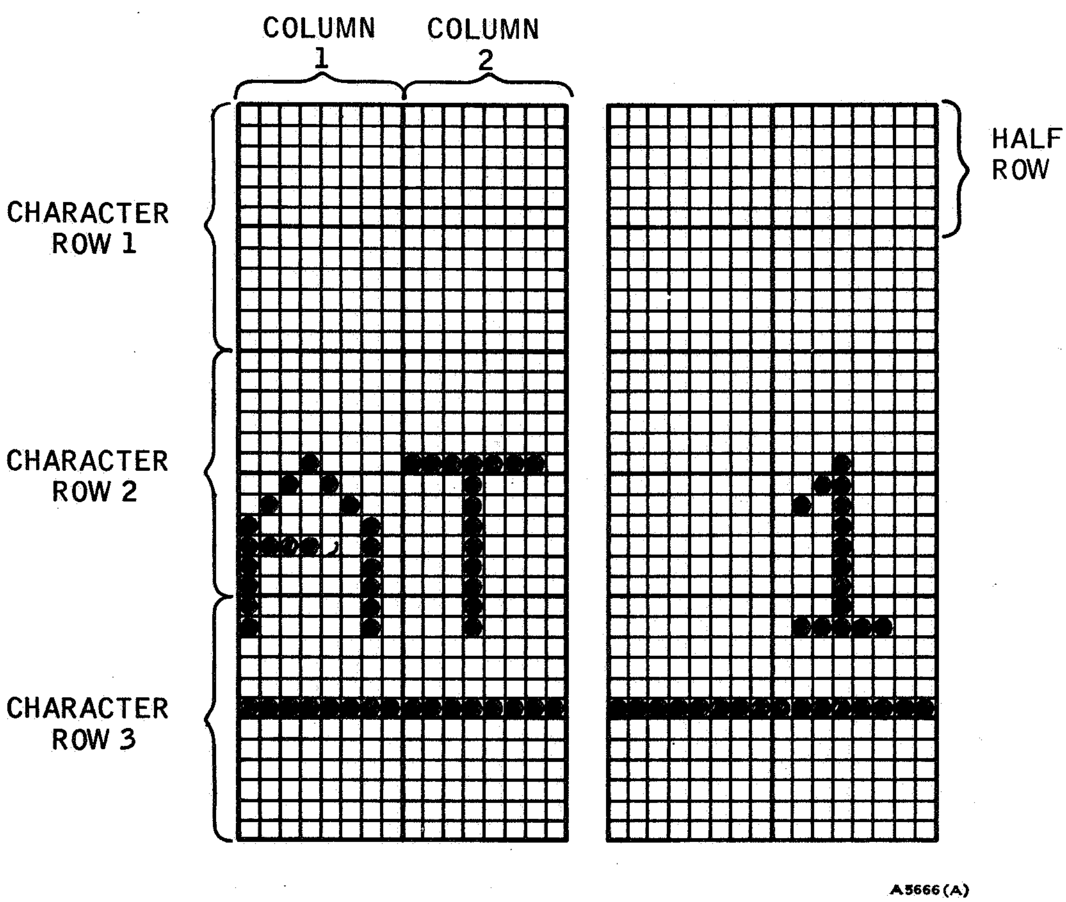
cc NO. ________



THIS FORM WAS DEVELOPED BY PHO TO ASSIST IN ANALYZING THE PROCEDURES AN AUTHOR MUST PERFORM IN PREPARING CAI MATERIALS AND TO DEMONSTRATE THE MECHANICS INVOLVED IN PREPARING GRAPHIC DISPLAYS

Figure 3.2-57 (Cont'd)

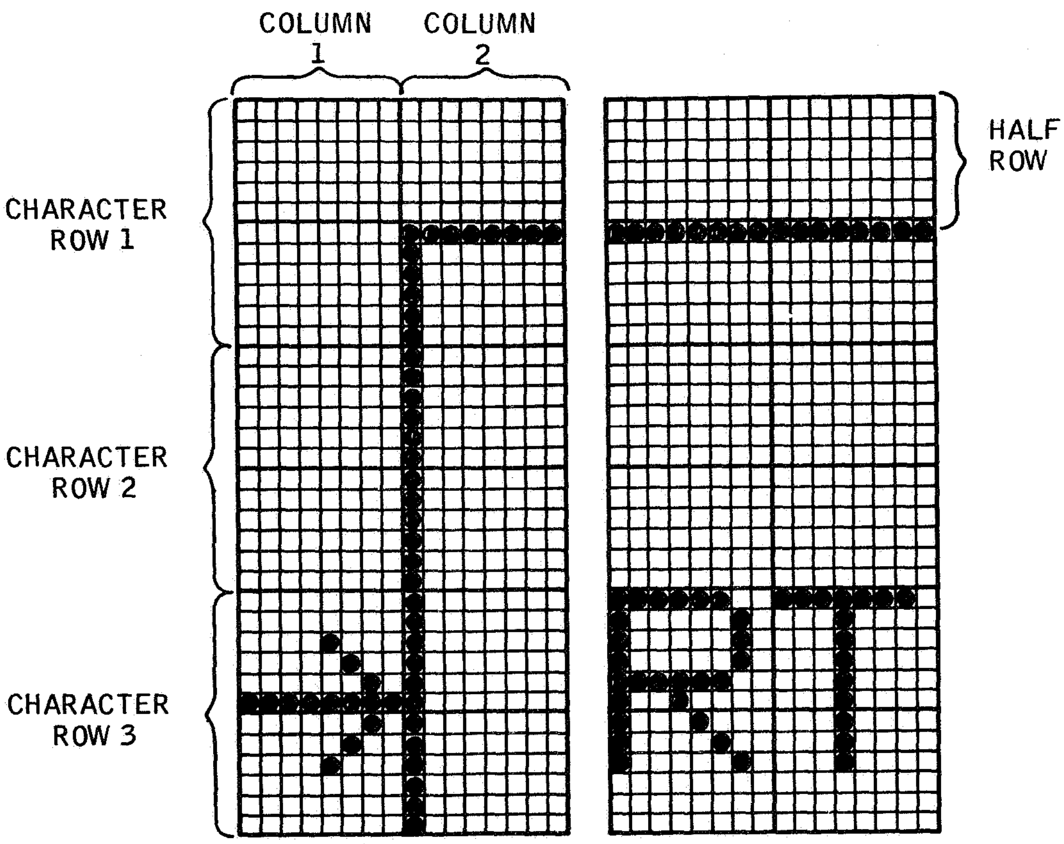
SECTOR NO. 14 & 15
rr NO. ____
cc NO. ____



THIS FORM WAS DEVELOPED BY PHO TO ASSIST IN ANALYZING THE PROCEDURES AN AUTHOR MUST PERFORM IN PREPARING CAI MATERIALS AND TO DEMONSTRATE THE MECHANICS INVOLVED IN PREPARING GRAPHIC DISPLAYS

Figure 3.2-57 (Cont'd)

SECTOR NO. 16 & 17
rr NO.
cc NO.



A5666(A)

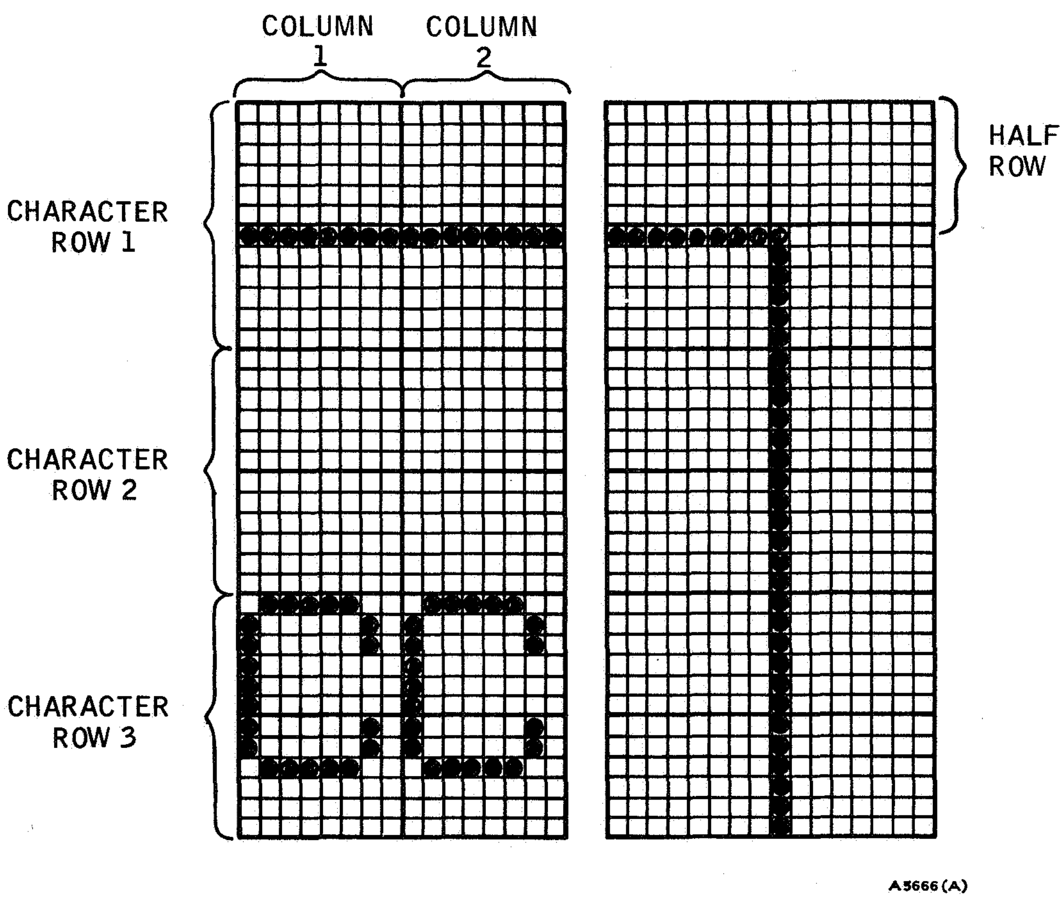
THIS FORM WAS DEVELOPED BY PHO TO ASSIST IN ANALYZING THE PROCEDURES AN AUTHOR MUST PERFORM IN PREPARING CAI MATERIALS AND TO DEMONSTRATE THE MECHANICS INVOLVED IN PREPARING GRAPHIC DISPLAYS

Figure 3.2-57 (Cont'd)

SECTOR NO. 18 & 19

rr NO. ________

cc NO. ________



THIS FORM WAS DEVELOPED BY PHO TO ASSIST IN ANALYZING THE PROCEDURES AN AUTHOR MUST PERFORM IN PREPARING CAI MATERIALS AND TO DEMONSTRATE THE MECHANICS INVOLVED IN PREPARING GRAPHIC DISPLAYS

Figure 3.2-57 (Cont'd)

3.2.4.3.5 Summary

This summary is not intended to compare and contrast the two languages, INFORM and Coursewriter II, rather, it is intended to compare each with the evaluative criteria outlined in Subparagraph 3.2.4.3.1,A and B. Refer to Table 3.2-23 as a comparison guide. Each language will be compared in terms of conceptual and economic efficiency, instructional applications, language adaptability, system reliability, data reliability, naturalness, and editing/debugging.

A. Conceptual Efficiency. Conceptual efficiency is demonstrated in the following manner:

1. Indicating the number of instructions required to present 28 characters of text to the student on Rows 13 and 14 of the display. The text is "CSM means Command Service Module".

2. Indicating the number of instructions required to present a question, consisting of characters, to the student on Rows 15 and 16 of the display. The text is "What are the bit rates from the CSM?"

3. Increment counter 01 by 1. (This can only be performed by the INFORM language during a branch routine.)

4. Update a register by replacing the contents with the contents of a counter. (This can only be performed during a branch routine.)

5. Show a graphic display of a block covering 16 character columns and 4 character rows with the following label "CAPACITANCE PROBE FUEL NO. 2".

NOTE: The information depicted by Figure 3.2-58 must be stored in a graphic table in the computer when using Coursewriter.. The dg command and concomitant arguments are used to properly locate the information on the display surface and eventually sequence this data to the student. With reference to Figure 3.2-60 (2 pages) the graphic display information is constructed on the Graphic Layout Form which is used to initialize the computer. The data is fetched from storage at the appropriate time by the GRA:CAP 1 command.

6. Illustrate adaptive sequencing by examining and comparing the contents of counters and branching to less difficult material when the contents of one counter is less than the contents of the other counter. For example, "If the contents of the student performance counter (C19) is less than the contents of the minimum performance counter (C20) present a less difficult sequence of material to the student".

B. Economic Efficiency. Economic efficiency is a difficult parameter to measure. As an illustration: The amount of time required to update a display (using the Philco system) requires a maximum of 80 milliseconds. This is based on a 100 percent update of the entire display surface (800 characters). Other factors that must be considered as major contributors are:

   1. Location of the program or information necessary to perform the next function; i.e., is it in working core or in mass storage?

   2. The number or requests received simultaneously.

   3. Program organization

C. Instructional Applications and Language Adaptability. The applicability of these languages for use in a variety of instructional applications is virtually nonexistent. As noted in Table 3.2-23, both have limited computational power, and neither is capable of on-line data base querying or responding to simulation models.

   Neither language is adaptable to other operating systems. The major parameters affecting language adaptability are outlined in Table 3.2-23.

D. System and Data Reliability. Information on system reliability is not available since neither system has been in operation long enough to provide data for a statistical calculation of the Magnetic Tape Buffer Formatter (MTBF). In addition, piece part failure rates, component part failure rates, etc., are unavailable.

E. Data Reliability. Data reliability (more specifically, error prevention and detection) is being considered but not to the extent required; e.g., memory protection features, software check routines, and hardware identification techniques are not being fully utilized.

TABLE 3.2-23

SUMMARY OF COMPARISON OF LANGUAGES WITH EVALUATIVE CRITERIA

EVALUATION CRITERIA	LANGUAGE	
	COURSEWRITER II	INFORM
<u>COMPUTER USAGE</u> <u>POWER</u> <u>CONCEPTUAL EFFICIENCY</u>	TO PRESENT "CSM MEANS COMMAND SERVICE MODULE" THE FOLLOWING CODED SEQUENCE MUST BE ENTERED VIA THE INSTRUCTOR KEYBOARD AFTER DEVELOPING ON CAI FORM: `dt 13,2/2,13/32,2/CSM MEANS COMMAND SERVICE MODULE`	TO PRESENT "CSM MEANS COMMAND SERVICE MODULE" THE FOLLOWING CODED SEQUENCE, PROPERLY POSITIONED ON FORM 01, IS REQUIRED: `D L,A 13 14 CSM MEANS COMMAND SERVICE MODULE`
	TO PRESENT "WHAT ARE THE BIT RATES FROM THE CSM" THE FOLLOWING CODED SEQUENCE MUST BE ENTERED VIA THE INSTRUCTOR KEYBOARD AFTER DEVELOPING ON CAI FORM: `dt 15, 2/2,13/32,2/WHAT ARE THE BIT RATES FROM THE CSM?`	TO PRESENT "WHAT ARE THE BIT RATES FROM THE CSM" THE FOLLOWING CODED SEQUENCE, PROPERLY POSITIONED ON FORM 01, IS REQUIRED: `Q L,A 15 16 WHAT ARE THE BIT RATES FROM THE CSM?`
	TO INCREMENT COUNTER 01 BY 1, THE FOLLOWING CODED SEQUENCE MUST BE ENTERED VIA THE INSTRUCTOR KEYBOARD AFTER DEVELOPING ON CAI FORM: `ld 1/C01`	TO INCREMENT COUNTER 01 BY 1, THE FOLLOWING CODED SEQUENCE, PROPERLY POSITIONED ON FORM 01 IS REQUIRED: `B ,C01+1`
	CW II CANNOT LOAD A REGISTER WITH A COUNTER	TO UPDATE A REGISTER, THE FOLLOWING CODED SEQUENCE, PROPERLY POSITIONED ON FORM 01, IS REQUIRED: `B ,R1=C01`
	TO ILLUSTRATE ADAPTIVE SEQUENCING PER THE EXAMPLE "IF THE... STUDENT" THE FOLLOWING CODED SEQUENCE MUST BE ENTERED VIA THE INSTRUCTOR KEYBOARD AFTER DEVELOPING ON CAI FORMS: `br 1/C19/L/C20`	TO ILLUSTRATE ADAPTIVE SEQUENCING PER THE EXAMPLE "IF THE... STUDENT" THE FOLLOWING CODED SEQUENCE, PROPERLY POSITIONED ON FORM 01 IS REQUIRED: `B 1,C19,LT,C20`

	TO PRESENT A GRAPHIC DISPLAY OF A BLOCK COVERING 16 CHARACTER COLUMNS AND 4 CHARACTER ROWS WITH THE FOLLOWING LABEL "CAPACITANCE FUEL PROBE NO. 2" THE FOLLOWING CODED SEQUENCE MUST BE ENTERED VIA THE INSTRUCTOR KEYBOARD AFTER DEVELOPING ON CAI FORM: (REFER TO FIGURES 3.2-58 AND 3.2-59 FOR FORM DEVELOPMENT PROCEDURES)
	`dg 12,6/43/44/45/46/47/48/49/50`
	`dg 18,6/63/64/65/66/67/68/69/70`
		TO PRESENT A GRAPHIC DISPLAY OF A BLOCK COVERING 16 CHARACTER COLUMNS AND 4 CHARACTER ROWS WITH THE FOLLOWING LABEL "CAPACITANCE FUEL PROBE NO. 2" THE FOLLOWING CODED SEQUENCE MUST BE ENTERED VIA THE INSTRUCTOR KEYBOARD AFTER DEVELOPING ON CAI FORM: (REFER TO FIGURE 3.2-60 FOR FORM DEVELOPMENT PROCEDURES)
		`GRA : CAP1`

TABLE 3.2-23 (CONT'D)

EVALUATION CRITERIA	LANGUAGE	
	COURSEWRITER II	INFORM
ECONOMIC EFFICIENCY	INFORMATION NOT AVAILABLE	ONLY GROSS EXECUTION TIMES ARE AVAILABLE AT THIS PRINTING AND ARE NOT INDICATIVE OF THE ECONOMIC EFFICIENCY. DUE TO CORE ORGANIZATION, APPROXIMATELY 100 μSEC ARE REQUIRED TO FORMAT EACH CHARACTER FOR A GRAPHIC DISPLAY. OTHER INSTRUCTIONS VARY IN TIME FROM μSEC TO 200 μSEC.
GENERALITY		
INSTRUCTIONAL APPLICATIONS	1. SIMULATION MODELS - NOT CAPABLE OF CONSTRUCTING SIMULATION MODELS. NOT CAPABLE OF RESPONDING TO MODEL STIMULI.	1. SIMULATION MODELS - NOT CAPABLE OF CONSTRUCTING SIMULATION MODELS. NOT CAPABLE OF RESPONDING TO MODEL STIMULI.
	2. PRESENTATION OF FACTS AND CONCEPTS - SPECIFICALLY DESIGNED FOR THIS APPLICATION.	2. PRESENTATION OF FACTS AND CONCEPTS - SPECIFICALLY DESIGNED FOR THIS APPLICATION.
	3. ON-LINE QUERYING OF DATA BASE INFORMATION - NOT CAPABLE OF PERFORMING THIS FUNCTION.	3. ON-LINE QUERYING OF DATA BASE INFORMATION - NOT CAPABLE OF PERFORMING THIS FUNCTION.
	4. COMPUTATIONAL AID - VERY LIMITED. CAN PERFORM SIMPLE ARITHMETIC OPERATIONS SUCH AS ADDITION, DIVISION AND MULTIPLICATION.	4. COMPUTATIONAL AID - VERY LIMITED. CAN PERFORM SIMPLE ARITHMETIC OPERATIONS SUCH AS ADDITION, DIVISION AND MULTIPLICATION.
LANGUAGE ADAPTABILITY	1. COMPILER - THE COURSEWRITER II COMPILER IS WRITTEN TO ACCEPT COURSEWRITER STATEMENTS AND CONVERT THESE STATEMENTS INTO MACHINE LANGUAGE COMPATIBLE WITH THE IBM 1500 OPERATING SYSTEM. IT IS NOT PRESENTLY COMPATIBLE WITH ANY OTHER MACHINE.	1. THE INFORM COMPILER (OR, MORE APPROPRIATELY TRANSLATOR) IS WRITTEN TO ACCEPT INFORM STATEMENTS AND CONVERT THESE STATEMENTS INTO MACHINE LANGUAGE COMPATIBLE WITH ANY OTHER MACHINE EXCEPT THE PHILCO 2000-212.
	2. COMPUTER HARDWARE - LANGUAGE USES COUNTERS, SWITCHES AND REGISTERS WHICH ARE 16 BITS IN LENGTH, ADDITIONAL PROGRAMMING OR HARDWARE MODIFICATION WOULD BE REQUIRED FOR LANGUAGES UTILIZING OR REQUIRING DIFFERENT REGISTER SIZES.	2. COMPUTER HARDWARE - LANGUAGE USES COUNTERS, SWITCHES AND REGISTERS WHICH ARE 48 BITS IN LENGTH. ADDITIONAL PROGRAMMING OR HARDWARE MODIFICATION WOULD BE REQUIRED FOR LANGUAGES UTILIZING OR REQUIRING DIFFERENT REGISTER SIZES.
	3. TERMINAL - LANGUAGE BASED ON 8 x 12 DOT MATRIX FOR DISPLAY OR GRAPHICS. ALTERATION OF THIS WOULD REQUIRE A MAJOR SOFTWARE MODIFICATION. SCREEN SIZE IS VARIABLE, HOWEVER, DATA DENSITY IS A FUNCTION OF THE NUMBER OF DOTS AND IN THIS SYSTEM IS RESTRICTED TO 16 ROWS OF 40 CHARACTERS. IN ADDITION, KEYBOARD CODES ARE UNIQUE TO THE 1500 SYSTEM.	3. TERMINAL - LANGUAGE BASED ON 8 x 12 DOT MATRIX FOR DISPLAY OF GRAPHICS. MODIFICATION WOULD REQUIRE AN EXTENSIVE SOFTWARE MODIFICATION. SCREEN SIZE IS VARIABLE: HOWEVER, DATA DENSITY IS A FUNCTION OF THE NUMBER OF DOTS AND IN THIS SYSTEM IS RESTRICTED TO 20 ROWS OF 40 CHARACTERS. IN ADDITION, KEYBOARD CODES ARE UNIQUE TO THE PHILCO 2000-211 SYSTEM.

TABLE 3.2-23 (CONT'D)

EVALUATION CRITERIA	LANGUAGE	
	COURSEWRITER II	INFORM
RELIABILITY		
SYSTEM	INFORMATION NOT AVAILABLE.	INFORMATION NOT AVAILABLE.
DATA	PRINTOUTS OF ALL MATERIAL PREPARED FOR CAI ARE PROVIDED. LABELS IDENTIFY COURSE SEGMENTS. A COURSE FLOW DECISION TABLE IS PROVIDED. THIS ESSENTIALLY PROVIDES A GUIDE IN THAT CERTAIN FUNCTIONS MUST BE PERFORMED OR CONDITIONS SATISFIED PRIOR TO PROCEEDING WITH THE NEXT INSTRUCTION.	WARNING ERROR NOTICES ARE PRINTED ON THE CURRICULUM EDIT LIST.
HUMAN FACTORS		
LEARNING TIME		
NATURALNESS	THE LANGUAGE IS NOT NATURAL. APPROXIMATELY 86 MNEMONIC CODES, SYMBOLS, ETC., ARE REQUIRED TO DESCRIBE THE PROCEDURES NECESSARY FOR DEVELOPMENT OF MATERIAL FOR CAI. CODING OF GRAPHIC DISPLAYS IS A TEDIOUS PROCESS WHICH THE AUTHOR SHOULD NOT BE REQUIRED TO PERFORM. ENTRY OF INFORMATION IS VIA A TYPEWRITER OR PUNCHED CARD. THESE FORMS OF ENTRY DO NOT PROVIDE THE AUTHOR WITH THE DEGREE OF NATURALNESS CONSIDERED NECESSARY FOR EFFECTIVE, NATURAL COMMUNICATION WITH THE COMPUTER. ALTHOUGH THIS IMPLIES THAT A STANDARD EXISTS, IT SHOULD BE NOTED THAT THE STANDARDS HAVE NOT BEEN DEVELOPED TO THE EXTENT THAT COMPARISONS OR ALTERNATIVES CAN BE OFFERED.	THE LANGUAGE IS NOT NATURAL. APPROXIMATELY 77 MNEMONIC CODES, SYMBOLS, ETC., ARE REQUIRED TO DESCRIBE THE PROCEDURES NECESSARY FOR THE DEVELOPMENT OF MATERIAL FOR CAI. CODING OF GRAPHIC DISPLAYS IS A STRAIGHTFORWARD "MECHANICAL" PROCESS WHICH THE AUTHOR SHOULD NOT BE REQUIRED TO PERFORM. ENTRY IS VIA PUNCHED CARDS. THE REMAINING COMMENTS AS TO THE DEGREE OF NATURALNESS, ETC., ARE IDENTICAL TO THOSE APPEARING UNDER COURSEWRITER.
MODIFICATION AND CHECKOUT		
EDITING/DEBUGGING	UTILIZING EITHER A TYPEWRITER OR INSTRUCTIONAL DISPLAY AND SPECIAL CODES, THE AUTHOR CAN OPERATE ON ANY COURSE SEGMENT WHICH IS AVAILABLE IN DISK STORAGE. THIS ENABLES THE AUTHOR TO EXAMINE, MODIFY, INSERT, RELOCATE, DELETE AND EXECUTE INSTRUCTIONS IN REAL TIME.	CAN PERFORM SAME FUNCTIONS AS COURSEWRITER II BUT IN A NONREAL-TIME ENVIRONMENT, I.E., PUNCHED CARDS.

F. Naturalness. As outlined in Table 3.2-23, neither INFORM or Coursewriter II communicates with the computer in a natural language. Both are composed of seemingly ambiguous mnemonics and symbols which require a significant amount of time to learn. An estimate of the learning time would be one week to ten days of intensive training with a competent instructor. This would only provide the author with the basic "mechanics".

It would certainly be in order to again note that the very heart of the CAI system is the curriculum, and that its development and presentation to the user is strictly a function of the author and the language. If either fails or proves inadequate, the entire system is degraded.

3.2.4.3.6 Conclusions

Based on the analysis and the comparison of each language with the evaluative criteria, it seems reasonable to conclude that either language would be used in flight controller training applications, but certainly on a very limited basis. In addition, it appears that neither language in its present form could prove useful to flight control. Further, the cost to modify these languages to increase capability would certainly be a time consuming and costly project. If one must use these languages, it should be restricted to utilization or the most useful concepts from which the base framework could be built for a powerful language for flight controller applications.

SECTOR NO. 43-50

ggg NO. ______

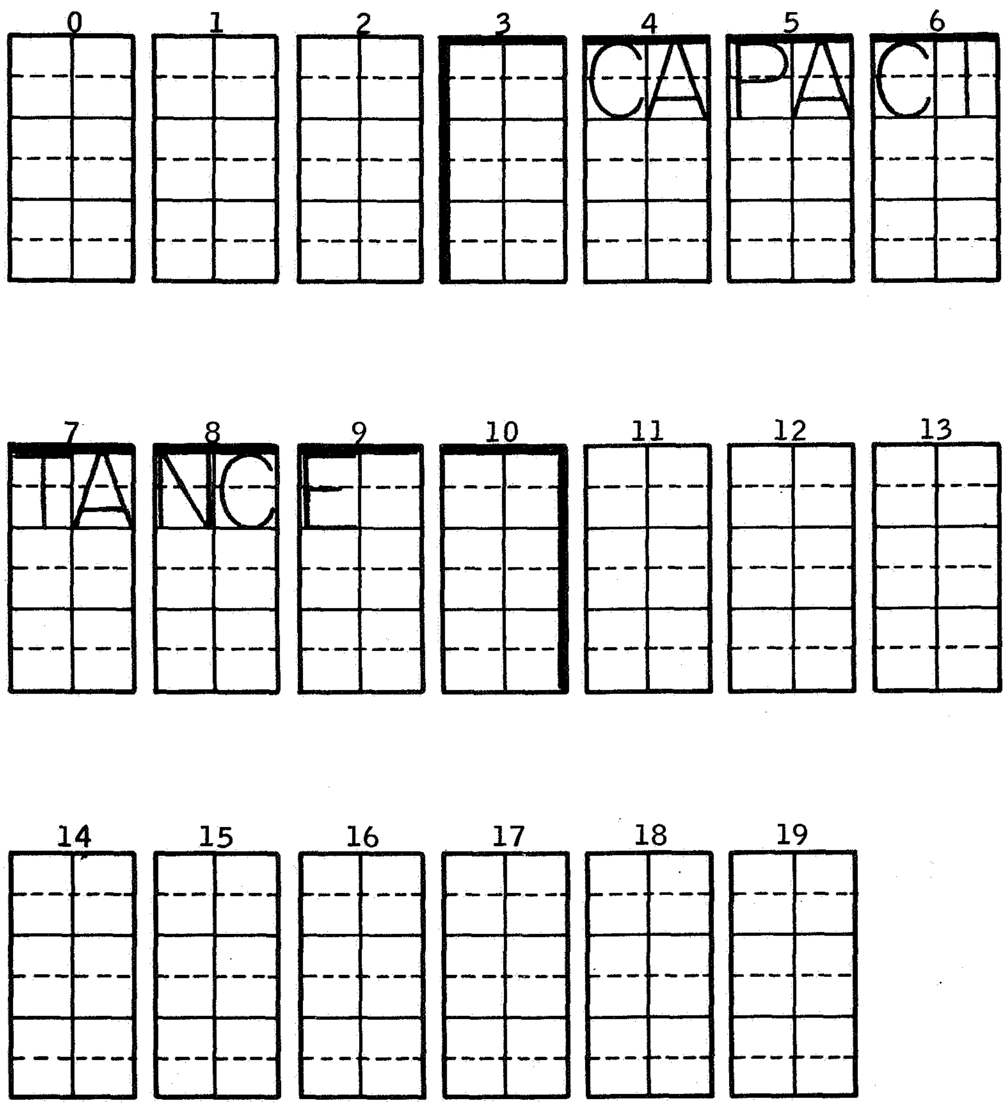
rr NO. 12

cc NO. 6

AUTHOR NAME: ______

GRAPHIC NAME: ______

DATE: ______



A5665(A)

THIS FORM WAS DEVELOPED BY PHO TO ASSIST IN ANALYZING THE PROCEDURES AN AUTHOR MUST PERFORM IN PREPARING CAI MATERIALS.

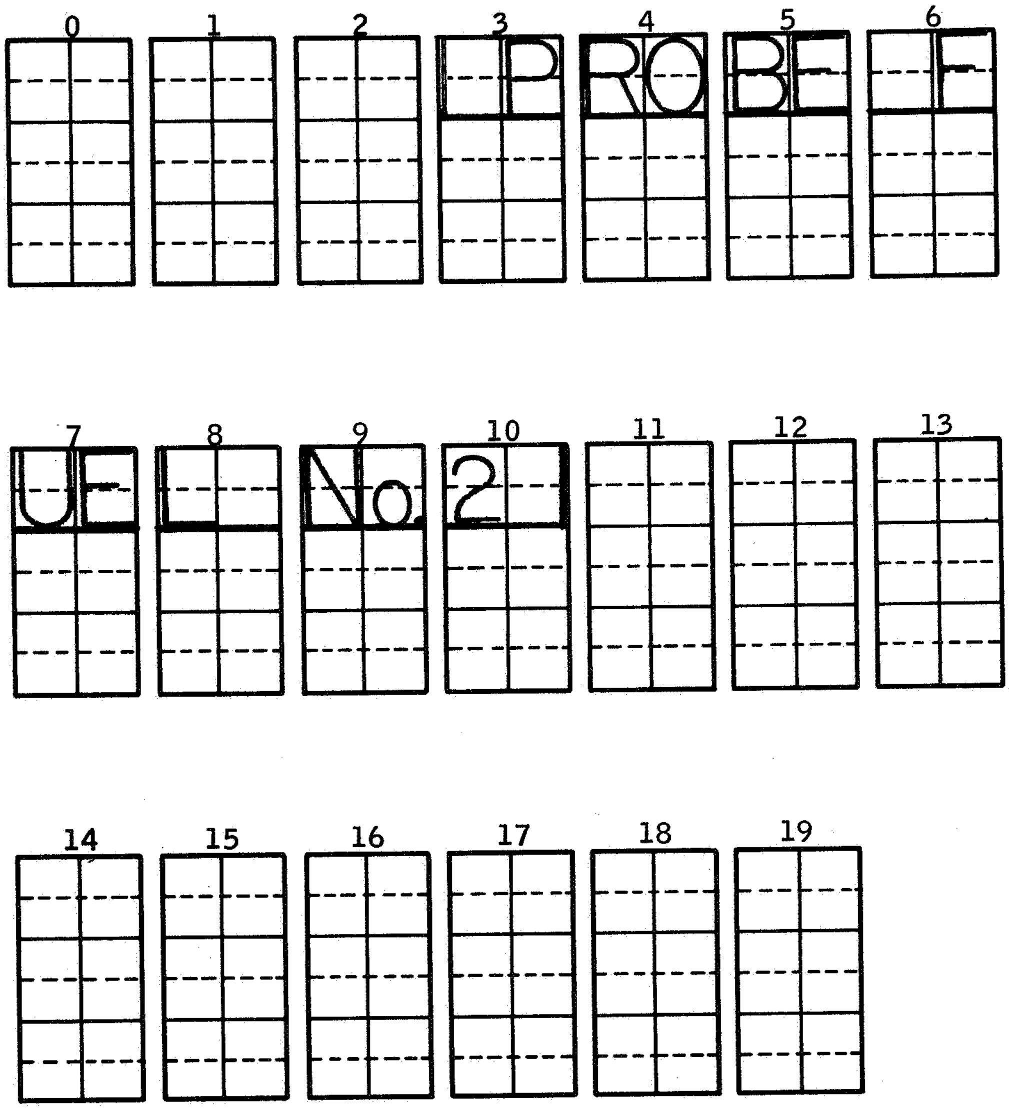
Figure 3.2-58 Detailed Planning and Coding Guide for Construction of CAPACITANCE PROBE FUEL NO. 2 Display Using Coursewriter II

SECTOR NO. 63-70 AUTHOR NAME: ______

ggg NO. 002 GRAPHIC NAME: ______

rr NO. 18 DATE: ______

cc NO. 6



A5665(A)

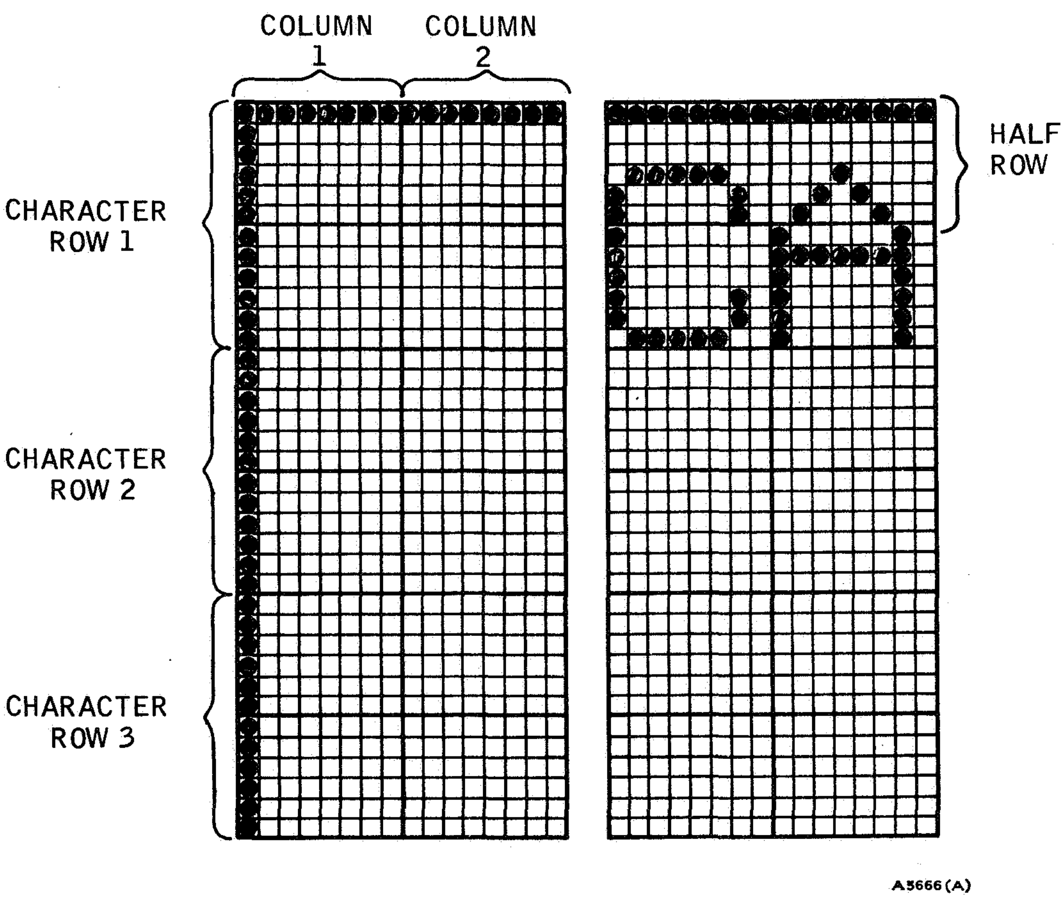
THIS FORM WAS DEVELOPED BY PHO TO ASSIST IN ANALYZING THE PROCEDURES AN AUTHOR MUST PERFORM IN PREPARING CAI MATERIALS.

Figure 3.2-58 (Cont'd)

SECTOR NO. 43 &44

rr NO. 12 & 12

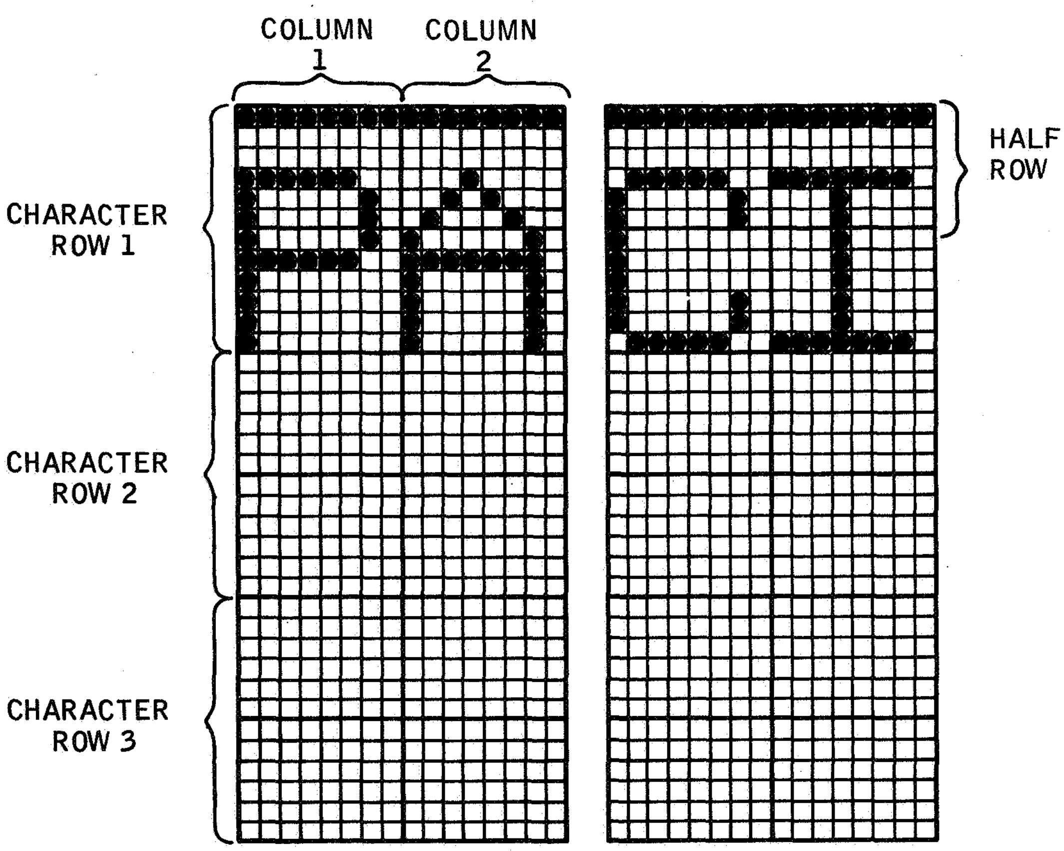
cc NO. 6 & 8



THIS FORM WAS DEVELOPED BY PHO TO ASSIST IN ANALYZING THE PROCEDURES AN AUTHOR MUST PERFORM IN PREPARING CAI MATERIALS AND TO DEMONSTRATE THE MECHANICS INVOLVED IN PREPARING GRAPHIC DISPLAYS

Figure 3.2-59 Detailed Translation of Graphic Requirements (Sectors 43 - 50 and 63 - 70) for Construction of CAPACITANCE PROBE FUEL NO. 2 Display Using Coursewriter II

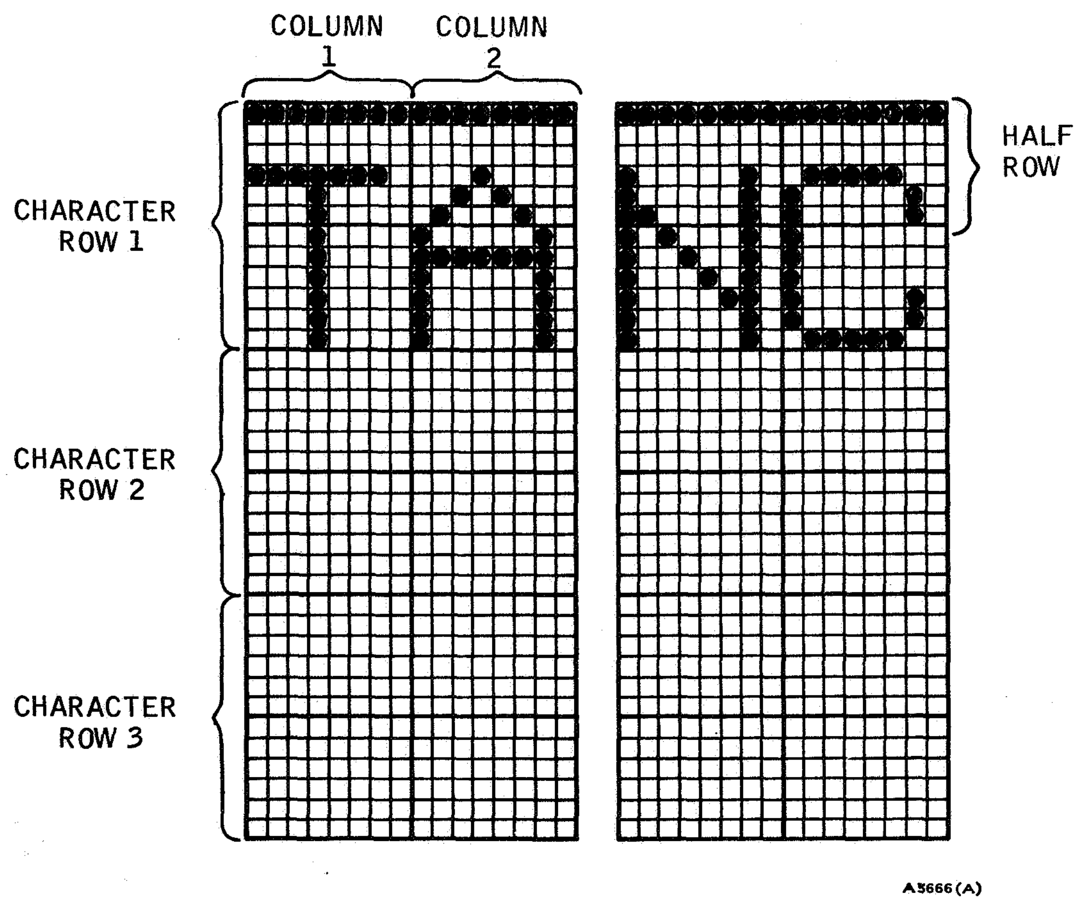
SECTOR NO. 45 & 46
rr NO. 12 & 12
cc NO. 10 & 12



THIS FORM WAS DEVELOPED BY PHO TO ASSIST IN ANALYZING THE PROCEDURES AN AUTHOR MUST PERFORM IN PREPARING CAI MATERIALS AND TO DEMONSTRATE THE MECHANICS INVOLVED IN PREPARING GRAPHIC DISPLAYS

Figure 3.2-59 (Cont'd)

SECTOR NO. 47 & 48
rr NO. 12 & 12
cc NO. 14 & 16



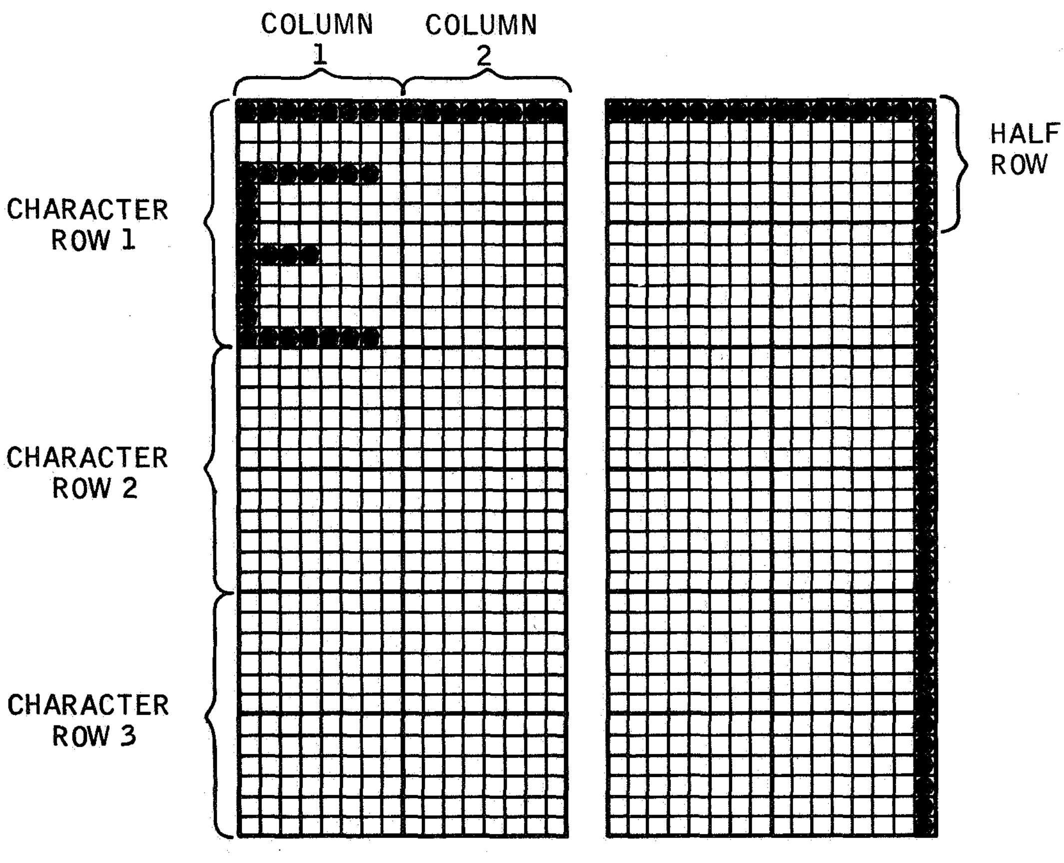
THIS FORM WAS DEVELOPED BY PHO TO ASSIST IN ANALYZING THE PROCEDURES AN AUTHOR MUST PERFORM IN PREPARING CAI MATERIALS AND TO DEMONSTRATE THE MECHANICS INVOLVED IN PREPARING GRAPHIC DISPLAYS

Figure 3.2-59 (Cont'd)

SECTOR NO. 49 & 50

rr NO. 12 & 12

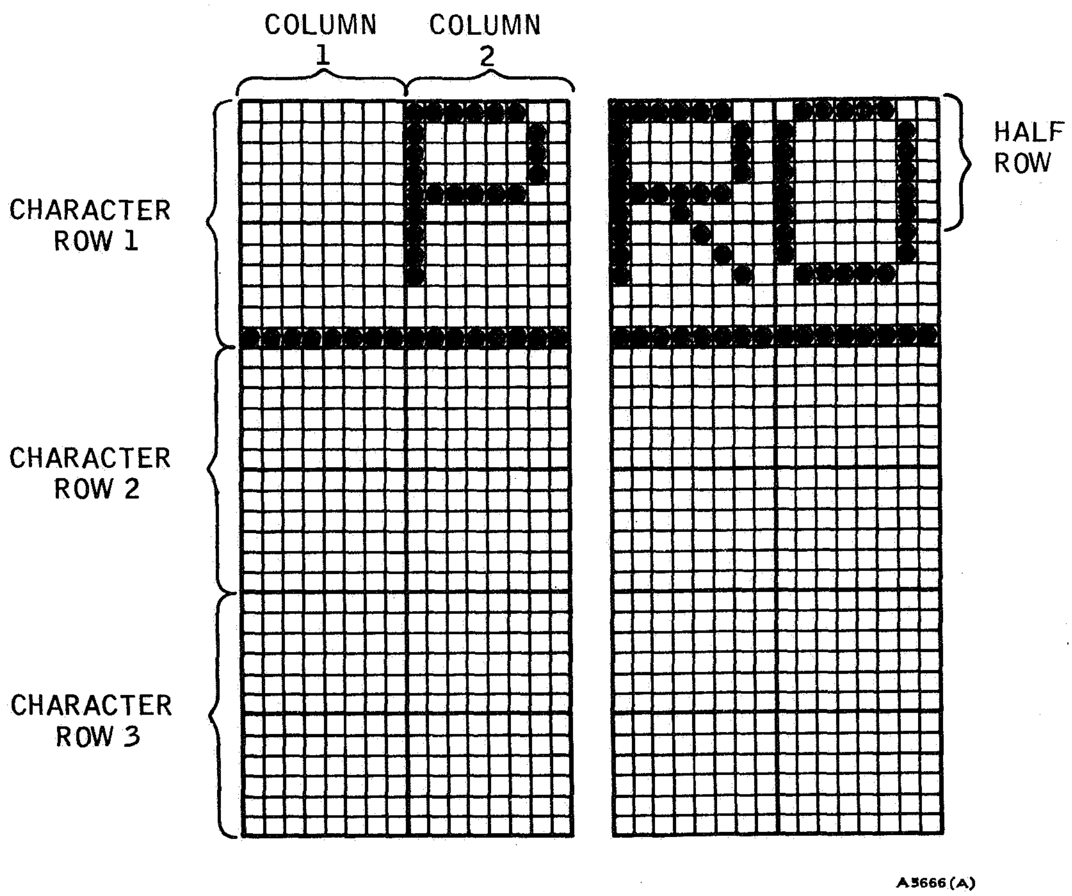
cc NO. 18 & 20



THIS FORM WAS DEVELOPED BY PHO TO ASSIST IN ANALYZING THE PROCEDURES AN AUTHOR MUST PERFORM IN PREPARING CAI MATERIALS AND TO DEMONSTRATE THE MECHANICS INVOLVED IN PREPARING GRAPHIC DISPLAYS

Figure 3.2-59 (Cont'd)

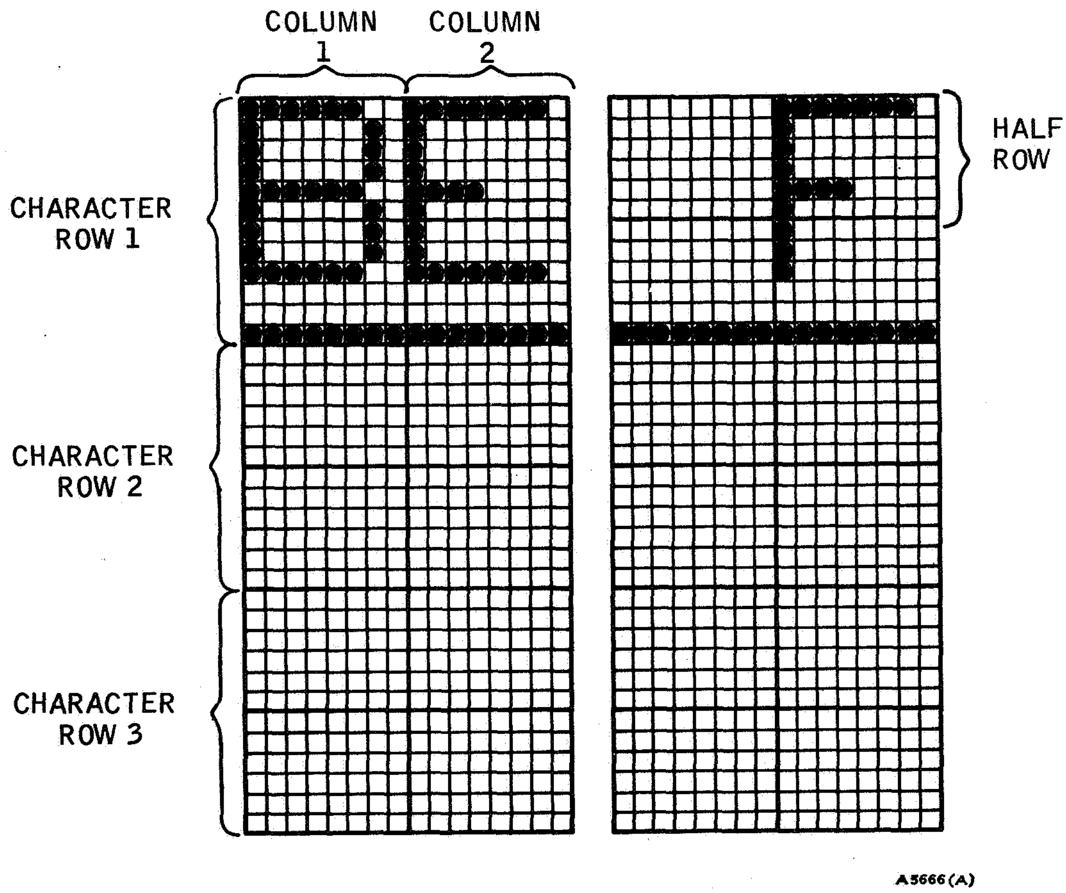
SECTOR NO. 63 & 64
rr NO. 18 & 18
cc NO. 6 & 8



THIS FORM WAS DEVELOPED BY PHO TO ASSIST IN ANALYZING THE PROCEDURES AN AUTHOR MUST PERFORM IN PREPARING CAI MATERIALS AND TO DEMONSTRATE THE MECHANICS INVOLVED IN PREPARING GRAPHIC DISPLAYS

Figure 3.2-59 (Cont'd)

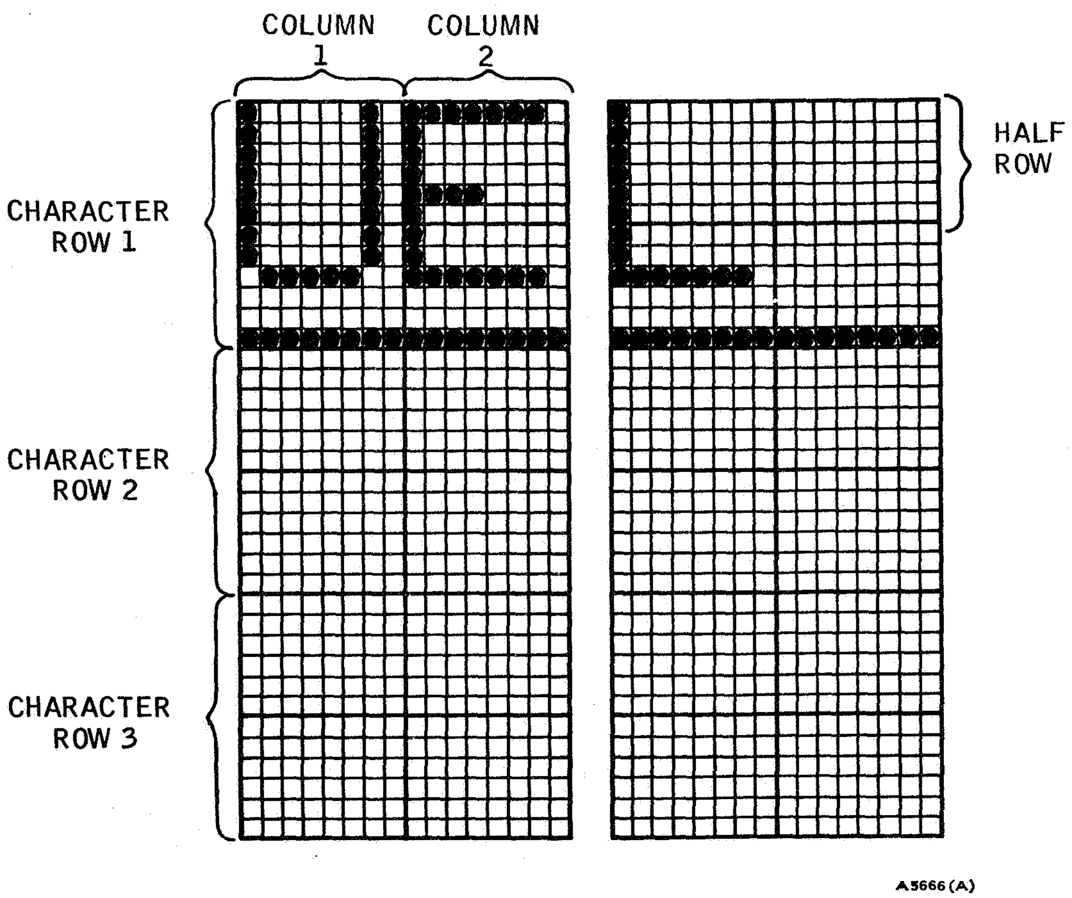
SECTOR NO. 65 & 66
rr NO. 18 & 18
cc NO. 10 & 12



THIS FORM WAS DEVELOPED BY PHO TO ASSIST IN ANALYZING THE PROCEDURES AN AUTHOR MUST PERFORM IN PREPARING CAI MATERIALS AND TO DEMONSTRATE THE MECHANICS INVOLVED IN PREPARING GRAPHIC DISPLAYS

Figure 3.2-59 (Cont'd)

SECTOR NO. 67 & 68
rr NO. 18 & 18
cc NO. 14 & 16



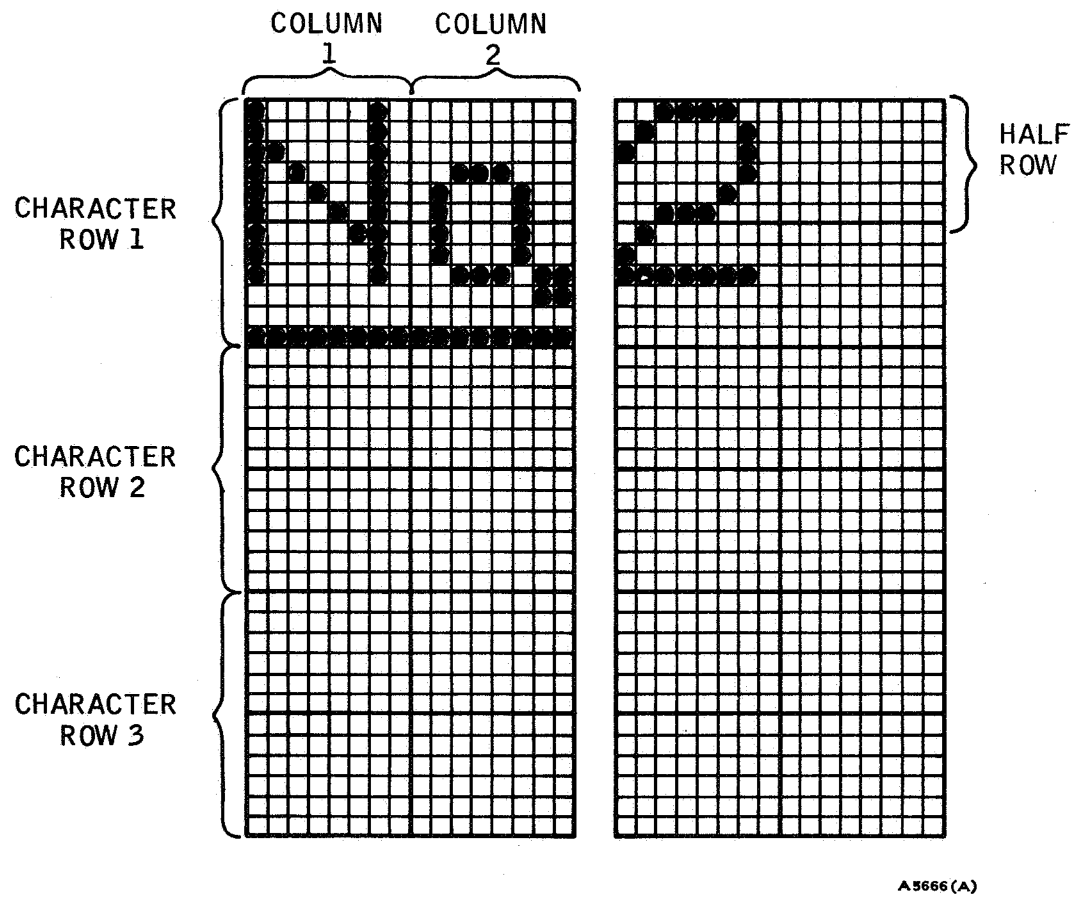
THIS FORM WAS DEVELOPED BY PHO TO ASSIST IN ANALYZING THE PROCEDURES AN AUTHOR MUST PERFORM IN PREPARING CAI MATERIALS AND TO DEMONSTRATE THE MECHANICS INVOLVED IN PREPARING GRAPHIC DISPLAYS

Figure 3.2-59 (Cont'd)

SECTOR NO. 69 & 70

rr NO. 18 & 18

cc NO. 18 & 20



THIS FORM WAS DEVELOPED BY PHO TO ASSIST IN ANALYZING THE PROCEDURES AN AUTHOR MUST PERFORM IN PREPARING CAI MATERIALS AND TO DEMONSTRATE THE MECHANICS INVOLVED IN PREPARING GRAPHIC DISPLAYS

Figure 3.2-59 (Cont'd)

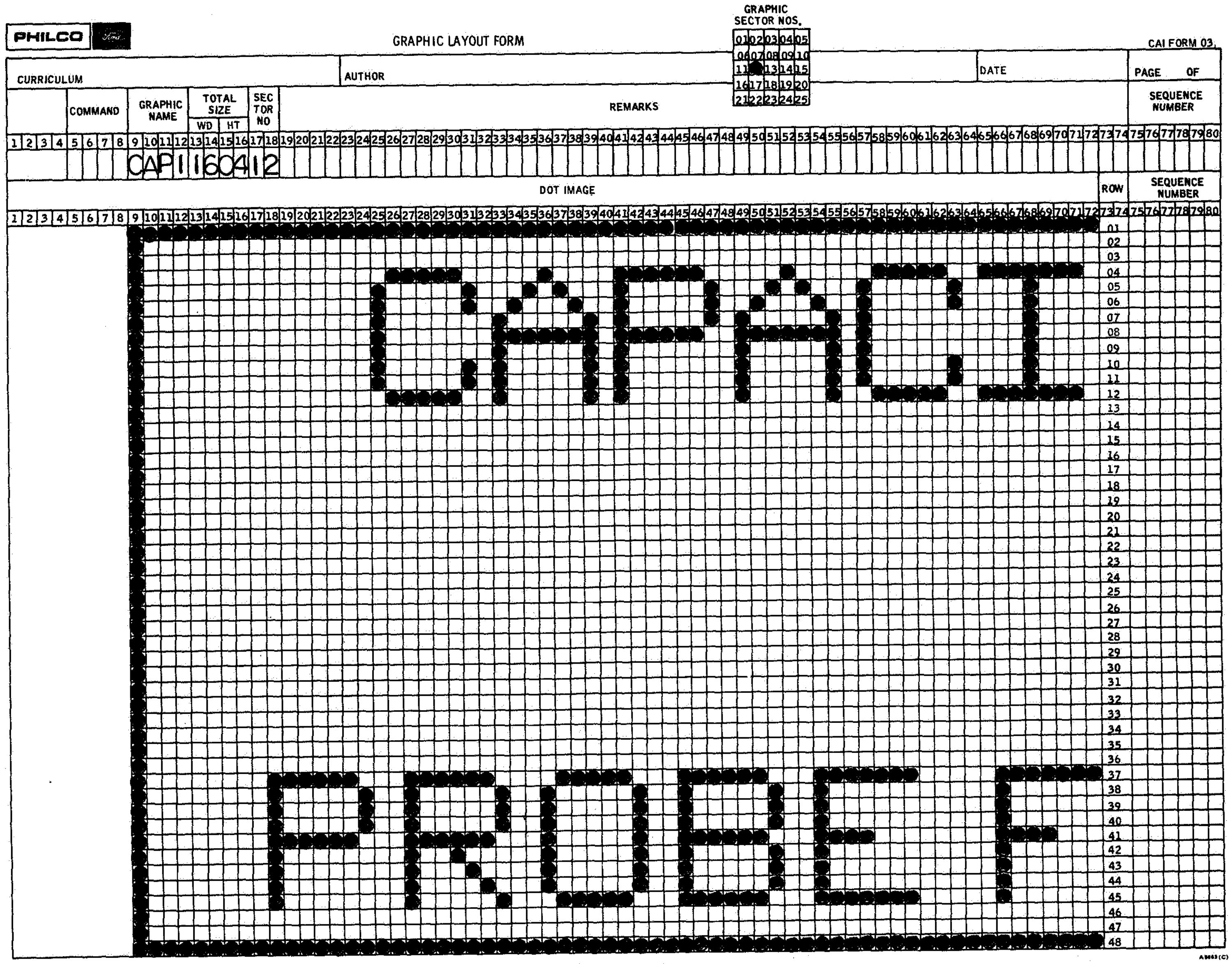


Figure 3.2-60 Graphic Layout Form Illustrating Development of CAPACITANCE PROBE FUEL NO. 2 Display Using INFORM

PHILCO

GRAPHIC LAYOUT FORM

GRAPHIC SECTOR NOS.

CAI FORM 03

CURRICULUM	AUTHOR	DATE	PAGE OF

COMMAND	GRAPHIC NAME	TOTAL SIZE WD HT	SEC TOR NO	REMARKS	SEQUENCE NUMBER
	CAP1	1604	13		

DOT IMAGE — ROW — SEQUENCE NUMBER

Figure 3.2-60 (Cont'd)

3.2.5 Comparison of CAI Systems Capabilities Relative to Flight Control Training Requirements

The following paragraphs compare the flight control curriculum with the curriculum and system characteristics of each CAI system analyzed. Each curriculum is addressed from the standpoint of course types (mathematics, engineering, etc.), course lengths, type of presentation logic utilized, preparation time, gross objectives, and relative level of complexity. A discussion of systems considers terminals, central processing units, author languages, system approach to curriculum control, and any special techniques utilized in the system. These characteristics are examined to determine if the system might be applied in its entirety or in part to flight control training requirements. An overview of the curriculum and system characteristics may be had by reference to Tables 3.2-24 and 3.2-25.

3.2.5.1 Existing Flight Control Curriculum Characteristics

The gross objectives of the entire flight control curriculum are to provide knowledge ranging from a familiarization level to a level of detailed conceptual and operational knowledge of the network (telemetry, command, tracking, consoles, and displays) and specific spacecraft systems in order to provide the technology required to enable each Flight Controller to perform his assigned tasks.

The types of courses taught are primarily technical systems courses which encompass mathematics, engineering, and science principals, and range in complexity from an order relative to that of a first-year college technical course to a post-graduate course. Also, included in some courses are organizational charts demonstrating the relative positions and functions of different groups or individuals within the NASA. Although the bulk of the curriculum concerns factual, technical information, some concepts are presented.

The range of subject length is from 3 to 40 class-hours with an average subject length of approximately 12 hours. The flight control courses are currently taught by conventional platform methods (lecturer utilizing slides, blackboard, diagrams, and handouts) and require about 120 hours of preparation for an instructor familiar with the course material to prepare a 6-hour course. Although the contents of a few subjects (viz., Orbital Mechanics, G&N Aspects of Space Rendezvous, CSM System Familiarization, and LM System Familiarization) are predominantly static, most of the subjects contain material that changes periodically. A cursory examination of the entire 432 class-hour curriculum indicates

TABLE 3.2-24

SUMMARY OF CHARACTERISTICS OF CURRICULUMS EXAMINED

CHARACTERISTICS OF CURRICULUM / INSTITUTION	COURSE TYPE	COURSE LENGTH	PREPARATION TIME	LEVEL OF CURRICULA	STUDENT POPULATION	TYPE OF LOGIC	GROSS OBJECTIVES
FLIGHT CONTROL	MATHEMATICS, ENGINEERING, SCIENCE, SYSTEMS TECHNOLOGY, INFORMATION & ORGANIZATIONAL FLOW	3 TO 40 CLASS HOURS (APPROXIMATELY 12 HOURS AVERAGE)	120 HOURS FOR EXPERIENCED INSTRUCTORS TO PREPARE A 6-HOUR COURSE	TECHNICAL SYSTEMS DATA	GROUPS OF APPROXIMATELY 25 PER CLASS	CONVENTIONAL PLATFORM	PROVIDE A LEVEL AND SCOPE OF KNOWLEDGE, RANGING FROM FAMILIARIZATION TO DETAILED TECHNICAL KNOWLEDGE WHICH WILL PREPARE STUDENTS TO PERFORM VARIOUS FLIGHT CONTROL FUNCTIONS
PLATO SYSTEM	MATHEMATICS, ENGINEERING, SCIENCE, LIBRARY USE, ELEMENTARY EDUCATION	1/2 HOUR TO 12 HOURS WITH ONE 28-HOUR SELF-CONTAINED COURSE (LIBRARY USE)	4 MONTHS TO PREPARE A 28-HOUR COURSE BY A NON-COMPUTER ORIENTED PERSON	PRE-SCHOOL THROUGH COLLEGE LEVEL	NO FIGURES AVAILABLE	TUTORIAL AND INQUIRY	RANGES FROM TEACHING THE ALPHABET TO 2- AND 3-YEAR OLDS TO TEACHING COLLEGE-LEVEL PROGRAMMING AND ENGINEERING. ALL ARE MERELY SUPPLEMENTS TO EXISTING COURSES WITH THE EXCEPTION OF THE LIBRARY USE COURSE WHICH IS COMPLETE.
GROW SYSTEM	NOT KNOWN BUT ASSUMED TO INCLUDE MATHEMATICS, SCIENCE, LANGUAGES	NOT AVAILABLE	NOT AVAILABLE	JUNIOR HIGH, HIGH SCHOOL, LIMITED COLLEGE LEVEL	2 HIGH SCHOOLS, AND 2 JUNIOR HIGH SCHOOLS	DRILL AND PRACTICE, TUTORIAL	PROVIDE INSTRUCTION RANGING FROM DRILL AND PRACTICE LEVEL TO COLLEGE-LEVEL CHEMISTRY TO STUDENTS IN JUNIOR HIGH AND HIGH SCHOOL
STANFORD (BRENTWOOD SYSTEM)	MATHEMATICS, READING	1/2 HOUR LESSON EACH DAY THROUGHOUT SCHOOL YEAR	NOT AVAILABLE	PRIMARY SCHOOL	100 STUDENTS	TUTORIAL	PROVIDE PRIMARY EDUCATION, SUPPLEMENTAL TO CLASSROOM INFORMATION, IN MATHEMATICS (SETS AND NUMBERS) AND READING TO PRIMARY SCHOOL CHILDREN
STANFORD (WALTER HAYS SYSTEM)	MATHEMATICS, SYMBOLIC LOGIC, SPELLING	APPROXIMATELY 10 MINUTES PER DAY THROUGHOUT SCHOOL YEAR	NOT AVAILABLE	ELEMENTARY SCHOOL, SOME HIGH SCHOOL	PORTIONS OF 5 ELEMENTARY SCHOOLS AND 1 HIGH SCHOOL	DRILL AND PRACTICE	PROVIDE DRILL AND PRACTICE IN MATHEMATICS, SPELLING, AND SYMBOLIC LOGIC TO ELEMENTARY SCHOOL STUDENTS
UNIVERSITY OF CALIFORNIA AT IRVINE	MATHEMATICS, SCIENCE, SOCIAL SCIENCE, LANGUAGES	2 TO 5 HOURS PER COURSE	100 TO 200 AUTHOR-HOURS PER COURSE HOUR	COLLEGE LEVEL WITH SOME REMEDIAL MATERIAL OF HIGH SCHOOL LEVEL	50 TO 400 STUDENTS PER COURSE	TUTORIAL	PROVIDE INTRODUCTORY COURSE MATERIAL TO COLLEGE-LEVEL STUDENTS AS WELL AS REMEDIAL MATERIAL FOR THOSE COLLEGE STUDENTS NOT MEETING COURSE PREREQUISITES
PLANIT, (SYSTEM DEVELOPMENT CORP.)	STATISTICS, COUNSELING	STATISTICS - 20 HOURS	60 TO 70 HOURS PER STUDENT HOUR (MINIMUM)	COLLEGE LEVEL	NOT AVAILABLE	TUTORIAL, INQUIRY	PROVIDE A COMPLETE COURSE, WITH SOME OUTSIDE REFERENCES, IN COLLEGE LEVEL STATISTICAL INFERENCE, AND A COLLEGE COUNSELING COURSE

TABLE 3.2-25

SUMMARY OF CHARACTERISTICS OF VARIOUS CAI SYSTEMS

SYSTEM \ SYSTEM CHARACTERISTICS	TERMINALS	CENTRAL SYSTEM	SYSTEM CONCEPT	LOGIC	AUTHOR LANGUAGE
PLATO SYSTEM	20 TERMINALS (EXPANDABLE TO 32); EACH TERMINAL CONSISTS OF MODEL UK-801 TTY KEYBOARD, CONRAC 8-INCH RV MONITOR, SLIDE PROJECTION CAPACILITY	CDC 1604 DEDICATED TO CAI PERFORMS FUNCTIONS OF: I/O INFORMATION SWITCHING, RT PROCESSING OF INPUT DATA, RT CONTROL OF SLIDE STORAGE, AND MASS STORAGE.	CENTRALIZED CURRICULUM CONTROL	TUTORIAL, INQUIRY	CATO, MODIFIED FORTRAN'60 COMPILER WITH FEATURES TO USE PLATO FOR TEACHING OPERATIONS. ALLOWS USE OF FORTRAN SUBROUTINES. REQUIRES KNOWLEDGE OF FORTRAN FROM INSTRUCTOR.
GROW SYSTEM	8 TO 64 TERMINALS, PHILCO SAVI TERMINAL CONSISTING OF CRT DISPLAY, KEYBOARD, AND LIGHT PEN. EXPANDABLE TO INCLUDE AUDIO QUEING.	CENTRAL PROCESSOR IS PHILCO 2000-211 DEDICATED TO CAI. EACH CLUSTER PROCESSOR IS PHILCO 102; HANDLES 8 TERMINALS.	CENTRALIZED CURRICULUM CONTROL WITH DECENTRALIZED AUTOMATIC OPERATION	TUTORIAL	INFORM, USER-ORIENTED AUTHOR LANGUAGE, PROVIDES FOR DISPLAY OF CURRICULUM AND PROCESSING OF STUDENT ANSWERS. THE LANGUAGE IS CAPABLE OF GENERATING GRAPHIC, TABULAR, OR AUDIO DATA. NO STRONG COMPUTATIONAL CAPABILITY IS AVAILABLE.
STANFORD (BRENTWOOD SYSTEM)	16 IBM 1510 TERMINALS WITH CRT, KEYBOARD/TYPEWRITER, SLIDES, LIGHT PENS, AUDIO	IBM 1800 DEDICATED TO CAI PERFORMS: I/O INFORMATION SWITCHING, RT INPUT DATA PROCESSING, RT IMAGE PROJECTOR AND AUDIO CONTROL, CRT DISPLAY CONTROL, MASS STORAGE.	CENTRALIZED CURRICULUM CONTROL	TUTORIAL	COURSEWRITER II, USER-ORIENTED LANGUAGE THAT ALLOWS OUTPUT BY MEANS OF CRT, TYPEWRITER, SLIDES OR AUDIO, AND ACCEPTS INPUTS FROM EITHER KEYBOARD OR LIGHT PEN. NO STRONG COMPUTATIONAL CAPABILITY IS AVAILABLE.
STANFORD (WALTER HAYS)	31 MOD. 33 TELETYPEWRITERS AND 12 PHILCO READ TERMINALS (FOR CURRICULUM DEVELOPMENT)	PDP-1 DEDICATED TO CAI PERFORMS: I/O INFORMATION SWITCHING, CONTROL OF EXERCISES, MASS STORAGE, STUDENT RECORDS.	CENTRALIZED CURRICULUM CONTROL	DRILL AND PRACTICE, TUTORIAL WITH ADAPTIVE SEQUENCING	PAL, PROGRAM ASSEMBLY LANGUAGE TSA, TEACHER/STUDENT ALGOL (INTERPRETIVE LANGUAGE) BOTH LANGUAGES ARE RELATIVELY PROGRAMMER-ORIENTED RATHERN THAN AUTHOR-ORIENTED.
UNIVERSITY OF CALIFORNIA AT IRVINE	18 IBM 1050 TERMINALS; I/O BY KEYBOARD/PRINTER	IBM 1440-1410 TIME-SHARED SYSTEM HANDLING CAI, ENROLLMENT, BUDGET, AND AN ALGEBRAIC LANGUAGE	CENTRALIZED CURRICULUM CONTROL	TUTORIAL	INTERPRETIVE COURSEWRITER, USER-ORIENTED LANGUAGE. NO PROVISION FOR CRT DISPLAY OR STRONG COMPUTATIONAL CAPABILITY.
PLANIT SYSTEM	53 TERMINALS OF MODEL 28 AND 33 TELETYPE TERMINALS: I/O BY KEYBOARD/PRINTER	CPU IS IBM Q-32/PDP-1 COMBINATION AND IS TIME-SHARING CAI, COMPILING AND DEBUGGING, AND ON-LINE PROGRAMMING. (A 360/67 SYSTEM WILL BE IN OPERATION IN THE FALL OF 1967)	CENTRALIZED CURRICULUM CONTROL	TUTORIAL, INQUIRY	PLANIT, HIGHLY USER-ORIENTED WITH ENGLISH LANGUAGE COMMANDS. AUTHOR MAY EASILY PREPARE AND MODIFY LESSONS ON THE TERMINAL, AND THEN PROCEED TO CHECKOUT THE MODIFIED LESSON. A STRONG COMPUTATIONAL CAPABILITY EXISTS FOR BOTH STUDENT AND INSTRUCTOR. ONLY TELETYPE I/O FOR STUDENTS AT PRESENT (PLANIT IN ITS 360 MODEL WILL ALLOW FOR CRT, TTY, AND AUDIO)

that subjects totaling 264 class-hours consist of material that changes less than 30 percent from presentation to presentation (normally, mission-to-mission). Fifty-eight class-hours out of the 432 consist of material which is 30 to 60 percent changing, while subjects totaling 110 class-hours have over 60 percent change in content.

3.2.5.2 PLATO Curriculum and System Characteristics

3.2.5.2.1 PLATO Curriculum

The PLATO system utilizes curriculums which consist of mathematics, engineering, science, library-use, and elementary education. These courses present both facts and concepts. The course lengths are from one-half to 10 hours with an average of 3 hours for the mathematics courses; one to 12 hours with an average of 6 hours for the engineering courses; one-half to 2 hours for the science courses; 28 hours for the library course and one hour for an elementary education course. All of these are demonstrations, exercises, or portions of a more complete course with the exception of the library-use course which is a complete course in itself.

The courses are presented in one-half hour to 2-hour units and utilize both tutorial and inquiry logic for material presentation. It was estimated that the 28-hour library course required approximately 4 months for a noncomputer oriented person to prepare. This equals approximately 25 manhours of preparation per course hour.

The mathematics courses have objectives which include instructing simple mathematics to primary school children, demonstration of PLATO features using geometric models, instruction of college level business and commerce students in the use of FORTRAN, and the instruction of college students in the development of mathematical proofs.

Engineering course objectives include the familiarization of first year college students with the construction of engineering circuit diagrams on the PLATO system, the introduction of electrical engineering students to the fundamentals of Maxwell's Equations, and the analysis of electrical circuits by advanced college-level electrical engineering students.

Scientific course objectives range from primary school demonstration level and high school level of demonstration concerning weight and volume measurements to analysis of scientific experimental data and demonstrations of bimetallic properties.

The elementary education course has the gross objective of teaching the alphabet to two- and three-year old children, while the library-use course has as its objective the instruction of library-use to nonlibrary-oriented science majors. The complexity ranges of the courses are: mathematics--primary school to college level; engineering--high school and college level; science--primary school, high school, and college level; elementary education--pre-school; library-use--college level.

3.2.5.2.2 Comparison of PLATO and Flight Control Curriculums

Both curriculums are similar in that the course types are mathematics, science, and engineering-oriented. The two wish to convey both facts and concepts, and the range of course lengths are reasonably equal.

However, there the similarities end. While the PLATO curriculum's objectives are limited to demonstrations, introductions, and partial background course material in which to build for greater knowledge, the objectives of the flight control curriculum are oriented more to provide a level of technology which may be called upon to elicit a correct operational response. The level of complexity differs in that the flight control curriculum encompasses technical systems data which ranges in complexity from early-college to the post-graduate level, and generally goes into extreme detail. The content of the flight control curriculum is partially changing while the courses taught by PLATO contain static data.

3.2.5.2.3 PLATO System

The PLATO system is of the central curriculum control type with instructors using both the tutorial and inquiry approach. The 20 terminals (expandable to 32) for the PLATO system consist of a CRT, slide display, and teletype keyboard with a mode lockout (to inhibit full keyboard operation until the student becomes completely familiar with its operation). The CPU is dedicated to CAI and performs the functions of I/O information switching, RT data input processing, RT slide storage control, and mass storage.

The instructional language, Compiler for Automatic Teaching Operations (CATO), is a modified FORTRAN 60 compiler with features to utilize the PLATO system. CATO provides for time-sharing of the instructional program by many students. FORTRAN subroutines as well as special PLATO subroutines are available to the user for a greater mathematical computation capability. The author, however, must know basic FORTRAN to use CATO unless he wants to adhere to a basic pattern of instruction prepared by a programmer.

Special techniques used by the PLATO system include a "help" sequence which allows a student-initiated branch for extra explanation, a "judge" sequence to examine the validity of a student input, and the capability to compile student responses for behavorial research purposes.

3.2.5.2.4 PLATO Systems Capabilities Applicable to Flight Control Training

The display flexibility of the terminals and computational capability of the CATO language make the PLATO system capabilities applicable to flight control training. The technical systems oriented nature of the flight control curriculum makes CRT display of models and schematics desirable, while also requiring a strong computationally capable language available to the student in order to fully utilize the capabilities of a computer for instruction.

The fact that the CATO language, in order to be flexible, requires a knowledge of FORTRAN is a disadvantage to utilization in flight control training. The dynamic nature of the flight control curriculum requires an author language that is usable by a non-programmer and that facilitates changes in the instructional program.

3.2.5.3 GROW Curriculum and System Characteristics

3.2.5.3.1 GROW Curriculum

The GROW project will utilize a tutorial logic (combination of linear with simple branching) to instruct junior high school and high school students in courses which will include simple mathematical drill, practice exercises, and college chemistry courses. No preparation time estimates or course-length figures are available at this time. It is assumed that the courses will be primarily supplemental to the existing curriculum and will encompass mathematics, science, languages, and social sciences.

The gross objectives of the courses will be to provide supplementary and introductory material in mathematics, science, languages, and social sciences at a complexity level ranging from junior high school through early college level to students in the seventh through twelfth grades.

3.2.5.3.2 Comparison of GROW and Flight Control Curriculums

The curriculum, as described for Project GROW, bears little similarity to the flight control curriculum. The course content differs in complexity, and the objectives are quite different in that the objectives of the flight control curriculum are much more stringent and require a far greater assurance of proper response based upon the system technology presented via the curriculum.

3.2.5.3.3 GROW System

The GROW system approach is that of a central curriculum control with decentralized automatic operation. The central processor develops and distributes curriculum to the terminal clusters, performs statistical analyses, and communicates with the cluster processor. The cluster processor controls the terminals and processes I/O messages, communicates curriculum data with the central processor, and stores and routes curriculum data.

The system can handle up to 64 terminals which consist of CRT display, keyboard, light pen, and expansibility to audio queueing.

INFORM, the Project GROW author language, provides logical and arithmetical operations for instructional purposes as well as the capability to generate graphic and tabular data for CRT display, effect audio queueing, and interact with keyboard and light pen response devices. A series of forms are provided to the author to provide curriculum input and are designed to eliminate confusion about the instruction/computer interface. The capability to enter curriculum descriptions, answers and displays, and graphical and character displays are provided by the forms.

Curriculum modifications are easily incorporated by the curriculum modification programs. In order to checkout the curriculum, the instructor need only utilize a curriculum checkout program which steps through selected portions of the curriculum and provides diagnostic reports on the curriculum. The Master Curriculum File is protected from accidental destruction by special protection programs.

Although the capability exists to keep student records and generate statistical analyses from them, the author language has no facilities for mathematics more advanced than simple arithmetic.

3.2.5.3.4 GROW System Capabilities Applicable to Flight Control Training

Terminals, as used by the GROW system, are flexible enough to adapt to flight controller training as they provide for CRT display of information and a variety of input devices.

The central system, while entirely adequate utilizes the approach of central curriculum control with decentralized automatic operation. This does not appear to be the best approach for flight control training needs as this approach is designed to minimize the number of data lines, but increases the initial and maintenance costs.

The author language has many desirable features which would facilitate expressing the flight control curriculum using CAI techniques. It allows for CRT display and a variety of terminal input modes; provides for a simple method of curriculum input utilizing special forms, facilitates curriculum checkout through special programs, enables the instructor to easily modify the curriculum, and provides programs to protect the Master Curriculum File from accidental destruction.

However, the language does not allow the author or student much flexibility in mathematical computations as only simple arithmetic codes are available. It may be feasible to overcome this by modifying the language to allow an algebraic language to be called up for author or student computational use.

3.2.5.4 Stanford/Brentwood Curriculum and System Characteristics

3.2.5.4.1 Stanford/Brentwood Curriculum

Tutorial logic is used to present facts and concepts to primary students at the Brentwood Elementary School. The curriculum consists of arithmetic, elementary sets and numbers, and reading exercises which are presented in steps of one-half hour per day to each student throughout the school year. Objectives of the system are geared to the presentation of extremely elementary subjects to primary school children. Sources at the Brentwood system estimated that one and one-half man weeks were required to prepare one instructional hour.

3.2.5.4.2 Comparison of Stanford/Brentwood and Flight Control Curriculums

The nature of the Brentwood School curriculum (primary objectives, elementary level of subject matter, and the static nature of the course contents) allow little parallel to be drawn between it and flight control curriculum; however, the system appears to be capable of handling most flight control curriculum requirements as will be discussed in the following paragraphs.

3.2.5.4.3 Stanford/Brentwood System

Brentwood School has an IBM 1500 Instructional System with 16 student terminals. The CPU is dedicated to CAI and provides the functions of I/O switching of information, RT processing of input data, mass storage, RT image projection control, audio queue control, and CRT display control. An approach of centralized curriculum control is utilized in this system.

The terminals consist of CRT display, keyboard, image projector, light pen, and audio queueing devices. A typewriter may be used in place of the keyboard in order that the student may check his responses for accuracy.

Coursewriter II, the author language for the Brentwood School CAI system, allows for CRT display generation, and the utilization of a full complement of input/output devices. The curriculum may be stored in segments on disk packs so that an entire course need not be presented when only one portion or specific area is desired. Coursewriter II does not have the capability for author or student use of mathematical computation facilities greater than simple arithmetic.

Student records are kept and processed by the system. The age of the student body necessitates several special techniques; such as, audio prompting for those students too young to read, and the use of light pens rather than keyboards for responses.

3.2.5.4.4 Stanford/Brentwood System Capability Applicable to Flight Control Training

The instructional system as utilized by the Stanford/Brentwood project could be utilized for flight control training with some constraints. The terminals are adequate as they provide CRT display capability and a wide variety of I/O devices. The author language, Coursewriter II, is versatile enough to be applicable since it allows for CRT display generation and image projection. It is an author-oriented language which does not require the author to know another programming language prior to using it; therefore, curriculum inputs and changes should be facilitated. Coursewriter II does not, however, have the capability to provide the student or author with a mathematical capability greater than simple arithmetic. Although the teaching problems differ greatly and some of the capabilities of the Brentwood system are not necessary for flight control purposes (i.e., light pens, audio prompting), the system, in general, has the capability to handle flight control training that does not require computational capability.

3.2.5.5 Stanford/Walter Hays Curriculum and System Requirements

3.2.5.5.1 Stanford/Walter Hays Curriculum

Facts and concepts are presented through a tutorial logic to students in primary and secondary school. The curriculum consists of arithmetic, symbolic logic, and spelling presented only on the drill and practice level as a supplement to classroom teaching. Each lesson lasts approximately 10 minutes each day throughout the school year. About 10,000 lessons have been prepared by Stanford at this time.

Adaptive sequencing is provided, as the curriculum is broken into five distinct levels of difficulty. The level in which a particular student is placed is determined by his performance on past lessons.

No curriculum preparation time figures are available.

3.2.5.5.2 Comparison of Stanford/Walter Hays and Flight Control Curriculums

The gross objectives of flight control training differ greatly from those of Walter Hays as does the course content, complexity, and length of courses. While the Walter Hays curriculum presents only drill and practice sessions of a simple nature, the flight control curriculum to be presented consists of longer lessons and complex systems-oriented information.

3.2.5.5.3 Stanford/Walter Hays System

The central processing system is dedicated to CAI and provides the functions of I/O information switching, control of exercises, mass storage, student records and analyses, and adaptive sequencing of curriculums to the individual student.

There are 31 teletype terminals in the system (9 of which are at the Walter Hays school, and the remainder at similar school projects), plus 14 terminals located at Stanford for curriculum development.

The author language is a modification of ALGOL and requires the instructor to know ALGOL before being able to use it. The ALGOL language is a programmer-oriented language, but is easily learned and should permit rapid instructor training. No CRT displays or I/O devices other than teletype can be handled for student terminals at the present.

The system concept is that of centralized curriculum control, and the teaching logic used is tutorial with adaptive sequencing. The adaptive sequencing technique allows the curriculum to be constructed in five levels of complexity. At the beginning of each lesson, the system determines, based upon the students' performance on recent lessons, whether or not he is suited for the present level and, if not, whether he should be doing more difficult or less difficult lessons.

The system collects and processes student records and at the end of each lesson provides the student with the time it took to complete the lesson and the percentage of correct answers. The system also provides the teachers with class averages, specific student averages, and student status reports.

3.2.5.5.4 Stanford/Walter Hays System Capability Applicable to Flight Control Training

The central processing capability of the system would be adequate for flight control needs, with the techniques of student data processing and adaptive sequencing begin particularly useful. The terminals, however, do not possess any graphic display capability; this would severely hinder application of this type of system to flight control training. The author language has several disadvantages. No capability exists for graphic display or use of algebraic computations by the student. The author must know ALGOL to fully utilize the system, thus rendering the author language more inconvenient for training of instructors, and more difficult for curriculum changes than a user-oriented author language.

3.2.5.6 UCI Curriculum and System Characteristics

3.2.5.6.1 UCI Curriculum

Courses of mathematics, sciences, languages, and social sciences present facts and concepts on a college level (high school level in the case of remedial courses) for from 50 to 400 students.

The lesson lengths are from 2 to 5 hours and are presented in a tutorial (combination linear and branching) fashion. The gross objectives of the courses range from remedial reviews of algebra and English, introduction to trigonometry, science, and FORTRAN to simulation of biology laboratory experiments.

It is estimated that preparation time for the courses at UCI was approximately 200 author-hours per instructional-hour.

3.2.5.6.2 Comparison of UCI and Flight Control Curriculums

The flight control curriculum is similar in some respects to portions of the UCI curriculum. Both present mathematics and science-oriented data; however, the flight control curriculum presents technical systems data with a greater level of complexity. The courses presented at UCI are generally much shorter in length than flight control courses. Objectives are less stringent at UCI than for the flight control curriculum, because of the critical nature of flight control duties. All course material taught at UCI consists of, primarily, static information, while the flight control curriculum contains data which changes from presentation-to-presentation.

3.2.5.6.3 UCI System

The CPU is a time-sharing system with provision for time-sharing computer assisted instruction, enrollment, budget, and an algebraic computing language (ISIS). It provides the CAI functions of I/O information switching, RT processing of input data, curriculum control, and mass storage. The system concept is one of central curriculum control.

Eighteen IBM Model 1050 terminals are presently in use. These terminals are similar to an electric typewriter and have no display or input capabilities other than the keyboard/printout capabilities.

Interpretive Coursewriter, the UCI author language, is a modified IBM coursewriter language which provides for relatively easy course construction and modification by a non-programmer. The language is oriented such that the instructor does not need to know any other programming language. The language has no provision for CRT display generation, nor does it allow mathematical computations more complex than simple arithmetic. Constructed responses are allowed (the student response from the keyboard is compared with stored alternatives; the results of this comparison determines the next computer reply).

3.2.5.6.4 UCI System Capability Applicable to Flight Control Training

The lack of a CRT or similar display device makes the UCI system unfavorable for flight control curriculum since a CRT display is desirable for mathematical models, flow charts, schematics, and similar graphic generations. The time-shared CPU provides all the necessary functions; however, it does not appear that a time-shared CPU is necessary for flight controller instruction.

Interpretive coursewriter is easily applied by non-programmer personnel and should provide for ease of entering or changing curriculum. But it does not have the capability for CRT display generation or mathematical computations more complex than arithmetic. A new course language (Course Author Language) to be used at UCI soon will allow the user to call up an algebraic language for computation. The present language does have the desirable feature of allowing for constructed responses to determine the next computer reply.

3.2.5.7 PLANIT Curriculum and System Characteristics

3.2.5.7.1 PLANIT Curriculum

Courses being developed on the PLANIT system include a college-level statistical inference course about 20 hours in length and a counseling course which performs the initial counseling for student educational counselors. The statistics course uses a tutorial logic while the counseling course is of the inquiry logic type.

The objectives of the statistics course are geared to teaching a complete college-level course in elementary statistics to students in the first two years of college. The course is not entirely self-contained as references are made to outside text material. Statistical models and examples are presented to the student and allows the student to become more familiar with statistics by working problems at the terminal. The curriculum is constructed so that the student may utilize the terminal as a calculator to work example problems from random data generated by the system. Sixty to 70 hours have been estimated as the lower bound of preparation time for one course-hour of this nature.

3.2.5.7.2 Comparison of PLANIT and Flight Control Curriculums

The limited curriculum developed for the PLANIT system is similar to the flight control curriculum. Both present mathematical information which requires computation and mathematical models to be meaningful to the student. The statistics course length is about the same as the average flight control course length. The flight control curriculum has a higher level of complexity, and has objectives which require greater student understanding and retention of information. The curriculum presented by the PLANIT system is, however, relatively static while the flight control curriculum has changing contents.

3.2.5.7.3 PLANIT System

The PLANIT system is a time-sharing system which allows simultaneous compiling and debugging of programs, on-line programming, and CAI. The system concept is that of centralized curriculum control. All terminal users are availed the full use of all computational powers of the computer and use of all service programs.

Fifty-three teletype terminals are in the system, and 25 to 30 may presently be used simultaneously. The terminals consist of only a typewriter terminal and have no other display capabilities. In its IBM 360 form, however, PLANIT will have the capability for teletype, CRT display, and audio.

The PLANIT author language is a highly user-oriented language with English language commands. There are four modes of operation which allow (1) editing by the lesson designer, (2) lesson building, (3) presenting the lesson to the student, and (4) student use of the system for computations. The lesson designer can enter questions, specify answers, and specify computer replies as a function of student answers. The language includes statistical functions and a mathematical computation capability, which allows problems to be presented, sample data to be generated for these examples, and computation of the solutions by the student. PLANIT allows student answers to be evaluated by phonetic comparison, keyword match, or equivalent algebraic matching. The instructor may modify his lessons at the keyboard and then immediately try them out; thus, allowing ease of lesson changes.

3.2.5.7.4 PLANIT System Capability Applicable to Flight Control Training

The overall system capability meets most of the needs for flight control training with one exception, the terminals. The author language allows mathematics-oriented problems to be presented and computational operations to be performed using the powers of the computer as an aid to learning. This capability is very important in presenting flight control curriculum. The ease of author use of the language and the ease which curriculum changes may be incorporated and verified make the PLANIT language extremely powerful. The flexibility of lesson design and variety of student responses allowed by PLANIT also lend to its usefulness as applicable to the flight control curriculum.

Lack of display capability other than typewriter printouts seriously limits the advantages of having a strong computational capability. The CRT or a similar display surface is desirable in order to present mathematical models and to observe the overall effect on example problems as certain parameters change. When PLANIT is implemented in its 360 configuration, it will have the capability for CRT display, as well as teletype and audio.

3.2.6 Development and Specification of Optimum CAI System Functional Requirements

This section defines the functional requirements for an optimally designed CAI system and is discussed in terms of total systems considerations, storage requirements, terminal requirements, and author language requirements.

The functional requirements for the optimum CAI system for flight controller applications are also specified. The paramenters considered are: machine and storage characteristics and terminal requirements, existing assets, special functional requirements, and location.

Based on these requirements and the short range goals, the functional requirements for a pilot or initial system have been developed and are specified herein.

Figure 3.2-61 illustrates the approach used in specifying the functional requirements for the optimum and initial systems.

It should be noted that because these systems elements are dynamically interrelated, a significant overlap between areas exists.

3.2.6.1 System Design Criteria for CAI Applications

As previously mentioned, the basic CAI system is composed of the following dynamically interrelated elements: (1) central processing unit, (2) terminal, and (3) author language.

Other elements which significantly influence the system design and must be considered as dynamically interrelated components are: (1) student, (2) instructor, and (3) administrator.

This and subsequent paragraphs delineate the functional requirements that optimize the design and interaction of these elements.

3.2.6.1.1 Total Systems Considerations

The system must be designed so that students and authors are not required to understand computer operation or utilization. This eliminates the necessity of training all personnel (students and authors) in these computer disciplines prior to presenting the curriculum.

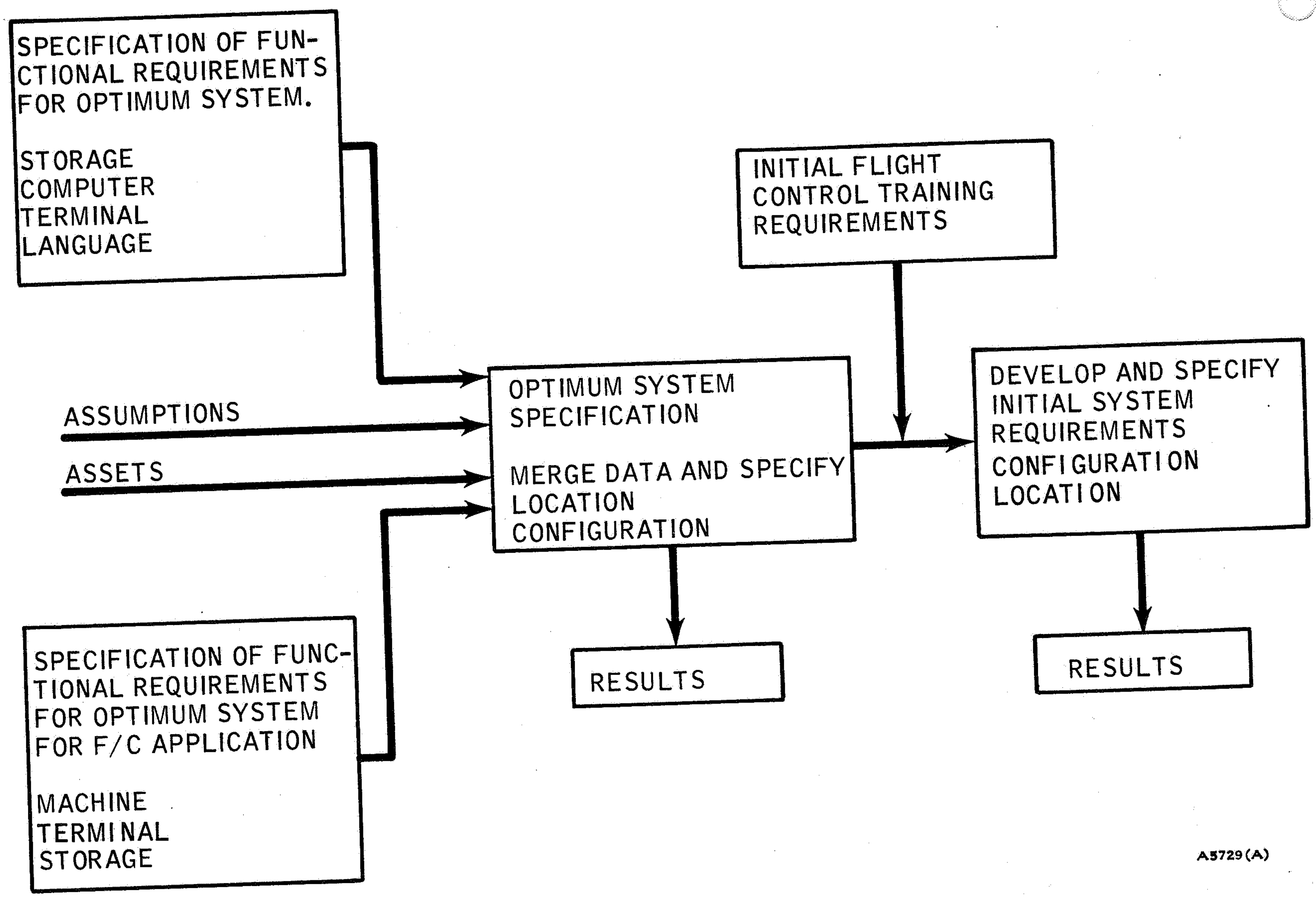


Figure 3.2-61 System Requirements Study Activities Block Diagram

The student must be provided with direct communication to the central processor. (This does not preclude the possibility of keyboard input multiplexing.) This eliminates the possibilities of costly delays, reduces equipment interfaces and increases reliability.

The system must function autonomously with each student. This ensures that self-pacing, adaptive sequencing and, in general, the basic tutorial environment will be maintained.

The system must provide for adaptive sequencing of each student. This enables the system to automatically determine, based on student performance, the level of difficulty of information that should be presented to the student and, thus, ensures student self-pacing.

The user must have the capability, by means of manual control, to step ahead to a new concept or return to a previously presented concept. For the author, this will provide rapid access for course modification, correction and addition, and enable segments within a concept to be selected for hardcopies, review, and evaluation. This eliminates time consuming sequencing through the curricular material. For the student, it provides the capability of selecting previously presented material for possible review or hardcopy and for selecting new material for which the student (with instructor approval) feels no preparation is required. In addition, this type of curricular material selection will enable students to select concepts or segments that were previously presented. As an example, concept blocks would be identified and easily accessed by the student by providing a dummy control, i.e., one that would simulate a student response. This would enable the student to rapidly sequence through the material to the desired information.

As an extension of the preceding requirement, the system must provide the capability to restart the student at the precise point at which instruction was terminated. This eliminates presentation of previously displayed material, reduces possibility of boredom, and more nearly approaches a classroom environment.

The system must have the capability to present the same curricular material to the entire class but allow each student to progress at an individual rate.

The system must also have the capability to simultaneously present different curricular material to each student. This eliminates the limitation on the number of courses of instruction that can be provided concurrently.

The system must be capable of driving each display independently of the remaining terminals. This will ensure that failures will be on an individual basis rather than a group basis.

The system must be designed to maximize the number of students that can simultaneously utilize the computing facilities. This reduces operating costs by increasing the number of students receiving instruction per unit time and by efficient utilization of machine time and peripheral equipments.

The system must be capable of providing a continuing analysis of student performance. This will provide the information necessary to properly sequence the student through the appropriate level of material and provide the background for evaluating response latencies, and other statistical data relating to performance.

The system must provide the flexibility and modularity to incorporate developments in author languages, procedures for curriculum preparation, various administrative functions, and student loading. This will reduce the overall long range system and operation costs by enabling the system to expand by modular addition rather than total system redesign.

The system must provide hardware and software data protection features. This reduces the probability of having to re-initialize the computing system's curricular material due to spurious signals, misaddressed data, or incorrect author commands which could cause accidental destruction of compiled curriculum segments.

The system must be physically and operationally self-contained in the sense that it can carry out all of its functions with a relatively minor dependence on subsidiary services. As a secondary requirement, and where permissible, the system should be electronically self-contained. Collectively, these items significantly reduce system and operation costs, increase data reliability (no long line-driving requirements), provide centralization of management responsibility, and increase system accessibility for maintenance, research and curriculum development.

The computer responses must have the capability of being derived from complex computations such as simulation models. This provides an additional instructional environment, i.e., gaming or modeling which can be used to provide sophisticated stimuli to the student and subsequent response processing.

The system must be capable of generating a paper hardcopy of displayed data through either an automatic process or by manual intervention from the terminal equipment. The automatic process would be controlled by the computer which could base the decision on current student performance or other author-stipulated criteria. This would automatically provide the student with copies of curricular material in those areas with which he is having apparent difficulty. The manual process would provide the student with reference material and the author with forms for proofreading, editing, and evaluation.

The system must provide an end-to-end response time (time from receipt of student or author input initiation until computer response is presented on terminal) of less than 2 seconds. Statistical data derived from several analyses and personal experiences of many educators indicated this response time is within the response limits (1 to 3 seconds) such that student attention and interests are maintained and the overall course-presentation time is not increased.

The system must be capable of supporting research and development in the areas of curriculum development, language development, and system utilization and application. This will enable the researcher to more fully utilize the power of the computer's speed and memory to experiment with application diversification, modeling or gaming, curriculum refinements, and techniques development.

The system must be capable of storing and administering: (1) programs requiring greatly different mixes of terminal control operations, logical branching and computation; (2) display oriented programs, (3) programs using highly structured problems, (4) problems involving real time adjustment of lesson presentation on historical and other criteria, (5) programs using complex tutorial teaching approaches, and (6) relatively complex simulation model programs. This provides the author with a full range of storage capability necessary to control the sequencing and process the curricular material presented to the student.

The system must be capable of maintaining a substantial number of unique course segments on line in ready storage (in mass storage transferable to main storage within approximately 1 second) for subsequent selection by the student. The exact number of course segments required to be on line is difficult to assess since it is essentially a function of mass storage and computer main storage, both of which are system variables. The exact number should consider these variables, and in addition be consistent with efficient storage and computer utilization techniques. In any case, the total time from student sign-on to presentation of the first textual statement, question, or graphic should not exceed four to five minutes - an arbitrary figure which is indicative of the time required to transfer data from a storage library to mass on-line storage and, subsequently, to main core.

The system must be capable of displaying two different character heights simultaneously.

The system must have the capability to prohibit the student from entering an author mode. This eliminates the possibility of curriculum destruction.

3.2.6.1.2 Storage Requirements

Redundant storage for curriculums must be provided in the optimum system design. The particular storage media selected is a function of required information access time and implementation costs--the most commonly used media being disk, tape, drum, and punched cards. Redundant storage would provide for on-line and library copies of the curriculum. This reduces the probability of total curriculum loss.

Segmented storage of curriculums is required to enable selection of a specific concept or block of information for subsequent presentation to the student. Segmented storage is the division of complex subject matter into logical breaking points (segments), and the provision for an individually addressable location for each segment.

Adequate storage must be provided for maintaining student records. Essentially, two types of storage are required for this function, viz., real time and off-line. Real time storage is required for the immediate holding and partial processing of student performance. (This ensures automatic adaptive sequencing by the computer). Off-line storage is required to store the bulk of student performance data. These data will be processed to record student response latencies, relative level of performance on questions and concepts, individual-item student-performance statistics, accumulated-item performance statistics, and selected data of special types retained from unusual student-machine interchanges as defined by the course author during course preparation.

Storage for various administrative functions is also required. This will provide management with the administrative data-base required to maintain accurate course schedules, course content, student schedules, student grades, equipment schedules, and other statistics relative to equipment maintenance and performance.

From the preceding discussion, the requirement for three types of storage have been identified; viz., (1) curriculum storage, (2) student record storage, and (3) administration storage. It should be noted that the curriculum storage requirements include the storage required for the curriculum presentation commands, as well as the curricular material.

3.2.6.1.3 Terminal

The student should be provided the capability of writing a response or entering data into the computer verbally. Although extremely desirable, these requirements are not within the current state-of-the-art technology and are therefore presently considered impractical. In lieu of these capabilities, a device is required that provides for a full range of alphanumeric entries or specially coded entries. This permits the student and/or author to assemble discrete entries or constructed messages for entry into the processing system.

The terminal is required to present curricular materials on a CRT display surface. The terminal must be capable of switching between computer-driven video and closed-circuit television (CCTV). In addition, the terminal must provide the capability to display static reference material from a slide projection system. This total capability is required for presentation of complex block diagrams, vectors, photographs, reference material and dynamic information which can be periodically updated. The overall terminal design, font standardization, character height, and spacing must be consistent with good human factors practices.

3.2.6.1.4 Author Languages

The author language requirements specified in the following paragraphs, when incorporated into the optimum system provide the power, generality, reliability, naturalness, and modification capability indicative of the optimum author language.

The author language requirements specified herein apply to the student inputs as well as the author inputs. Thus, the author language performs a dual role by accepting control signals, which govern course flow, from the author, and processing the responses from the student.

The language must provide the author with the capability to write curricular material, and to correct and evaluate the material. This provides the means for communications between the author and the processing system, and enables the author to develop applicable teaching strategies for various curricular material.

The user must have complete freedom, including the possibility of entering irrelevant or inappropriate remarks. It should be noted that this applies only to the student input and virtually eliminates user input format restrictions.

The language must be capable of processing natural language student responses. The user must not be required to learn complicated mnemonic codes in order to converse with the processing system, for to do so reduces student performance.

The language must be generic in structure. This simplifies system utilization, decreases author learning time and permits efficient curriculum modification. The result is a significant reduction in total preparation time.

The language must provide the capability to accept questions or declarative statements from either the student or author. This capability establishes an instructional environment which allows the computer/student interface to approach that of a true tutorial relationship. It is significant to note that the software state-of-the-art has not yet progressed to the extent that all these capabilities can be provided.

The language must provide the capability of accepting and processing complex student constructed answers using techniques other than exact match or key word comparisons. This enables the student to provide a natural response rather than simple discrete entries such as multiple choice or question completion entries.

The author language must be capable of performing complex mathematical computations or be capable of accessing another language which is computationally powerful. This will broaden the range of application to include all levels of technical ability and varying levels of subject complexity.

The author language must be capable of performing a variety of instructions to ensure effective and efficient sequencing of curricular materials to the student. This will provide for the control of visual displays, presentation of text, presentation of questions to students and processing of answers, branching to different areas of the curricular material, and record keeping. In addition, the language must provide the capability to respond with an appropriate comment regardless of the student input.

The language must provide the capability of monitoring author inputs and processing operations to ensure proper control execution and reduce the probability of data (curricular material) error.

The language must have the capability of operating with any computing system. This (1) reduces language development costs, (2) increases the efficiency and reduces the cost of system changeover due to increased applications loading, (3) standardizes system utilization, and (4) provides for a more optimal utilization of existing assets.

The language must be applicable to all types of CAI. This enables the author to (1) program stimuli and responses into simulation models and process student responses to these stimuli, (2) query data bases for on-line programming, and (3) utilize the computer as a computational aid.

3.2.6.2 Functional Requirements for the Optimum CAI System for Flight Controller Application

This paragraph outlines the method used in determining the functional requirements for the optimum CAI system for flight controller application, specification of the requirements, and the supporting rationale.

The primary objectives of this discussion are: (1) determination of the optimum location of the computing facilities, (2) determination of the relative size of the processor system, (3) determination of the quantity and type of terminals required, (4) determination of the location of these terminals relative to the processor and (5) development of special functional requirements that must be incorporated to process an author language whose characteristics parallel (within state-of-the-art limits) those specified in Subparagraph 3.2.6.1, System Design Criteria for CAI Applications. To accomplish these goals, four areas were addressed; viz., computer system size, quantity and type of terminals, special functional requirements, and existing assets.

The results were then merged to determine computer location, advantage and disadvantages of various terminal configurations and finally, the overall functional system design requirements.

Because of the complexity and changing nature of the curriculum, the diverse needs of the flight controller, and the ever present scheduling problems, a substantial number of assumptions have been made ranging in complexity from defining class length to estimating the percentage increase or decrease in learning time of CAI relative to existing conventional techniques.

These assumptions are noted throughout the text with their concomitant rationale.

3.2.6.2.1 Terminals

3.2.6.2.1.1 Quantity

The number of terminals required for a CAI system is a function of (1) the total number of terminal hours that must be presented within a given time frame, and (2) the number of hours that the terminal will be available for student use within that time frame.

The relationship is:

$$Tr = \frac{Th}{Ta}$$

Where Tr = total number of terminals required

Th = total number of terminal hours that must be presented

Ta = total number of hours terminals will be available

The number of terminal hours per day (Th) has been estimated by considering the average flight control class size (25 students), the average number of classes per day (2 classes per day), and the average class length (5 hours per class).

(Students/Class) x (Classes/Day) x (Hours/Student) =

Instructional hours per day or terminal hours/day.

For this calculation it will be assumed that total instructional hours equals total terminal hours.

The number of hours per day the terminal is available (Ta) will determine the number of terminals required for a given instructional load. It is assumed that some of the time that the terminal is available will not be productive; for these calculations it is assumed that 10 percent of the time would be taken for student changeovers, scheduling problems, and down time. Thus, the true terminal availability would be 90 percent.

(Terminal Availability) x (Utilization Factor) = True terminal availability time.

Thus, the total number of terminals required (Tr) is calculated in the following manner:

$$Tr = \frac{S \times C \times H \times R}{T \times U}$$

$$\text{Where: } \begin{cases} S = \text{Students/Class} \\ C = \text{Classes/Day} \\ H = \text{Hours/Student} \\ R = \text{Ratio of Terminal hours to Class Hours} \\ T = \text{Time Terminal is Available for CAI (hours/day)} \\ U = \text{Utilization factor} \end{cases}$$

To estimate the number of terminals that are necessary for the optimum CAI system, the following assumptions have been made:

A. A major portion of the present flight control curriculum will be presented to the student via CAI methods.

B. The present student loading averages will continue (25 students per class, 2 classes per day, 5 hours per class). This totals 250 student instructional hours per day.

C. The primary instructional schedule will be 8 hours per day for 5 days a week, but these hours could be extended to accommodate student overflow.

D. The system and terminals will be used only for CAI and related functions.

E. Student scheduling is flexible enough to provide uniform demand and usage of terminals throughout the day.

F. There will be compressed time schedule cases which must be accommodated either through extension of the length of time that terminals are available or through the addition of extra terminals.

G. Curriculum development will be performed off-line with the exception of some curriculum editing and trial runs.

H. Maintenance of the system will be provided during those periods when curriculum presentation is not scheduled.

I. Terminal utilization will occur 90 percent of the time that terminals are available. This allows 10 percent for student changeovers, scheduling errors, and down time.

J. Programmed instruction will not provide a savings in instructional time.

NOTE

Although most case studies indicate that programmed instruction and CAI provide a significant savings in average instructional time over conventional methods, a significant variation exists in the quality of both the methods to be replaced by CAI and the CAI methods to be employed. Therefore, for this estimation the number of student instructional hours presently required will also be treated as the number of terminal hours required. This will allow calculation of the number of terminals required in a worst case eventuality. It is significant to note, however, that over 100 subjects reviewed by one organization indicated that in comparison with conventional instruction, the programmed packages indicate an average mean reduction of 33 percent training time.

To determine the final systems requirements, seven alternatives were investigated. These alternatives are example calculations performed to demonstrate the rationale used to determine the number of terminals required for the optimum flight control CAI system. Alternatives, A, B, and C maintain the present volume of curriculum presentation, but vary the number of hours per day the terminals are available. Alternative D extends the time frame necessary to present the material, but maintains the 8-hour per day terminal availability. Alternative E combines a reduction of curriculum volume with an increase in the number of hours the terminals are available. Alternative F maintains the present curriculum volume and 8 hours per day terminal availability, but assumes an average savings of 25 percent in presentation times for the curriculum because of the use of programmed instruction. (As will be seen in Subsection 5.1, this appears to be a valid assumption.)

The number of terminals determined in each example is the number to be used for student instruction. The total number of terminals required for the system will be two greater than the numbers shown. Curriculum preparation, editing, and testing will require that two terminals be available to the instructors.

A. Alternative A. Maintain curriculum volume and time frame with terminals available 8 hours per day.

1. Example. Present the existing volume of curriculum to the existing number of students on an 8 hour per day schedule.

- (S) Average number of Students per class = 25
- (C) Average Classes per day = 2
- (H) Average class Hours per student
- (R) Ratio of terminal hours to instructional hours = 1
- (T) Time terminal is available for CAI = 8 hours per day
- (U) Utilization factor = .90

The number of student terminals*

$$\frac{S \times C \times H \times R}{T \times U} = \frac{(25)\ (2)\ (5)\ (1)}{(8)\ (.9)} \doteq$$

$$\frac{250 \text{ terminal hours/day}}{7.2 \text{ hours/day}} \approx 35 \text{ terminals}$$

(*Alternative A, B, and C are examples of the effect of terminal availability time on the number of terminals required, assuming a constant volume of curriculum presentation. Refer to Figure 3.2-62 for a graphic presentation of this relationship.)

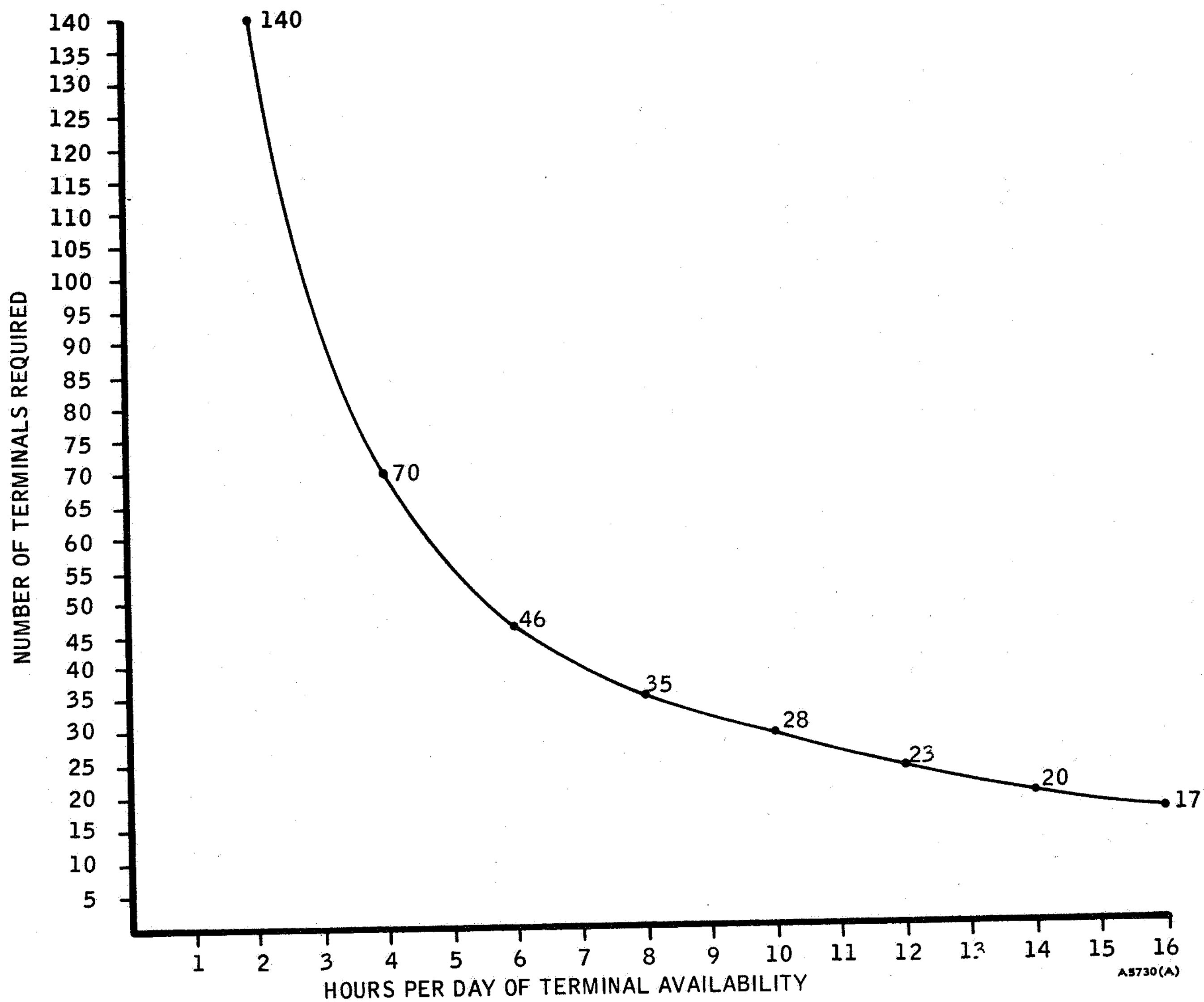


Figure 3.2-62 Flight Control Student Terminals Required as a Function of Terminal Availability

B. Alternative B. Maintain curriculum volume and time frame but decrease the number of hours per day terminals are available.

1. Example. This alternative is to present the same volume of curriculum (250 terminal hours/day) as Alternative A but attempts to do so in 4 hours per day. (Identical to existing scheduling techniques).

The number of student terminals =

$$\frac{250 \text{ terminal hour/day}}{(4 \text{ hours/day})\ (.9)} \approx 70 \text{ Terminals}$$

C. Alternative C. Maintain curriculum volume and time frame while increasing the number of hours per day terminals are available.

1. Example. This alternative presents the same volume of curriculum (250 terminal hours/day) as Alternatives A and B, but seeks to present the material during a 10 hour per day schedule.

The number of student terminals =

$$\frac{250 \text{ terminal hours/day}}{(10 \text{ hours/day})\ (.9)} \approx 28 \text{ terminals}$$

D. Alternative D. Maintain 8 hour per day terminal availability schedule but either decrease volume of curriculum or increase time frame in which material is presented.

1. Example. Alternative D is to extend the time frame available for presentation or reduce the volume of curriculum to be presented--the net effects of which are identical. This example assumes doubling of the time frame in which the material is presented.

The number of student terminals =

$$\frac{250 \text{ terminal hours/2 days}}{(8 \text{ hours/day})\ (.9)} \approx 18 \text{ terminals}$$

E. Alternative E. Increase the number of hours per day terminals are available, and reduce the curriculum volume (or increase time frame in which to present the curriculum).

1. Example. This example reduces curriculum volume by 25 percent and extends the number of hours per day the terminal is available to 12.

The number of student terminals =

$$\frac{188 \text{ terminal hours/day}}{(12 \text{ hours/day})\ (.9)} \approx 18 \text{ terminals}$$

F. Alternative F. Same as Alternative A, but assume a significant savings because of CAI techniques.

1. Example F. This example makes the assumption that CAI will effect an average 25 percent savings in instructional time over that of conventional instruction. It also assumes the present level and volume of curriculum is presented and the terminals are available for 8 hours per day.

(R) Ratio of terminal hours to class hours = .75

The number of student terminals =

$$\frac{(250 \text{ terminal hours})\ (.75)}{(8 \text{ hours/day})\ (.9)} \approx 26 \text{ terminals}$$

Alternative A requires a moderate number of terminals and yet permits presentation of the current volume of curriculum while adhering to a 40 hour instructional week.

While Alternative B allows presentation of the entire curriculum in a compressed time frame, it requires a significant investment in terminals.

Although Alternative C provides a savings in terminal investments (seven terminals less than the Alternative A example), while presenting the entire curriculum at its present volume, this alternative requires the expenditure of overtime for students and administrators as well. Using Alternative C, the recurring costs would exceed the initial cost savings in approximately one year.

While showing a significant savings in the number of terminals required, Alternative D assumes that the time frame in which the course material may be presented can be extended without affecting other schedules. In looking at individual courses this appears to be an efficient alternative, however, when it is considered that a certain volume of curriculum must be presented every day in order to meet flight control needs, it appears an unrealistic approach.

Alternative E also reduces the number of terminals required, but could compromise the quality of flight control training by eliminating 25 percent of what appears to be necessary curriculum. It also requires additional hours per day of overtime for students and administrators.

Alternative F reduces the number of terminals required. However, until experience indicates that an actual time savings can be realized, this assumption is eliminated. This is not an unreasonable assumption since one authority at the University of Illinois has quoted case studies which indicate 30 to 50 percent average time savings through the use of programmed instruction PI or CAI. In addition, a large corporation heavily committed to programmed instruction has experienced 25 to 50 percent time reductions through the use of PI. However, these figures should not be heavily relied upon for our purposes, warns the University of Illinois authority, because instructional conditions and techniques (both conventional and programmed) vary so greatly that these time savings may not actually materialize.

In conclusion, it seems that Alternative A will provide the most logical method for determining the number of terminals necessary. Alternative A requires neither an excessive number of terminals, nor does it compromise quality of instruction by requiring deletion of portions of the curriculum. Neither does it require overtime for students or administrators except for compressed time schedule cases.

Using Alternative A, 35 terminals would be required for student presentation. In addition to these, 2 terminals would be required for instructor and administration use, bringing the total to 37 terminals.

3.2.6.2.1.2 Display

The type of display system, i.e., digital or analog, the system capacity and capability required are a function of (1) data type and complexity, (2) data density requirements, and (3) required system accuracy. These three factors are directly influenced by the specific curriculum being taught.

The flight control curriculum to be programmed for CAI consists of (1) general information subjects; e.g., introduction to flight controlling, orbital mechanics, and guidance and navigation aspects of rendezvous, (2) MSFN subjects; e.g., tracking, command, and telemetry, (3) spacecraft subjects; e.g., Command Service Module (CSM) systems, Apollo Lunar Module (LM) systems and booster systems, (4) experiments courses; e.g., ALSEP experiments, and (5)delta training courses which incorporate the changes on a mission or system basis. The foregoing statements are based on the following assumptions: (1) extensive use of the system will be made and, in fact, it will be the primary instructional medium employed; (2) where necessary, the contractor will develop the appropriate teaching strategies and deliver the material in coded form or in a form which can be readily coded and entered into the computer; and (3) where highly complex or intricately designed material is to be provided to the user, a suitable means other than CAI will be used to convey this information. This eliminates increasing display densities to the extent that the material is so densely packed that difficulty is encountered in interpreting the information.

Curricular material is required to be displayed to the user in various combinations of characters, symbols, and vectors. The basic categories in which these combinations are required are: (1) textual information, such as: statements or questions, (2) diagrammatic displays; such as system and organizational block diagrams, schematics and logic circuit diagrams, and combinations of each, and (3) graphic interpretations such as those encountered in orbital mechanics. These catergories are not unique to flight control operations but apply to all types of curriculums in all types of applications.

A. Textual Data. A variety of densities will be required when displaying textual data. Refer to Figure 3.2-63. This is representative of the type and quantity of textual information presented to students in the Introduction to Flight Controlling course. Densities may range from less than the density of the data illustrated to several times the densities illustrated in the figure. The teaching strategy determines the conditions under which the data is presented, e.g., a simple "display" command to enable the student to read the material or a constructed response whereby the student actually develops the display as requested by a previously displayed statement. This particular type of display requires only symbols and characters.

Figure 3.2-64 illustrates typical tabular display requirements. This was extracted from a network operations subject which contains a combination of textual information and vectors. Again, different teaching strategies will determine the conditions for data presentation. In both examples, two different character sizes were utilized.

COMMAND COMMUNICATOR
(MISSION PERIOD)

- RESPONSIBLE FOR THE REMOTE SITE TEAM
- VERIFIES SITE READINESS TO SUPPORT MISSION
- SUPERVISES AND DIRECTS OPERATION OF REMOTE SITE
- REPORTS SPACECRAFT STATUS TO FLIGHT DIRECTOR
- RELEASES ALL MANUAL TELETYPE TRAFFIC

Figure 3.2-63 Typical Display for Introduction to Flight Controlling Course

RADAR STAIONS

STATION	STATION SYMBOL	RADAR	ANTENNA C 10'	C 12'	C 16'	C 29'	S 10'	S 60'
*CAPE KENNEDY	**CNV	*FPS-16		1				
*MERRITT ISLAND	MLA	TPQ-18				1		
*PATRICK AIR FORCE BASE	PAT	*FPQ-6				1		
*GRAND BAHAMA ISLAND	**GBI	*FPS-16		1				
		TPQ-18				1		
*GRAND TURK ISLAND	**GTK	TPQ-18				1		
BERMUDA	BDA	FPS-16		1				
*ANTIGUA	ANT	VERLORT					1	
		FPQ-6				1		
GRAND CANARY ISLAND	CYI	VERLORT					1	
		MPS-26	1					
*ASCENSION ISLAND	**ASC	FPS-16		1				
		TPQ-18				1		
*PRETORIA, AFRICA	PRE	MPS-25			1			
CARNARVON, AUSTRALIA	CRO	FPQ-6				1		
		VERLORT					1	
WOOMERA, AUSTRALIA	WOM	FPS-16		1				
*KAUAI ISLAND, HAWAII	HAW	FPS-16		1				
		VERLORT					1	
*PT. ARGUELLO, CALIFORNIA	CAL	FPS-16		1				
		VERLORT					1	
GUAYMAS, MEXICO	GYM	VERLORT					1	
*WHITE SANDS, NEW MEXICO	WHS	FPS-16		1				
CORPUS CHRISTI, TEXAS	TEX	VERLORT					1	
*EGLIN, FLORIDA	EGL	FPS-16		1				
*WALLOPS ISLAND, VIRGINIA	WLP	FPS-16		1				
		FPQ-6				1		
		SPANDAR						1
RANGE TRACKER (SHIP)	RTK	FPS-16		1				

LARGE CHARACTERS - 230
SMALL CHARACTERS - 393
SYMBOLS - .63
LINES - 20

Figure 3.2-64 Typical Display for Network System Operation Course

B. Diagrammatic Displays. Figures 3.2-65 through 3.2-73 illustrate typical systems and operational block diagrams and schematic and logic circuit diagrams extracted from the existing flight control curriculum which are required to be displayed. Clearly, the type and complexity of the diagrmas vary over a wide range.

Figures 3.2-74 through 3.2-77 illustrate typical graphics which would require display.

The particular teaching strategy employed with Figure 3.2-74 could be one in which a statement and an accompanying display of a Manual Selection Keyboard (MSK) are displayed on the CRT. The statement generated by the computer and displayed on the CRT would instruct the student to request a specific channel on the left monitor utilizing as an entry device the picture of the MSK. The textual statement could be displayed separately or displayed along with the keyboard display. The student's response via the terminal entry device would be processed and, depending on the results, the computer would sequence to remedial text or advance to another segment or concept associated with the MSK.

C. Graphic Interpretations. Similar unique teaching strategies could be employed with the material illustrated in Figure 3.2-75. In this example the boost angle or injection point could be varied by the computer (per author inputs) and the student would be required to respond with the appropriate orbital and translunar trajectory characteristics.

NOTE

The information illustrated in the referenced figures is not necessarily organized such that it would be indicative of the format of the actual data displayed to the user.

Table 3.2-26 illustrates the total number of large characters (LC), small characters (SC), symbols (SY), and vectors (V) associated with each figure. Table 3.2-27 illustrates the high, low, and average values associated with the figures and the high, low, and average values for the total number of characters, symbols, and vectors per figure. As an example, the greatest number of small characters that would be required to be displayed is 506 (Figure 3.2-73) while the average is 210. The most dense display (Figure 3.2-73) would require a total of 805 characters, symbols, and vectors while the average is 378.

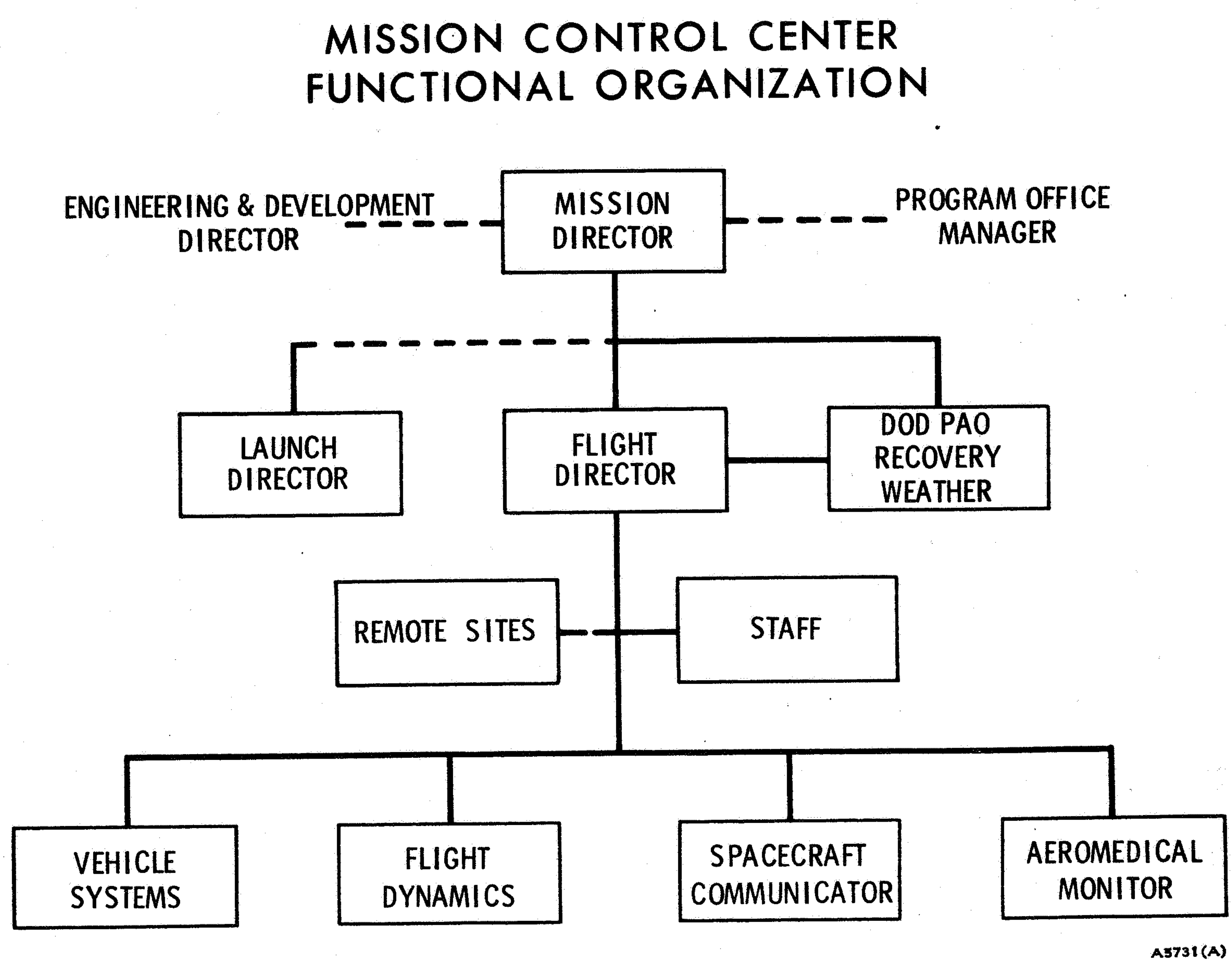


Figure 3.2-65 Typical Display for Introduction to MCC-H Course

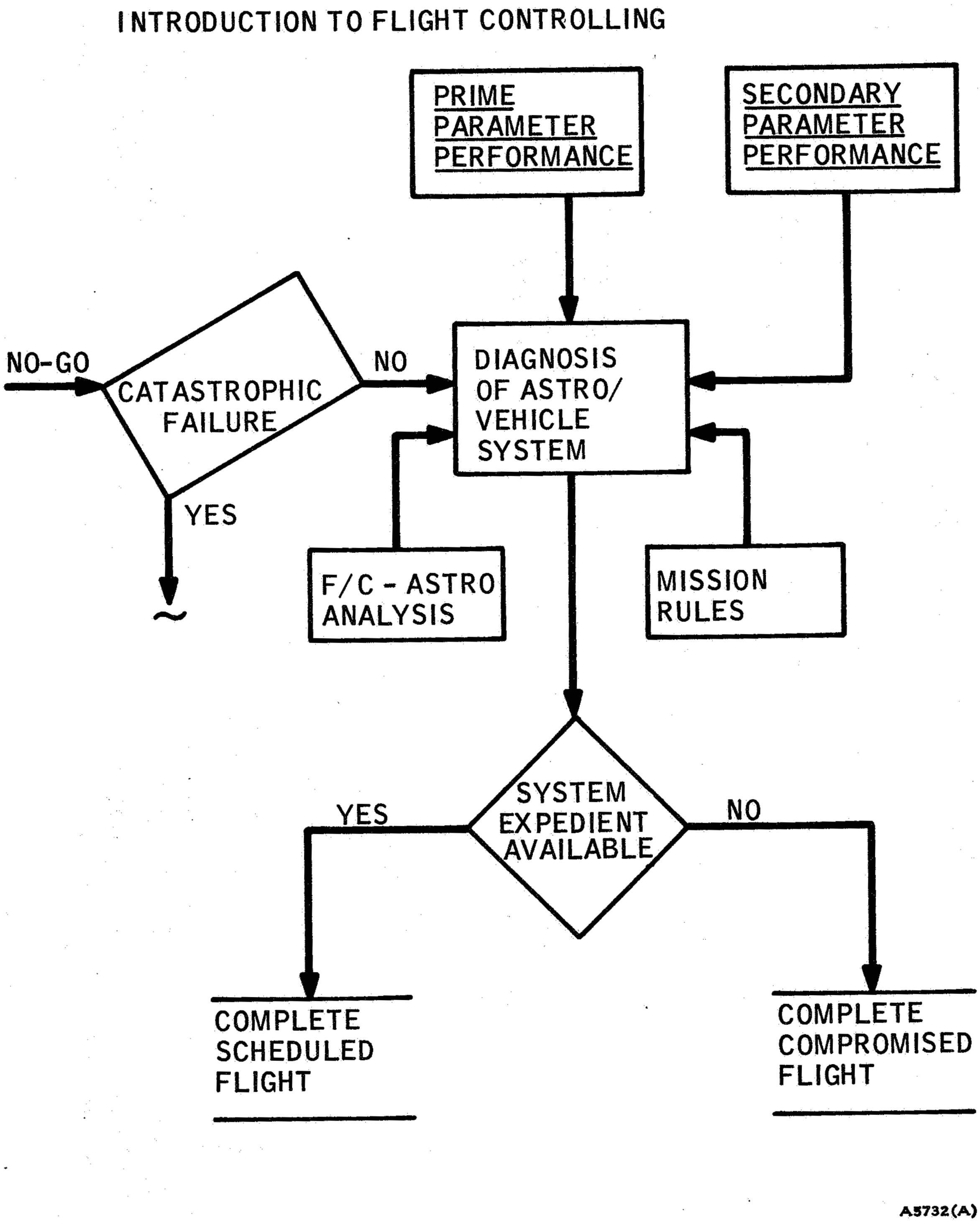


Figure 3.2-66 Typical Diagrammatic Display for Introduction to Flight Controlling Course

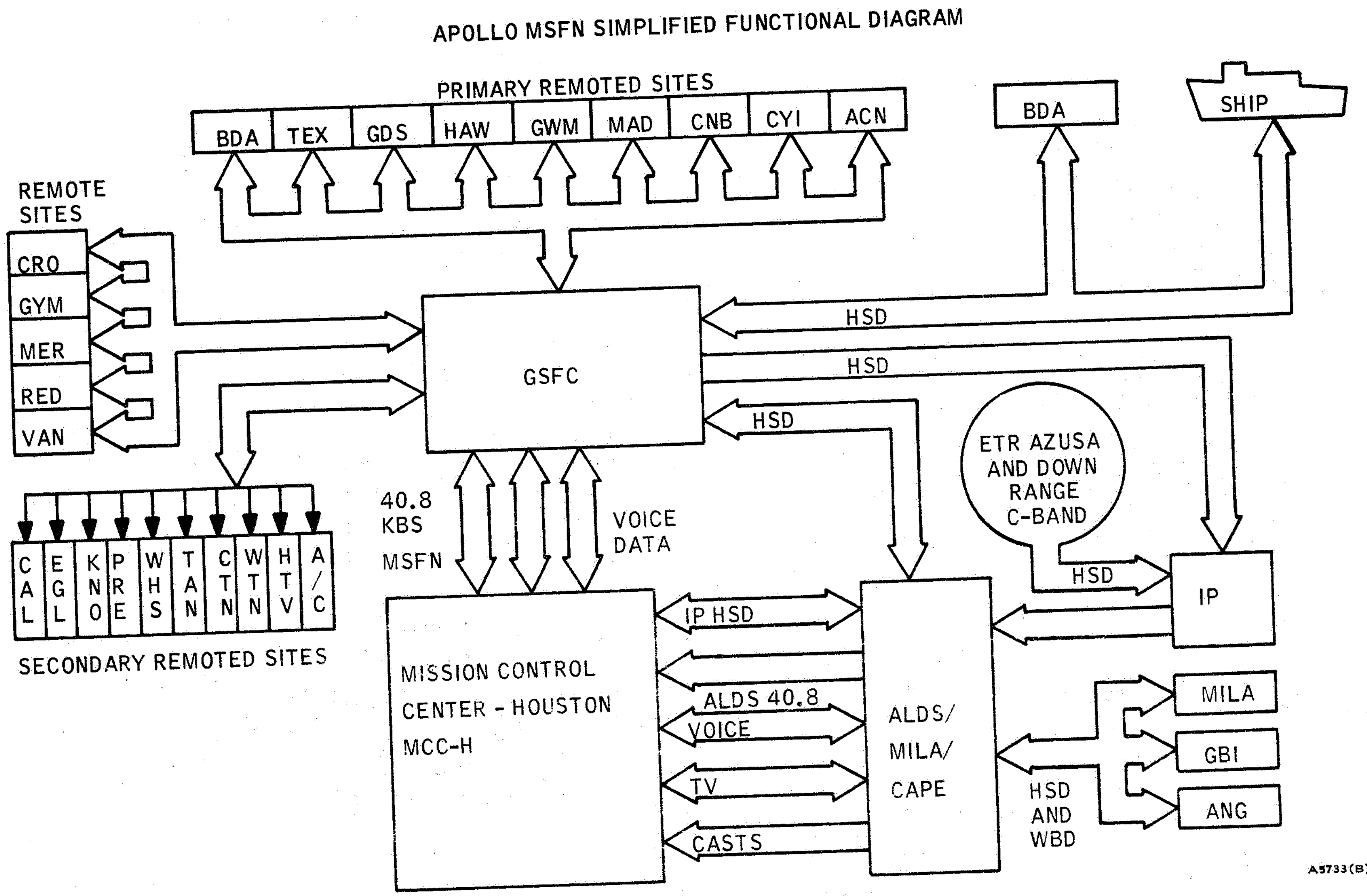


Figure 3.2-67 Typical Display for MSFN Course

CCATS INTERFACE

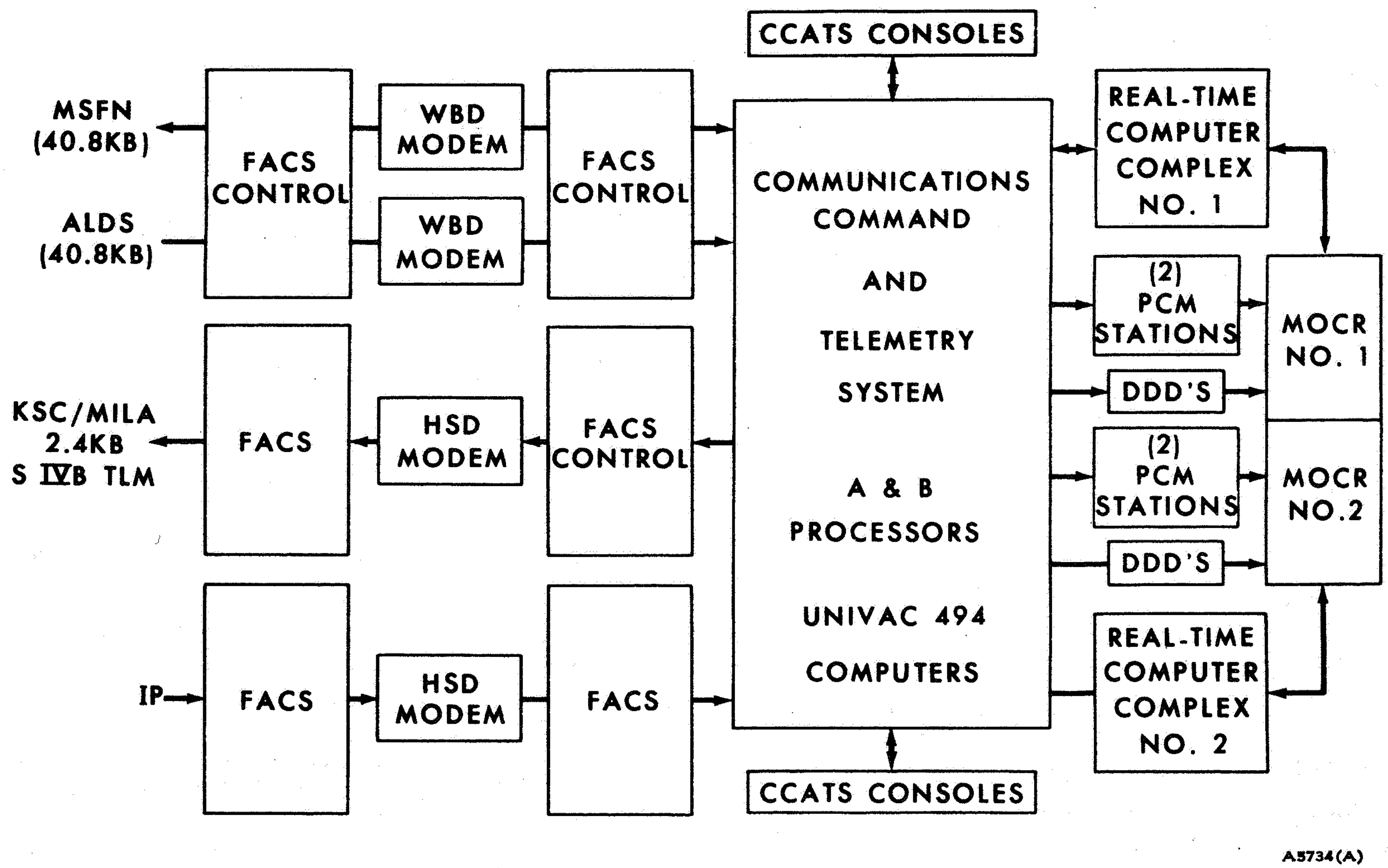


Figure 3.2-68 Typical Display for MCC-H Consoles and Displays Course

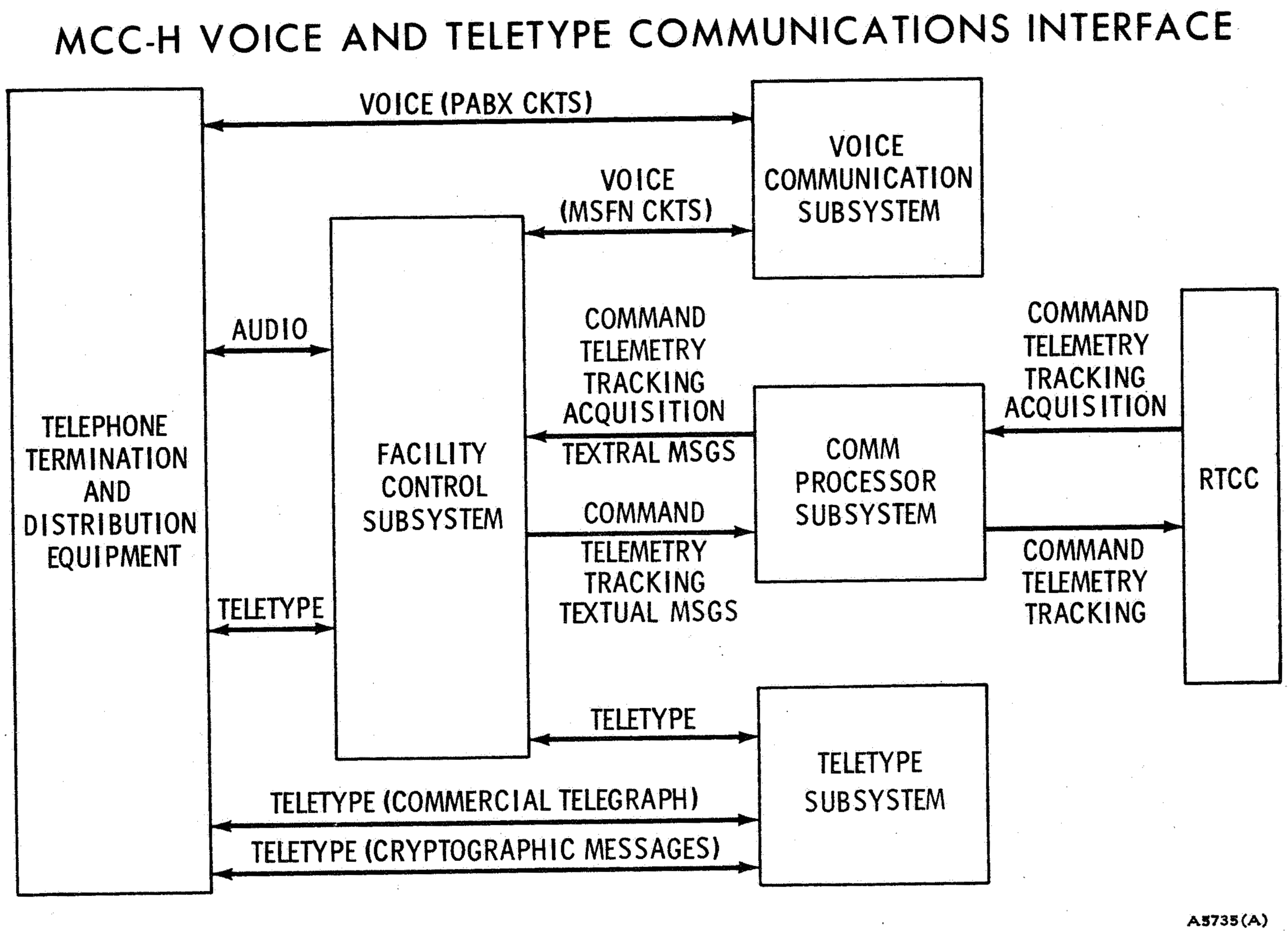


Figure 3.2-69 Typical Display for Communications Course

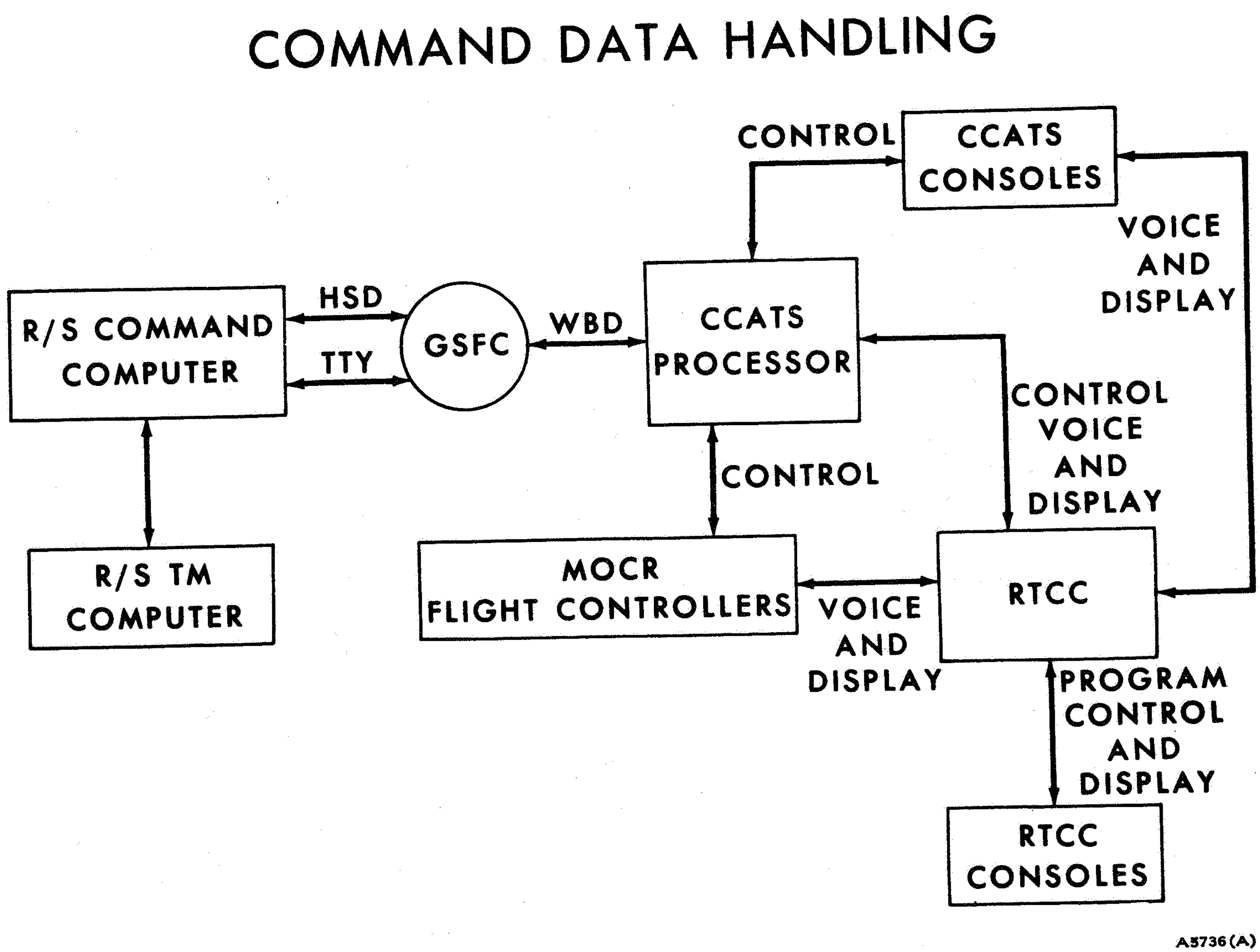


Figure 3.2-70 Typical Display for Command Communications Course

MCC-H TELEMETRY DATA HANDLING

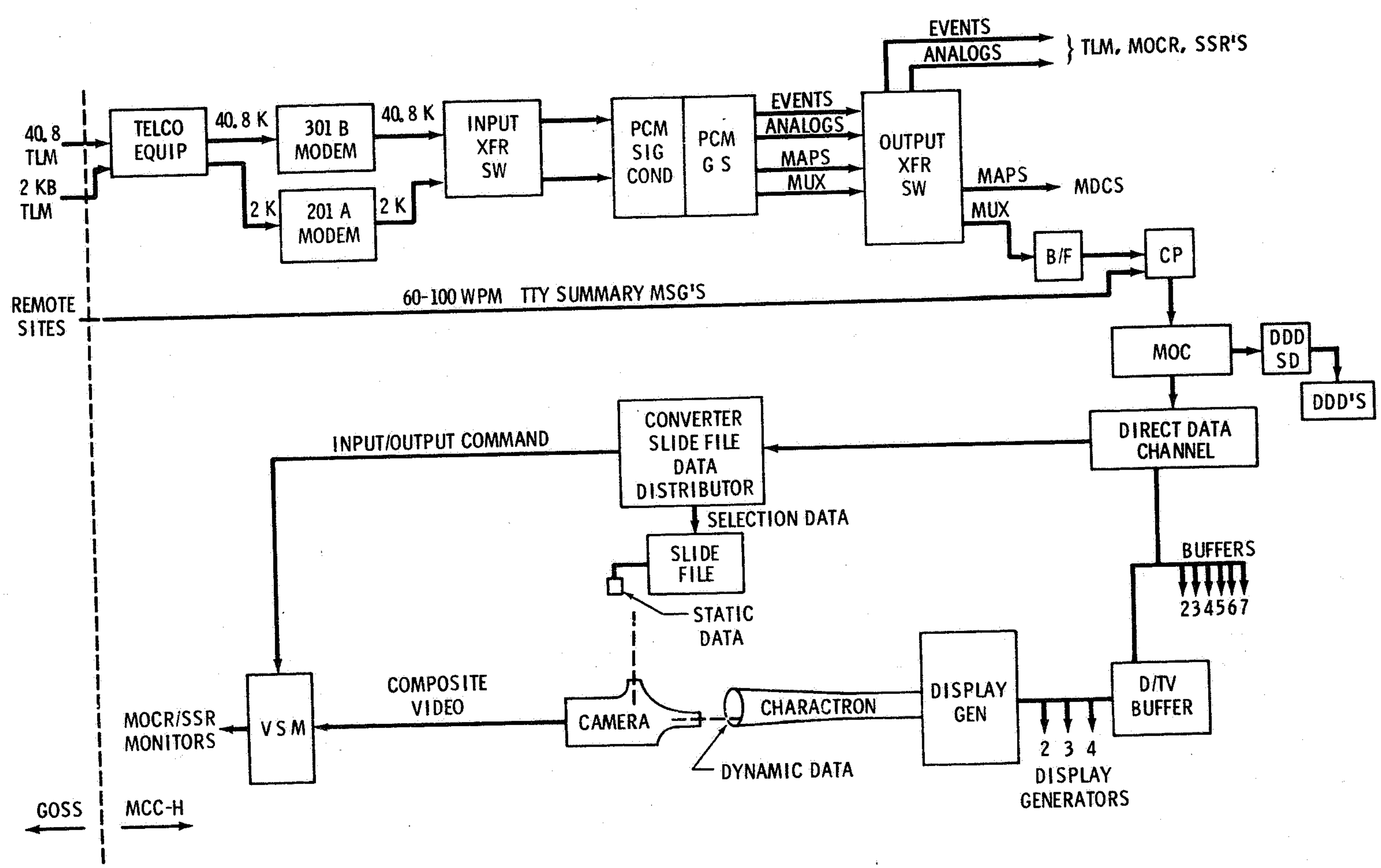


Figure 3.2-71 Typical Display for Telemetry Network Course

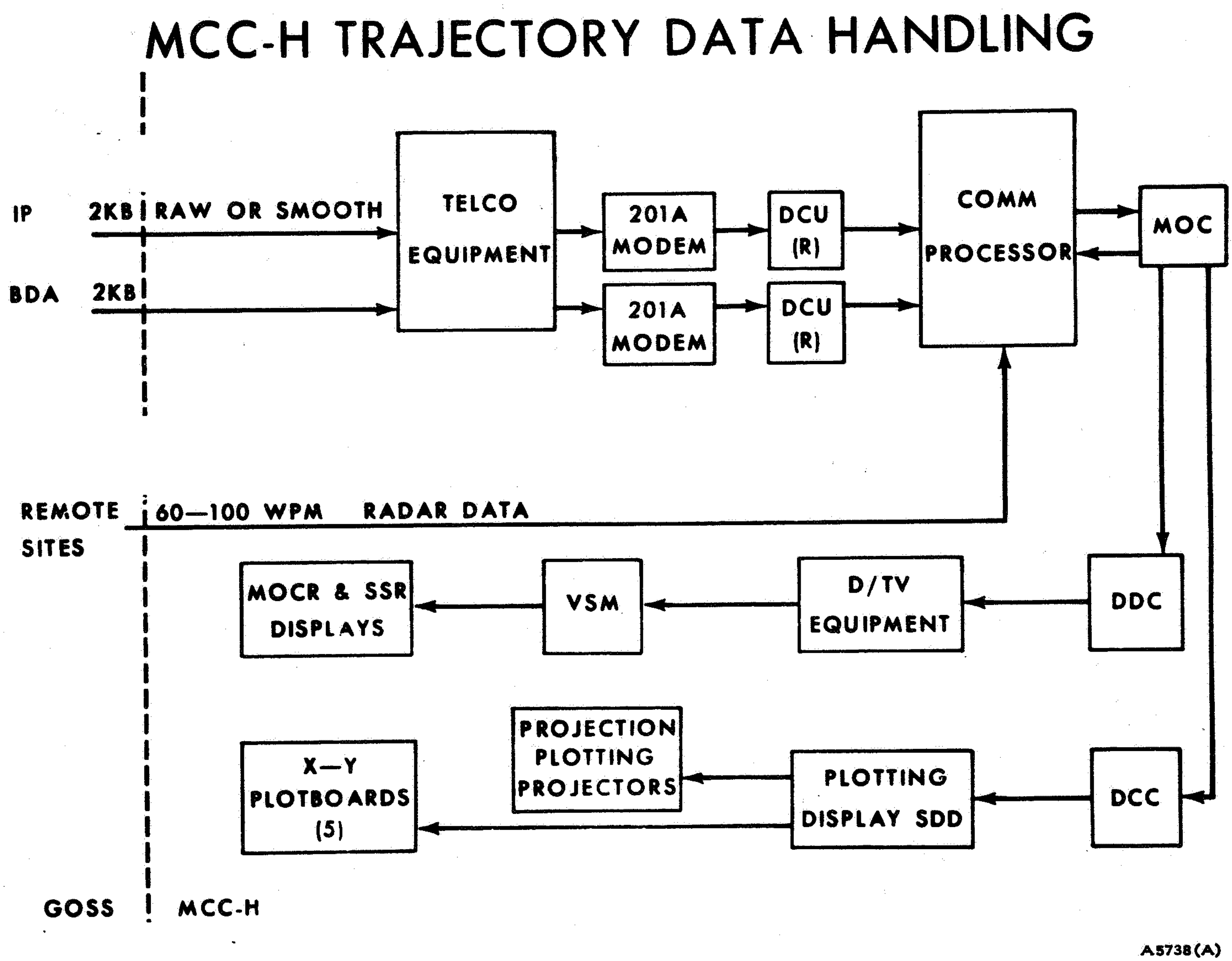


Figure 3.2-72 Typical Display for Tracking System Course

ΔV DISPLAY BLOCK DIAGRAM

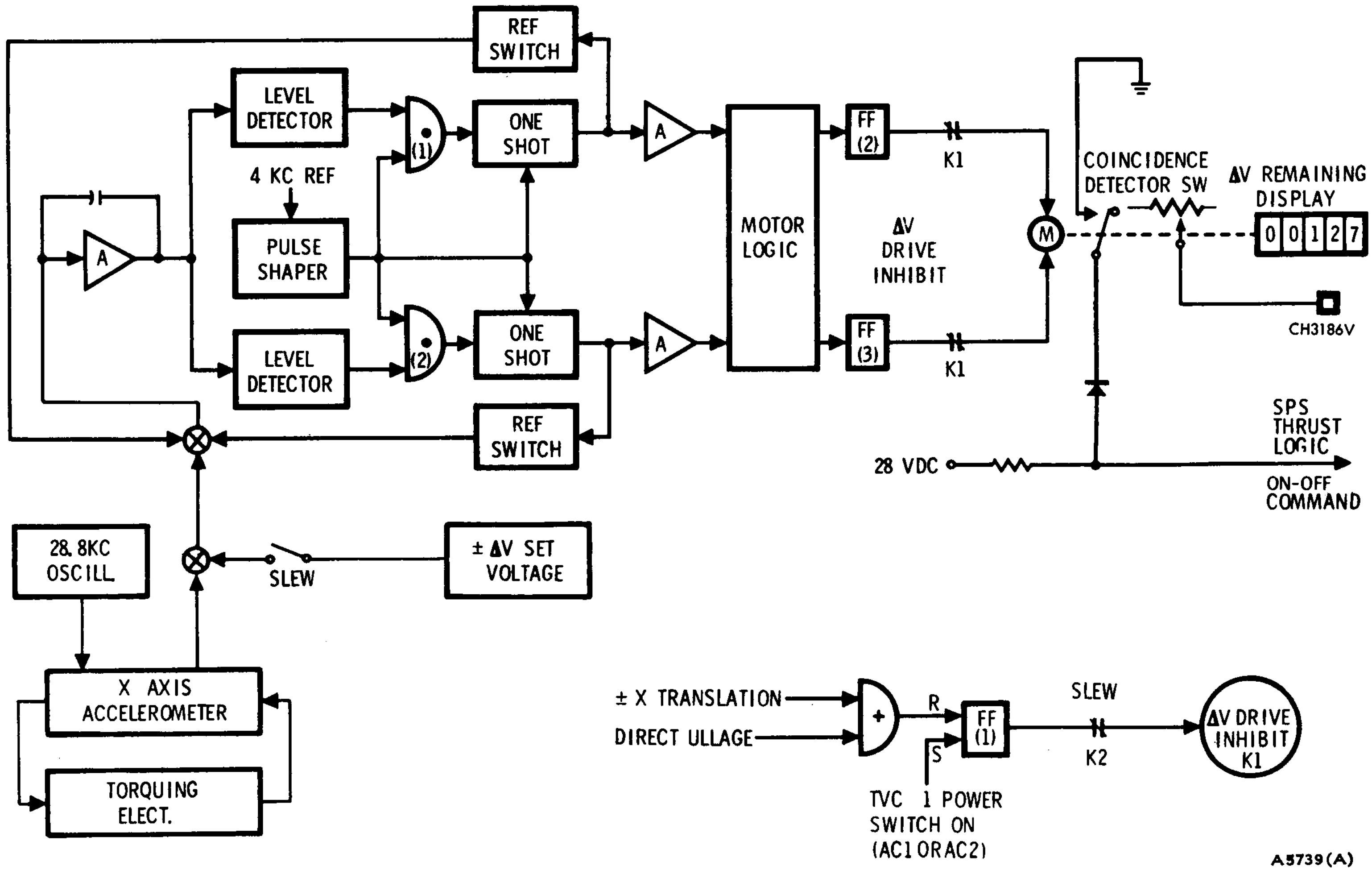


Figure 3.2-73 Typical Display for Apollo Guidance and Control System Course

ZERO & GAIN SWITCH CIRCUITRY TO ALARM AMPLIFIER

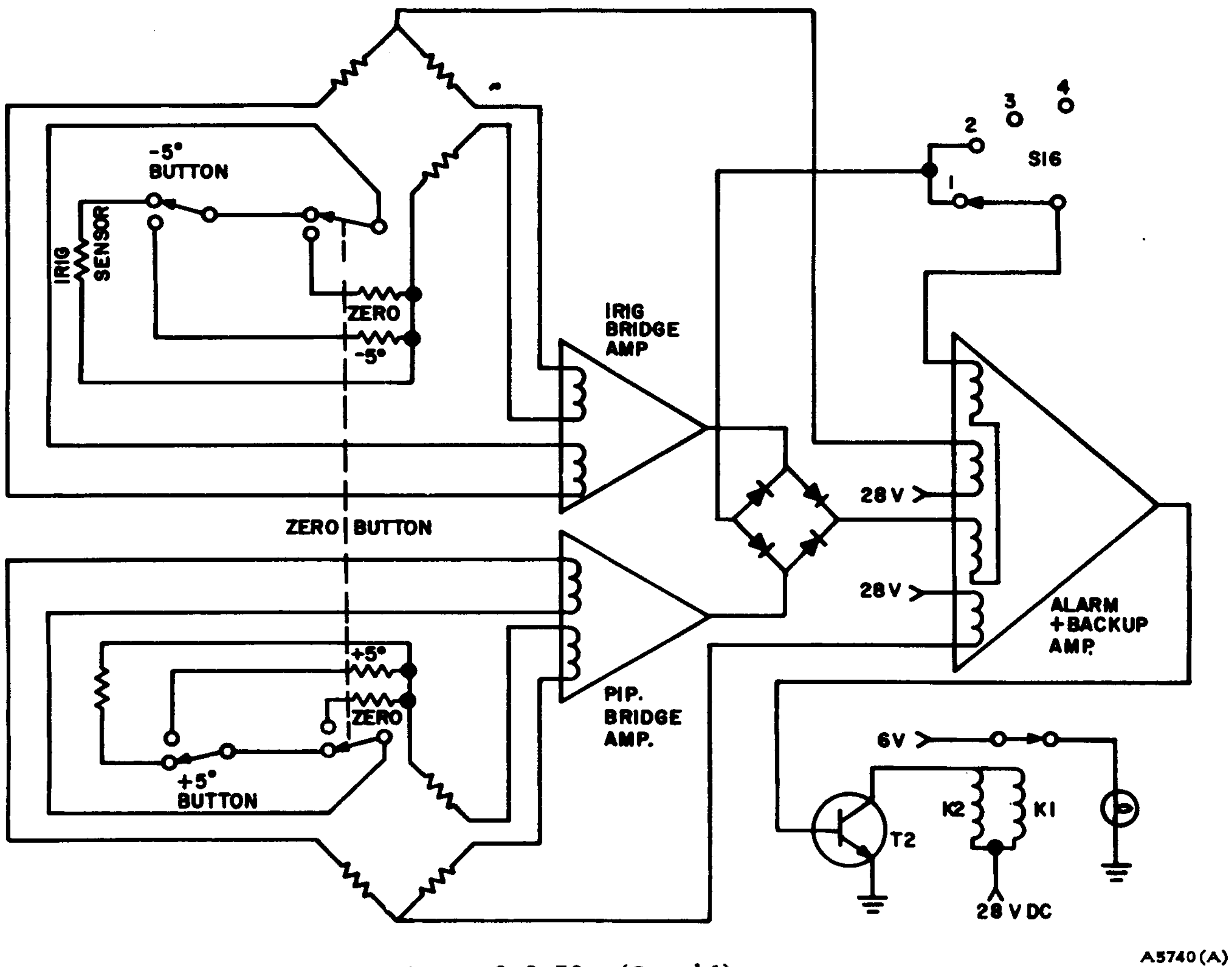


Figure 3.2-73 (Cont'd)

PROPORTIONAL TEMP
CONTROL MODE IN AUTO OVERRIDE POSITION

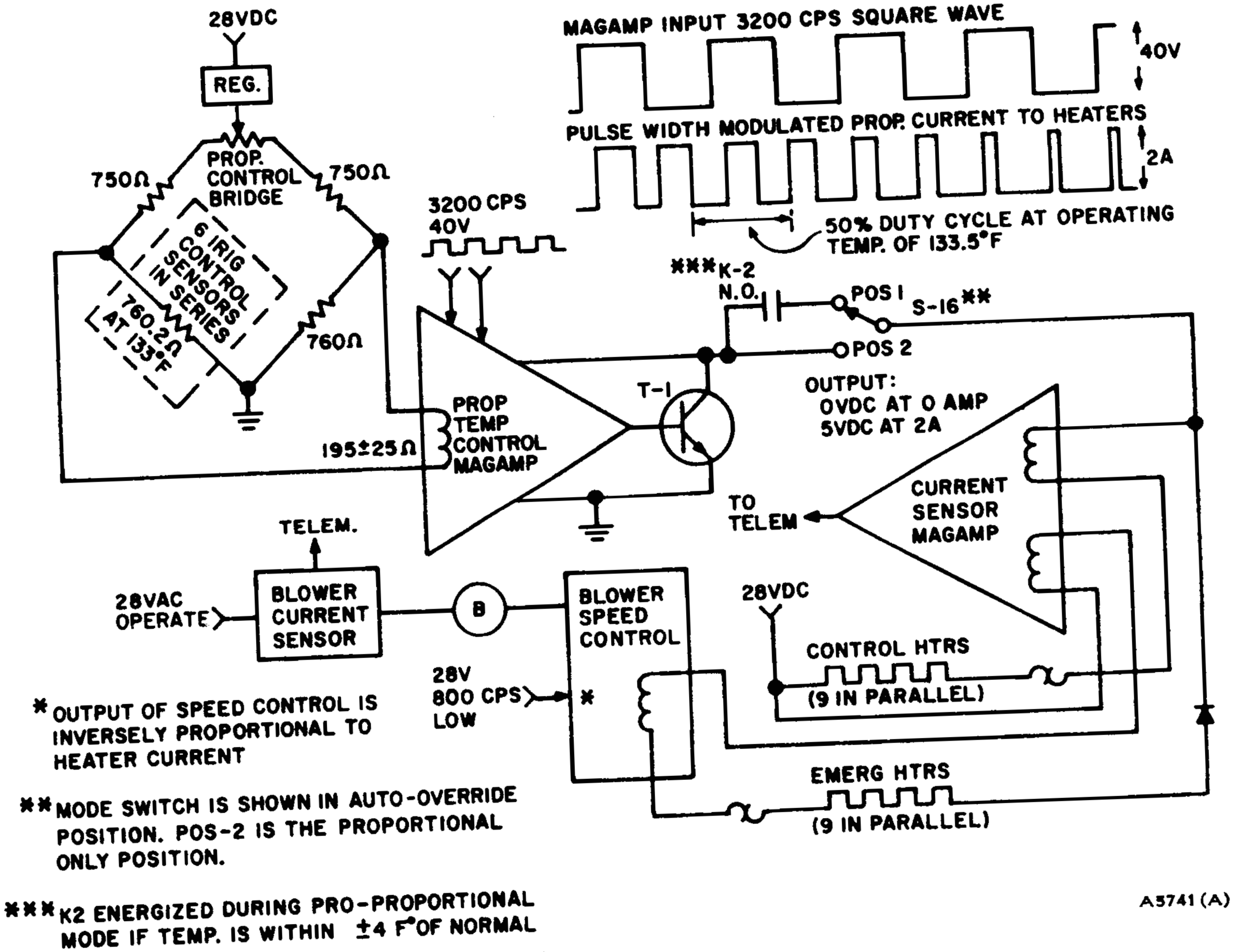


Figure 3.2-73 (Cont'd)

MSK

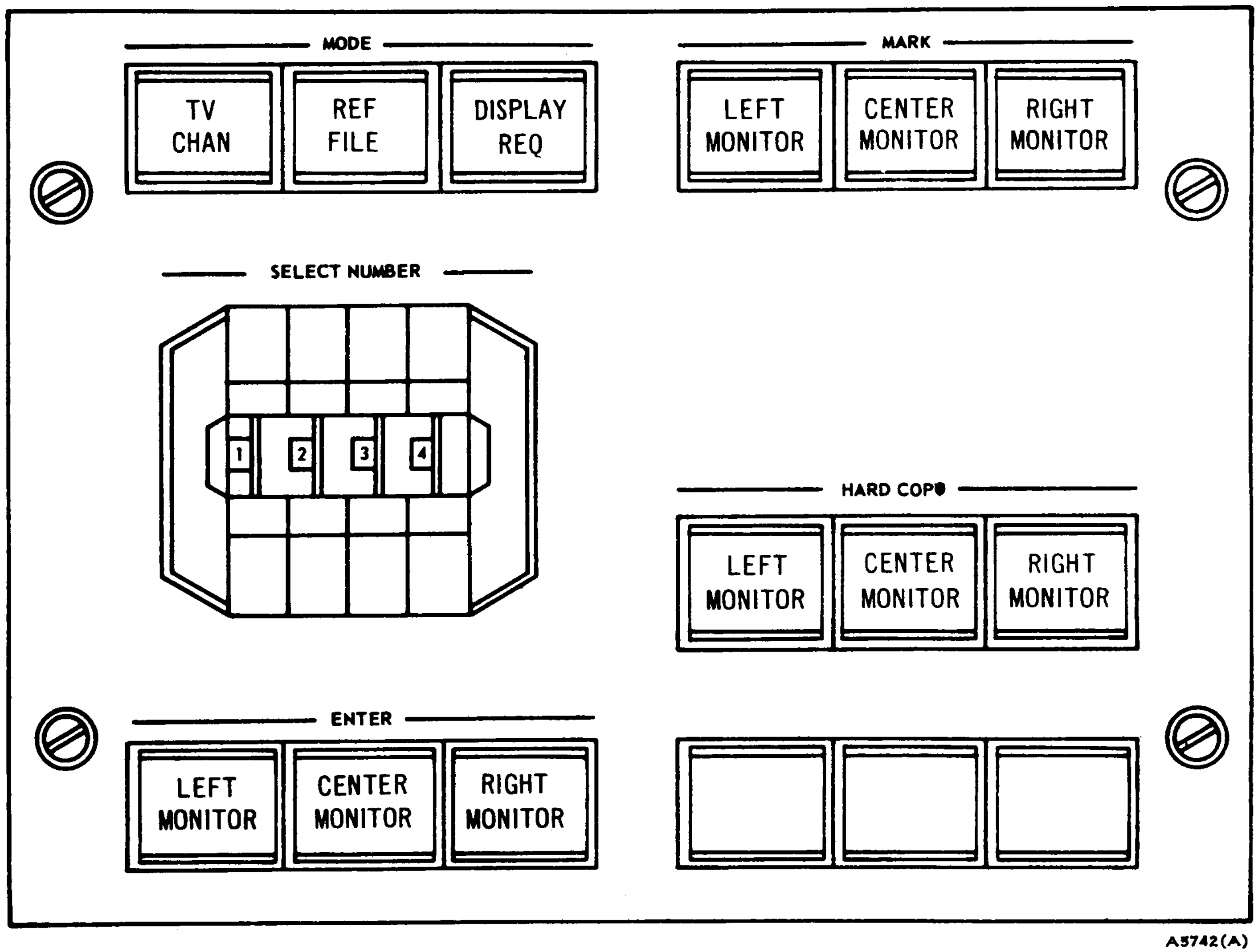


Figure 3.2-74 Typical Display of Graphic Data for MCC-H Consoles and Displays Course

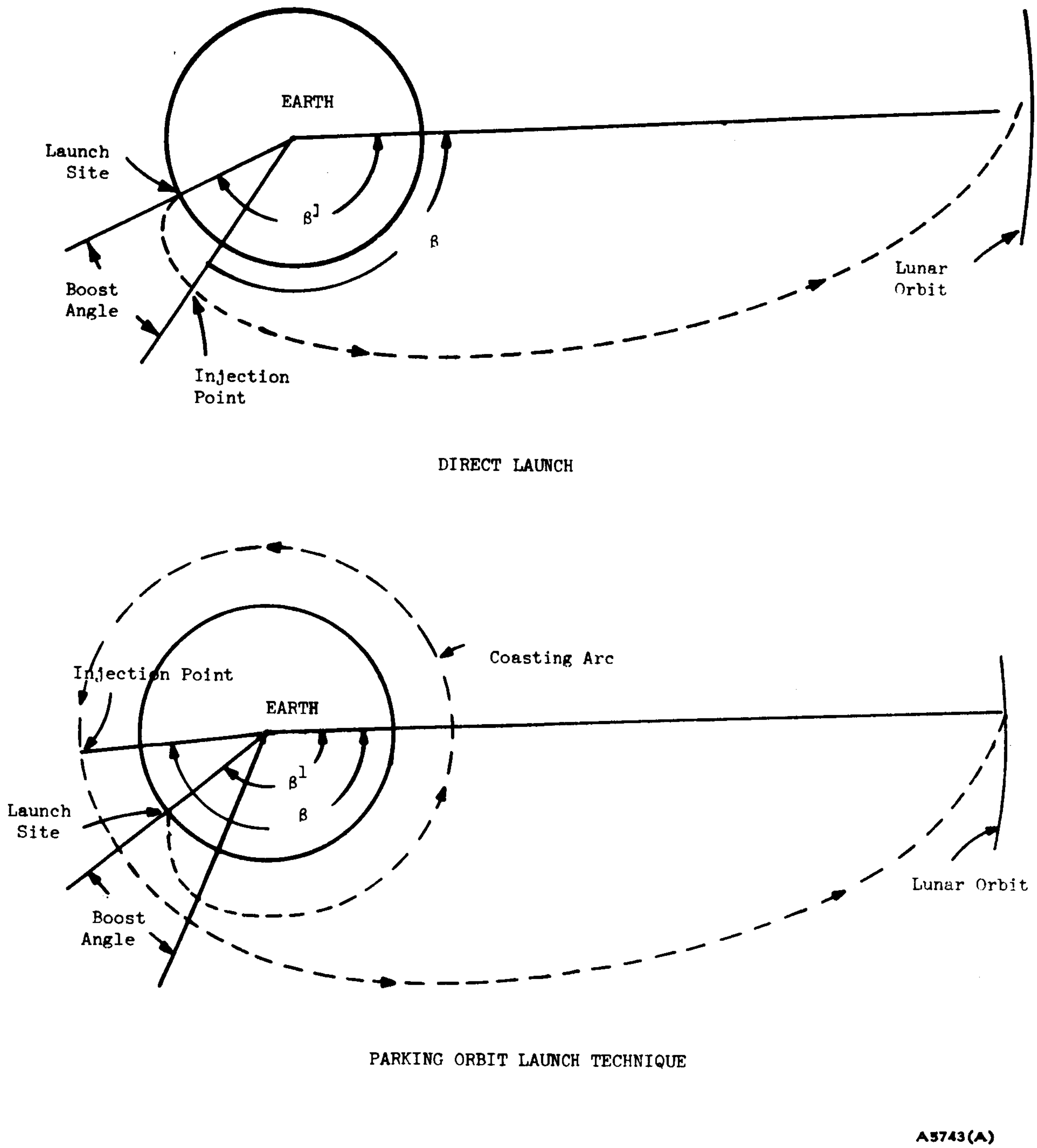


Figure 3.2-75 Typical Display for Guidance and Navigation Aspects of Lunar Missions

FLIGHT TIME

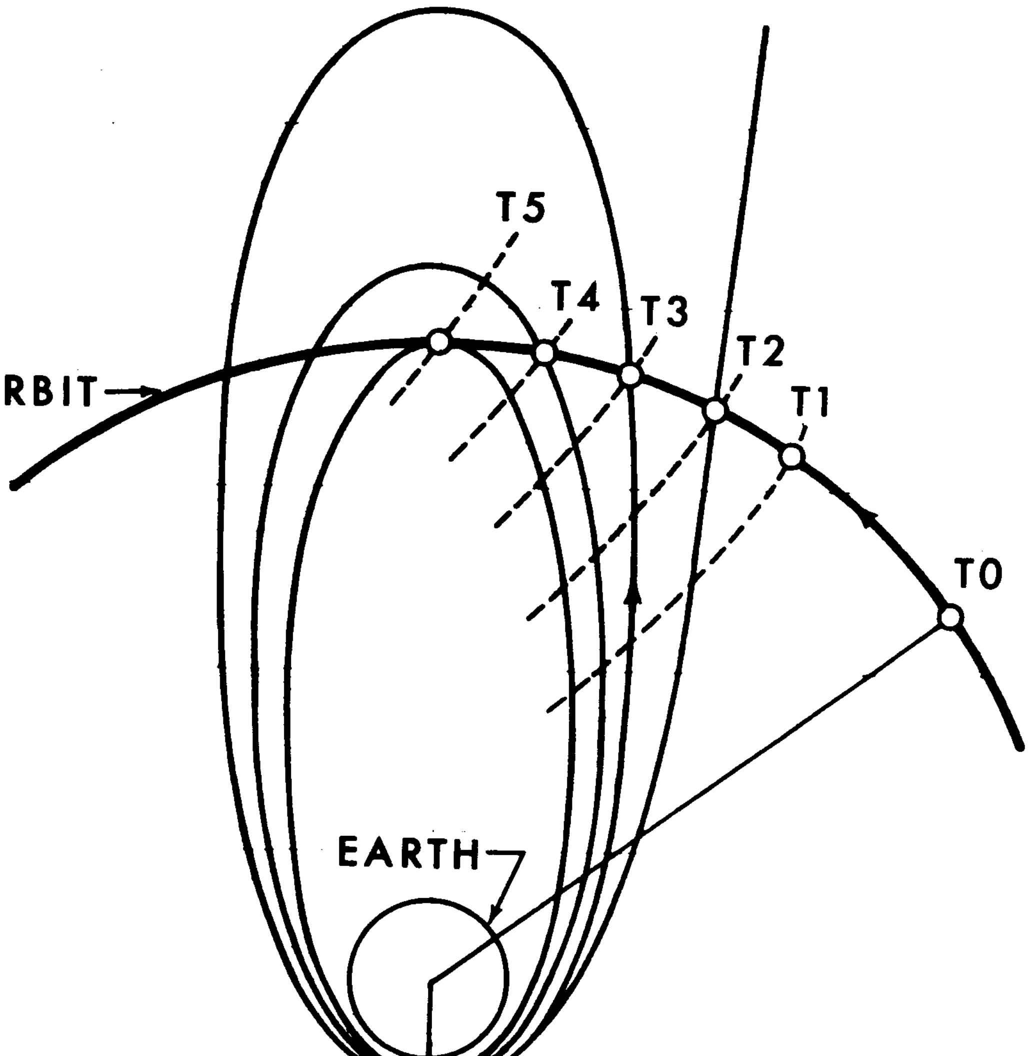
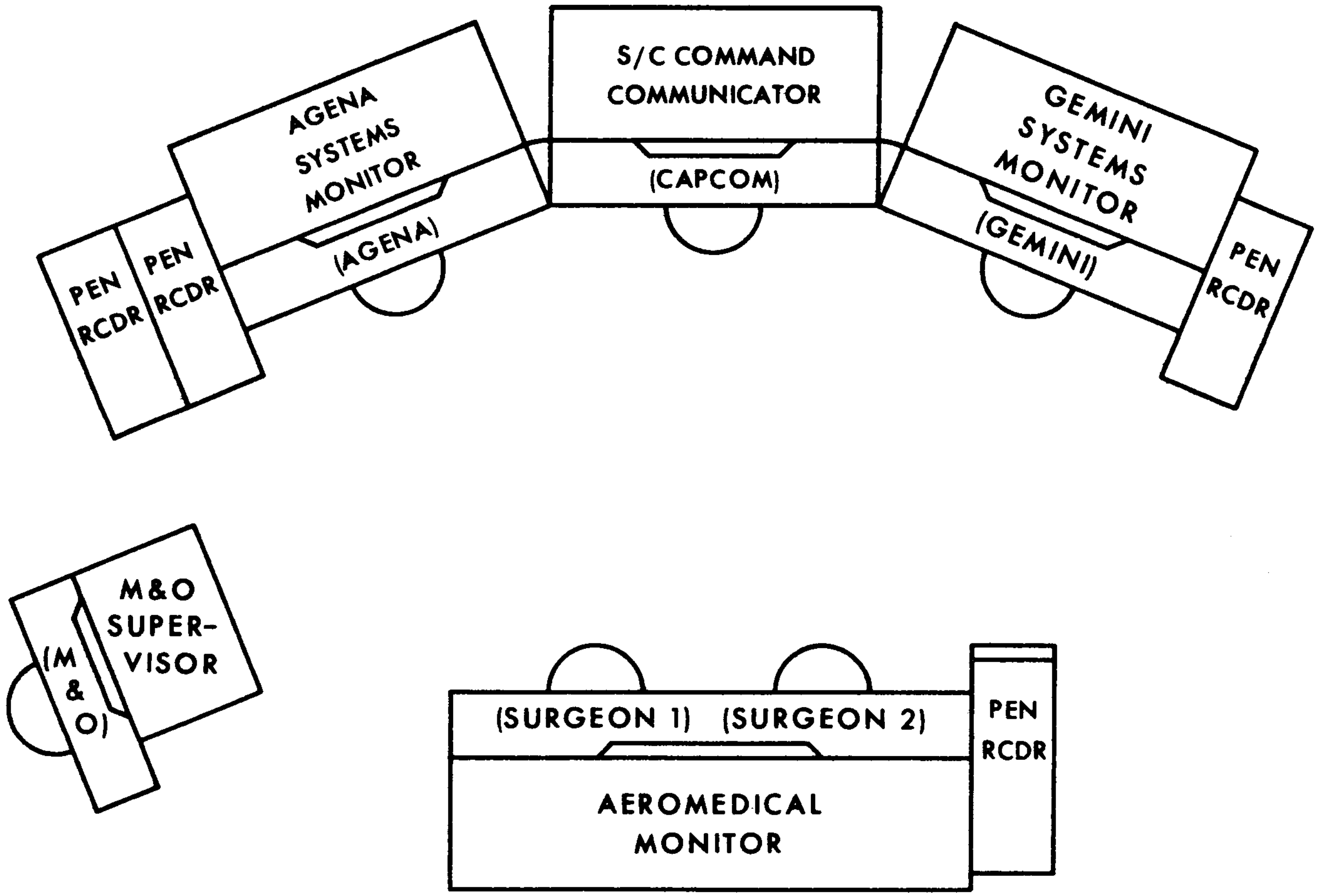


Figure 3.2-75 (Cont'd)

REMOTE SITE
OPERATIONS ROOM CONSOLE LAYOUT, GEMINI



FOR TRAINING ONLY

A5745(A)

Figure 3.2-76 Typical Display of Graphic Data for Introduction to Flight Controlling Course

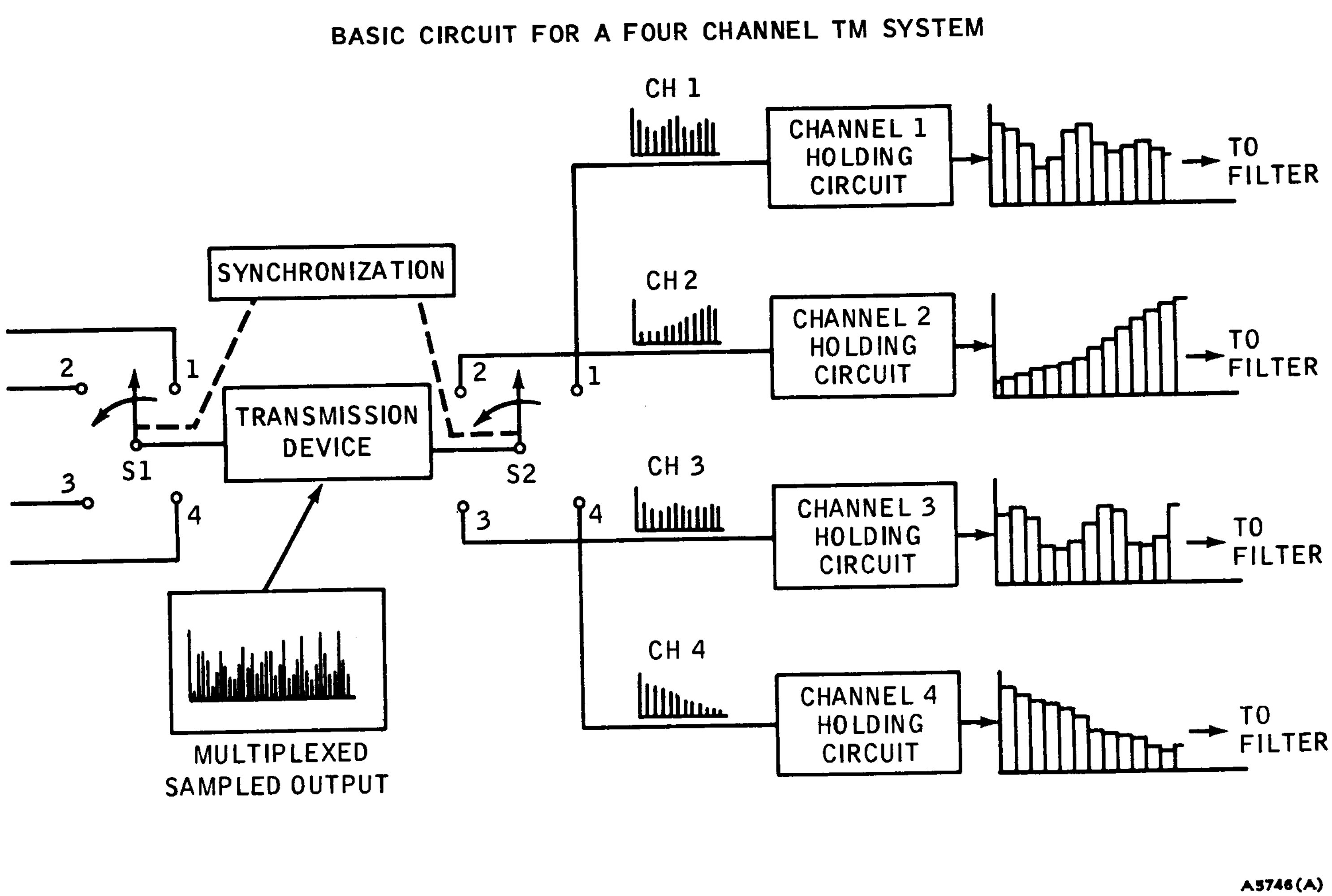


Figure 3.2-77 Typical Display of Graphic Data for Telemetry Network Course

TABLE 3.2-26

SUMMARY CHART FOR CHARACTERS, SYMBOLS AND VECTORS ASSOCIATED WITH TYPICAL DISPLAYS

FIGURE	LARGE CHARACTER	SMALL CHARACTER	SYMBOL	VECTOR
FIGURE 3.2-63	19	193	7	0
FIGURE 3.2-64	230	394	63	20
FIGURE 3.2-65	42	198	1	54
FIGURE 3.2-66	54	32	4	51
FIGURE 3.2-67	88	198	10	378
FIGURE 3.2-68	14	307	9	113
FIGURE 3.2-69	43	285	6	35
FIGURE 3.2-70	19	206	2	43
FIGURE 3.2-71	25	300	1	36
FIGURE 3.2-72	26	209	7	84
FIGURE 3.2-73	21	339	18	163
FIGURE 3.2-73*	40	109	10	247
FIGURE 3.2-73**	16	506	27	256
FIGURE 3.2-74	136	33	0	146
FIGURE 3.2-75	45	99	4	12
FIGURE 3.2-75*	25	12	0	15
FIGURE 3.2-76	43	156	15	60
FIGURE 3.2-77	35	202	0	199

PHO-603

* 2ND PAGE
** 3RD PAGE

TABLE 3.2-27

SUMMARY OF HIGH, LOW, AND AVERAGE VALUES FOR TYPICAL DISPLAYS

	LARGE CHARACTER	SMALL CHARACTER	SYMBOL	VECTOR
HIGH	230	506	63	378
LOW	14	12	0	0
AVERAGE	51	210	11	106

TOTAL NUMBER CHARACTERS, SYMBOLS, VECTORS/DISPLAYS

HIGH	850
LOW	52
AVERAGEQ	378

NUMBER UNIQUE CHARACTERS USED - APPROXIMATELY 56 (26 UPPER-26 LOWER)

NUMBER UNIQUE SYMBOLS USED - 11

PHO-603

To reiterate, the figures (3.2-63 through 3.2-77) were selected at random from the existing flight control curriculum and are therefore only representative of the complexity and densities required. Certain information to be displayed may exceed the most dense display illustrated by a factor of two.

From the foregoing discussion of display complexity and relative data densities, it is concluded that the terminals associated with the systems reviewed and those with which we are knowledgeable are inadequate for flight control applications.

3.2.6.2.1.3 Functional Requirements

The preceding discussion has examined the data type, complexities, and densities to be encountered in the flight control curriculum. Based on this evaluation, the functional requirements necessary to support flight control training operations are specified in the following text.

Prior to specifying the display requirement, a basic assumption has been made; viz., computer driven 35 mm slide projectors or carrousels are not required since the increased equipment costs, interface costs, software costs, and curriculum integration problems appear to cancel any significant advantages this method may have had over student handouts, computer storage, and generation of display material.

Therefore, the display types, complexities, and densities required are such that the display system must provide the following basic display capacity:

A. Repertoire. A repertoire of 128 characters, symbols, and numerals with 2 character sizes is required. Although only 67 characters, symbols, and numerals were identified, it should be recognized that (1) additional symbols are required for Orbital Mechanics, and Guidance and Navigation, (2) different applications will impose unique operation requirements, and (3) a growth factor is required.

B. Textual Mode. Approximately 1000-1200 displayable characters are required. This will (1) provide the capability to handle the highest density display illustrated (Figure 3.2-73, 2nd page), (2) provide the flexibility that is anticipated will be required for other system applications, and (3) provide a growth factor for system expansion.

C. Random Mode. Approximately 600 randomly plotted points or symbols are required. This will provide for a mode other than the standard typewriter mode and will enhance the capability to analyze such items as orbital equations by supplying the initial parameters and allowing the computer to plot the resultant data points.

D. Vector Mode. Approximately 20 full length vectors (diagonal measurement of display surface) and 300 to 400 randomly positioned vectors (with the capability to extend up to one quarter length of the display surface) are required. This will enable constructing the most complex diagram presently anticipated. Thus, it will provide the capability for presentation of displays for complex subjects such as: Guidance and Navigation, Orbital Mechanics, and Modeling. In addition, continuous point vectors are required to provide smoothing and shaping of data curves and objects not in the symbol repertoire.

E. Mixed Modes. This capability is required for generating displays which combine all three of the above with a proportional decrease in the number of symbols and vectors generated in each mode.

Since flight controller decisions during training would not be based on relative data positioning on the CRT (e.g., a point on a graph or a plot of a consumable), character-positioning accuracy requirements are not considered to be a significant factor and are, therefore, not discussed.

3.2.6.2.1.4 Criteria for Choosing Specific Systems

The recommendation for the specific type of system, i.e., digital or analog, is based on the following criteria:

A. Maximum Display Density Anticipated. (If complex maps are to be constructed and viewed during group-paced functions the digital system appears to be the most desirable.) The density of display data is a critical parameter in determining which of two basic approaches to display design is preferable for this application. In the stroke-writing technique, the data to be displayed is stored in the Display Refresh Memory in logical format. The CRT representation of a given display, or display element is regenerated on each refresh pass. If a display has an average density (see Table 3.2-28) of approximately 400 elements and each element requires 2 microseconds to generate, the time required to refresh that display is about: 60 refresh cycles/second x 4 microseconds/element x 400 elements = 48000 US/S. Then, only about 10 displays can be refreshed without blinking by that system. The number of displays that can be refreshed by common electronics without blinking decreases as the number of elements goes up.

In digital raster-scan displays, however, display element generation takes place only once, and this occurs prior to storage. In this type of system, displays are stored in Refresh Memory in "image" format as opposed to logical format. For this reason, in digital raster-scan systems, refresh rate is independent of data loading per display.

Since, in fact, complex data presentations will be required, digital display systems would be preferred.

B. System Costs. Digital systems are considerably cheaper provided a large quantity of terminals are to be driven in a cluster from one central source. An estimated breakover point is 20 to 25 terminals.

With reference to Figure 3.2-78, it can be seen that the strokewriting system consists of (1) a controller--the components of which are memory for storing instructions and a character and vector generator, and (2) the display channels which are essentially the terminal device. As previously mentioned, each channel must be refreshed (updated) approximately every 1/60 of a second. A point is reached (too many devices being driven by one controller causing display flicker) where an additional controller is required to drive the channels. This accounts for the periodic sharp rise in costs of the strokewriting system. (Refer to graph.)

By contrast, the digital system can drive any number of channels. The limiting factor is the system response time. The relative cost is depicted by the graph in Figure 3.2-78. The asterisk denotes the point at which the systems costs are comparable (approximately 20-25 terminals). Beyond this point D/TV per channel costs are less than those for the strokewriting system.

C. System Expansion Costs. Digital system expansion requires the addition or activation of an I/O channel raster storage and a monitor device, whereas the analog system requires core storage, writing electronics with each monitor, and a monitor. With proper system planning, e.g., modular design and inclusion of expansion capability, the digital system will prove to be the most cost-effective system.

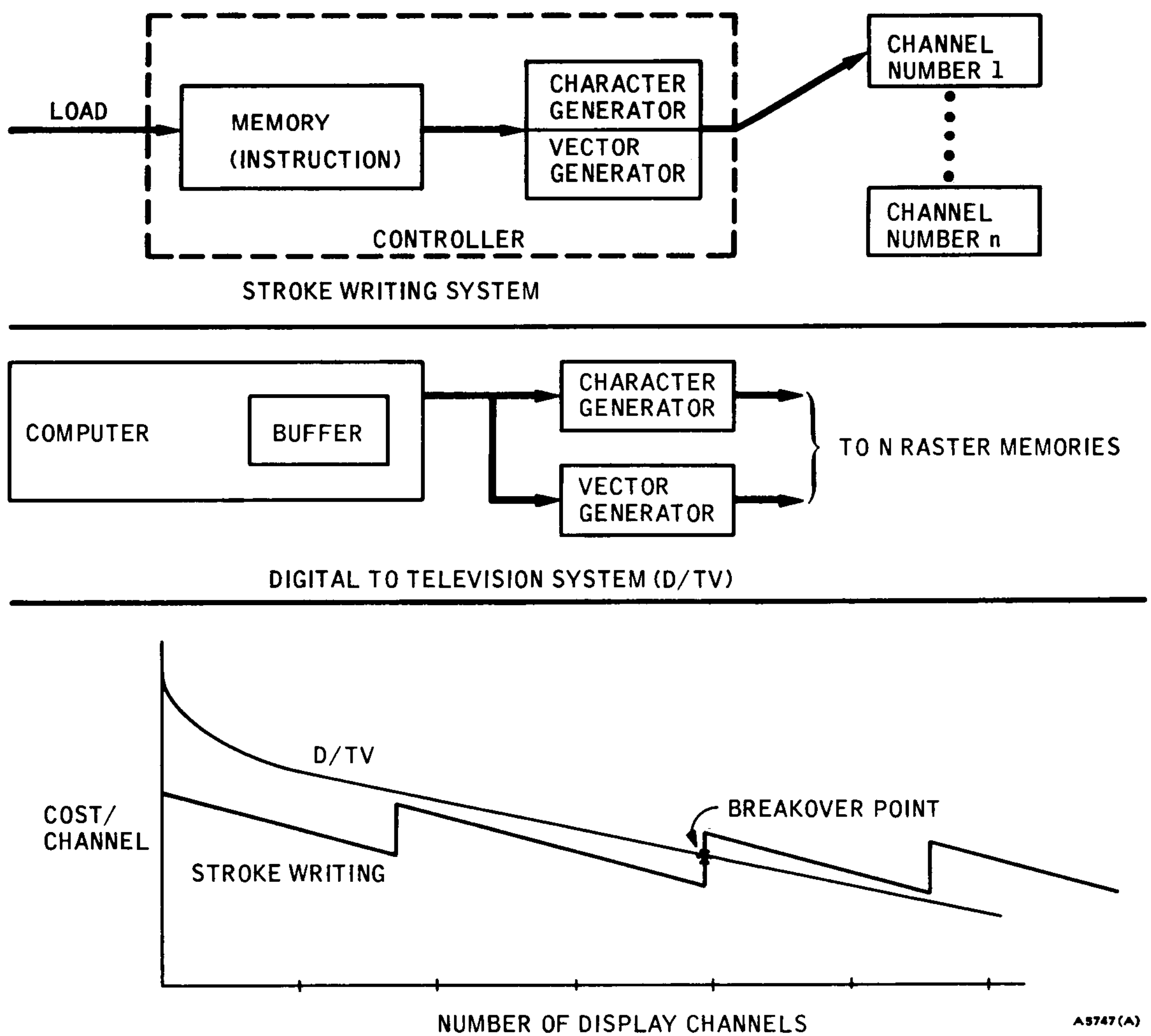


Figure 3.2-78 System and Relative Cost Comparison of Analog and Orbital Display Techniques

D. Display Distribution. Distribution of digital information destined for a strokewriting system is considerably easier because of transmission rates. However, distribution of a common display to many users via the analog system presents a more difficult situation than does distribution through the digital system.

Based on the following assumptions; (viz., that maps will be required in the Network, Guidance and Navigation, and Orbital Mechanics courses; that the quantity of terminals will exceed 15; and that system growth capability is a requirement), it is concluded that a digital display system is required for the optimum CAI system for flight control applications.

Table 3.2-28 summarizes the display system requirements.

3.2.6.2.1.5 Entry Devices

The type of entry device(s) (i.e., teletype or typewriter-like keyboards, special keyboards, light pens and writing tablets), and the input capability required are a function of (1) complexity of input entry, (2) input repertoire, and (3) student-to-computer access time. These factors are directly influenced by the complexity of the curriculum and the teaching strategy utilized.

As previously noted in Paragraph 3.2.5, Comparison of CAI Systems Capabilities Relative to Flight Control Training Requirements, the courses taught are primarily technical and encompass mathematics, engineering, and science principles, and range in complexity from an order relative to that of a first-year college technical course to a post-graduate course. It is assumed that the teaching strategies will range from simple testing (requiring a single entry) to complex inquiries requiring lengthy student constructed responses.

The student-to-computer input repertoire is required to provide the following capability: (1) character entry to enable English sentence construction; (2) numeric entry to enable operation with computationally-oriented languages and specification of numeric inputs; and (3) symbolic inputs to enable the student to identify unique functions related to flight dynamics, mathematics, etc.

These capabilities are required to function independently or in a mixed-entry mode. This will ensure the capability to construct all types of syntactic inputs.

Student-to-computer access times are not time-critical and therefore do not necessarily require rapid entry into the computer, e.g., entries of less than two seconds.

In the final analysis, two questions have to be answered; viz., what type or types of entry are required and why are they required?

TABLE 3.2-28

SUMMARY OF DISPLAY REQUIREMENTS SYSTEM

OPTIMUM SYSTEM FUNCTIONS/REQUIREMENTS				
TYPE SYSTEM DIGITAL CHARACTER REPERTOIRE 128 CHARACTER SIZES 2 DISPLAY DENSITY (TEXTUAL MODE) 1000-1200 CHARACTERS DISPLAY DENSITY (RANDOM MODE) 600 RANDOM POINTS OR CHARACTERS DISPLAY DENSITY (VECTOR* MODE) 20 FULL LENGTH, 300 TO 400 RANDOMLY-POSITIONED VECTORS DISPLAY DENSITY (MIXED MODE) PROPORTIONATE DECREASE ACCURACY - CURRENT ENGINEERING DESIGN TECHNIQUES RESPONSE TIME - LESS THAN 2 SECONDS AT PEAK LOAD				
ANTICIPATED INITIAL LOADING (DISPLAY DENSITIES)				
	LARGE CHARACTER	SMALL CHARACTER	SYMBOL	VECTOR
HIGH	230	506	63	378
LOW	14	12	0	0
AVERAGE	51	210	11	106
TOTAL NUMBER CHARACTERS, SYMBOLS AND VECTORS/DISPLAY				
HIGH	805			
LOW	52			
AVERAGE	378			
DISPLAY TYPE				
OPERATIONAL BLOCK DIAGRAMS SYSTEM BLOCK DIAGRAMS SCHEMATICS AND LOGIC CIRCUIT DIAGRAMS GRAPHIC INTERPRETATIONS				

*WITH D/TV, VERTICAL AND HORIZONTAL VECTORS ARE A FUNCTION OF SCAN LINES AND THE SUM OF THE DOTS ALONG THE HORIZONTAL AXIS.

The teletype keyboard, e.g., the Model 33 or Model 35 provides constructed responses and discrete entry responses; however, it is limited in the number of symbols provided to the user, and entry of numeric data for instructing the computer to perform computations is both limited and cumbersome. For these reasons, the basic teletype keyboard unit is eliminated as a possible input device.

The light pen is primarily a data management tool and in certain configurations a display construction device. This type of application (CAI) does not require extensive management of data nor will the construction of displays be required. For these reasons, the light pen is eliminated as a possible input device. It is significant to note that as advanced curriculum development and presentation techniques are established, the light pen will be required to provide additional data management of displayed information.

The Grafacon or writing tablet is primarily a data management device similar in function to the light pen yet different in operating principle. This type of device cannot be utilized to input mnemonic coding for to do so would require pattern-recognition programs in the computer--a technique not yet thoroughly developed.

Special keyboards, for this discussion, are defined as either a (1) modification of a typewriter or teletype keyboard capable of entry on a character basis or (2) an array of pushbuttons which, through initialization, provides a number of operators (verbs), nouns, and connectives which provide the capability to construct or assemble messages for entry into the computing system. The latter type, i.e., item (2), is eliminated on the basis of software complexity and curriculum variation which would require that an extensive vocabulary be associated with each device. However, this <u>does</u> <u>not</u> <u>preclude</u> the use of this type of device when programming techniques and CAI technology have progressed to the extent that development and operational complexities have significantly diminished.

Thus, the requirement is for item (1) which is a modified teletype or typewriter-like keyboard (one per terminal) capable of (1) constructing series of mnemonic codes formed from upper- and lower-case letters, symbols, and numerals, (2) entering numeric data is response to a query or for computational processing, (3) providing an extended symbolic library to include symbols utilized in orbital mechanics and electronics, (4) displaying CAI system status, and (5) providing unique user oriented control capability, such as input message correction capability.

3.2.6.2.2 Computer Requirements

The requirements for the CAI computer system and the relative size of the system are primarily a function of curriculum complexity, complexity of teaching strategies, diversification of application, and the number of simultaneous users and their response-time requirements.

Whether the system is to be time-shared or dedicated to CAI is another consideration. In order to reduce the computer program complexity and to assure a satisfactory response time, the system is assumed to be fully dedicated to CAI.

The computer system requirements are discussed in terms of main memory size, mass storage, peripheral equipments, word size, and machine speed. In addition, the factors unique to CAI that influence the number of machines are also discussed. The exact number of machines required will be specified only after detailed hardware and software requirements are specified.

3.2.6.2.2.1 Quantity

The number of machines required for a specific system or application is determined by flow charting the program, identifying critical paths, compiling external interrupts and response requirements and, essentially, adding up the operation times to determine if they are within a prescribed reference period (usually one second).

The quantity required is perturbated by the type of machine utilized, e.g., one "large scale" computer may perform the same functions that would require 3, 4 or more "small scale" machines.

Redundancy is another factor influencing quantity. In this application, redundant machines are not required since: no critical functions are being performed which could endanger lives or systems; no critical time constraints are imposed on the system, and data loss or overflow is not a major problem.

In CAI systems, and in particular the optimum system for flight control operations, the number of machines required is a function of four parameters; viz., the curriculum sequencing and presentation, the complexity of the curriculum, quantity of terminals and response times required by the student, and diversification of application.

A. Curriculum Sequencing and Presentation. This parameter identifies the particular teaching approaches to be used, i.e., tutorial and inquiry and the variations of either being: linear (extrinsic), branching (intrinsic), mathetics, or drill and practice (each of which can rely on adaptive sequencing techniques). The more involved the teaching strategy becomes, the more time is required for execution, and the more sophisticated the instructional repertoire must be, i.e., the number and complexity of machine instructions required to present a specific item of curricular material (per unit time) is a function of teaching strategy complexity.

B. Curriculum Complexity. This parameter has a major influence on the number of machine(s) required. As an example, a "small" computer (limited instructional repertoire and I/O drive capability) could easily provide drill and practice exercises to a number of terminals simultaneously; however, the same machine is incapable of simulating a complex situation or system by means of a dynamic mathematical model. Nor could a "small" computer provide the computational capability required for complex problem solving or provide the internal processing necessary for adaptive sequencing or data base querying.

C. Quantity of Student Terminals. The quantity of terminal devices, electronic sophistication, and user response times also influence the number and type of machines to be used. As an example, machines are limited to the number of external devices that can be efficiently driven--the limiting factor being the hardware multiplexing device (or number of I/O channels), and the response time. In general, the "larger" the machine, the more I/O capability available. Thus, two small machines may satisfy the I/O and response time requirements that one large machine would. Another example is that of display generation. If full display capability is required, i.e., vector generation, selective display erasing, etc., a "small scale" machine will prove inadequate.

D. Diversification of Application. The number of machines, and specifically the type of machine, are dependent on the different applications with which the system is involved. The obvious reason for this dependence is the complexity of individual applications, e.g., while certain applications may prove relatively simple and well within the capabilities of a small machine, other applications may be so complex a large machine or perhaps several small machines would be required. Another reason, more subtle, yet perhaps as important as task complexity, is that of application continuity, i.e., can machine operation be halted to reload, isolate a fault or re-cycle a program, in one application and still maintain continuity in the other applications.

In the final analysis, the quantity of machines required will be a function of which machine(s) is being considered.

3.2.6.2.2.2 Main Memory Requirements

The evaluative criteria developed for determining the requirements for main memory or working core for CAI applications are as follows: (1) the number of terminals simultaneously in operation, (2) the size (number of computer words) of concepts or segments that must be stored for each terminal, (3) the complexity of the curriculum, (4) the complexity of the presentation logic, (5) real-time student performance storage, (6) accessibility of mass storage for handling main-memory overflow, and (7) diversity of application. The requirements associated with the preceding criteria are outlined in the following text.

Until additional experience is gained in CAI technology associated with the flight control curriculum, it seems reasonable to make extensive use of repeated reference to existing information, procedures and techniques.

The requirements and supporting rationale are outlined as follows:

A. The main memory will be required to provide each terminal with a portion of core which is dedicated to that terminal. In the flight control application, 37 portions of core are required to be dedicated to CAI, thus corresponding to the number of terminals requiring simultaneous access to the computer. This is consistent with existing technology and techniques and varies only in the total number of portions of core dedicated.

B. Each dedicated portion of core will require a minimum of 1200 computer words for storage of curriculum frames and presentation logic. Project GROW, UCI, and the Brentwood system require an average 720 words of storage. An increase in curriculum complexity (refer to Paragraph 3.2.5), presentation logic, and the amount of information presented in each frame is the rationale used for increasing the storage by approximately 90 percent.

C. In addition to the curriculum and presentation logic, the main memory will be required to provide storage for the following items:

- Real-time student performance records (to be used for adaptive sequencing)
- Display-processing routines

- Model or gaming processors
- Computational language
- Hardware I/O processing
- Reference tables (dictionaries)
- Error-checking routines
- Input-editing routines.

NOTE

Table 3.2-29 outlines the estimates for the number of computer words required to be stored in main memory. While Items 1, 2, 3, and 6 of Table 3.2-29 are consistent with existing techniques, Items 4, 5, 7, 8, and 9 deviate from the normal. The rationale supporting these figures is provided in the following text.

It is anticipated that the mathematical models to be programmed will approach the existing sophistication and complexity of the Saturn, LM and CSM models presently used in simulation. The optimum CAI system will provide the capability to stimulate the student and monitor the results through interactions with a model of a particular environment, situation, or system. Existing mathematical models consume approximately 30,000 to 40,000 words of 32-bits/word rapid access memory. Using this as a reference and considering the level of sophistication of CAI models, 25,000 words is consistent with existing programming techniques.

It is significant to note that this figure could be reduced by modularizing the programs and storing them in random-access memory. The figure stated is an estimated worst-case situation.

With reference to Item 5 of Table 3.2-29 a computational language capable of performing addition, subtraction, multiplication, square root, trigonometric functions (sine, cosine and tangent), and calculus has been specified as a system requirement. BASIC was developed to provide this type of capability. An examination of the storage requirements for BASIC revealed that approximately 6400 6-bit characters were required for each user. For flight control, this would amount to approximately $\frac{6400 \times 37}{6\text{(bytes/word)}} =$ 38.4 thousand words. By proper implementation

TABLE 3.2-29

SUMMARY OF MAIN MEMORY REQUIREMENTS

PARAMETER	ESTIMATED MAIN MEMORY REQUIREMENTS *
1. CURRICULUM AND TEACHING LOGIC	1200 (WORDS) X 37 (TERMINALS) 44.4 THOUSAND WORDS
2. STUDENT PERFORMANCE RECORDS	200 X 37 = 7.4 THOUSAND WORDS
3. DISPLAY PROCESSING ROUTINES	5000 WORDS
4. MODEL OR GAMING PROCESSOR(S)	25000 WORDS
5. COMPUTATIONAL LANGUAGE	25000 WORDS
6. HARDWARE I/O	100 X 37 = 3.7 THOUSAND WORDS
7. REFERENCE TABLES	5 5000 WORDS
8. ERROR CHECKING ROUTINES	** 1000 WORDS
9. INPUT EDITING ROUTINES	2000 WORDS
	TOTAL 116.6 THOUSAND WORDS

* WORD SIZE IS ASSUMED TO BE 32 TO 36 BITS.

** THIS IS A GROSS ESTIMATE AND ASSUMES THAT HARDWARE MEMORY-PROTECT FEATURES AND OTHER ERROR-PROTECTION FEATURES ARE AVAILABLE.

of software techniques and removing the response-time requirements, less core would be required but response-time would be sacrificed. Again, 25,000 words indicates an estimated worst case condition.

Items 7, 8, and 9 of Table 3.2-29 are extremely gross estimates of the quantity of core required. Item 8 is primarily a function of the level of error checking and memory protection required. Item 9 is based on information gleaned from independent research and development programs conducted at the Philco Houston Operations.

As indicated in Table 3.2-29, the main memory requirements are for 116.6 thousand words of rapid-access storage. To provide for inaccuracies that may exist in the techniques used in deriving these figures, the main memory storage requirements have been increased to 130,000 words. By time-sharing common core, the main memory could be reduced by approximately 35,000 words to 95,000 words. This, however, tends to complicate programming of the software package.

3.2.6.2.2.3 Mass Storage Requirements

The evaluative criteria developed for determining the mass storage requirements for CAI applications are as follows:

- Number and size of concepts to be stored
- Complexity of presentation logic
- Diversification of application
- Administrative capabilities
- Display storage.

The analysis of the computer facilities associated with the CAI systems reviewed and an examination of the flight control curriculum have established the requirement for two types of storage media; viz., random access and magnetic tape.

A. Random-access storage is required to provide the following capabilities:

   1. Storage for A Maximum of Four Complete Subjects. This will ensure the capability to provide two different subjects to each of two groups. Two subjects per

group will enable students to utilize the inherent characteristic of self-pacing. This is based on the assumption that each group of students is taking the same basic program of instruction.

2. Display Storage for 37 Terminals. This will provide for refreshing and updating of all displays operating concurrently and independently.

3. Storage for other Applications. This will provide storage for large tables or libraries (associated with modeling or gaming), the computational language, and data base querying.

4. Storage for Administrative and Student Records. This will provide storage for student performance records on an individual and group basis. In addition, selected student performance records, such as response latencies and incorrectly answered questions will be stored for subsequent use in evaluating the curricular material. The administrator will require limited storage of student performance records necessary for adaptive sequencing.

B. Magnetic-tape storage is required to provide the following capabilities:

1. Storage for All Flight Control Subjects Taught. This minimizes the use of random-access storage and provides a relatively inexpensive medium for storing large quantities of data. In addition, data is required to be retrieved and placed in rapid-access within 5 minutes, thus enabling any subject to be placed on line at any time.

2. Bulk Storage. This ensures that the administrator is provided with student and curriculum scheduling, student and group grading, and curriculum updating. These data will be used to perform off-line functions.

The recommended random-access storage medium for curriculum, other applications and administration functions, is magnetic-disk files. This type of storage medium provides a range of 48 to 224 million characters, while magnetic drums range in capacity from 4 million to 132.3 million as on the Univac Fastrand II Drum. The recommended storage for display refresh and update is drum or magnetostrictive delay lines (a discussion of the media is presented later in this text).

Although the average rotational delays encountered in drum storage are considerably less than disk-access delays, the system response-time requirements are such that this is not a limiting factor.

From a convenience standpoint, it may be desirable to select a cartridge-loaded disk. The limitation is the disk capacity, which is nominally 3 million characters; the obvious advantage of the cartridge loaded disk is its portability and rapid-disk changeover capability.

Having specified the functional requirements for the random-access storage media, the subsequent text is concerned with estimating the amount of random-access storage required. As mentioned previously, this is a function of the number of subjects on-line, storage for other application, and administrative functions.

3.2.6.2.2.4 Random-Access Storage (Curriculum)

For the purpose of this study, a subject is considered to be subordinate to a course by one level. The heirarchy for the curriculum is as follows: a course subject is within a course, a segment is within a subject, a concept is within a segment and a frame within a concept. Example: The MSFN sourse has, as a subject, Apollo telemetry which has seven segments, one of which is basic telemetry. The basic telemetry segment has three concepts; viz., introduction to basic telemetry, development of a composite telemetry signal, and principals of encoding telemetry signals as applied to PCM coding. Each of these concepts can contain many frames of information which are required in order to develop the concept.

To present this subject material requires a massive amount of storage--every character associated with the curricular material and presentation logic must be stored. (This ignores possible use of handouts and eliminates the use of slides.)

The basic relationship between storage required and curriculum is illustrated below:

$$C_t = C_c + C_p$$

Where:

C_t = Total characters required to store material to be presented to user

C_c = Total characters required to store curricular material

C_p = Total characters required to store presentation logic

C_c is derived in the following manner:

C_c = Average number segments/subject x average number concepts/segment x average number frames/concept x average number characters/frame

C_p is derived in the following manner:

C_p = Average number presentation statements/frame x average number characters/presentation statement x average number frames/concept x average number concepts/segment x number of segments

C_c and C_p can also be estimated by considering the amount of CAI instructional time required. If the number of CAI instructional hours are known (IH_{CAI}), an estimate of the number of frames that comprise an instructional hour of CAI is available (F/H), and the average number of characters per frame can be estimated (C_a/F). The total characters required to store curricular material (C_c) can be calculated. The basic relationship is:

$$C_c = IH_{CAI} \times F/H \times C_a/F$$

F/H is a constant and is estimated to be 60 frames/hour. This estimate is based on information received during the systems review and represents a rough average.

C_a/F is 500 characters/frame. This assumes the average density of the displays presented to the student and that a totally new character set is presented each frame.

C_p can be calculated by determining the number of CAI instructional hours (IH_{CAI}), average number of frames that comprise an hour (F/H), average number of instructions per frame (I/F), and the average number of characters/instruction (C/I).

Thus:

$$C_p = IH_{CAI} \times F/H \times I/F \times C/I$$

Where:

F/H equals 60 frames/hours

I/F equals 10 (an estimate based on the author language analysis)

C/I equals 6 (an estimate based on the author language analysis)

Therefore:

$$C_t = IH_{CAI} \times F/H \times C_a/F + IH_{CAI} \times F/H \times I/F \times C/I$$

Factoring:

$$C_t = IH_{CAI} \times F/H\ (C_a/F + I/F \times C/I)$$

C_t is further dependent on (1) the particular author, (2) the type and complexity of the curricular material, and (3) the method of presentation the author uses. As an example, more characters must be stored for a branching program than for a linear program of the same subject. This isn't easily quantified since C_t is a function of the number of branches.

As previously mentioned, two methods are used in programmed instruction; viz., tutorial and inquiry. Linear, branching, combination, mathetics, and drill and practice are approaches that can be taken, using the tutorial method.

From the information gathered during the study, it seems reasonable to rank the methods and approaches in descending order of complexity (for this example, complexity is a measure of the number of characters required) as follows:

- Inquiry
- Mathetics
- Branching
- Combination
- Linear

From this ranking, it can be concluded that for an identical teaching problem, linear would require the least storage while inquiry (and possibly mathetics) would require the most storage.

Because of these variables, it is virtually impossible to make an analytic estimate of mass-storage requirements. The experience gained in other CAI systems shows that:

- Brentwood has approximately 21.5 million characters
- Irvine has approximately 22 million characters
- Santa Barbara has approximately 60 million characters
- Walter Hays has approximately 56 million characters
- Project GROW has approximately 1 million characters

A gross estimate of the random-access storage required can be made by assuming an average subject length of 12 hours (refer to Paragraph 3.2.5.1, Existing Flight Control Curriculum Characteristics). The total number of instructional hours to be stored is the product of the four subjects and average length or 48 instructional hours.

Using the relationship:

$$C_t = IH_{CAI} \times F/H \; (C_a/F + I/F \times CI),$$
$$C_t = 48 \times 60 \; (500 + 10 \times 6),$$
$$C_t = 2880 \; (560),$$
$$C_t = 1{,}612{,}800 \text{ characters.}$$

To allow for inaccuracies in the estimating technique, approximately 3 million characters have been added, thus bringing the total to 5 million characters. (This is for curriculum and presentation logic for four 12-hour subjects.)

3.2.6.2.2.5 <u>Random-Access Storage (Display)</u>

The type of storage required for display refresh and update is a function of the type of display system utilized, i.e., digital or analog. Since digital display techniques were recommended for the optimum CAI system, the following discussion is applicable to only the digital technique.

Three types of storage are available, each having inherent advantages and disadvantages.

A. <u>Magnetic Disc Storage</u>. The first considered, magnetic disc storage, may prove to be slow for this application, since refresh rates of 30 per second are required to reduce flicker. Another disadvantage is that of speed control. Presently, most discs (cartridge type) are belt-driven and tend to "slow down" with increased operation, which could eventually cause misreading or positioning of a bit or bits of video data. The obvious advantage is that of data storage, averaging as much as 10 times that of the drum.

B. Magnetic Drum Storage. The second medium, magnetic drum storage, provides the rapid access required for display update; however, failure of the drum will affect all the users of that drum (the number of users being a function of the number of channels). This would be a violation of one of the system functional requirements delineated in Paragraph 3.2.6.1.2, Storage Requirements. For this reason, a drum is not the most desirable storage medium. However, this method should not be dismissed as a possible alternative. Using a digital display system with a 525-line monitor that has approximately 256,000 bits visible and approximately 123,000 bits definable, approximately 4000 words of storage would be required. Thus, the total requirement would be for 148,000 words of drum storage (assuming 32 bits/word) to refresh the 37 display terminals.

C. Magnetostrictive Delay Lines Storage. The third medium is magnetostrictive delay lines. This method eliminates disc or drum storage. Storage requirements are expressed in terms of the number of delay lines per monitor. Obvious advantages are cost reduction, which is technically feasible through the use of data compression techniques, and independent operation (each terminal would have individual delay line storage). A significant disadvantage is that display data can be lost if power to the storage system fails.

The most significant disadvantage is that of space. Using the same digital system outlined in the preceding text, approximately 12 standard racks would be required to house the delay-line storage devices and control electronics. With existing techniques, raster storage and update can be accommodated by using approximately 10 to 12 delay lines per terminal or a total of approximately 370 to 444.

3.2.6.2.2.6 Random-Access Storage (Other Applications)

A. Modeling/Gaming. Storage requirements for other application, i.e., modeling, gaming, and data base querying, are difficult to assess. However, assuming that a particular model requires 20,000 to 35,000 bytes (8 bites/byte) and there exist 5 models, e.g., GUIDO, BOOSTER, FIDO, and two system models, then approximately 165,000 bytes of storage would be required.

B. Administrative. Administrative storage would be an insignificant amount and would be required for adaptive sequencing and grading student responses. A gross estimate would be a total of 30,000 characters.

3.2.6.2.2.7 Total Random Access Storage Requirements

As a working figure, the total random access storage required is approximately 20 million characters. This includes the random-access for curriculum, display, other applications, and 15 million characters for growth and inaccuracies in assumptions and calculations.

3.2.6.2.2.8 Tape Storage

The requirement is not for the number of characters required to be stored, although this will certainly approach the 60 to 100 million mark, but rather for the number of tape transports required. This is to some extent determined by the type of machine purchased and the program organization. If the transports that load the operating programs are not available for curriculum input, the requirement exists for one additional tape transport to be used for inputting curricular material, and administrative programs and histories. There is presently no requirement for simultansous input of curricular material and administrative material.

3.2.6.2.2.9 Peripheral Equipments

There is a requirement for the standard peripheral equipments; i.e., (1) typewriter, (1) printer, (1) card-punch, and (1) card reader. This will provide the capability to prepare curriculum, store curricular material, and edit and debug programs.

3.2.6.2.2.10 Word Size

This parameter does not appear to significantly influence the computing system. In those systems analyzed, word size ranged from 16 bits to 48 bits. It seems reasonable to select a word size which is a multiple of a character or byte. These range from 6 bits to 8 bits, thus indicating a 30-bit to 48-bit word size.

3.2.6.2.2.11 Memory-Access Time

This parameter did not appear to have a significant effect on the systems reviewed ranging from 2 microseconds to 5 microseconds. However, in flight control, with the diversity of application, the required machine speed is 2 microseconds or less.

3.2.6.2.3 Special System Functional Requirements

This subparagraph is concerned with elaborating on and clarifying certain special system functional requirements.* The overall system must adhere (where feasible, from a technical and cost posture) to the requirements outlined in Subparagraph 3.2.6.1.1.

3.2.6.2.3.1 Author Language

The author language to be implemented with the system must not constrain the overall system operation and must adhere to the following generic requirements:

A. It must be capable of entering the computer from the terminal, typewriter, or card reader.

B. It must be capable of driving a digital system. This will include the construction of vectors, symbols, and characters.

C. It must be user-oriented.

D. It must have repertoire such that branches, questions, grading, adaptive sequencing, and hard copy capability can be specified by the author.

E. It must have the capability to perform computation or have control over a computationally-oriented language for both the instructor and the student.

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*These requirements are additional or are reiterative to those outlined in Subparagraph 3.2.6.1.1; however, they will significantly influence the overall design and utilization and for this reason are given special emphasis.

3.2.6.2.3.2 Hard Copy

Hard copies are required to be generated in a manual mode and automatic mode.

A. Manual Mode. The system must have the capability to accept manually activated control signals from the student terminal. This will provide the student with the capability to copy certain frames (block diagrams or textual material) of data presented on the display surface for subsequent review. This capability is not intended to be used as means of electronically generating a "CAI book" for later use, for to do so would be extremely expensive (an estimated $1.5 million annually) and a gross misuse of system capability.

B. Automatic Mode. The system must have the capability to accept author-input codes to be interpreted by the computer as hard copy requests. This will enable the author to pre-establish certain performance criteria which, when not attained, will request the computer to provide the student with a hard copy of the data causing the apparent difficulty.

3.2.6.2.4 Location of Computing Facilities

The factors determining the location of the optimum CAI system computer are the availability of adequate space, adequate air conditioning for component cooling, ease of maintenance (the proximity of maintenance staffs already in existence is one consideration), accessibility of the facility for the instructor, and the ease of installing the system.

Those locations considered are Buildings 30, 12, 422 and 45. Each factor will be discussed as it applies to each location choice. A table of location factors for each prospective location is presented in Table 3.2-30; each building is rated in order of desirability (from 1 to 4 with 1 being the most desirable) for each location factor.

3.2.6.2.4.1 Space Availability

Buildings 30, 12 and 422 are filled almost to capacity at present and space for another computer system is not readily available. Buildings 30, 12 and 422 are concerned primarily with mission control, bulk data processing, and simulations respectively; therefore facilities are constrained by rigid schedules which might interfere with effective utilization of a training-oriented computer system.

TABLE 3.2-30

FACTORS INFLUENCING LOCATION

ASSETS \ LOCATIONS	BLDG. 30	BLDG. 12	BLDG. 422	BLDG. 45
SPACE AVAILABILITY	2	2	2	1
ADEQUATE COOLING	1	1	1	1
EASE OF MAINTENANCE	1	2	1	3
STUDENT ACCESSIBILITY	2	3	4	1
INSTRUCTOR ACCESSIBILITY	2	2	3	1
EASE OF INSTALLATION	1	1	1	2
EASE OF MANAGEMENT CONTROL	2	3	2	1

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Building 45, while it does not have an abundance of space available, does appear to have adequate space more readily available than the other choices. In addition, there are no computer systems and personnel located in Bldg. 45 whose schedules would conflict with the schedules and objectives of a CAI system.

3.2.6.2.4.2 Adequate Cooling

Adequate air conditioning facilities for component cooling of a computer system does not appear to be a problem in any of the building choices.

3.2.6.2.4.3 Ease of Maintenance

Buildings 30 and 422 would seem to have the best facilities for maintenance of the system as there are already experienced real-time systems maintenance staffs at hand. Building 12's facilities include experienced systems maintenance personnel familiar with data processing systems. Building 45, however, has no systems maintenance crews at present.

3.2.6.2.4.4 Student and Instructor Accessibility

Since Building 45 houses the majority of students to be using the system, locating the system there would provide maximum accessibility. Building 30 houses some of the students and is convenient to the remainder; therefore, it would be an acceptable location. Building 12, although few of the training program students are located there, is conveniently located. Building 422 has the disadvantage of being remotely located and would require transportation for students.

The fact that the instructors are located in Building 45 makes Building 45 the most desirable computer location in terms of instructor accessibility. Buildings 30 and 12 are easily accessible to instructors although not as convenient as Building 45. Locating the computer in Building 422 would require transportation and involve a considerable time delay for instructors.

3.2.6.2.4.5 Ease of Installation

Existing facilities at Buildings 30, 12 and 422 are about equal in that each is configured such that it will accept a computer system. Building 45, however, would require modification in that cable routing and installation would be required for the implementation of a computer system.

3.2.6.2.4.6 Ease of Management Control

This is primarily a function of the proximity of management to the computer system for which they are responsible. In order to facilitate managerial control over the system and allow for effective planning, scheduling, and utilization of the system, locating the system in Building 45 would be the first choice. Since both Buildings 30 and 422 facilities fall within the responsibility of Flight Control Division, either would be an acceptable location. Building 12 is not extremely convenient to management, nor is it operated by the Flight Control Division--for this reason it is the least desirable in terms of managerial control.

3.2.6.2.4.7 Summary

In summarizing, it appears that Building 30 is desirable in terms of maintenance and installation ease, but is not as desirable as other locations in terms of space availability, student accessibility, instructor accessibility, or managerial control.

Building 12 also is desirable in terms of installation ease, but is not the most desirable in terms of space availability, maintenance ease, student accessibility, instructor accessibility, or managerial control.

The factors in favor of Building 422 are maintenance and installation ease, while space availability, student accessibility, instructor accessibility, and managerial control factors indicate that another location would be more desirable.

A location other than Building 45 would be more desirable in terms of maintenance and installation ease, but Building 45 is most desirable in terms of space availability, student accessibility, instructor accessibility, and managerial control.

For these reasons it appears that Building 45 is the best choice for location of the computer to be used in the optimum CAI system and is, therefore, the location recommended.

3.2.6.2.5 Terminal Location

3.2.6.2.5.1 General

There are three basic methods by which the terminal devices could be configured; viz.:

- Centralized. A cluster of terminals adjacent to the computing facilities.
- Remote Clustered. Individual terminals clustered together but remote from the computer.
- Remote Decentralized. Individual terminals remote from the computer and remote from each other.

An analysis of the various configurations available indicates that the parameters that have a major impact on the final selection of a specific location (hence configuration) are:

- Access to equipment (by student, instructor and M&O)
- Space requirements
- Maintenance
- Reliability
- Control of utilization
- Scheduling of equipments and personnel
- Permanency of installation
- Ease of obtaining additional instruction
- Cost

The advantages and disadvantages of each configuration are discussed and compared in terms of the major parameters outlined in the preceding text.

The location of the computer as mentioned in Subparagraph 3.2.6.2.4.7 is Building 45. Thus, when addressing the centralized configuration, the terminals are assumed to be in Building 45 in an adjacent equipment area.

3.2.6.2.5.2 Access to Equipment

In the centralized configuration, the student, as well as the instructor, will have ready access to the equipments. This is based on the premise that all of the instructors and a large majority (approximately 75 percent) of the students are located in Building 45. This particular configuration would require a small M&O staff with office space in Building 45. Because of existing and anticipated space requirements, this could develop into a significant disadvantage.

The remote clustered configuration has the advantage of possible location in an area staffed with M&O personnel. (It should be noted that a small cadre of M&O personnel will still be required in Building 45.) The obvious disadvantage is the removal of the equipment from the student and instructor. This would require transit time for both the student and instructor, thus, increasing the overall operating expense. Past experience indicates that training must be made convenient for the student.

The remote decentralized configuration (because of physical distances) may not provide easy access to the instructional staff. Assuming that terminals were located near the student population, e.g., within the physical domain of each flight control branch, then it is readily apparent that accessibility to equipment is excellent. However, there are certain minor limitations; viz., the M&O personnel would have to perform maintenance at the location which could prove distracting to other uninvolved personnel, and operation of the terminal could also prove distracting to personnel not engaged in the training activity. In addition, the equipment is easily accessible by unauthorized individuals. These limitations are not insurmountable and in this respect the remote decentralized configuration appears to be the most desirable.

3.2.6.2.5.3 Space Requirements

This problem is present in all the configurations to be examined.

Building 45 does have space available in the form of existing classrooms. The optimum system would require approximately two of the existing classrooms. This does not present a serious problem since it is assumed that CAI will be the primary instructional medium and will virtually eliminate the need for classroom presentation. (A possible exception is the existing delta courses; however, as the CAI technology increases it is expected that it will no longer present a problem.) Depending on location, the remote clustered configuration may present space-availability problems. For example, the logical remote-clustered locations would be either Building 30 or Building 422 (Building 12 is eliminated on the basis of known space availability and the undesirability of inter-division location of assets). Based on existing plans to incorporate SOCR's and D/TV, it can be seen that Building 30 (MOW) is virtually 100 percent loaded. A quick tour of Building 422 precipitates the same conclusion.

The remote decentralized configuration would also present space availability problems. Assuming the terminals would be remote from the computer yet remain in Building 45 (a selected number situated in each branch area), an even more serious problem than experienced in the centralized system may exist. For example, the room layouts would have to be altered or reorganized in an attempt to incorporate the terminals.

It seems more reasonable to take existing classrooms which will eventually be "phased-out" and cluster the terminals together rather than attempt to reorganize floor space within each branch. In terms of space requirements the centralized cluster is the most desirable.

3.2.6.2.5.4 Maintenance

This is an important factor in any system and experience indicates that the more convenient the equipment to the M&O personnel and their test equipment, the better maintained the equipment will be.

The centralized cluster would provide the ideal configuration in that the operating equipment, test equipment, and M&O personnel are all centrally located. The remote clustered configuration would also provide centralization of maintenance. The remote decentralized configuration is not efficient when considering the procedures one would have to follow when performing maintenance on the equipment. For example, the technician would be required to remove the electronics from the terminal and take it to a central repair area or take the test instruments to the terminal. For this reason either the centralized configuration or remote clustered configuration is the most desirable.

3.2.6.2.5.5 Reliability

Although the component or device level reliability factors are the same, there can be significant variation in communication link reliability.

In the centralized configuration, it is assumed that the maximum cable length will not exceed 200 feet, thus, making a hardwired computer/terminal interface. At the relatively high transfer rates which will be experienced (approximately 2 megacycles for the digital video data), this is an extremely desirable interface configuration. In the remote cluster and the remote decentralized, special hardware and software precautions must be taken to transfer these rates and minimize line noise and bit errors. In this respect, the centralized cluster is the most desirable.

3.2.6.2.5.6 Permanency of Installation

The centralized cluster would provide two CAI system-dedicated rooms. The permanency would be a function of the flight control operations and in particular the mission simulation branch. However, this does not preclude or eliminate the possibility of an eventual relocation.

It is reasonable to assume the same relative level of permanency when considering the remote cluster configuration. The major factor to consider is intra-facility growth of other systems non-related to CAI. This could cause a reorganization and reconfiguration of assets within the remote installation. The remote decentralized configuration would not provide the permanency of installation required. Consider the number of times and the frequency with which personnel within a branch and in fact entire branches have been moved. As an example, what once might have been the optimum terminals location for Branch X suddenly becomes the location for part of Branch Y and Branch Z. This situation cannot be prevented; it can only be relieved by removing the terminals and reinstalling them in their new optimum location.

Considering permanency of location, the centralized cluster is the most desirable.

3.2.6.2.5.7 Ease of Obtaining Additional Instruction

As previously noted, the instructional staff has offices in Building 45. Should a student require human tutoring, the instructor is conveniently located to provide this service.

The remote cluster configuration would require either the instructor or student to travel to the other's location. The remote decentralized configuration (if contained within Building 45) would provide a reduced level of instructor/student interface. Either the centralized cluster configuration or remote decentralized configuration could be used with the former being the most desirable based on convenience of rapid availability of instructional personnel.

3.2.6.2.5.8 Scheduling of Equipments and Personnel

The significance of maintaining equipment and personnel schedules is to ensure a uniform demand and usage of the student terminals.

The centralized cluster configuration will maximize the utilization of equipments and personnel. This can be accomplished by continuing the present basic scheduling techniques. With this configuration, the training section governs who uses the system and when the system is to be used. In this manner, strict scheduling control can be maintained.

The remote centralized cluster could provide significant scheduling problems. For example, assume the terminals are located in an area that has restricted access during mission or simulation periods; this could seriously delay training operations to the extent of cancellation (this is a function of NASA mission operation procedures).

The remote decentralized configuration would also provide scheduling and utilization problems. There would be virtually no control over the demand and usage of the terminals. Consider the example where several terminals are situated in each branch. Assume, too, that vehicle systems personnel are not interested nor required to be taught booster or FIDO subjects. A situation then exists where the terminals are utilized only for systems classes and are inactive a major portion of the time. If there are more personnel in a branch desiring instruction than there are terminals to provide the data, the only alternatives are to wait or request the use of a terminal located in another branch. This type of situation is intolerable. For these reasons the centralized cluster is the most desirable.

3.2.6.2.5.9 Cost

The basic areas where costs are incurred are design, installation, operation, and maintenance.

The design of the terminal device will be the same regardless of the final system configuration. However, certain interface costs will vary as a function of the configuration.

The centralized cluster will be most cost effective from an interface standpoint. Operation and maintenance of the system will also be within established limits for this type of system.

The major cost will be incurred in installation. An efficient method will have to be devised for laying cable between the computing facilities and the adjacent terminals. This is necessitated since Building 45 does not have cable trays. This could represent a considerable cost.

The remote cluster if located in Buildings 30 or 422 would not have installation problems which could effect costs nor would the increase in operations and maintenance be significant. The major cost would be encountered in the communication interface between the computing facilities and the terminal devices. Recall that the bit rate approaches 2 megacycles/terminal.

Installation and interface costs for the remote decentralized configuration will be quite expensive. Operation and maintenance will increase, but will not influence the overall costs. The interface will require special transmit/receive equipments capable of handling the high-frequency video signals. In addition, installation costs will exceed those encountered for either of the other two systems since data distribution will be more complex (distributing data between floors and for distances approaching a maximum of 1000 feet will be required).

For these reasons the centralized cluster and remote cluster are the most desirable. The tradeoff, to determine which is more cost-effective and hence more desirable, is between communication interface costs for the remote cluster and installation costs for the centralized cluster. More information than is presently available will be required to assess this factor.

3.2.6.2.5.10 Control of Utilization

Supervision and control of the terminal utilization is an important factor in any CAI system. Control must be exercised over the scheduling of terminal utilization, as well as the use to which a terminal is put. For example, if the system has a strong computational capability, an unauthorized user might tie up a terminal by using it as a desk calculator unless sufficient supervision is provided.

The degree of utilization control is primarily determined by the proximity of the terminals to the central system and the managerial personnel. The centralized cluster provides for strong control over student scheduling and terminal utilization. The reporting of failures and administration of maintenance is easily facilitated.

The remote cluster does not provide for supervision of scheduling or control of utilization. Administration and supervision of maintenance work is also more difficult. The remote decentralized configuration merely weakens the control that management has over the scheduling of students and the type of utilization a terminal is given. The reporting of needed maintenance to these terminals and the administration of this maintenance is more difficult with individual, remotely located terminals.

A centralized cluster of terminals appears, for the preceding reasons, to be the most efficient in terms of control of utilization.

3.2.6.2.5.11 Summary

When considering all factors as a composite input to the configuration, the centralized configuration appears to be the most effective and efficient method of integrating the terminals into the system. This is based on the following conclusions:

A. Accessibility for students, instructors and technicians, although not as convenient as from the remote decentralized configuration standpoint, is adequate.

B. Space is available (existing classrooms) which could be dedicated to the system.

C. Maintenance would be as readily available as in the remote cluster.

D. Reliability (transmission) is much better because of the method of interfacing.

E. Strict control can be maintained over equipments and personnel.

F. The location is more convenient from the aspect of instructor availability.

G. The configuration is more permanent than the other two.

H. Administrative and technical cognizance is more effective and can be easily maintained.

3.2.6.2.6 Summary of Functional Requirements for the Optimum CAI System for Flight Controller Application

The following references are to tables and/or figures which summarize the terminal requirements, computer and special system functional requirements, and illustrate the configuration of a typical CAI facility for flight control application.

A. Refer to Table 3.2-31 for a summary of terminal requirements.

B. Refer to Table 3.2-32 for a summary of computer requirements and special functional requirements.

C. Refer to Figure 3.2-79 for a functional system block diagram.

D. Refer to Figure 3.2-80 for an illustration of a typical terminal and associated carrel.

E. Refer to Figure 3.2-81 for an illustration of a typical floor layout for the optimum system.

TABLE 3.2-31

TERMINAL REQUIREMENTS SUMMARY

PARAMETER	COMMENTS
QUANTITY	TOTAL 37, 35 FOR CAI, 2 FOR CURRICULUM DEVELOPMENT
TYPE	DIGITAL
CHARACTER REPERTOIRE	128
CHARACTER SIZE	2
DISPLAY DENSITIES	1000-1200 CHARACTERS (TEXTUAL MODE)
STORAGE REQUIREMENTS	DRUMS OR DELAY LINES
SYSTEM CONFIGURATION	CENTRALIZED CLUSTER
LOCATION	BUILDING 45

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TABLE 3.2-32

COMPUTER AND SYSTEMS REQUIREMENTS SUMMARY

PARAMETER	COMMENTS
MAIN MEMORY	95,000 WORDS (36 BITS NOMINAL) TO 130,000 WORDS RAPID ACCESS CORE MEMORY
MASS STORAGE RANDOM ACCESS	20 MILLION CHARACTERS FOR ON-LINE CURRICULUM, ADMINISTRATION AND MODELING INCLUDED IN THIS ESTIMATE ARE 148,000 WORDS FOR DISPLAY REFRESH IF DRUM STORAGE REQUIRED
TAPE STORAGE	2 TAPE TRANSPORTS
HARD COPY	MANUAL AND AUTOMATIC
PERIPHERAL EQUIPMENT	1 PRINTER, 1 PUNCH, 1 READER, AND 1 TYPEWRITER
WORD SIZE	30 TO 48 BITS
SPEED	2 μSEC OR LESS
CONFIGURATION	CENTRALIZED CURRICULUM CONTROL
LOCATION	BUILDING 45
TYPE OF OPERATION	FULLY DEDICATED TO CAI APPLICATIONS

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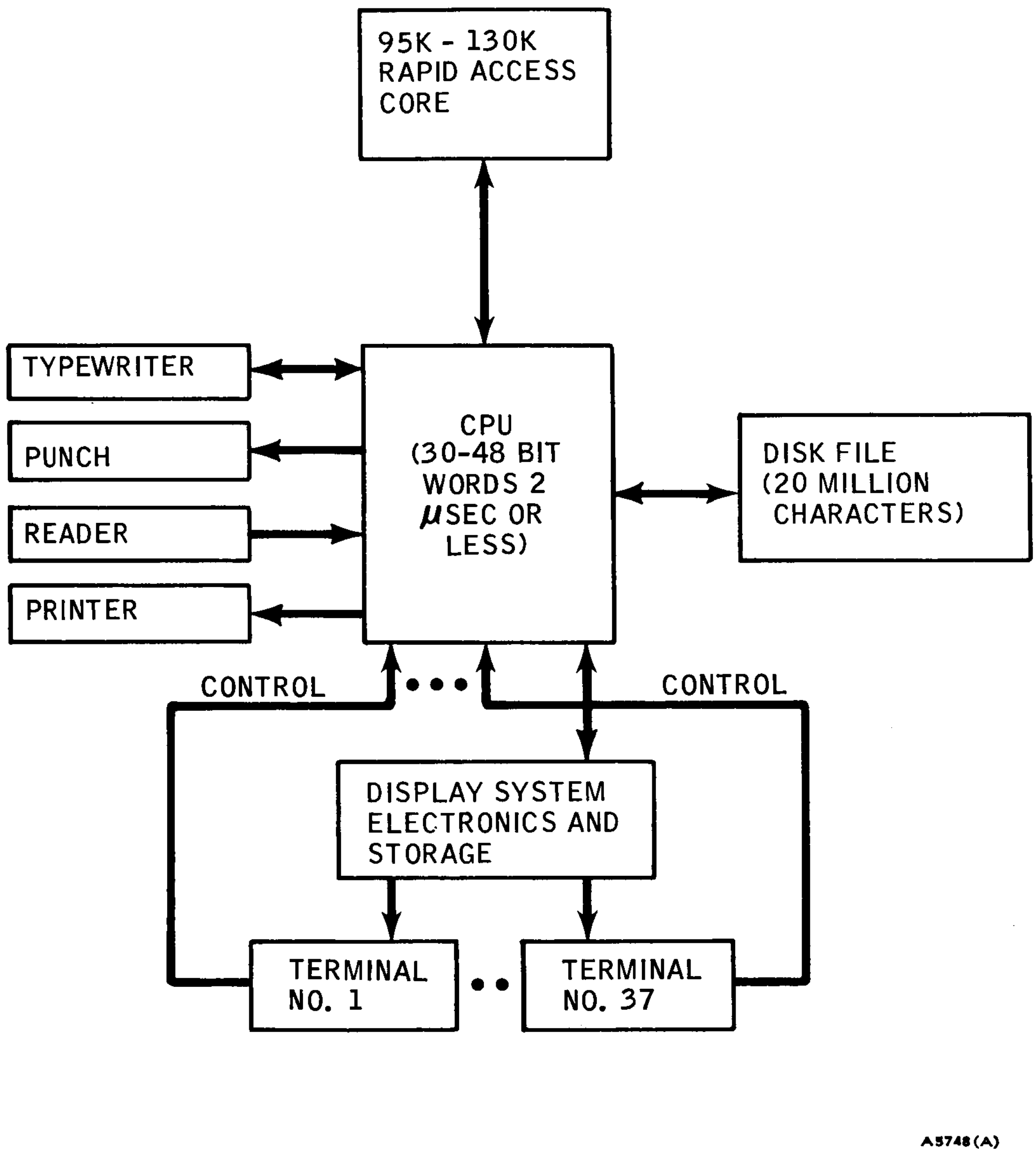

Figure 3.2-79 Functional Block Diagram of Optimum CAI System for Flight Control Applications

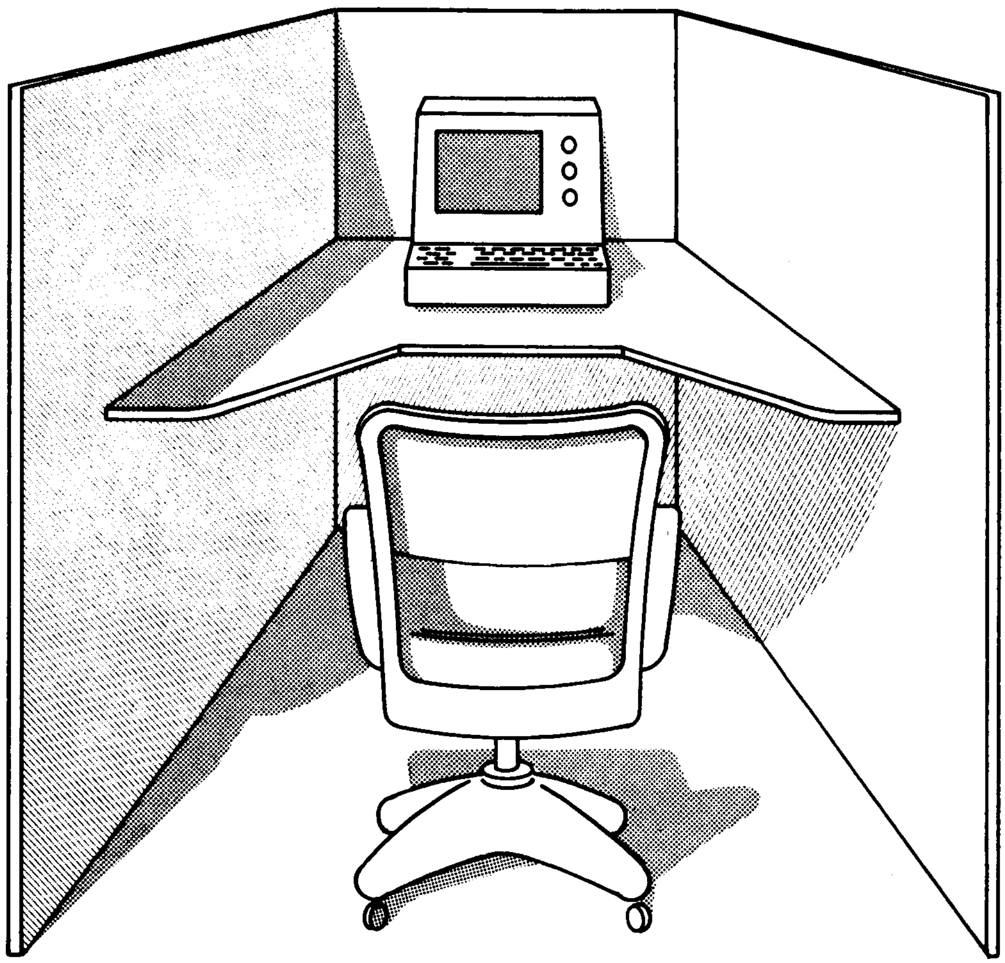

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Figure 3.2-80 Typical Terminal and Carrel for Flight Control CAI Applications

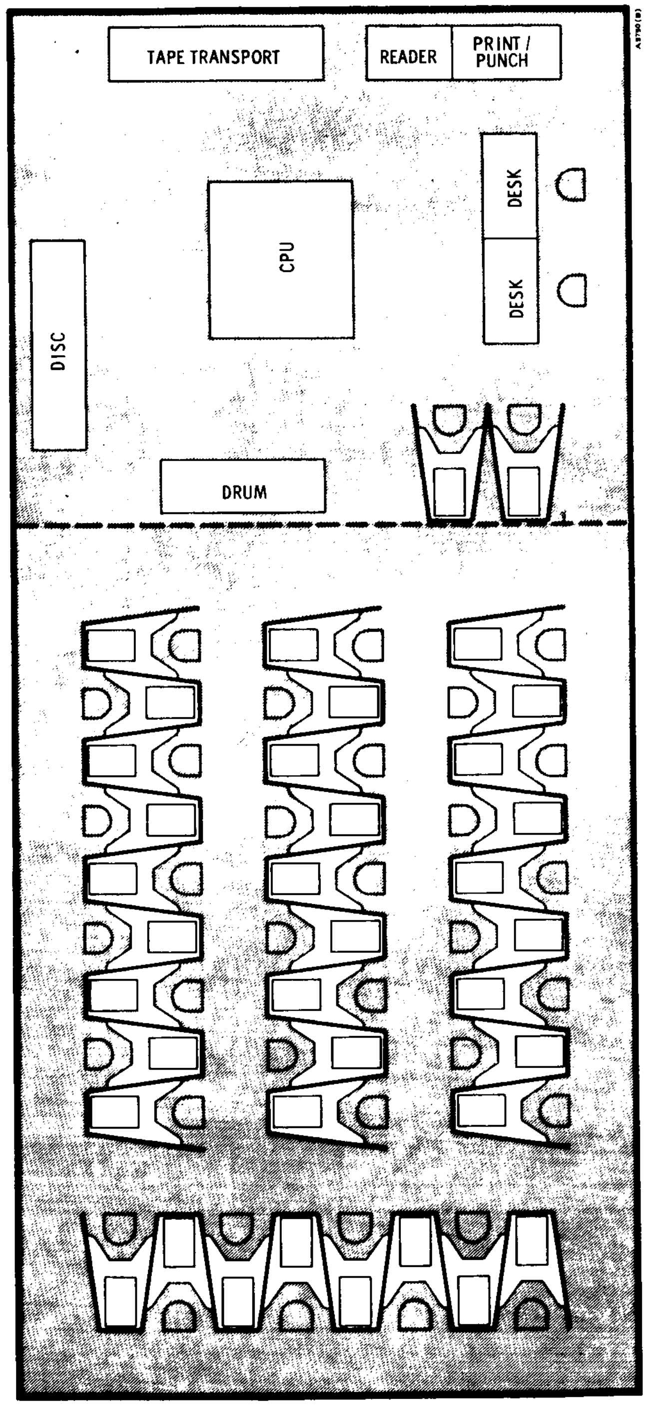

Figure 3.2-81 Typical Floor Plan Layout for Optimum CAI System for Flight Control Applications (Artist's Conception)

3.2.6.3 Initial System Functional Requirements

The following discussion outlines the functional requirements for the initial system and recommends a system configuration which can be used to demonstrate the feasibility of CAI, and provide limited flight control training.

3.2.6.3.1 Functional Requirements

Two categories of requirements exist; viz., (1) those that are a function of curriculum preparation and presentation characteristics, and (2) systems hardware and software requirements.

3.2.6.3.1.1 Curriculum Preparation and Presentation

A. The initial CAI system must provide the capability to store approximately 1 to 2 instructional hours of curricular material with immediate (inherent capability) storage growth to approximately 30 instructional hours. This constitutes an approximation of the number of hours in the Apollo MSFN which could be programmed for CAI. A summary of the subjects to be programmed, and an estimate of the number of hours programmable for CAI is illustrated in Table 3.2-33. The MSFN course was chosen for several reasons; viz., the subject matter experts and lesson programmers for these subjects are located at the MSC; the requirements levied on the MSFN are governed primarily by the MSC, and the equipment is to be located at the MSC.

   Because of apparent subject matter stability, it is suggested that the programming effort proceed in the following order: Orbital Mechanics, G&N Aspects of Space Rendezvous, Tracking, USB Operational Aspects, MCC-H Consoles and Display System, Communications, Telemetry, Remote Site (R/S) Consoles and Displays, Introduction to MSFN, Introduction to Flight Controlling, and Command.

   A gross approximation of the random-access memory required to store the curricular material can be made by using the formula developed in Paragraph 3.2.5.2.2, Computer Requirements.

TABLE 3.2-33

SUMMARY OF MSFN HOURS RECOMMENDED TO BE PROGRAMMED FOR CAI

SUBJECT	TOTAL SUBJECT LENGTH (CONVENTIONAL)	ESTIMATED HOURS FOR CAI	COMMENTS
APOLLO TRACKING	6 HOURS	2 HOURS	TO INCLUDE: A REVIEW OF TRACKING CONCEPTS AND COMPUTING TECHNIQUES AND BASIC ROUTING AND DATA FLOW
APOLLO TELEMETRY NETWORK	5 HOURS	3 HOURS	TO INCLUDE: BASIC TELEMETRY CONCEPTS AND PRINCIPALS, DOWNLINK FORMATS. INTRODUCTION TO TELEMETRY DATA PROCESSING AND COMPRESSION TECHNIQUES AND FAMILIARIZATION WITH INTRA NETWORK TRANSMISSION MEDIA
APOLLO COMMAND NETWORK	7 HOURS	2 HOURS	TO INCLUDE: REVIEW OF TERMS AND COMMAND FUNCTIONS, DATA FLOW AND GENERAL DESCRIPTION OF CARD LOADS AND TYPES
APOLLO MCC-H CONSOLES AND DISPLAY SYSTEM	6 HOURS	4 HOURS	TO INCLUDE: DESCRIPTIONS OF FUNCTIONAL INTERFACES, DATA HANDLING, CONSOLES MODULES, P-TUBE SYSTEM AND DISPLAY SYSTEM.
APOLLO COMMUNICATIONS NETWORK	3 HOURS	2 HOURS	TO INCLUDE: A REVIEW OF "S" HAND REQUIREMENTS AND COMMUNICATIONS CIRCUITS.
APOLLO R/S CONSOLES AND DISPLAY SYSTEM	4 HOURS	2 HOURS	TO INCLUDE: INTRODUCTION TO BASIC EQUIPMENT AND PHYSICAL LAYOUTS, DESCRIPTION OF REMOTE SITE DISPLAY SYSTEM AND CONSOLE
UNIFIED S-BAND	4 HOURS	4 HOURS	TO INCLUDE: GENERAL DESCRIPTION OF USB CONCEPTS, CONFIGURATION TRANSMISSION METHODS AND INTERFACES
INTRODUCTION TO FLIGHT CONTROLLING	8 HOURS	4 HOURS	TO INCLUDE: PROGRAM OBJECTIVES, MISSION OBJECTIVES, NETWORK CONFIGURATION, ORGANIZATIONAL CONSIDERATIONS, AND RESPONSIBILITIES
INTRODUCTION TO MSFN	4 HOURS	1 HOUR	TO INCLUDE: ALL CONVENTIONAL DATA FLOW PATHS, RATES AND GENERAL FORMATS
ORBITAL MECHANICS	3 HOURS	3 HOURS	ENTIRE SUBJECT
G&N ASPECTS OF SPACE RENDEZVOUS	3 HOURS	3 HOURS	ENTIRE SUBJECT

PHO FORM 358 (10-65)

$C_c = IH_{CAI} \times F/H \times C_{\wedge}/F$ (10 instructional hours) x (60 frames/hour) x (500 characters/frame) = 300,000 characters requiring storage.

NOTE:

> It seems reasonable to assume that three different subjects (a total of 10 instructional hours) resident in random-access memory would suffice for interim system operation.

This is a gross estimate of storage requirements for curricular material.

Assuming approximately 10 instructions are required to present each frame, and each instruction requires an average of 6 characters, then the total storage required to store the presentation logic is (10 instructions/frame) x (6 characters/instruction) x (60 frames/hour) x (10 instructional hours) = approximately 36,000 characters.

Thus, the requirement exists for a total random-access storage of approximately 336,000 characters. This is a gross estimate of the total storage requirements for curricular material and presentation logic. The remaining 20 hours could be stored on magnetic tape and placed in random access are required.

NOTE:

> The storage figures may vary from those specified in Subparagraph 3.2.6.2 (Functional Requirements for Optimum CAI System for Flight Controller Application) for two basic reasons; viz., the curricular material is assumed not to be as complex and the presentation techniques and teaching strategies are not as sophisticated.

B. The system must be capable of presenting textual information, block diagrams, and graphic information. These data will be primarily static. The basic core of the curricular material consists of these kinds of data and for this reason it is imperative that the system present the information to the student in that form.

C. The system must be capable of presenting information using the tutorial method with the type of presentations being linear, branching, and combination. As experience is gained and a powerful computational language is obtained, the inquiry method should be utilized and the mathetical technique should be employed.

D. The system must be capable of extracting student events, processing the events, and providing storage for off-line record-keeping. This will provide the instructor and administrator with immediate knowledge of student performance. Consideration should be given to incorporating adaptive sequencing techniques, although this is not a specific requirement.

E. As the system progresses from the initial feasibility demonstration unit to the interim system, the language available for curriculum preparation must be natural and cover the full instructional range from question commands to hard copy. However, initially, the system must also provide the following author capability:

1. Display textual data and examine student.

2. Recognize and process student responses--discrete entries as well as 3- or 4-word constructed responses.

3. Branch or sequence to next frame or back to start of preceding frame.

4. Provide standard computer replies to incorrect student responses.

5. Maintain student records to include: student response times and grading.

6. Selectively erase data from the CRT.

F. The system must provide a response time (elapsed time from student-control initiation to presentation of display data) of less than two seconds. This is consistent with the optimum system requirements.

G. The computer system must be capable of accepting control inputs from a teletype machine or typewriter such that single-entry or constructed-entry responses (initially limited to several words) can be initiated by the student and accepted and processed by the computer.

H. The computer system must be capable of accepting curricular material via punched cards or through terminal control. Terminal input control will provide the capability to experiment with curriculum preparation techniques in addition to editing and modifying.

3.2.6.3.1.2 Systems Hardware and Software Functional Requirements

A. As mentioned in Subparagraph 3.2.6.3.1.1,A, Curriculum Preparation and Presentation, random-access storage is required to maintain storage for approximately 336,000 characters. Because of the limited storage requirements, a magnetic drum is recommended for the initial system. The initial system will require approximately 8 to 10 terminals. This is based on the following rationale and assumptions.

1. The MSFN course is presented to approximately 40 students.

2. As an additional check on the effectiveness and applicability of programmed instruction, the class would be divided into controlled groups, i.e., one-half receiving the MSFN course through conventional techniques while the other half received the course through CAI techniques.

3. Assume 20 students each receive 4 hours of instruction per day*; assume also an 8-hour day and an expanded 10-hour day. Using the formula developed in Subparagraph 3.2.6.2.1 (Terminals):

$$T_r = \frac{T_h}{T_a}$$

$$T_r = \frac{(10)(2)(4)}{8}$$

$$T_r = 10$$

or:

$$T_r = \frac{T_h}{T_a}$$

$$T_r = \frac{(10)(2)(4)}{10}$$

$$T_r = 8$$

*Assume one instructional hour equals one terminal hour.

B. The initial system must provide the capability to display the following:

1. A minimum of 900 characters and symbols in a typewriter mode. This will provide more than adequate density for the displays to be presented.

2. A mixed mode of operation which will provide the capability of providing approximately 150 vectors and 300 to 400 characters and symbols. This will provide the capability of displaying Level 1 diagrams and graphics.

3. The system must provide the capability to display a minimum of 100 dynamic characters updated as the data changes.

C. The terminal is required to provide the following control capability to the computer:

- Upper case alphabet
- Standard teletype or typewriter symbol repertoire
- Input correction and/or editing capability
- System status indicators.

This will provide the capability to construct inputs destined for the computer. In addition, it will provide the basic control capability necessary to operate with the planned curriculum

D. Assuming a main memory organization similar to the optimum system and considering curriculum and presentation logic, approximately 9000 word locations would be required for terminal utilization (assume 8 terminals), approximately 10,000 words (30 to 36 bits/word) for display generation, and another 5000 words for I/O and executive. Thus, a total of 24,000 words of main memory rapid-access core is required.

E. Two tape transports are required to provide off-line mass storage for the remaining 20 hours of curricular material, presentation logic, and utility programs. This provides simultaneous read-write capability.

F. Standard peripheral equipment will be required and will include: card reader, printer, card punch, and typewriter. This will provide the capability to load curricular material via card or typewriter.

G. Based on the requirements specified for the optimum system, it seems reasonable to specify a machine speed of 2 to 4 microseconds with a word size of 30 to 36 bits.

3.2.6.3.2 Initial System Configuration Alternatives

Two primary alternatives should be investigated when considering the initial system configuration which would best satisfy the system requirements; namely, (1) utilize equipments located in Building 422 through system reconfiguration and (2) supply terminal equipment to Building 45 and distribute the curricular material from Buildings 30, 12, or 422.

With the assumption that either configuration can satisfy system requirements, three major factors enter into the final comparisons and recommendations for the initial system. They are: cost, utilization of existing assets, and schedule; subordinate to these are implementation and utilization.

Four alternate configurations exist in which the initial system could function. Each is discussed in the following text.

3.2.6.3.2.1 Alternate Configuration No. 1

In this configuration the curricular material would be generated in Building 30 and transmitted to Building 45 for presentation on classroom terminals. Refer to Figure 3.2-82.

To implement this configuration would require the use of either a mission-dedicated computer (RTCC or CCATS) or the 1218 computer which is utilized approximately 85 percent of the time and, in addition, does not have adequate existing storage facilities. A new data link would be required between buildings necessitating additional terminal equipment. Finally, display storage and terminals would have to be installed in Building 45.

3.2.6.3.2.2 Alternate Configuration No. 2

In this configuration a CPU located in Building 12 generates the curricular material and transmits the data to Building 45 for presentation on classroom terminals. Refer to Figure 3.2-83.

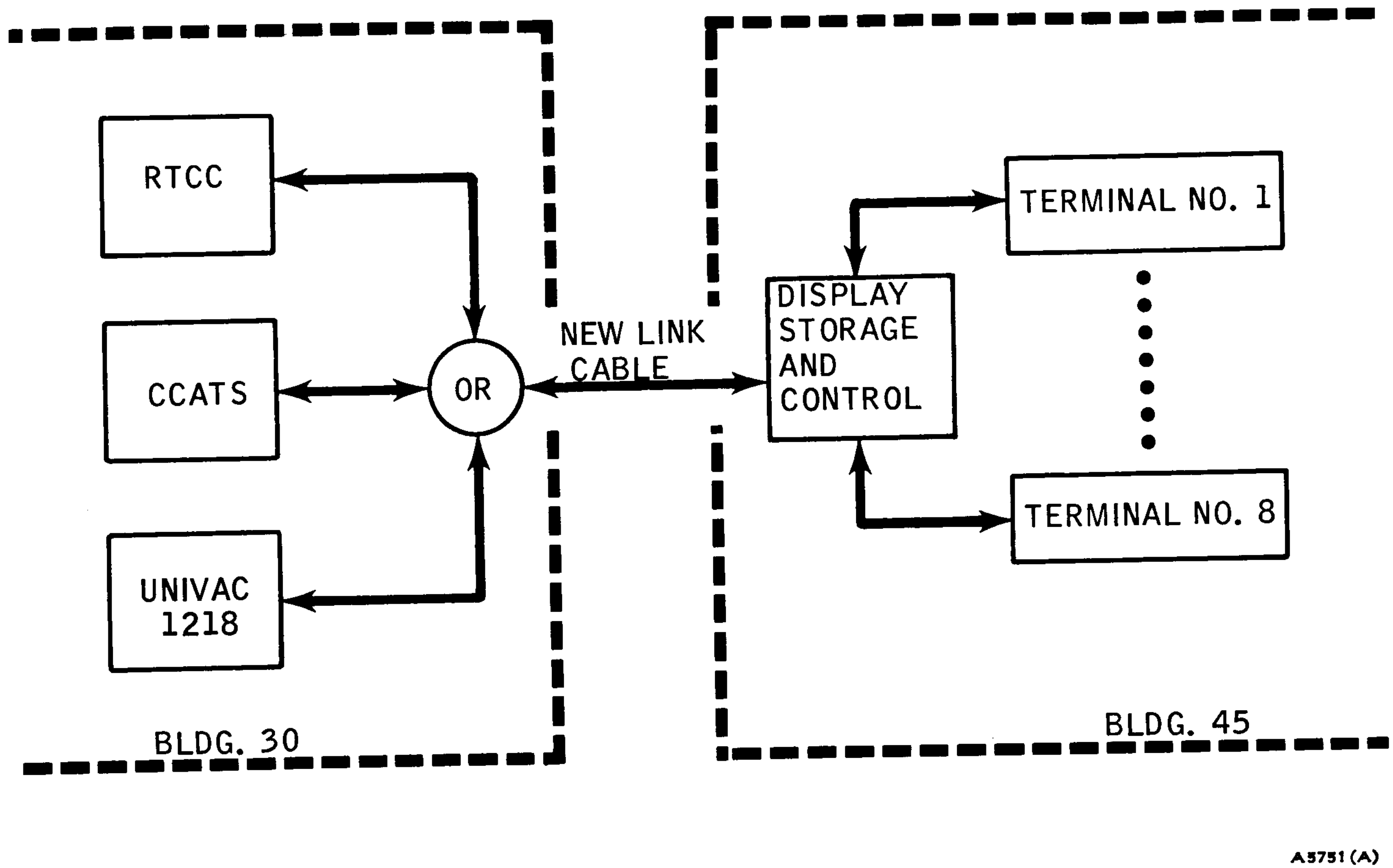

Figure 3.2-82 Alternative 1 Configuration

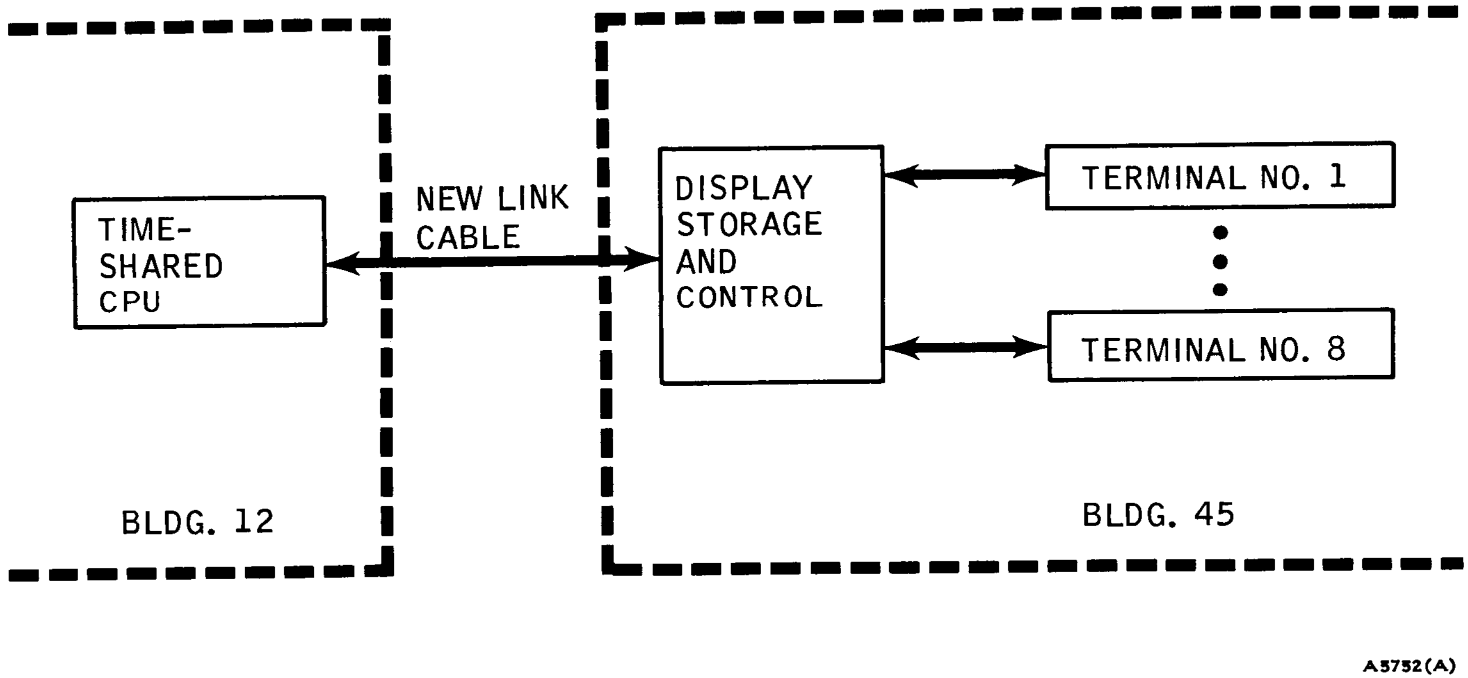

Figure 3.2-83 Alternative 2 Configuration

To implement this configuration would require the development of a time-sharing program. A new transmission cable would be required between the two buildings and, in addition, display storage and terminal equipments would have to be installed in Building 45.

3.2.6.3.2.3 Alternate Configuration No. 3

In this configuration a CPU located in Building 422 would generate the curricular material and relay this data to Building 45 for presentation on classroom terminals. Refer to Figure 3.2-84.

To implement this configuration would require the use of the 494, 360, or 418 computer (this assumes the 418 is to be installed in Building 422 in the immediate future). Either a time-sharing program would have to be written to accommodate CAI or time would have to be scheduled on machines whose schedules are already 90 percent utilized. In addition, new data links between buildings would have to be installed and interface relationships established. Also, display terminals and associated refresh electronics would have to be installed in Building 45.

3.2.6.3.2.4 Alternate Configuration No. 4

In this configuration either the 494, 360 or the 418 computer would generate the curricular material and transfer these data to console CRT's in the ASCA. Refer to Figure 3.2-85. Since appropriate interfaces exist, very little reconfiguration would be required. Because of present loading, the 494 or 360 computers would possibly require a time-sharing program. It is unlikely that schedules would permit CAI utilization throughout the day.

3.2.6.3.3 Conclusions and Recommendations

A. Cost. The first three alternate configurations will incur significant costs in:

- Establishing interfaces
- Program development
- Equipment procurement
- System checkout.

The cost to implement Alternate Configuration No. 4 will consist mainly of equipment reconfiguration.

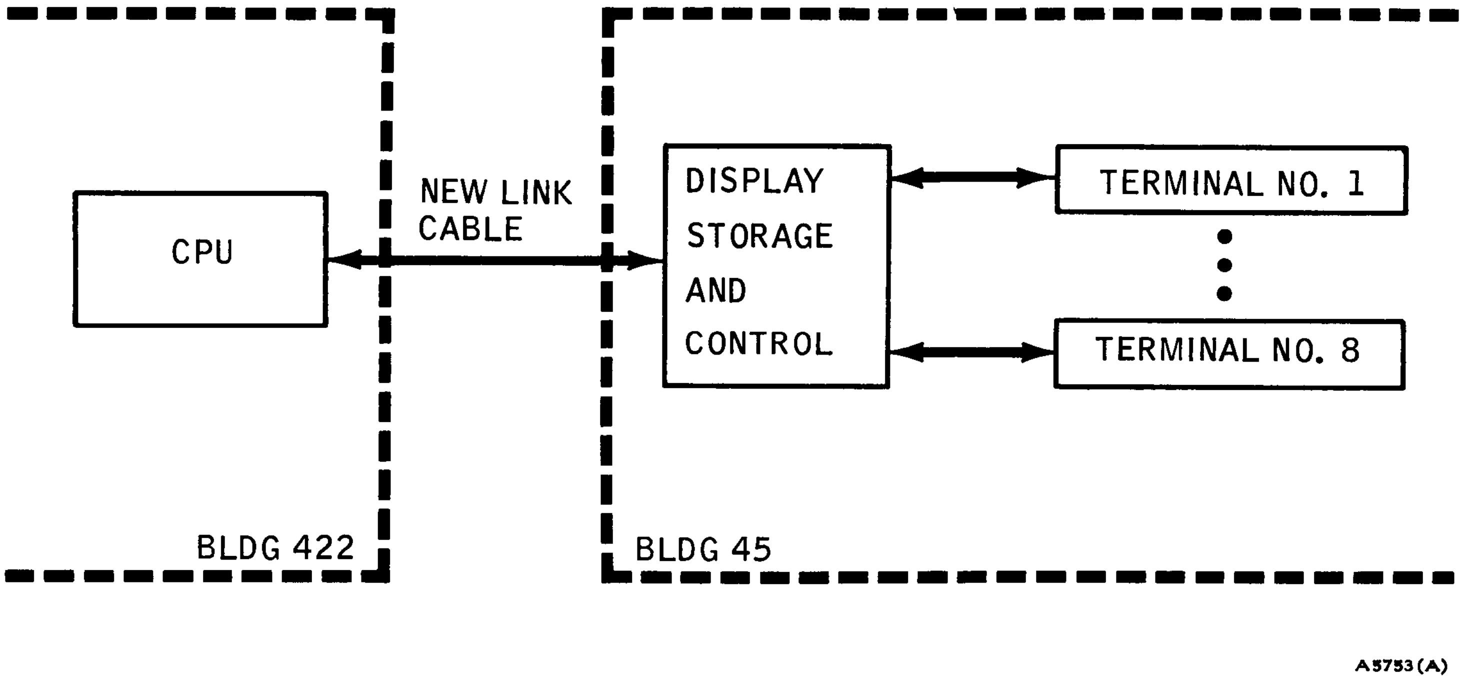

Figure 3.2-84 Alternate 3 Configuration

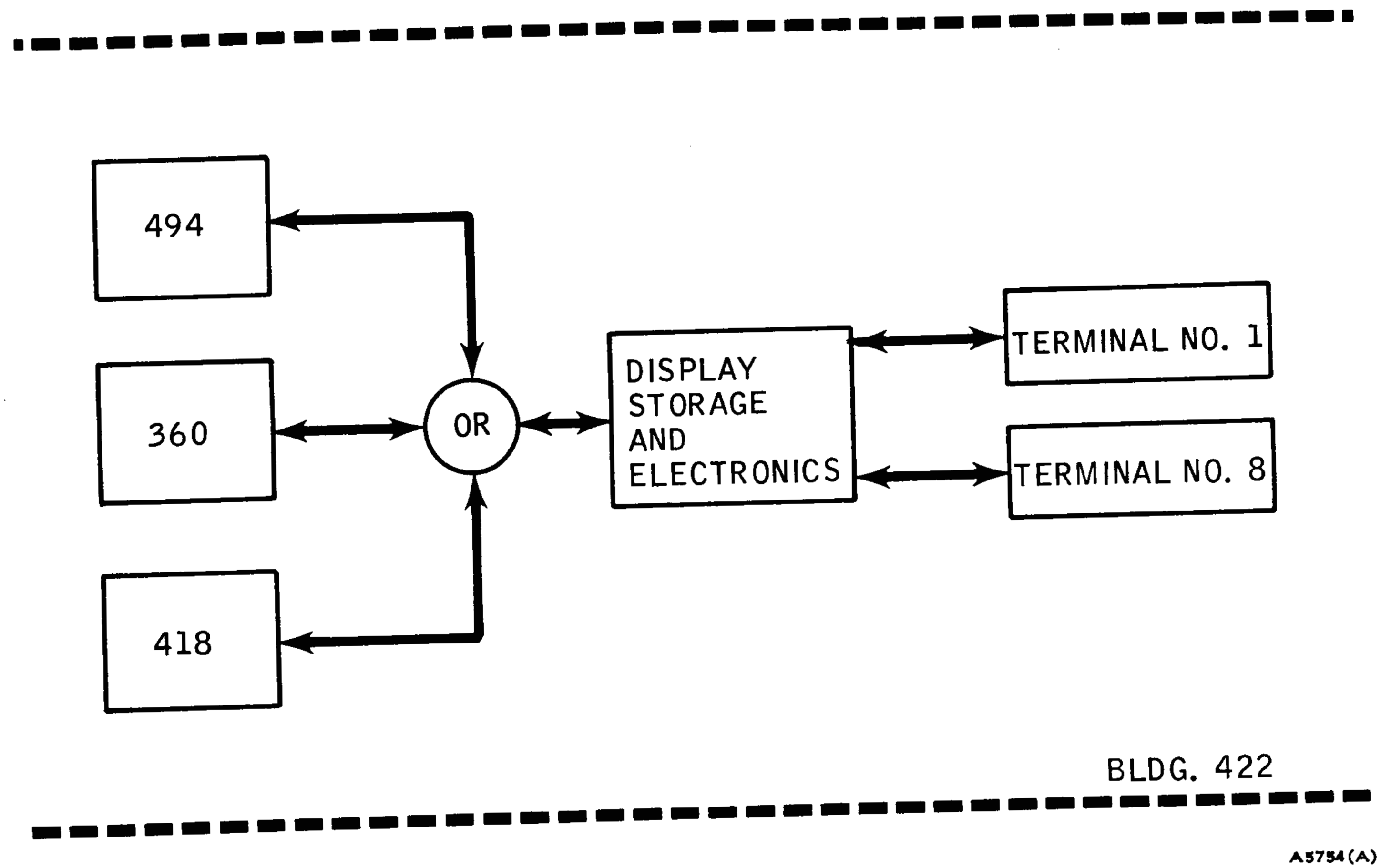

Figure 3.2-85 Alternative 4 Configuration

B. Utilization of Existing Assets. The first three alternate configurations make use of existing computer assets; however, interface and terminal devices would have to be purchased. The only items that would have to be leased or purchased for Alternate Configuration No. 4 are additional ASR's and a tape transport.

C. Schedule (Implementation and Utilization). The first three alternate configurations will require extensive software and hardware implementation. With No. 1 and No. 3, utilization schedules would require strict control, since the CPU's selected are approaching capacity. Alternate Configuration No. 2 would be excellent since the program and utilizations could be time shared.

Alternate Configuration No. 4 will require very little implementation with the exception of extensive machine software programming. Scheduling for utilization of equipment may prove a problem for several simulation-dedicated interfaces and equipments which would be required for the application.

Based on the preceding subparagraphs, Alternate Configuration No. 4 is recommended as the configuration best suited for the initial and interim system design.

Because of existing computer utilization loading of the 494 and 360 computers, it is further recommended that the 418 computer be used as the central processing unit and existing CRT's and ASR's in the ASCA be utilized as display terminals. This basic configuration will fulfill all the initial systems functional requirements in the most cost-effective manner.

Figure 3.2-86 illustrates the recommended initial system configuration. The random-access drum associated with the 418 computer has a capacity of 250,000 18-bit words or 750,000 characters. There are 32,000 18-bit words of rapid-access memory to store the curriculum for each terminal. The channels can be strapped to provide a 30-bit output to the SMCVG via the switch buffer (no interface modifications are required since logic levels and bit patterns are compatible). From the SMCVG, the analog signals (representing the curricular material and positioning data) are applied to the CRT electronics. This configuration would require additional cabling between the 418 computer and the switch buffer.

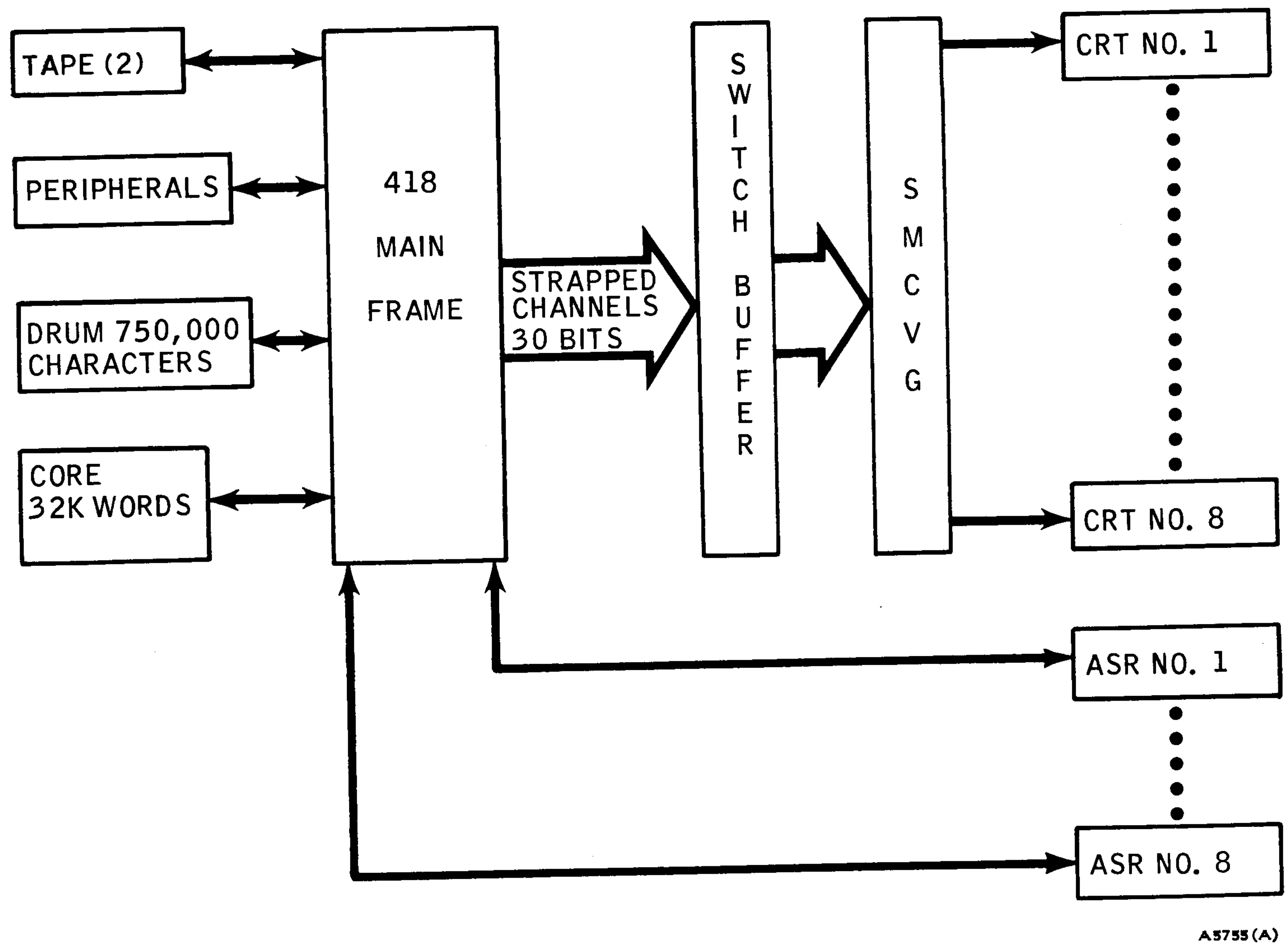

Figure 3.2-86 Recommended Initial System Configuration

SECTION 4

INITIAL SYSTEM PROCEDURES, TECHNIQUES, AND OPERATIONAL CONSTRAINTS

4.1 GENERAL

Specific procedures, techniques, and operational constraints for the initial CAI system must be developed as a result of initial system constraints (including those constraints imposed upon the system by the author language). Techniques will be developed, where possible, to alleviate system constraints. System utilization will be addressed as follows: (1) curriculum planning and preparation, (2) programming of course material and the input of material to the system, and (3) user operational techniques (terminal operations).

4.2 ASSUMPTIONS

Prior to discussing the utilization of the initial CAI system, it is necessary to assume the following specific curriculum and system characteristics and constraints.

A. The initial CAI system will be the system recommended in Subparagraph 3.2.6.3, Initial System Functional Requirements, and will possess all the characteristics as specified therein.

B. Student responses will be generated from a typewriter form of keyboard, allowing alphanumeric and limited special characters to be used for discrete or constructed responses.

C. A user-oriented author language (or equivalent) will be compatible with the recommended system. Computational capability will not be provided.

D. The initial curriculum will be limited to introductory courses such as "Introduction to Flight Control" and "Apollo Tracking and Trajectory." The static portions of the remainder of the MSFN course will also be programmed.

E. The curricular material presented will require the presentation of graphics and flow charts. No dynamic models will be required.

F. The student population will consist of approximately 20 students.

G. The schedule can be expanded to 10 hours/day.

H. The teaching approach will be tutorial and a combination of linear and branching presentation will be used.

I. The majority of the subjects will be presented by the computer system and no outside references and very few handouts will be necessary.

J. The system will be required to record and process student records such as student responses, response latencies, grade results, and length of time required to present a course.

K. The course author or instructor will prepare the bulk of the program for computer input.

With these assumed system characteristics and constraints in mind, the procedures, techniques, and operational constraints are discussed in the following paragraphs.

4.3 SYSTEM UTILIZATION TECHNIQUES AND PROCEDURES

4.3.1 Curriculum Planning and Preparation

The following curriculum planning and preparation procedures are recommended for use with the initial system. Figure 4.3-1 illustrates the basic flow of information suggested for the initial system. Extensive modification to this procedure will be made as additional experience is gained with materials preparation.

The procedures are discussed in the following text with reference made to the appropriate blocks.

4.3.1.1 Curriculum (Block 1)

In general, the curriculum will be affected by : system modifications, flight control requirements, and mission constraints. For the MSFN course, information will be derived from: (1) mission specific trajectory studies, (2) network operations directives, (3) RTCC data processing requirements (PHO-TR165, Real-Time Computer Program Requirements for Apollo C1-B), (4) CCATS processing requirements (PHO-TR231, CCATS Operational Computer Program Requirements), and (5) FCDAR and SR's for console and display configuration requirements.

These data will be analyzed and organized by the instructor with special emphasis placed on subject matter stability. Initially, only that material deemed static will "flow" into Block 2.

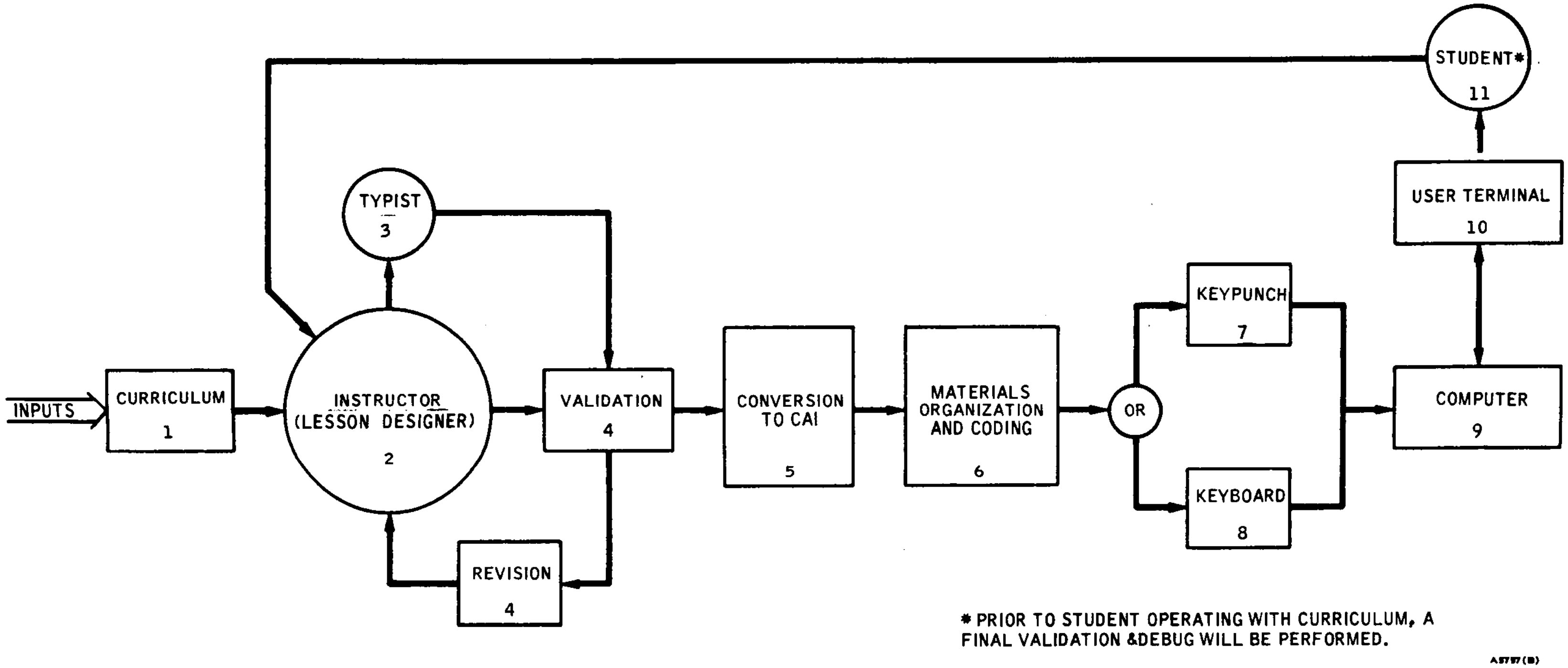

Figure 4.3-1 System Procedural Flow for the Initial System

4.3.1.2 Instructor/Lesson Designer (Block 2)

The following functions will be performed in this block and are listed in the order in which they should be performed.

A. Select the subject to be programmed

B. Specify the general training objectives (this takes into account broad training objectives, trainee characteristics, and training and the environment)

C. Specify the specific training objectives and terminal behavior (performance)

D. Specify the initial behavior of the student

E. Organize the course material depending on the discriminations that the learner must make before final behavior is attained

F. Develop an examination (criterion tests) to determine whether terminal behavior has been obtained

G. Construct the program. This will include: outlining the program (list concepts), determining the format (to be written as if a program test were the final product); writing the frames (as each frame is written, consideration should be given to: Alternate correct answers, computer replies, relative positioning of data for display, alternate questioning methods, whether text is to be displayed or a question asked, unanticipated responses, and where program will branch upon completion of a frame. These items will be contained on different development sheets but will be keyed to the frame with which it is associated); and finally, testing short segments of the program as they are written.

NOTE: As additional experience is gained, this approach should be modified to eliminate frame development by replacing it with program flow charting technique for developing the various teaching strategies.

4.3.1.3 Typist (Block 3)

This function will provide the rough draft copies of each frame. It is recommended that frames be presented on individual pages backed up by supporting CAI notes and a frame comment sheet for use during evaluation.

4.3.1.4 Validation/Revision (Block 4)

A. Group test the first rough draft of the completed program by using from 5 to 10 test subjects from flight control.

B. Revise the program based on testing results. (Rewrite questionable frames.)

C. Upon completion (100/90* or better), a final rough draft will be provided for conversion to CAI.

4.3.1.5 Conversion to CAI (Block 5)

The following functions will be performed in this block:

A. Review the rough draft, including frames and CAI support material.

B. Commence developing HOW the material is to be presented, WHERE the data is to be presented (relative position on CRT), and WHEN the data is to be presented (sequencing). In essence, the HOW is the teaching strategy and the WHERE and WHEN are the presentation methods. Examples of what must be included are: (1) whether data is a textual statement or question; (2) how much of the text is to appear on the CRT with the initial input; (3) relative positioning of graphs or block diagrams with textual data; (4) if data is to be erased and replaced with new data, indicate the erasure and the data to replace the old information; (5) when presenting question--identify it as such; when specifying answers--ensure that all possible answers are included; (6) if wrong response is received, consider the various courses of action to take and specify the appropriate action(s), e.g., branch back to start of frame--re-phrase question and display to student or display correct answer to student; (7) specify at which points in the course flow that student actions are to be recorded, e.g., each sequence through a particular frame; and (8) specify the student response times and length of time data are to remain on the CRT.

After this process is performed the data is relayed to Block 6.

*100/90 is a measurement of the effectiveness of the course and means that 100 percent of the students understood 90 percent of the material.

4.3.1.6 Materials Organization and Coding (Block 6)

The following functions will be performed in this block:

A. Labeling of each concept or program entry point with a mnemonic code, e.g., a code must be provided if a frame is to be entered or a question within that frame can be accessed by specifying a branch to that question.

B. Development of graphs and textual data. This will include the following: coding of graphic data to ensure proper positioning (this will require specification of X and Y coordinates); segregation of data into statements and questions, and adding appropriate author language instructions; (if a procedure or language is used similar to the INFORM then several types of coding sheets must be completed).

C. Provide completed code sheets to Block 7 or Block 8.

4.3.1.7 Keypunch or Keyboard (Block 7 or Block 8)

The following function will be performed in this block: Enter the textual and graphic data into the computer in conjunction with the presentation logic. If keypunch is used, a permanent record will be provided.

4.3.1.8 Computer, User Terminal and Student (Blocks 9, 10 and 11)

The following functions will be performed in this block:

A. Presentation of curricular material to the student or to the instructor for validation.

B. Receiving and process responses from the user.

4.3.1.9 Summary

In summary, the procedural aspects of program application may appear to be trivial. However, they are not. Proper attention must be given to the mechanics of programming. Several significant points about programming have been observed during the study and are as noted:

A. Programming takes time. The majority of time required to develop a program is not writing time, but rather that of planning and testing.

B. Considerable planning of objectives and course content will have to be done before one item is written.

C. Each program will usually be tested and revised a minimum of three times prior to finalization.

D. The writing of the program is somewhat of a creative task requiring considerable concentration.

As is evident, the mechanics can be small, almost petty; but they are extremely important. They can hinder the application of programmed learning if not recognized and attended to.

There is one distinction between the applicability and the application of programming which emerges from the points noted here. Applicability is a programming problem in which advice can be solicited from consultants and professional programmers. Application is primarily a management function. Through its handling of the problems of application, management can, in the final analysis, determine the effectiveness of the programming effort.

4.3.2 Programming of Material and Input to the System

The prepared curriculum will have the author repertoire applied to it to present the text and graphics, recognize and process student responses, and determine and present the appropriate computer reply to the student.'

Presentation of textual data must be programmed such that the capacity of the display is not exceeded at any time. The display surface has the capability of presenting a maximum of 2595 small (0.28-inch x 0.14-inch) characters in 18 rows of 36 characters per row. This is in the typewriter mode only. As a precautionary measure (experience indicates that this density cannot be attained), the display density should not exceed 1500 characters in the typewriter mode. The position of the text on the display must be specified.

Graphics must be presented by the generation of vectors on the display screen. The vector components may be generated at <u>any angle</u> in stroke <u>sizes of 0.5 inch</u>. These must be programmed so as to prevent the graphic frame exceeding the 10-inch x 10-inch display area. The <u>exact</u> position of the graphic on the display must be specified.

Combinations of graphics and text may be presented as long as they are contained within the 10-inch x 10-inch usable display area or do not exceed the display buffer, e.g., the more complex the mixture of data, the more core required to present the data; therefore, considerably less than 2592 characters are available in this mode.

A requirement for 100 dynamic characters and symbols has been specified; therefore, consideration should be given to this when working with dynamic computer responses or display data that must be dynamic.

Since selected areas of the display may be erased and new information displayed, the curriculum should be programmed with caution to prevent erasure of the wrong data or presentation of new data in the wrong area.

Although the application of the author language presentation repertoire to the curriculum frames can be done easily by the instructor, it may be desirable to allow a technician to prepare the graphics for display since they are time consuming.

The program must include instructions to the computer to allow the recording and processing of data desired for student responses (responses, response latencies, time required for the curriculum presentation, percent of correct answers, etc.). This information should be carefully programmed to ensure the computer of the correct instructions for processing the correct records at the proper time. The program should include in student records the place in the lesson of each student so that the program may present the next frame when the student next signs on for continuation of the course.

If branching is used, ensure that conditions for branching are specified and the "branch to" location identified.

Sufficient time should be allowed for the student to respond before he is "timed out." This time must be specified by the author.

The curricular program may either be keypunched and input to the computer by cards or it may be manually input from the terminal.

4.3.3 Terminal Operations

The terminal of the initial system may be utilized by the instructor for curriculum input to the system and program modification or testing, as well as by the student.

Each user must identify himself with sign-on information, such as name or student number and course name, in order that the system will be able to determine whether it is to receive data from an author or present curriculum to a student. The system will automatically begin the curriculum at the proper place, based on where the student ended his previous lesson.

As the number of terminals is limited, rigid student scheduling must be enforced for terminal usage. Program input, modification, or testing requiring use of a terminal should be scheduled at times other than student utilization hours.

User inputs to the system will be through utilization of a typewriter keyboard.

Student responses will be limited to discrete entries or simple constructed responses consisting of four words or less and will be formed through a series of key depressions representing characters and symbols.

The initial system will not allow the student to request or retrieve data from the computer.

The initial system will not provide for computations performed from the terminal by either instructor or student.

SECTION 5

COST EFFECTIVENESS ANALYSIS

5.1 INSTRUCTIONAL SYSTEM DEVELOPMENT PROCEDURES

The purpose of this discussion is to compare and contrast those points in the three instructional media, i.e., conventional instruction, programmed text, and CAI which have an impact on the cost of instruction.

The major elements which affect the overall development of the instructional system are: (1) course planning, (2) curriculum preparation, (3) curriculum presentation, and (4) curriculum modification.

Each medium has been compared with these common criteria and their manhour/cost relationships established.

Although the equations presented in the text are similar, the derivation of the terms is significantly different. This is largely due to the approach taken by the media in conforming to the training development elements and the relative level of adherence to these factors.

The study did not uncover statistical data which would indicate the manhour/cost relationships for each medium when applied to each major element. For this reason, the parameters that influence costs in each medium have been determined and are provided in subsequent paragraphs.

5.1.1 Course Planning

Specification of job requirements, analysis of the overall training requirements, and specification of detailed training objectives are the major steps of course planning.

The detailed tasks that must be performed in each step are as follows:

A. Specification of Job Requirements

- Specification of duties and responsibilities.
- Specification of task performance procedures.
- Specification of standards for performance.
- Specification of task performance conditions.

B. Analysis of Generic Training Requirements

- Determination of attitudes and qualifications of trainees, e.g., academic background, work experience, age and level of motivation.

- Study of deficiencies in existing training.

- Specification of general scope or broad objectives of the training programs.

C. Specification of Detailed Training Objectives

- Specification of objectives, which will produce the desired terminal behavior. This is the same or nearly the same as the specific job requirements. When detailing the specific training objectives, the abilities, i.e., skills and knowledge required must be specified and the terminal behavior achievement criteria must be specified, i.e., what the student will be doing when demonstrating proficiency, under what conditions the behavior will occur and the acceptable level of performance.

Each medium is discussed in terms of relative adherence to these tasks. The basic parameters affecting cost are outlined and an equation developed to describe their basic relationships.

5.1.1.1 Course Planning for Conventional Instruction

5.1.1.1.1 General

In conventional instruction, reliance is often placed on the instructor to perform the course planning function and more specifically to specify the detailed job requirements and detailed training objectives. In many cases, the instructor relies on outlines and assumes that it is unnecessary to document the instructional details. In such cases, there may not be any course documentation.

Often the instructor either completely ignores the training objectives and desired terminal behavior or, worse yet, writes poorly stated objectives which produce the wrong terminal behavior. Emphasis on course planning is often lacking in conventional instruction.

The parameters that influence course planning costs have been determined and are provided in the following text. Since a direct relationship exists between planning manhours and planning costs, the discussion is oriented toward manhours.

5.1.1.1.2 Planning Costs

Planning costs (C_{plan}) are equal to the number of instructor manhours expended during the course planning phase (MH_i) plus typist manhours expended (MH_{typ}) plus other costs (OC).* That is:

$$\boxed{C_{plan} = MH_i + MH_{typ} + OC}$$

The time required to sepcify each requirement or objective varies dependent upon the complexity of the terminal behavior.

This is a function of the complexity of the facts and concepts that must be learned. In other words, the fact that one objective requires a given length of time to develop does not imply that development of subsequent objectives will require the same length of time.

5.1.1.2 Course Planning for Programmed Text

The same planning/cost relationships developed for conventional instruction apply to programmed text efforts. Although nomenclature may change, e.g., the instructor may be known as subject matter expert, the same function must be performed.

As previously mentioned, the number of hours required for course planning depends primarily upon the nature and complexity of the material. A project that is primarily research oriented will ordinarily require more planning time than will an operationally oriented training program.

A subject that has never been taught before or that is being developed in an area where the present training materials or methods are very poorly detailed will, of course, require more time.

The most significant point is that programmed instruction requires a definition of precise objectives and measurable statements. Whenever possible these objectives must be specified in terms of observable behavior. As an example: the training objectives for a course on gyroscopes, when established in terms of observable terminal behavior, could

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*Other costs (OC) will be used throughout the costing sections as a term to include costs other than manhour expenditures, such as: materials, reproduction, per diem, travel, classroom facilities, and equipment.

be stated as: "The student will be able to independently remove and install the Titan III Flight Control System gyros. Using available test equipment, he could check out the gyros and identify those which are either manfunctioning or out of tolerance. This must be performed within a 30 minute period." Such specific description of terminal behavior leads to an objective evaluation system.

The objectives must be written in terms of what the student will be doing when he is demonstrating proficiency, under what conditions the behavior will occur, and what level of performance is acceptable (MAGER R. F, "Preparing Objectives for Programmed Instruction," 1962).

The best statement of an objective is the one that minimizes the number of possible alternatives to reaching the desired goal.

Listed in Table 5.1-1 are typical course planning figures that were collected during the study. These figures are dependent on the complexity of the terminal behavior and are therefore gross estimates which are indicative of the wide variations that exist among programming efforts.

It is worthwhile at this point to note the problems encountered in one particular effort. "Poorly established objectives on one program cost us at least one rewrite which would not have been necessary had the objectives been clearly and concisely developed in the first place" (Walker, R. W., "Empirical Data on 28 Tasks in the Preparation of Programs").

It can be concluded that course planning, and specifically the development of terminal behavior, is a complex, time-consuming, and critical task.

5.1.1.3 Course Planning for CAI

The same planning costs relationships developed for conventional instruction apply to CAI. The discussion of course planning in Subparagraph 5.1.1.2 is applicable to CAI and therefore is not discussed.

5.1.2 Curriculum Preparation

Six major steps must be performed in the curriculum preparation cycle; viz., (1) determination and specification of lesson objectives, (2) lesson sequencing, (3) organization and preparation of detailed instructional content, (4) developmental testing and validation of

TABLE 5.1-1

TYPICAL COURSE PLANNING FIGURES

TOTAL COURSE PLANNING TIME	COMMENTS
Approximately 1/2 of time consumed preparing objectives.	This value resulted from a telephone conversation with personnel with the Communicable Disease Center, Atlanta, Georgia. Their efforts are oriented primarily toward the development of programs utilizing the mathetics technique. Although total course length was not mentioned, this was translated into 6 to 9 months.
5 days	This was extracted from an article by R. W. Walker of the Martin Company, Denver, Colorado. The program consists of 180 frames on "The Use of Logic Symbols." The entire program was developed in 18 days.
17 days	This was extracted from information provided by M. Larue of the Martin Company, Orlando, Florida. The program consists of 450 frames and was developed in 120 days.
Approximately 10% to 20% of total time required to develop objectives.	This value resulted from a telephone conversation with personnel from the E. I. du Pont de Nemours & Co., who have developed more than 80 programs for personnel with an average of an 11th grade education.

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instructional materials, (5) development of criterion tests, and (6) testing and evaluation of completed material.

The items that must be performed in each of these steps are identified and each instructional medium is discussed in terms of these tasks.

A. Determination and Specification of Lesson Objectives. This consists of breaking down the training objectives and terminal behavior attributable to each particular lesson or portion (i.e., class or subject) of the training curriculum.

B. Lesson Sequencing. This is the development of the lesson strategy or approach to the subject and the arrangement of lessons in the sequence most effective for learning.

C. Organization and Preparation of Detailed Instructional Content. This consists of researching the subject and gathering data pertinent to the subject. The facts and concepts to be presented within each lesson to achieve the lesson objectives (and hence, the terminal behavior) must be determined.

   At this point the specification of the abilities and knowledge of personnel who will take the training will help determine the training content.

D. Development of Criterion Tests. This consists of developing tests to determine if the student has attained the desired terminal behavior. These tests are not designed for student grading, but rather to extract measurable behavioral characteristics. Generally, criterion test items require a constructed response from the student which can be used to measure his acquisition of learning and to determine if the objectives are being met.

E. Developmental Testing of Materials. This consists of testing instructional materials as they are prepared to determine their effectiveness, e.g. in conventional instruction it could easily be a complex block diagram or circuit schematic while in programmed text it will, more than likely, be several programmed frames. The material is then revised until it is of an acceptable standard.

F. Testing and Evaluation of Completed Material. This consists of validating the complete package and revising the material, if necessary, based on the results of the criterion tests.

5.1.2.1 Curriculum Preparation for Conventional Instruction

5.1.2.1.1 General

Lesson objectives are generally performed on a superficial level similar to the extent to which course planning is performed for conventional instruction.

Lesson sequencing is performed more from an outlining method rather than from a behavioral standpoint which considers the most effective course sequence. Normally, the convenience of the instructor sequencing the material is a prime consideration in determining effectivity of the sequence.

The detailed course contents are formulated by collecting the material, writing a course outline, and preparing teaching notes and handouts. Generally, the student gets information, which has been neatly bound into a lesson handout. The instructor retains the specific information in the form of notes and more often in his head.

Testing of materials during conventional instruction development seems to be non-existent. Occasionally, an instructor will attempt to validate a handout; however, this normally consists of a cursory examination of the contents and a general critique by several of his fellow instructors.

Criterion testing and testing evaluation of completed material are virtually non-existent.

The preceding critique of how well conventional instructional practices adhere to the ideal guidelines specified in Paragraph 5.1.2, Curriculum Preparation, has not singled out a specific training group. However, most organizations using conventional instruction techniques do not even provide minimal adherence to these basic yet extremely important guidelines.

5.1.2.1.2 Curriculum Preparation Costs

Curriculum preparation costs (C_{prep}) are equal to the number of instructor manhours expended during curriculum preparation (MH_i) plus technician manhours expended (MH_{tech}) plus typist manhours expended (MH_{typ}) plus other costs (OC). That is:

$$\boxed{C_{prep} = MH_i + MH_{tech} + MH_{typ} + OC.}$$

MH_i is a function of the total number of instructor hours required to (1) specify lesson objectives, (2) develop lesson sequences, (3) prepare instructional content, (4) develop criterion tests, (5) test materials, and (6) evaluate completed materials.

$$C_{prep} = MH_i + MH_{tech} + MH_{typ} + OC$$

$$C_{prep} = T_c \times T_{conv} + T_c \times T_{tech} + T_c \times T_{typ} + OC$$

Factoring:

$$C_{prep} = T_c\ (T_{conv} + T_{tech} + T_{typ}) + OC$$

Where:

T_c = Number of hours of conventional instruction

T_{conv} = Time required for instructor to prepare one hour of conventional instruction

T_{tech} = Time required for technical support, e.g., illustrators, draftsmen, proof-readers, etc., per hour of instruction

T_{typ} = Time required for typing support per hour of instruction

OC = Other Costs (materials, reproduction, travel)

From the foregoing discussion two things should be noted, viz.,

A. The number of manhours required for the instructor can, to some extent, be quantified by personnel experienced with the instructional process. However, the number of hours required to state objectives would be purely subjective since it is a function of the complexity of the terminal behavior.

B. Although cost figures are not available, curriculum preparation appears less costly for conventional instruction than it does for programmed text or CAI. Since objectives are normally not specified and testing is not performed, the number of hours expended is essentially equal to the number of hours used in sequencing material and organizing content.

5.1.2.2 Curriculum Preparation for Programmed Text

5.1.2.2.1 General

When properly performed, programmed text curriculum preparation is a time-consuming and complex effort requiring an instructor or subject-matter expert who exhibits a high degree of creativity.

Lesson objectives must be outlined in great detail to ensure proper terminal behavior. This process is similar to specification of training objectives during the course planning phase.

Lesson sequencing is a time consuming task. When teaching facts, concepts, or attitudes, each stimulus or frame must be in its proper place.

Preparation of detailed instructional content consists of writing and editing each frame of information, developing and preparing illustrations, specifying responses, typing the textual material, and reproducing the texts.

Each frame or small group of frames is checked and revised as necessary. Criterion tests are written and evaluated, and finally, testing of completed materials is performed.

5.1.2.2.2 Curriculum Preparation Costs

The curriculum preparation cost relationship for programmed text is similar to that for conventional instruction, the significant difference being the relative performance of details required for preparation. Thus:

$$\boxed{C_{prep} = MH_i + MH_{tech} + MH_{typ} + OC.}$$

If the length of the course (in conventional hours) is known or can be estimated, the following relationship exists which could be used to estimate curriculum preparation manhours.

$$C_{prep} = (T_c \times R_{p/c})\ T_{pi} + (T_c \times R_{p/c}) \times Tech + (T_c \times R_{p/c}) \times T_{typ} + OC$$

Factoring:

$$C_{prep} = T_c \times R_{p/c}(T_{pi} + T_{typ} + T_{tech}) + OC$$

Where:

T_c = Number of hours of conventional instruction.

$R_{p/c}$ = Ratio of programmed instruction (mean student completion time) to classroom time.

T_{pi} = Time required for instructor to develop one hour of programmed instruction where an hour is a group-paced linear program function.

T_{typ} = Time required for typing support per hour of instruction.

T_{tech} = Time required for technical support, e.g., illustrators, draftsmen, proof-readers, etc., per hour of instruction.

OC = Other costs (materials, reproduction).

$R_{p/c}$, which is a ratio of programmed instruction time to classroom time, is expressed in Table 5.1-2 as an overall percentage savings. The significant points are the wide variation and the fact that all show an overall decrease in presentation line. This ratio is required in the curriculum preparation calculations to estimate the number of programmed instructional hours which are used in calculating MH_i. An example is provided for clarification. Assume a course is taught by conventional procedures in 10 hours and further assume that programmed instruction will reduce this time by 25 percent. Thus, $R_{p/c}$ equals .75. The hours of programmed instruction that result are: (10) x .75 = 7.5 hours. This, then, forms the basis for calculating MH_i.

T_{pi} is the time required for an instructor to develop one hour of programmed instruction. Typical figures are illustrated in Table 5.1-3 and are expressed as a ratio of the average number of frames/instructional hour, and the number of frames prepared per instructor hour. Therefore, if an instructor can prepare one frame/hour and there are 60 frames/instructional hour, the number of hours required by the instructor to prepare one instructional hour of material is 60 hours. Carrying this one additional step, the 7.5 hours of programmed instruction ($R_{p/c}$) x 60 (T_{pi}) yields 450 - the number of instructor hours required to prepare 7.5 instructional hours.

5.1.2.3 Curriculum Preparation for CAI

5.1.2.3.1 General

The procedures and basic manning requirements for specifying lesson objectives, sequencing of lesson components, criterion testing, and

TABLE 5.1-2

SUMMARY OF TYPICAL TIME SAVINGS RESULTING FROM USE OF PROGRAMMED INSTRUCTION

VALUE	COMMENTS
33% less	American Management Association Programmed Instruction
34% less	Colonel Gabriel D. Ofiesh
19% less	Ralph Walker, Martin Denver Internal Dev. Costs
34% less	Ralph Walker, Martin Denver Internal Dev. Costs
15%-25% less	Telephone Conversation - Dupont Personnel
30%-50% less	Telephone Conversation - U of Illinois Personnel
40% less	Article - Programmed Instruction as a Systems Approach to Education
25% less	NSPI article concerning Air Defense Command findings
40% less	Entelek - Dr. Albert Hickey 1962 - Costs and Payoffs of Programmed Instruction
30% less	Kopestein and Cave 1962 - Preliminary Cost Comparison of Technical Training by Conventional and Programmed Learning Methods

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TABLE 5.1-3

SUMMARY OF TYPICAL INSTRUCTIONAL HOUR DEVELOPMENT TIMES

T_{pi} VALUES*	COMMENTS
84 frames/instructional hour ÷ 1 = 84 instructor hours/ instructional hour	Derived from articles authored by R. Walker Martin, Denver
60 frames/instructional hour ÷ 1 = 60 instructor hours/ instructional hour	Dr. Albert Hickey, Entelek, 1962
40 frames/instructional hour ÷ 1 = 40 instructor hours/ instructional hour	Telephone conversation with Mr. Harris Shettal, American Institute for Research
60:1 Ratio	Mr. Joseph Rosenbaum, SDC - experience with statistical inference course
200:1	Mrs. Penny Daugherty, @ U of C, Irvine, experience with development of several courses.
34:1, 110:1, 35:1, 11:1, 112:1, 55:1, 138:1, 60:1, 97:1, 290:1, and 47:1	These are the ratios of instructor time per hour of instruction produced for 11 case histories. Typical subjects programmed were: operating sales register, missile familiarization, computer programming and coding and filing system

* One frame per hour is assumed to be both a convenient and cautious figure. A. C. Sparkplug reports approximately 1.25 hours per frame and Dr. Albert Hickey of Entelek reports 1 hour per frame. The number of frames per instructional hour are estimates which are derived by the authors identified under the COMMENTS column.

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testing of completed materials are in concept the same as those for curriculum preparation for programmed text. The major difference is in the area of preparation of detailed instructional content.

There are two general approaches that could be used to develop the course content for CAI, viz., (1) development of frames of data (similar to programmed text preparation) to which are added the necessary commands, alternate answers, computer responses, and branches, and (2) development of flow charts which contain all the necessary decision blocks, commands, branches, and alternatives. Since the former approach is to be used by the NASA in developing materials for the initial system, the latter approach is not discussed.

Preparation of the detailed instructional content consists of writing and editing each frame until the instructional sequence is complete and then modifying each frame by performing the following:

- Specifying responses and alternate responses.
- Specifying computer replies to responses.
- Specifying branches.
- Defining commands required.
- Determining student records to be retained and processed.
- Coding and keypunch.

Subparagraph 5.1.2.3.2 delineates the factors that affect preparation costs.

5.1.2.3.2 Curriculum Preparation Costs

The curriculum preparation manhours relationship vor CAI varies from the relationship for programmed text in that coding and keypunch operation must be considered. The curriculum preparation costs (C_{prep}) equal instructor manhours expended (MH_i) plus coder manhours expended (MH_{coder}) plus keypunch manhours expended (MH_{kp}) plus typist manhours expended (MH_{typ}) plus other costs (OC).

That is:

$$\boxed{C_{prep} = MH_i + MH_{coder} + MH_{kp} + MH_{typ} + OC}$$

Or:

$$C_{prep} = (T_c \times R_{p/c}) \times T_{cai} + (T_c \times R_{p/c}) \times T_{coder} + (T_c \times R_{p/c}) \times T_{kp} + (T_c \times R_{p/c}) \times T_{typ} + OC$$

Where:

T_c = Number of hours of conventional instruction.

$R_{p/c}$ = Ratio of CAI (mean student completion time) to classroom time.

T_{cai} = Time required for the instructor to prepare one hour of CAI.

T_{coder} = Coder time required per hour of instruction.

T_{kp} = Keypunch time per hour of instruction or time required to enter an hour of instruction from terminal.

T_{typ} = Typing time per hour of instructor.

OC = Other costs (materials, reproduction).

It seems reasonable to assume that $R_{p/c}$ for CAI would indicate the same savings as programmed text, i.e., 25 percent. This amount of time savings may not be realized as more complex teaching strategies are employed.

Representative systems do not have data available for estimating T_{cai}. This is determined, to some extent, by the amount of work performed by the instructor prior to giving the material to the coder and keypunch operator. Another important factor is the complexity of the teaching strategy and presentation logic. An estimate of this value is .75 frames per instructor hour.

T_{coder} is the coding time required per hour of instruction. The basic responsibility in this area is to code graphics, and to add coded commands to instructor-prepared materials as required.

T_{kp}, which is the keypunch time required, is estimated to be 2.6 hours per instructional hour. This assumes the following:

- 40 strokes (characters)/card
- 520 Characters/displayed frame

- 13 Cards/frame
- Keypunch rate of 300 cards/hour
- 60 frames per instructional hour

An example is provided to show the calculation of instructor manhours. Using the same parameters as outlined in Paragraph 5.1.2.2.2, i.e., 10 conventional instructional hours, 25 percent savings and 60 frames/instructional hour, the following calculations are performed.

T_c = 10 hours

$R_{p/c}$ = .75 (or 25 percent savings over conventional instruction)

T_{cai} = 1.25 hours/frame x 60 frames/hour = 75 hours to prepare one hour of CAI

MH_i = (10) (.75) (75)

MH_i = 562.5 hours

MH_i = the number of instructor hours required to prepare 7.5 CAI instructional hours. (The assumed equivalent of 10 conventional hours)

5.1.3 Curriculum Presentation

The first two elements of the instructional system, i.e., course planning and curriculum preparation, should be performed by each medium with essentially the same steps involved. However, there is considerable variation in the curriculum presentation techniques for each medium. These techniques and their concomitant cost relationships are discussed in the following subparagraphs.

5.1.3.1 Curriculum Presentation for Conventional Instruction

5.1.3.1.1 General

Curriculum presentation for conventional instruction consists primarily of lecture presentation time. The class is normally conducted using a lecture approach as opposed to the conference approach. In the former method, the instructor conveys various facts and concepts in a rapid-fire manner, stopping only when interrupted by a student question. With the conference approach, the instructor plans a series of questions which are asked during the course presentation. This slows the pace of the instruction, enables the instructor to check student comprehension and encourages student participation.

5.1.3.1.2 Curriculum Presentation Costs

The curriculum presentation costs (C_{pres}) equals the instructor manhours expended (MH_i) plus total student manhours (MH_s) plus other costs

That is:

$$\boxed{MH_{pres} = MH_i + MH_s + OC}$$

Where:

MH_i = ($T_c + T_t \times T_c$) (total classroom time plus testing) x

N_i (number of instructors/class, generally one).

MH_s = ($T_c + T_t \times T_c$) (total classroom time plus testing) x

N_s (number of students per class).

And where:

T_t = percentage of T_c allocated for testing

OC = Other costs (materials, reproduction, travel, classroom facilities)

Therefore:

$$MH_{pres} = (T_c + T_t \times T_c) \times N_i + (T_c + T_t \times T_c) \times N_s + OC$$

$$MH_{pres} = T_c(1 + T_t) x (N_s + N_i) + OC$$

When calculating these costs, particular attention should be given to the amount of travel required (for the student as well as the instructor) and classroom availability requirements. Travel expenses could prove to be a significant expenditure. Refer to Paragraph 5.2.1 for additional information on these parameters.

5.1.3.2 Curriculum Presentation for Programmed Text

5.1.3.2.1 General

Curriculum presentation for programmed text primarily consists of the student time expended in completing the curricular material. To a lesser extent, consideration must be given to the administration necessary for grading and evaluating student performance as the student progresses through the curriculum.

Classroom facilities and the services of instructors for student counseling are not required since curricular material is distributed to the student for home or office study. (It has been assumed that this is common to all media and is a unique factor which cannot easily be quantified. Therefore, this parameter is not discussed.)

5.1.3.2.2 Curriculum Presentation Costs

Curriculum presentation costs (C_{pres}) equal the number of student manhours (MH_s) plus other costs (OC).

That is:

$$\boxed{\begin{aligned} C_{pres} &= MH_s + OC \\ MH_s &= (T_c \times R_{p/c}) \times N_s \end{aligned}}$$

Where:

T_c = Conventional instruction time

$R_{p/c}$ = Ratio of programmed instruction to classroom time (This ratio includes student testing time.)

N_s = Number of students

OC = Other costs (materials, travel)

From the preceding discussion it can be seen that the number of manhours expended is a direct function of the student population.

Curriculum presentation costs are also affected by the location chosen by the student for program study. For example, assume 50 percent of the students elect to study the material at home after working hours, then the costs incurred would be reduced by 50 percent. No attempt has been made to illustrate typical presentation costs since the predominate factor is the student's salary, which varies over a wide range.

5.1.3.3 Curriculum Presentation for CAI

5.1.3.3.1 General

Curriculum presentation for CAI consists primarily of the student time expended in completing the curricular material. Additional factors that must be considered are: (1) equipment operating expenses, i.e., computer, terminals, and peripherals, (2) computer specialist, and (3) a student proctor which may be available to assist students having difficulty. The use of a proctor full time may not be the most economical method of assisting the student. An alternative would be to have an instructor available for counseling but active on other projects.

The general procedure for CAI is to administer the curriculum using the computer to generate and process the material, and the terminal to present the information. Testing is administered by the computing system, as is grading and evaluation.

5.1.3.3.2 Curriculum Presentation Costs

Curriculum presentation costs for CAI (C_{pres}) equal the student manhours (MH_S) plus proctor manhours (MH_P) plus equipment support manhours (MH_{es}) plus other costs (OC).

That is:

$$\boxed{C_{pres} = MH_s + MH_p + MH_{es} + OC}$$

Where:

$$MH_s = (T_c \times R_{p/c}) \times N_s$$

$$MH_p = LCT \times N_p$$

$$MH_{es} = LCT \times N_{es}$$

Thus:

$$C_{pres} = (T_c \times R_{p/c}) \times N_s + LCT \times N_p + LCT \times N_{es} + OC$$

Where:

LCT = Total time required to accommodate all students.

N_p = Number of proctors.

T_c = Classroom time in hours.

$R_{p/c}$ = Ratio of programmed instruction (mean student completion time) to classroom time.

N_s = Number of students.

N_{es} = Number of equipment support personnel

OC = Other costs (materials, computer and terminal facilities).

An important consideration is the CAI hardware and software system, and the number of personnel required for maintenance and operation. Computer and terminal rental or amortization costs have not been included. This requires a basic understanding of the system design and whether the equipment is purchased or leased. The total manhours increase or decrease as a function of the self-pacing characteristic inherent in programmed instruction. Limits are imposed on the upward fluctuation through the use of strict equipment utilization scheduling.

5.1.4 Curriculum Modification

The curriculum may require modification after the course is implemented because of changing course content and in some instances because of poorly designed materials. Should the latter be required, the objectives must be partially modified or totally re-defined, and the course strategy and sequencing may require altering. This extensive modification could occur with conventional instruction; however, this is less likely in programmed instruction since programmed materials are of necessity tested and revised <u>until</u> they work and <u>not</u> presented to the students to see <u>if</u> they work.

Changes to course content, which require the addition of new material or the modification and replacement of old material, will occur, requiring additional manhours and expense.

Curriculum modification involves two factors associated with curriculum preparation, viz., organization and preparation of detailed instructional content, and materials testing.

5.1.4.1 Curriculum Modification for Conventional Instruction

5.1.4.1.1 General

Conventional instruction curriculum modification requires little more than the instructor's reworking of his notes and course outline and preparation of revised lecture aids, e.g., slides and handouts. Seldom are the materials tested and evaluated. Thus, the factors determining manhour requirements and costs are confined to modification and reorganization of content. Because of the reduced stringency of effort, the number of manhours that must be expended are significantly reduced.

Subparagraph 5.1.4.1.2 delineates the parameters involved in manning and costing, and discusses their interrelationships.

5.1.4.1.2 Curriculum Modification Costs

Curriculum modification costs (C_{prep}) equal the instructor manhours (MH_i) plus technician manhours (MH_{tech}) plus typist manhours (MH_{typ}) plus other costs (OC). That is:

$$\boxed{C_{mod} = MH_i + MH_{tech} + MH_{typ} + OC}$$

Where:

$$MH_i = T_m \times T_i$$

$$MH_{tech} = T_m \times T_{tech}$$

$$MH_{typ} = T_m \times T_{typ}$$

And where:

T_m = Number of hours of conventional instruction to be modified.

T_i = Instructor time required per hour of instruction modified.

T_{tech} = Technician (illustrator, draftsman, slide prep) time required per hour of modified material.

T_{typ} = Typist time required per hour modified.

OC = Other costs (materials, reproduction, travel).

Therefore:

$$C_{mod} = T_m \times T_i + T_m \times T_{tech} + T_m \times T_{typ} + OC$$

Or:

$$C_{mod} = T_m \times (T_i + T_{tech} + T_{typ}) + OC$$

The important factor in this relationship is T_i. What determines the time required to modify an hour of instruction? Although this value cannot be quantified, the parameters can be identified and from this an estimate can be made.

T_i is a function of the number and nature of the operations that must be performed during the modification process. For conventional instruction, this would include items such as: rewriting notes, correcting or replacing diagrams and internally organizing lesson handouts. The ease and timeliness with which these tasks can be performed is further influenced by the degree to which a change at one point in the course changes the validity of the course at other points.

An additional factor that determines the extent of the modifications is the length of time from the previous update, e.g., a course that has not been modified or updated for 6 months would probably require a more extensive update than the same course which had not been updated for 3 months.

With the knowledge that some updates may require only 20 minutes (as an example), while others could conceivable require more time than originally taken during the instructional content preparation phase, it is estimated that T_i will equal 40 percent to 50 percent of the initial course content development time per hour.

5.1.4.2 Curriculum Modification for Programmed Text

5.1.4.2.1 General

Modification or revision of material for programmed text requires rewriting and validating frames, revising illustrations as necessary, and development of new testing criteria to take into account the new or updated material.

Again, the assumption is made that the modification is due to data changing rather than poorly written materials which would require the entire curriculum preparation procedure to be reiterated.

5.1.4.2.2 Curriculum Modification Costs

The cost relationships are identical to those specified for conventional instruction in Subparagraph 5.1.4.1.1. The significant difference is in the number of instructor hours required to update the material.

It should be noted that the instructor time required to modify programmed text is significantly greater than for conventional instruction because of the writing and editing of frames, the specification of responses, and the development of testing criteria. These functions are not performed when modifying courses employing conventional instruction techniques.

Because of the many variables involved, only a gross estimate can be made. An average of 50 to 60 percent of the initial course-content preparation time is required for course modification. It should be noted that no objective rationale can be provided to support this estimate.

Using a frame of programmed instruction as a basis to determine modification time will yield an estimate of the modification time required. This is a function of the number of frames to be modified times the number of frames that can be written per hour (an estimated average is one frame per hour). This can be equated to instructional hours by assuming an average of 60 frames per instructional hour.

5.1.4.3 Curriculum Modification for CAI

5.1.4.3.1 General

CAI program modification requires the revising of frames, specifying of responses and alternate responses, determining the appropriate computer reply for each response, applying the author-language repertoire (coding), and performing the keypunch operation. In addition, new testing criteria and materials testing must be developed. The assumption is made that the modification is due to changing data rather than poorly written materials.

5.1.4.3.2 Curriculum Modification Costs

The curriculum modification costs (C_{mod}) equal the instructor manhours (MH_i) plus coder manhours (MH_{coder}), plus keypunch (MH_{kp}), plus typist manhours (MH_{typ}) plus other costs (OC). That is:

$$\boxed{C_{mod} = MH_i + MH_{coder} + MH_{kp} + MH_{typ} + OC}$$

Where:

$MH_i = T_m \times T_i$

$MH_{coder} = T_m \times T_{coder}$

$MH_{kp} = T_m \times T_{kp}$

$MH_{typ} = T_m \times T_{typ}$

And where:

T_m = Number of hours of CAI program to be modified.

T_i = Instructor time required per hours modified.

T_{coder} = Coder time required per hour modified.

T_{kp} = Keypunch time required per hour modified.

T_{typ} = Typist time required per hour modified.

OC = Other costs (materials, reproduction, travel).

Combining and factoring:

$$C_{mod} = T_m(T_i + T_{coder} + T_{kp} + T_{typ}) + OC$$

In this relationship the key variable is T_i. This can be computed by estimating the number of CAI frames* that require redevelopment, and multiplying by the time required by the instructor to develop one frame.

Using 1.25 instructor hours per frame as an estimate (refer to Subparagraph 5.1.2.3.2), and assuming 500 frames out of a 5000-frame program require modification, then $MH_i = 500 \times 1.25 = 625$ hours.

This value will probably be less than indicated, since the number of hours required to prepare each frame is not constant (refer to Subparagraph 5.1.2.3.2).

It is estimated that $MH_{coder} + MH_{kp} + MH_{typ}$ would approach 100 manhours, thus, expending a total of 725 manhours for modification for 500 frames (500 frames is equivalent to approximately 8-1/3 instructional hours).

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*A frame in CAI is considered to be that data (stimulus) which must be presented to the student to produce a response. This could require more than one display format to be presented to the student.

The major cost will be incurred by the instructor and is dependent on the extent of the modification required and the rate of which frames can be rewritten.

5.1.5 Summary

Table 5.1-4 summarizes the manhour/cost relationships for each medium relative to each of the major elements which affect the development of the instructional system.

In addition to the cost relationships illustrated in Table 5.1-4, the costs may be calculated in terms of cost per instructional hour, cost per student, and cost per student-hour as follows:

Cost per instructional hour

$$\boxed{\text{Total Cost}_{IH} = \frac{MH_{plan} + MH_{prep} + MH_{pres} + MH_{mod} + OC}{IH}}$$

$$\boxed{{}^{*}\text{Development Cost}_{IH} = \frac{MH_{plan} + MH_{prep} + OC}{IH}}$$

MH_{plan} = Total manhours required for planning

MH_{prep} = Total manhours required for preparation

MH_{pres} = Total manhours required for presentation

MH_{mod} = Total manhours required for modification

OC = Other costs (reproduction, materials, travel, facilities, equipment)

IH = Total curricular hours (class hours for conventional, average student completion time for programmed text and CAI).

Cost per student

$$\boxed{\text{Total Cost}_{s} = \frac{MH_{plan} + MH_{prep} + MH_{pres} + MH_{mod} + OC}{N_s}}$$

N_s = Total number of students accommodated by the curriculum.

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* The characteristic costs referenced in the cost comparison discussions are presented only in terms of development costs per instructional hour (planning + preparation costs); hence, those relationships are presented here.

Cost per student-hour

$$\boxed{\text{Total Cost}_{sh} = \frac{MH_{plan} + MH_{prep} + MH_{pres} + MH_{mod} + OC}{(IH)\ (AV_s)}}$$

IH = Total curricular or instructional hours.

AV_s = Average student loading per curricular hour.

TABLE 5.1-4

SUMMARY OF MEDIA MANHOURS AND COST CHARACTERISTICS

TRAINING DEVELOPMENT ELEMENTS / TRAINING MEDIA	CONVENTIONAL INSTRUCTION	PROGRAMMED TEXT	COMPUTER ASSISTED INSTRUCTION
COURSE PLANNING 1. SPECIFICATION OF JOB REQUIREMENTS 2. GENERIC TRAINING REQUIREMENTS ANALYSIS 3. DETERMINATION OF DETAILED TRAINING OBJECTIVES	THIS PHASE IS GENERALLY OMITTED OR PERFORMED SUPERFICIALLY FOR CONVENTIONAL INSTRUCTION. OFTEN NO SPECIFIC JOB REQUIREMENTS OR DETAILED OBJECTIVES ARE DETERMINED. COURSE PLANNING USUALLY CONSUMES VERY LITTLE OF THE OVERALL TIME AND EFFORT REQUIRED TO IMPLEMENT A CONVENTIONAL COURSE. THE COST RELATIONSHIPS FOLLOW: $\boxed{C_{plan} = MH_i + MH_{typ} + OC}$	PROPER AND DETAILED PLANNING FOR P.I. REQUIRES A SIGNIFICANT EFFORT AND LARGE PORTION OF THE TOTAL TIME TO IMPLEMENT THE PROGRAM. EACH POINT UNDER PLANNING MUST BE CONSIDERED IN DETAIL IF THE PROGRAM IS TO BE EFFECTIVE. TIME REQUIRED DEPENDS UPON THE EXPERIENCE OF THE PLANNER AND THE NATURE AND COMPLEXITY OF THE COURSE CONTENT. THE COST RELATIONSHIPS FOLLOW: $\boxed{C_{plan} = MH_i + MH_{typ} + OC}$	AS PLANNING FOR CAI REQUIRES THE SAME STEPS AND DETAILED EFFORT AS A PROGRAMMED TEXT, THE CAI PLANNING ASPECTS ARE NOT DISCUSSED SEPARATELY. THE COST RELATIONSHIPS FOLLOW: $\boxed{C_{plan} = MH_i + MH_{typ} + OC}$
CURRICULUM PREPARATION 1. SPECIFICATION OF LESSON OBJECTIVES 2. LESSON SEQUENCING 3. PREPARATION OF DETAILED INSTRUCTIONAL CONTENT 4. DEVELOPMENTAL TESTING OF MATERIALS 5. DEVELOPMENT OF TESTING CRITERIA 6. TESTING OF COMPLETED INSTRUCTIONAL MATERIALS	LITTLE EFFORT AND TIME IS EXPENDED IN CONVENTIONAL COURSE PREPARATION. THE SPECIFIC STEPS OF PREPARATION AS DELINEATED ARE GENERALLY PERFORMED ONLY SUPERFICIALLY. THE DETAILED INSTRUCTIONAL CONTENT IS PREPARED IN THE FORM OF LECTURE NOTES, COURSE OUTLINE, LECTURE AIDS. COST RELATIONSHIPS FOLLOW: $\boxed{C_{prep} = MH_i + MH_{tech} + MH_{typ} + OC}$ OR: $\boxed{C_{prep} = T_c \times T_{conv} + T_c \times T_{tech} + T_c \times T_{typ} + OC}$	EACH OF THE STEPS FOR PREPARATION MUST BE PERFORMED AND ARE EXTREMELY TIME CONSUMING FOR PROGRAMMED INSTRUCTION. THE DETAILED INSTRUCTIONAL CONTENT PREPARATION CONSISTS OF WRITING AND EDITING FRAMES, SPECIFYING RESPONSES, PREPARING ILLUSTRATIONS, TYPING AND REPRODUCTION. THE COST RELATIONSHIPS FOLLOW: $\boxed{C_{prep} = MH_i + MH_{tech} + MH_{typ} + OC}$ OR: $\boxed{C_{prep} = (T_c \times R_{p/c})T_{pi} + (T_c \times R_{p/c}) \times T_{tech} + (T_c \times R_{p/c})T_{typ} + OC}$	CAI PREPARATION MUST MEET THE SAME STANDARDS AS PROGRAMMED TEXT PREPARATION. THE FOLLOWING STEPS ARE TYPICAL OF THOSE REQUIRED FOR THE INSTRUCTIONAL CONTENT PREPARATION: WRITING AND EDITING FRAMES, SPECIFYING RESPONSES, SPECIFYING COMPUTER REPLIES, DETERMINING WHICH STUDENT RESPONSES ARE TO BE RETRAINED OR PROCESSED, CODING AND KEYPUNCHING THE MATERIAL. THE COST RELATIONSHIPS FOLLOW: $\boxed{C_{prep} = MH_i + MH_{coder} + MH_{kp} + MH_{typ} + OC}$ OR: $\boxed{C_{prep} = (T_c \times R_{p/c})T_{cai} + (T_c \times R_{p/c})T_{coder} + (T_c \times R_{p/c})T_{kp} + (T_c \times R_{p/c}) \times T_{typ} + OC}$
CURRICULUM PLANNING PRESENTATION OF CURRICULAR MATERIAL TO THE STUDENT POPULATION	CONVENTIONAL CURRICULUM PRESENTATION REQUIRES INSTRUCTOR AND STUDENT TIME, AND CLASSROOM FACILITIES. THE COST RELATIONSHIPS FOLLOW: $\boxed{C_{pres} = MH_i + MH_s + OC}$ OR: $\boxed{C_{pres} = (T_c + T_t \times T_c)N_i + (T_c + T_t \times T_c) \times N_s + OC}$	PROGRAMMED TEXT PRESENTATION REQUIRES ONLY THE STUDENT TIME NECESSARY FOR COMPLETION OF THE COURSE AND RELATED TESTING. THE COST RELATIONSHIPS FOLLOW: $\boxed{C_{pres} = MH_s + OC}$ OR: $\boxed{C_{pres} = (T_c \times R_{p/c})N_s + OC}$	CAI CURRICULUM PRESENTATION REQUIRES STUDENT TIME, PROCTOR TIME, CAI SYSTEM TIME, SYSTEM SUPPORT PERSONNEL TIME. THE COST RELATIONSHIPS FOLLOW: $\boxed{C_{pres} = MH_s + MH_p + MH_{es} + OC}$ OR: $\boxed{C_{pres} = (T_c \times R_{pk})N_s + LCT \times N_p \pm LCT \times N_{es} + OC}$
CURRICULUM MODIFICATION REVISION OF COURSE BECAUSE OF CRITIQUES OR COURSE CONTENT CHANGE *1. SPECIFICATION OF LESSON OBJECTIVES 2. LESSON SEQUENCING 3. PREPARATION OF DETAILED INSTRUCTIONAL CONTENT 4. DEVELOPMENTAL TESTING OF MATERIALS 5. DEVELOPMENT OF TESTING CRITERIA 6. TESTING OF COMPLETED INSTRUCTIONAL MATERIALS	RELATIVELY LITTLE EFFORT IS EXPENDED IN THE REVISION OF CONVENTIONAL MATERIAL. INSTRUCTORS MODIFY NOTES, HANDOUTS, AND LECTURE AIDS. GENERALLY, TESTING OF MATERIALS IS NOT PERFORMED. THE COST RELATIONSHIPS FOLLOW: $\boxed{C_{mod} = MH_i + MH_{tech} + MH_{typ} + OC}$ OR: $\boxed{C_{mod} = T_m \times T_i + T_m \times T_{tech} + T_m \times T_{typ} + OC}$	FRAMES MUST BE REWRITTEN, NEW RESPONSES SPECIFIED, NEW TESTING CRITERIA DEFINED, AND REVISED INFORMATION INPUT TO EACH TEXT. THIS REQUIRES CONSIDERABLE EFFORT AND TIME TO MODIFY. THE COST RELATIONSHIPS FOLLOW: $\boxed{C_{mod} = MH_i + MH_{tech} + MH_{typ} + OC}$ OR: $\boxed{C_{mod} = T_m \times T_i + T_m \times T_{tech} + T_m \times T_{typ} + OC}$	PROGRAM MUST BE MODIFIED BY REWRITING FRAMES, SPECIFYING NEW RESPONSES, DETERMINING NEW COMPUTER REPLIES AND TESTING CRITERIA. THE REVISED MATERIAL MUST THEN BE CODED AS NECESSARY AND KEYPUNCHED OR KEYED IN TO THE COMPUTER. IF THE MODIFICATION IS SUCH THAT THE NEW OBJECTIVES AND LESSON SEQUENCING ARE UNNECESSARY, THE TIME REQUIRED WILL BE CONSIDERABLY LESS THAN FOR COURSE PREPARATION. THE COST RELATIONSHIPS FOLLOW: $\boxed{C_{mod} = MH_i + MH_c + MH_{kp} + MH_{typ} + OC}$ OR: $\boxed{C_{mod} = T_m \times M_i + T_m \times T_{coder} + T_m \times T_{kp} + T_m \times T_{typ} + OC}$

*GENERALLY ONLY A FEW OF THE ABOVE STEPS ARE NECESSARY FOR COURSE CONTENT MODIFICATION.

5.2 MEDIA COMPARISON

The purpose of this paragraph is to compare and contrast conventional instruction, programmed text, and CAI. The factors involved in the comparison are: (1) time/cost relationships which include: development times, presentation times, and modification times, and (2) effectivity, which considers the relative levels of achievements for each medium and the underlying reasons for the exhibited variations.

Programmed instruction requires more time to develop than conventional instruction, and, therefore, is more costly. However, it was concluded that conventional instruction would also require approximately the same development time if properly performed.

Development costs connected with programmed instruction are more expensive than those connected with conventional instruction. A thorough investigation of conventional instruction costs, as concluded in the study, would indicate that the difference in cost between programmed instruction and conventional instruction is substantially less than was originally thought.

Presentation time can be reduced by approximately 25 percent through the use of programmed instruction. This represents the significant cost and time savings application of CAI to the flight control curriculum. When consideration is given to certain hidden cost savings factors, i.e., after-hours study, programmed instruction may provide an overall reduction in presentation costs in excess of 20 percent. This is in addition to the 25 percent saved in the presentation of the material.

Programmed instruction, on the average, is 15 percent more effective than conventional instruction. In almost every case studied, the increase in achievement was accompanied with a savings in presentation time.

Programmed instruction, and in particular CAI, is expensive. Consequently, a persistent yet practical question must be asked, viz., "What can a computer do that is superior to that which could be done with less expensive, non-computer teaching machines or textual materials?"

The question of computer capability could be stated in this manner: "What are the limitations of existing programming techniques and what can the computer contribute to overcome these limitations?"

Programmed text, as generally conceived (even with its various branching formats), is limited in its ability to account for a wide range of individual differences. The "linear" format, although adjustable to small differences by virtue of its self-pacing feature, is inefficient when used for training populations having divergent levels of ability and/or relevant subject matter knowledge. The utilization of a "branching" format improves the effectiveness and efficiency of these programs somewhat, but still permits only limited alternatives without becoming too cumbersome. No real adaptation of the program can take place within these formats, since each of the alternatives can be used in only one way. If a student does "X," he always gets "Y" no matter what he may have done previously.

In contrast, CAI has the potential for almost unlimited flexibility. In many ways the problem is to know when and how to best use this flexibility, since it is limited mostly by the ingenuity of the programmer of curricular materials and knowledge of training and human learning, and not by the hardware itself. In addition to great flexibility in adapting to the requirements of various students, the computer can provide a greater depth of instructional possibilities than can a programmed text. The student may use the computational capabilities of the computer to solve problems and experiment to gain experience through simulations which is not possible with other instructional media.

These general areas prove the computer's superiority over programmed text techniques. It seems reasonable to argue that only when the computer is asked to do one or more of the things for which it is uniquely qualified should it be considered as a practical solution to a training problem.

The many diverse applications in which the NASA Flight Control Qualification Section will become engaged will maximize the utilization of the computers' capabilities.

However, the utilization of a computer is not an <u>all</u> or <u>none</u> situation. The answer to computer utilization isn't black or white, i.e., either it is used or it is not. <u>Rather, the computer must be considered as only one instructional resource in designing an instructional system.</u>

The question, "What techniques will produce the highest real and consistent gains in performance for a given student body required to learn specified skills and knowledge" will, in the final analysis, determine the instructional resource utilized.

5.2.1 Time/Cost Relationships

The following text discusses and contrasts, the time and cost relationships inherent in development (planning and preparation), presentation, and modification of curricular materials for each instructional medium.

5.2.1.1 Development Time

The time required to develop curricular materials, regardless of the medium used, is a function of planning time and preparation time. As noted in Paragraph 5.1.1, Course Planning, and in Paragraph 5.1.2, Curriculum Preparation, the planning and preparation manhours relationships are as follows:

$$MH_{conv} = (MH_i + MH_{typ}) + (MH_i + MH_{tech} + MH_{typ})$$

$$MH_{pt} = (MH_i + MH_{typ}) + (MH_i + MH_{tech} + MH_{typ})$$

$$MH_{cai} = (MH_i + MH_{typ}) + (MH_i + MH_{coder} + MH_{kp} + MH_{typ}).$$

Table 5.2-1 depicts the number of personnel required for each medium to perform the planning and preparation tasks. The precise number of personnel required for each task is a function of instructional hours to be developed.

The development time for each medium can be calculated using the following simplified relationship:

$$\boxed{T_{dev} = T_{plan} + T_{prep}.}$$

Initially, it appears that the development times are identical since the basic relationship used in calculating these times is the same. However, considerable variation in development times does exist. The following paragraphs delineate the factors attributable to the wide variation.

Table 5.2-2(A) contains an itemized listing of the parameters involved in the development phase. The basic media under consideration, i.e., conventional, programmed text and computer assisted instruction, are rated in terms of the relative level of adherence to the parameters during the development phase. Although the ratings for conventional instruction are primarily based on the NASA Flight Control Qualification Section development procedures, they could apply to most conventional instruction systems.

A numerical rating scale (1, 2, 3, 4, and 5) is used to indicate the "relative degree of adherence" to each parameter listed. A "1" indicates very little adherence while a "5" is, essentially, perfection. It should be noted that the ratings for conventional instruction are primarily subjective, although discussions with the NASA Flight Control Qualification Section personnel and other personnel in the instructional

TABLE 5.2-1

COMPARISON OF PERSONNEL REQUIREMENTS

MEDIUM	PERSONNEL REQUIREMENTS
CONVENTIONAL INSTRUCTION	INSTRUCTOR(S) TECHNICIAN(S) TYPIST(S)
PROGRAMMED TEXT	INSTRUCTOR(S) TECHNICIAN(S) TYPIST(S)
COMPUTER ASSISTED INSTRUCTION	INSTRUCTOR(S) CODER(S) KEYPUNCH OPERATOR(S) TYPIST(S)

field influenced the final ratings.

Table 5.2-2(B) is a summary of typical development-time figures for conventional instruction, programmed text, and CAI.

Table 5.2-3 compares several programs in terms of time spent gathering data, writing and revising, reproduction, and testing. This data was extracted from "Programmed Learning--A Progress Report" by Geary A. Rummler, University of Michigan. Table 5.2-2(B) reveals that programmed instruction development-time ratios range from 11 hours of development for every instructional hour to 320 hours per instructional hour. Conventional values range from 7 hours of development time for each instructional hour to 20 hours per instructional hour. CAI figures range from approximately 50 hours of development for each instructional hour to approximately 64 hours per instructional hour.

Only two figures were available for conventional instruction. It is surmised that this is due, in part, to poor record keeping and overall lack of adherence to the development criteria.

CAI is still in its infancy and development-time ratios are difficult to obtain. As stated in subparagraph 5.1.2.3, Curriculum Preparation for CAI, the time required to develop CAI material is estimated to be 25 percent more than required for programmed text. Obviously, the values for CAI as shown in Table 5.2-2(B) are in conflict with this estimate.

The question, then, is "Why the conflicts between development times for conventional instruction, programmed text and CAI?" There appears to be two answers. The first is that of curriculum complexity. The more complex the material, the longer the development time required. The second is apparent from glancing at Table 5.2-2(A). Conventional instruction does not and has not adhered to the planning and preparation criteria outlined.

In conclusion, it seems reasonable to assume that conventional instruction, if properly treated, would require approximately the same amount of development time as programmed instruction. Looking at Table 5.2-2(B), it appears that even in programmed instruction, varying levels of performance are experienced in applying the development criteria to the curricular material.

Against this background, it becomes apparent that development times cannot be quantified and that valid and meaningful development times must rest squarely on the validity of the estimates and assumptions made during the determination process.

TABLE 5.2-2

MEDIA SUMMARY FOR THE DEVELOPMENT PHASE

PARAMETERS INFLUENCING TIME		MEDIA CONV	MEDIA P.I.	MEDIA CAI
COURSE PLANNING	SPECIFY JOB REQUIREMENT	1.0	4.8	4.8
	GENERIC TRAINING REQUIREMENTS ANALYSIS	1.5	4.5	4.5
	SPECIFICATIONS OF DETAILED TRAINING OBJECTIVES	1.5	4.8	4.8
CURRICULUM PREPARATION	DETERMINATION AND SPECIFICATION OF LESSON OBJECTIVES	1.0	4.9	4.9
	LESSON SEQUENCING	2.5	4.8	4.8
	ORGANIZATION AND PREPARATION OF DETAILED INSTRUCTIONAL CONTENT	3.0	4.8	4.8
	DEVELOPMENT OF CRITERION TESTS	1.0	4.5	4.5
	DEVELOPMENTAL TESTING OF MATERIALS	1.0	4.8	4.8
	TESTING AND EVALUATION OF COMPLETED MATERIALS	1.0	4.8	4.8

TABLE 5.2-2 (A)

DEVELOPMENT TIME					
CONVENTIONAL	COMMENTS	PROGRAMMED TEXT	COMMENTS	CAI	COMMENTS
7 INSTRUCTOR HOURS/CLASS HOUR	R. WALKER MARTIN DENVER	1.5 MAN MONTH PER INST	COMMENTS BY PERSONNEL AT THE UNIVERSITY OF CALIFORNIA AT IRVINE	4.5 MAN MONTHS FOR 28 INSTRUCTIONAL HOURS	THESE COMMENTS BY DR. BITIZER AND DR. E. LYMAN DURING A VISIT OF THE PLATO FACILITY AND TELEPHONE CONVERSATION WITH THE ABOVE. THE 4.5 MAN MONTH WAS FOR DEVELOPMENT OF A COURSE ON USE OF THE LIBRARY.
20 INSTRUCTOR HOURS/CLASS HOUR	ESTIMATE MADE BY PERSONNEL IN FLIGHT CONTROL QUALIFICATION SECTION	60-70 MAN-HOURS/INSTRUCTIONAL HOUR	COMMENT BY MR. J. ROSENBAUM OF SDC. THIS REPRESENTS THE "LOWER BOUND"	"RULE OF THUMB" 12 MAN-MONTHS FOR 40 INSTRUCTIONAL HOURS	
		APPROXIMATELY 24 MAN MONTHS/20 INSTRUCTIONAL HOURS	SDC - DR. J. E. COULSON	1 MAN-WEEK PER INSTRUCTIONAL HOUR.	STANFORD-BRENTWOOD SYSTEM. CURRICULUM MATERIAL IS SIMPLE FACTS AND CONCEPTS.
		2 MAN MONTHS/INSTRUCTIONAL HOUR 1 MAN MONTH/INSTRUCTIONAL HOUR	COMMENTS BY DR. W. DETERLINE OF GENERAL PROGRAMMED TEACHING. THE FIRST FIGURE REPRESENTS THE TIME REQUIRED FOR ONE PROGRAMMER DOING EVERYTHING. THE SECOND IS AFTER DEVELOPING AN "ASSEMBLY LINE" APPROACH.		
		34/1, 110/1, 35/1, 11/1, 112/1, 55/1, 138/1, 60/1, 97/1, 290/1, AND 47/1	THESE FIGURES ARE THE RESULTS OF A SURVEY BY THE CENTER FOR PROGRAMMED LEARNING FOR BUSINESS AT THE UNIVERSITY OF MICHIGAN. EACH VALUE IS A RATIO OF PROGRAMMER HOURS PER INSTRUCTIONAL HOUR. THE RATIOS ARE FOR THE FOLLOWING TOPICS: (1) OPERATING SALES REGISTERS, (2) BEGINNING SALESMANSHIP, (3) SALES SYSTEMS, (4) SALES SYSTEMS, (5) PACKAGE DELIVERY, (6) PLANT MAINTENANCE, (7) CODING & FILING SYSTEM, (8) MILITARY CORRESPONDENCE, (9) COMPUTER PROGRAMMING, (10) WORK STANDARDS, & (11) MISSILE FAMILIARIZATION. FOR EXAMPLE, 34/1 IS THE RATIO FOR OPERATING SALES REGISTER, ETC.		

TABLE 5.2-2 (B)

TABLE 5.2-3

CLASSIFICATION OF PROGRAM DEVELOPMENT COSTS BY TIME

PROGRAM TOPIC	INFORMATION GATHERING AND SUBJECT ANALYSIS HOURS/% OF TOTAL	WRITING AND REVISION HOURS/% OF TOTAL	REPRODUCTION HOURS/% OF TOTAL	TESTING HOURS/% OF TOTAL	TOTAL HOURS
BEGINNING SALESMANSHIP	15/5	170/65	65/25	12/5	262
PLANT MAINTENANCE	3/4	35/44	26/31	17/21	81
CODING AND FILING SYSTEM	80/9	644/60	192/19	62/6	978
WORK STANDARDS REVISION	164/17	440/46	58/6	284/30	946
MISSILE FAMILIARIZATION	16/23	344/50	104/15	190/27	696
AVERAGE TIME SPENT ON EACH PHASE	278/10	1633/62	445/16	309/12	2680

5.2.1.2 Development Costs

The primary factors which determine the cost of an instructional system are manhours expended, materials, reproduction, per diem travel, and facilities (classrooms computer system, etc.). The development costs consist of those factors required for the course planning and preparation stages. Manhour requirements have been stated in the preceding paragraphs, and when considered with salary and overhead factors, determine the manning costs for a particular application. Table 5.2-4 shows the cost determining factors inherent in each stage of implementation for each medium. Refer to the planning and preparation columns for development cost factors.

The primary differences in costs are related to the extra manhours that must be expended for the development of programmed instruction materials. Programmed textbook development requires a greater cost in materials and labor because many copies of the finished product must be furnished; however, this is offset by the savings incurred by the fact that no instructors or classrooms are necessary for presentation. CAI, on the other hand, incurs greater preparation costs than conventional, because of the requirement for coder and keypunch operators to effect curriculum input to the computer. Table 5.2-5 presents an illustration of the relative costs of each instructional medium.

It is apparent, from the preceding discussion, that programmed text and CAI development costs are much higher than conventional development costs. However, the development costs of programmed instruction are generally one-time expenditures, while the development costs incurred for conventional instruction are recurring expenditures. Also, the initial cost of programmed instruction is indicative of the planning and great attention to detail necessary to develop effective instructional material. The apparently high cost of development becomes a limitation only when the cost of training per student becomes excessive in relation to the benefits that programmed instruction can provide.

Tables 5.2-6, 5.2-7, and 5.2-8 illustrate typical development costs and cost determining factors experienced by various firms in a variety of applications utilizing programmed instruction.

5.2.1.3 Presentation Time

The time required to present a specific subject is a function of the curriculum complexity and the desired terminal behavior. As noted in

TABLE 5.2-4

MEDIA EXPENDITURE GUIDE

COST EXPENDITURE	COURSE PLANNING			COURSE PREPARATION			COURSE PRESENTATION			COURSE MODIFICATION		
	CONV.	PT	CAI	CONV.	PT	CAI	CONV.	PT	CAI	CONV.	PT	CAI
INSTR. MAN-HRS	x	x	x	x	x	x	x			x	x	x
TYPIST MAN-HRS	x	x	x	x	x	x				x	x	x
TECHNICIAN MAN-HRS				x	x					x	x	
STUDENT MAN-HRS							x	x	x			
CODER MAN-HRS						x						x
KEYPUNCH MAN-HRS						x						x
EQUIP. SUPP PER. MAN-HRS									x			
PROCTOR MAN-HRS									x			
MATERIALS				x	x	x	x			x	x	x
REPRODUCTION				x	x	x				x	x	x
FACILITIES							x		x			
TRAVEL	x	x	x	x	x	x	x					

TABLE 5.2-5

RELATIVE COST COMPARISON

COSTS FOR	CONV.	P.T.	CAI
PLANNING	1 ⓐ	2 ⓑ	2 ⓑ
PREPARATION	1 ⓐ	2 ⓑ	3 ⓓ
PRESENTATION	2	1 ⓒ	3 ⓔ
MODIFICATION	1	2	3

1 - 3 Ascending Costs

ⓐ It should be noted that preparation and planning are seldom performed in detail for conventional instruction. What costs are incurred for conventional planning and preparation are generally recurring costs, while these tasks are one-time expenditures for programmed text and CAI.

ⓑ Requires great detail, but output is a finished course.

ⓒ Does not require instructor or classroom facilities.

ⓓ Requires technicians (coder, keypunch opr.), but output is a finished course.

ⓔ Does not require instructor, but requires computer system facilities and equipment support personnel. However, the fact that instructor and instructor travel/per diem expenses are <u>not</u> required for CAI, as they are for conventional, could result in CAI presentation actually being less expensive than conventional presentations.

TABLE 5.2-6

SUMMARY DATA FOR 5 PROGRAMS

FIRM	TOPIC	AVERAGE STUDENT TIME TO COMPLETE	NO. OF TRAINEES PER YEAR*	PROGRAMMER TIME PER HOUR OF INSTRUCTION PRODUCED	DEVELOPMENT COST	ADMINIS- TRATION COST	TOTAL COST	DEVELOPMENT COST PER TRAINEE HOUR
DEPARTMENT STORE	BEGINNING SALESMAN- SHIP	2.0 HRS.	1,000	110/1	791	3,960	4,751	$0.39
OIL REFINERY	PLANT MAINTE- NANCE	1.1 HRS.	475	55/1	664	3,151	3,815	$1.27
GOVERN- MENT	CODING AND FILING SYSTEM	5.3 HRS.	250	138/1	3,729	4,638	8,367	$2.81
AUTOMO- BILE MANU- FACTURER	WORK STANDARDS	1.3 HRS.	1,500	290/1	4,993	9,497	14,490	$2.56
AERO- SPACE	MISSILE FAMILIAR- IZATION	9.0 HRS.	1,600	47/1	8,101	48,276	56,377	$0.66

*Assumed program life of one year.

TABLE 5.2-7

TYPICAL PROGRAM DEVELOPMENT COST DATA FOR 5 PROGRAMS

FIRM	TOPIC	PROGRAMMER WAGE	CLERICAL WAGE	TEST SUBJECTS WAGE	"EXPERTS" WAGE	TRYOUT MATERIAL	TRAINEE WAGE	ADMINISTRATORS WAGE	FINAL PUBLICATION
DEPARTMENT STORE	BEGINNING SALESMANSHIP	665	47	24	8	47	2,534	436	990
OIL REFINERY	PLANT MAINTENANCE	539	13	86	-	26	2,457	157	537
GOVERNMENT	CODING AND FILING SYSTEM	2,418	713	222	188	188	2,229	2,085	324
AUTOMOBILE MANUFACTURER	WORK STANDARDS	2,041	244	2,214	100	394	8,740	380	379
AEROSPACE	MISSILE FAMILIARIZATION	2,108	972	3,968	324	229	43,906	2,410	1,960

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TABLE 5.2-8

TYPICAL DEVELOPMENT COSTS FOR PROGRAMMED INSTRUCTION

FIRM	COST/FRAME	NO. FRAMES	APPROX. COST/HOUR
BUSINESS MACHINES CO.	$10	2500	$600 TO $1000
BANK & TRUST CO.	$11	1600	$660 TO $1100 TOTAL COST
AEROSPACE CO.	$9	613	$550 TO $900 NOT INCLUDING REPRO.
CHEMICAL CO.	---	---	$2000 AVERAGE
DEPARTMENT STORE	---	---	$395
TELEPHONE CO.	---	---	$2000 TOTAL COST
OIL REFINERY	---	---	$600
AEROSPACE CO.	---	---	$900
ELECTRONICS CO.	$38	660	$2300
GOVERNMENT	---	---	$710
RESEARCH GROUP	---	---	$200 TO $3500
AUTOMOBILE	---	---	$3840

Paragraph 5.1.3, Curriculum Presentation, the presentation manhour relationships are as follows:

$$MH_{conv} = MH_i + MH_s$$

$$MH_{pt} = MH_s$$

$$MH_{cai} = MH_s + MH_p + MH_{es}$$

From these relationships it is seen that conventional instruction requires the expenditure of time by instructor(s) and students; programmed text requires only the students' time expenditure; and CAI requires students, proctor(s) and equipment support personnel.

The comparison to be made between the media, relative to presentation time, is the length of time required to present a subject and the personnel required to provide the presentation. In either case, the savings realized are expressed in terms of dollars. When each medium is compared and contrasted, the result is a percentage of the presentation time saved by one medium as compared to the others.

If the assumption is made that each medium requires the same amount of presentation time for curricular materials, then any savings that will occur will be in the area of manning. With an assumed average student population of 30 and a 4-hour subject, programmed instruction is the least costly medium while CAI is the most costly. With reference to Table 5.2-9, it can be seen that CAI requires an increase in manhours of 13 percent over programmed text, while conventional instruction requires 3 percent more manhours than programmed text.

When the total number of hours taught by the NASA Flight Control Qualification Section during 1966 (approximately 1,906) are applied to each medium, the results are significant. Conventional instruction presentation would take approximately an additional 1900 manhours and CAI would require an additional 6624 manhours over programmed text. (This assumes that all 1906 hours could be programmed.)

An additional savings (somewhat more subtile and indirect) can be realized with the use of programmed text. If each student is equipped with all the necessary curricular material, as is the case with programmed text, it is very probable that a large percentage of the students will complete the courses at home. This would be true of CAI provided terminal facilities are available after normal working hours.

It is entirely conceivable that student manhour savings of 20 percent or more could be realized. With an assumed 20 percent savings,

TABLE 5.2-9

SUMMARY OF SAVINGS RESULTING FROM MANPOWER LOADING

MEDIUM	PERSONNEL REQUIREMENTS	TOTAL MANHOURS EXPENDED	TOTAL MANHOURS EXPENDED FOR 1966
CONVENTIONAL INSTRUCTION	1 INSTRUCTOR 30 STUDENTS	124 HOURS	59,086
PT	30 STUDENTS	120 HOURS	57,180**
CAI	1 PROCTOR 3* ENGINEERING SUPPORT PERSONNEL 30 STUDENTS	136 HOURS	64,804**

* This figure assumes one M&O technician for terminal equipments and 2 for computer operations and maintenance.

** This assumes that the total number of hours taught (1906) could be programmed.

the programmed text manhours expended for 1906 hours of instruction would decrease by 11,436 student hours. This savings is unique to programmed text only.

The second manner in which savings can occur is reduction in overall presentation time. Subparagraph 5.1.2.1.2, Curriculum Preparation Costs and Table 5.1-2 illustrate the percentage savings realized by programmed text over conventional instruction methods. The lowest percentage savings was reported at 15 percent with a high of 50 percent (the average being 32 percent).

It seems reasonable to assume that a programmed text would represent a time savings of at least 25 percent. Since CAI is an extension of programmed text, it also seems reasonable to assume the same percentage of time saved.

Assume that programmed text and/or CAI is used by the NASA Flight Control Qualification Section to present the curricular material that has less than a 30 percent change (approximately 264 instructional hours), the curriculum could be reduced by 66 instructional hours. Further, assuming that programmed text or CAI could eventually be used with the entire curriculum (presently 432 instructional hours), a curriculum length reduction of 108 instructional hours would be realized.

Applying the 25 percent savings to the total instructional hours presented in 1966 (1906 hours), the number of hours saved by programmed instruction would be 477. Assuming that an average of 30 students were present during each instructional hour, a savings of 14,310 student hours would be realized (477 x 30).

If programmed text were used and if the student manhours saved by home study (<u>inherent only in programmed text</u>) are added to the student manhours saved by the 25 percent reduction in presentation time, the total number of student hours saved (over conventional instruction) would be significantly greater.

An additional area in which a savings in manhours could occur is instructor travel. Programmed text and CAI would eliminate the need for the extensive travel presently performed by contractor personnel. (It is assumed that contractor personnel would be required as subject-matter experts for materials preparation.)

Over the last 12-month period, the three major contractors have expended approximately 753 days with per diem and travel expenses for approximately 224 trips. These expenses are essential for conventional instruction; however, they could be reduced to periodic coordination trips if programmed instruction were used. This would represent a significant cost savings.

5.2.1.4 Presentation Costs

The preceding paragraphs have discussed relative manhours and time savings for each instructional medium. Those discussions were directly applicable to costs and are, therefore, not repeated here.

Costs other than manhours include travel expenses, material expenditures, and facilities expenditures.

Reference to Table 5.2-4 will indicate the cost expenditures necessary during the presentation phase for each instructional medium. While conventional instruction presentation requires an instructor and classroom facilities, programmed text requires neither, resulting in a significant cost savings. It is also probable that many students will complete portions of a programmed text on their own time, thus, resulting in further savings. CAI, while requiring neither instructor nor classroom for presentation, does require facilities for computer system and terminals, and would require a proctor and equipment support personnel.

Table 5.2-5 depicts the relative level of expenditures for each stage of implementation for each instructional medium.

5.2.1.5 Modification Time

The time required for curriculum modification is a function of the extent of the modification and how stringently the curriculum modifidation criteria are adhered to. Modification of programmed instruction materials does require more time than modification of conventionally prepared materials. A detailed discussion of curriculum modification is provided in Paragraph 5.1.4, Curriculum Modification.

5.2.1.6 Modification Costs

Modification costs are tied almost entirely to the manpower costs, with the exception of programmed text, where modifications to the texts incur large costs for materials and reproduction. A gross estimate of modification costs can be made by determining the percentage of the course to be modified and using that percentage of the original preparation costs as an estimate.

Tables 5.2-4 and 5.2-5 delineate the cost factors required for course modification and the relative cost comparison of media.

5.2.2 Effectivity

Effectivity, as discussed in the following text, is considered in terms of proficiency and retention of material exhibited by the student as a result of training.

It is assumed that CAI is as effective as programmed text. Therefore, the comparison between programmed text and conventional instruction should be considered as a comparison between CAI and conventional instruction.

Table 5.2-10 illustrates several typical figures relative to effectivity. In each example a significant increase in achievement using programmed text is shown. In each case a savings in presentation time accompanied the increased achievement.

Table 5.2-11 illustrates the results of an Air Force study of programmed instruction by Colonel Gabriel Ofiesh. Of the 46 programs tested, only 5 indicated a loss in achievement.

Tables 5.2-12, 5.2-13, 5.2-14 and 5.2-15 were extracted from a report entitled, "Development of Programmed Instructional Materials for Selected Subject Matter in the Ordnance Guided Missile School." The report was prepared for the U. S. Army Ordnance Guided Missile School, Redstone Arsenal, Alabama by the American Institute for Research.

The scores from the programmed instruction group show increases in achievement averaging more than 15 percent.

Only four of the 30 programs for which comparison scores are available show a loss in achievement, and two of these four resulted in achievement losses of less than 2 percent. Also to be considered is the fact that for 3 of the 4 programs, the achievement loss was offset by rather large savings in training time. "Arithmetic Units" resulted in a 27 percent reduction in presentation time. The program "Controller Registers" while showning an achievement reduction of approximately 6 percent, showed a reduction in training time amounting to 69 percent. "Binary Conversion" shows a loss in achievement of 6.5 percent; however, there was a 64 percent reduction in training time. Figure 5.2-1 illustrates the percentages of programs which produced an increase.

Figure 5.2-2 is a comparison of written test scores for students taking a programmed course in General Electronics. The information was provided by Mr. G. Valentine of the American Telephone and Telegraph.

The bars at the left in Figure 5.2-2 show the distribution of written exam scores for 36 trainees who took the past four classes of conventional electronics training in the fall of 1962. The bars to the right in Figure 5.2-2 give the distribution of scores on the same exam for the 59 trainees who "completed" the programmed course from January, 1964, through November, 1964. Sixty percent is a passing score.

Using this 60 percent mark as a passing score, 47 percent of the "conventional" trainees "failed" to meet this score. In the programmed course, 30 percent of the trainees "failed" to complete the course.

Most studies and experimental results indicate that programmed text, and hence CAI, is approximately 15 percent more effective than conventional instruction, i.e., the post test scoring is an average of 15 percent higher for programmed text and CAI.

This CAI feasibility study has revealed that the higher the percentage achievement attained, the more costly the program development. (Based on discussion with R. Walker, Martin Co., Denver, Colorado, and conversations with personnel at the American Institute for Research and the Communicable Disease Center.)

The most obvious question that must then be asked is "What percentage of achievement is required?" This prompts a second question, viz., "How much will it cost?" <u>The avoidance of critical errors, improved performance, and reduced supervision may offset the cost increases</u>.

Increased effectiveness or achievement is not without cost saving factors. Consider the typical conventional instruction environment. It has been observed and reported ("Programmed Instruction--A Guide for Management," G. D. Ofiesh) that one-third of the employees end up retraining the other two-thirds <u>after</u> attending courses taught by conventional instruction. In effect, the training process continues, on the job, that which should have been accomplished in the classroom.

It can be concluded that by using CAI and/or programmed text, it is possible to achieve a higher resultant level of proficiency. The primary reason for this increase is that each program is tested and retested until satisfactory performance is obtained. The generally accepted proficiency goal is 90/90. By that it is meant that 90 percent of the students score 90 percent or higher when tested on the subject material.

The final tradeoff is between achievement and development costs rather than achievement and time savings, since programmed instruction has demonstrated that a higher achievement can be attained along with a savings in training time.

TABLE 5.2-10

GENERAL COMMENTS RELATIVE TO EFFECTIVITY

EFFECTIVITY	COMMENTS
11% INCREASE IN ACHIEVEMENT OVER CONVENTIONAL INSTRUCTION	46 PROGRAM PACKAGES TESTED BY AIR TRAINING COMMAND
13% INCREASE IN ACHIEVEMENT OVER CONVENTIONAL INSTRUCTION	COURSE WAS ENGINEERING DRAWING DEVELOPED BY EI DUPONT
15% INCREASE IN RETENTION OVER CONVENTIONAL INSTRUCTION	THIS SAME COURSE WAS ADMINISTERED IN 25% LESS TIME
9.5% INCREASE IN ACHIEVEMENT OVER CONVENTIONAL INSTRUCTION	ROBERT WALKER MARTIN DENVER
12% INCREASE IN ACHIEVEMENT OVER CONVENTIONAL INSTRUCTION	REPORT BY ROBERT CORRIGAN, CRITERION EXAMINATION CONSISTED OF 100 QUESTIONS. COURSE WAS GIVEN TO COLLEGE STUDENTS AND WAS ON THE HUMAN SKELETAL SYSTEM.

TABLE 5.2-11

PROGRAMMED INSTRUCTION AND CAI VS CONVENTIONAL ACHIEVEMENT GAINS AND LOSSES

SUBJECT	CONV ACHIEV %	PROG ACHIEV %	ACHIEV % +GAIN -LOSS
1. USE - OSCILLOSCOPE	57	98	+42
2. HOW TO STUDY	54	87	+33
3. CONCEPT OF AIR FORCE MAINTENANCE	49	81	+32
4. RADIATION DETECTION	66	96	+30
5. PRINCIPLE OF LEARNING	60	88	+28
6. A-28 CAMERA MOUNT	71	96	+25
7. THEORY OF WEAPONS CONTROLLING	56	79	+24
8. BATTERY & MAINTENANCE	62	85	+23
9. INTERPRETING ELECTRICAL WIRING DIAGRAMS	70	91	+21
10. PRINCIPLE OF PITOT-STATIC SYSTEM	71	91	+20
11. FUEL SPECIALIST CONV FUEL	76	94	+18
12. MODEL 19 COMPOSITE SET	74	91	+17
13. BASIC NAVIGATION EQUIPMENT	73	89	+16
14. HAND TOOLS	69	85	+16
15. EW FUNDAMENTALS	74	89	+15
16. AIR FORCE TECHNICAL PUBLICATION SYSTEM	75	89	+14
17. GYROSCOPIC PRINCIPLES	72	84	+12
18. AN/ARN-6 RADIO COMP	69	81	+12
19. AIRCRAFT OXYGEN SYSTEM	77	88	+11
20. WATER SUPPLY	85	96	+11
21. VACUUM TUBES - DIODES	84	93	+ 9
22. AIR FORCE ACCTG STRUCTURE & CODES	78	87	+ 9
23. CONCEPTS OF SUPERVISION	65	72	+ 7
24. BASIC HYDRAULICS & PNEUMATIC PRINCIPLES	75	82	+ 7
25. WEATHER (NAV COURSE)	77	84	+ 7
26. MESSAGE STRUCTURE - JOINT MESSAGE FORM	75	81	+ 6
27. EVALUATION & MEASUREMENT	83	88	+ 5
28. ROTARY WING AERODYNAMICS	91	96	+ 5

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TABLE 5.2-11 (CONT'D)

SUBJECT	CONV ACHIEVE %	PROG ACHIEVE %	ACHIEVE % +GAIN -LOSS
29. BASIC NAVIGATION	83	87	+ 4
30. INSTALLATION SECURITY RESTRICTED AREA PASS	78	82	+ 4
31. RADAR RETURN (NAVIGATOR BONBADEAR)	82	86	+ 4
32. AERODYNAMICS	94	97	+ 3
33. INTRODUCTION AC&W RADAR	74	77	+ 3
34. CAMAFLAGE & EVALUATION MOVEMENT	77	80	+ 3
35. COMMUNICATIVE SKILLS	89	92	+ 3
36. FLIGHT PLANNING	81	82	+ 1
37. MESSAGE FORMAT - SINGLE ADRESS MESSAGE	94	95	+ 1
38. AVIATION PHYSIOLOGY	93	93	0
39. HYDRALICS FOR FIREFIGHTERS	90	90	0
40. PROTECTION FROM THE ELEMENTS	87	87	0
41. QUESTION TECHNIQUE	80	80	0
42. FOOD PROC (SURVIVAL SCHOOL)	94	93	- 1
43. AIR FORCE LETTER	89	87	- 2
44. FLIGHT INSTRUMENTS	77	75	- 2
45. TESTING & GRADING	71	66	- 5
46. PRINCIPLES OF FLIGHT	86	79	- 7

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TABLE 5.2-12

COMPARISON OF TIME AND POST TEST SCORES BETWEEN THE PROGRAMMED INSTRUCTION GROUP AND THE CONVENTIONAL INSTRUCTION GROUP IN THE INTRODUCTION TO MISSILE DIGITAL CONTROL CLASSES

PROGRAM	MEAN TIME AND RANGE	CLASS* TIME	% SAVINGS IN TIME	P.I. POST TEST SCORE	CONVENTIONAL POST TEST SCORE	% GAIN IN ACHIEVEMENT**
INTRODUCTION TO MDC	1 HR 58 MIN (1 HR 33 MIN- 2 HR 20 MIN)	2 HR	- 18%	84	84	0%
LOGIC CIRCUITS	1 HR 21 MIN (1 HR 10 MIN- 1 HR 25 MIN)	4 HR	+ 60%	87	78	+ 12%
CONTROLLER ARITHMETIC	2 HR 28 MIN (1 HR 28 MIN- 3 HR 35 MIN)	3 HR	+ 1%	79	84	- 6%
MDC UNITS	52 MIN (32 MIN- 1 HR 10 MIN)	2 HR	+ 48%	83	83	0%
CONCEPTS OF SYMBOLIC LOGIC	2 HR 23 MIN (2 HR 8 MIN- 2 HR 54 MIN)	2 HR	- 43%	87	83	+ 5%
CONTROLLER REGISTERS	46 MIN (32 MIN- 1 HR 1 MIN)	3 HR	+ 69%	80	85	- 6%
ARITHMETIC UNITS	1 HR 50 MIN (1 HR 15 MIN- 2 HR)	3 HR	+ 27%	78	79	- 1%
MEMORY UNITS	1 HR 47 MIN (1 HR 34 MIN- 2 HR)	2 HR	- 7%	85	78	+ 9%
CONTROL UNITS	1 HR 12 MIN (1 HR 1 MIN- 1 HR 27 MIN)	2 HR	+ 28%	83	78	+ 6%

*NOTE: In computing percent time saved per instructional hour, 10 minutes has been subtracted for the class times shown in the table in order to correct for breaks.

**NOTE: Gain in achievement is computed as follows: Difference between scores divided by the conventional score. This, in effect, uses the conventional score as an original ceiling and asks, "What percentage of this ceiling (above or below) does the programmed group achieve?"

TABLE 5.2-13

COMPARISON OF TIME AND POST TEST SCORES BETWEEN THE PROGRAMMED INSTRUCTION GROUP AND THE CONVENTIONAL GROUP IN THE MISSILE DIGITAL CONTROL CLASSES

PROGRAM	MEAN TIME AND RANGE	CLASS* TIME	% SAVINGS IN TIME	P.I. POST TEST SCORE	CONVENTIONAL POST TEST SCORE	% GAIN IN ACHIEVE-MENT
NUMBER SYSTEMS AND POSITIONAL NOTATION	2 HR 55 MIN (1 HR 55 MIN-3 HR 25 MIN)	3 HR	- 17%	92	64	+ 44%
BINARY ARITHMETIC	38 MIN (55 MIN-1 HR 55 MIN)	1 HR	+ 24%	92	77	+ 20%
BINARY TRANSMISSION AND REPRE-SENTATION	38 MIN (25 MIN-1 HR)	2 HR	+ 62%	92	85	+ 8%
OCTAL NUMBERING SYSTEM	1 HR 2 MIN (45 MIN-1 HR 55 MIN)	2 HR	+ 38%	92	83	+ 11%
BINARY CONVERSION	53 MIN (40 MIN-1 HR 20 MIN)	3 HR	+ 64%	87	93	- 7%

*NOTE: In computing percent time saved per instructional hour, 10 minutes have been subtracted for the class times shown in the table in order to correct for breaks.

TABLE 5.2-14

COMPARISON OF TIME AND POST TEST SCORES FOR THE PROGRAMMED INSTRUCTION GROUP AND THE CONVENTIONAL INSTRUCTION GROUP IN THE HAWK CW RADAR CLASSES

PROGRAM	MEAN TIME AND RANGE	CLASS* TIME	% SAVINGS IN TIME	P.I. POST TEST SCORE	CONVENTIONAL POST TEST SCORE	% GAIN IN ACHIEVE-MENT
INTRODUCTION TO THE HPI TRANSMITTER ASSEMBLY	1 HR 55 MIN (1 HR 7 MIN-3 HR 8 MIN)	2 HR	- 15%	95	86	+ 11%

TABLE 5.2-15

COMPARISON OF TIME AND POST TEST SCORES FOR THE PROGRAMMED INSTRUCTION GROUP AND THE CONVENTIONAL INSTRUCTION GROUP IN THE GUIDANCE AND CONTROL (JUPITER) COURSE

PROGRAM	MEAN TIME AND RANGE	CLASS* TIME	% SAVINGS IN TIME	P.I. POST TEST SCORE	CONVENTIONAL POST TEST SCORE	% GAIN IN ACHIEVE-MENT
CLIPPER CIRCUITS	2 HR (1 HR-2 HR 40 MIN)	4 HR	+ 40%	74	56	+ 32%

*NOTE: In computing percent time saved per instructional hour, 10 minutes have been subtracted for the class times shown in the table in order to correct for breaks.

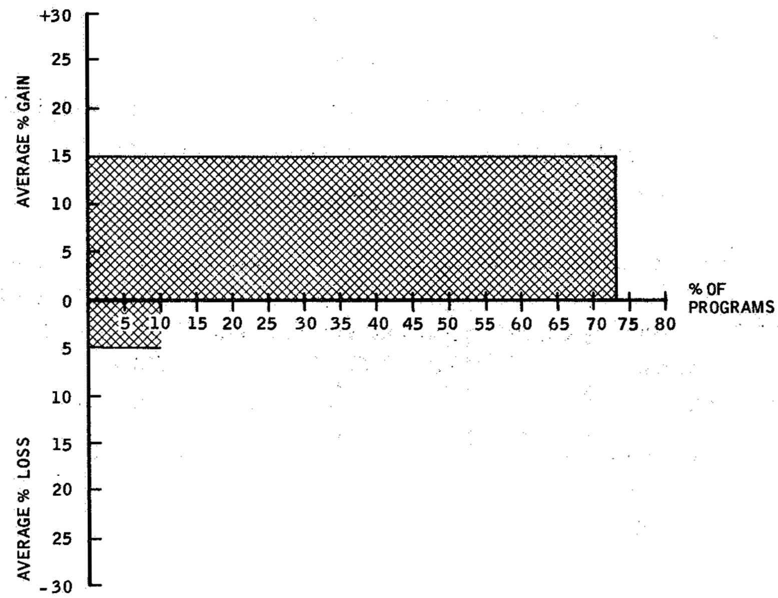

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Figure 5.2-1 Comparison Between Percentage of Programs which Produced an Increase in Achievement and the Percentage of Programs which Produced a Loss in Achievement

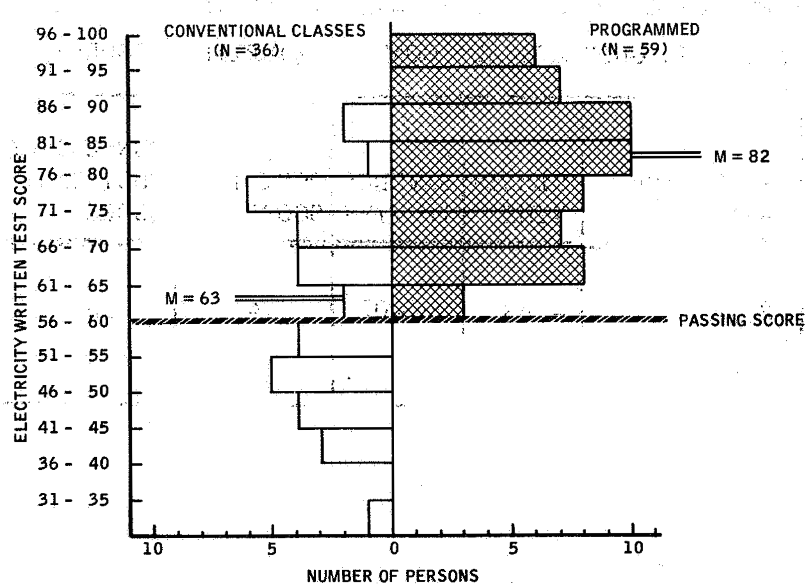

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Figure 5.2-2 Comparison of Written Test Scores for Trainees from Lecture-Discussion Classes and Students taking the Programmed Course in General Electronics

APPENDIX A

DEFINITIONS

-A-

ADAPTIVE TEACHING MACHINE. Teaching machines which automatically alter the instructional presentation sequence as a function of the pupil's performance. Example: The machine may shift to a smaller step size if the pupil is making more than four incorrect responses out of every ten frames.

ADAPTIVE SEQUENCING. The capacity of the teaching machine and its associated program to adjust in one or more ways, on the basis of the learner's responses, to his specific needs.

AUTHOR. One who writes a course for Computer-Assisted Instruction and has complete control over the course content.

AUTHOR LANGUAGE. The language used by persons (authors) who prepare curriculums for Computer-Assisted Instruction (CAI).

AUTOMATIC TUTORING. The term for programmed instruction most frequently used with intrinsic programming.

ARGUMENT. A field in the text of a course instruction. The contents of the field depend on which operation is being performed.

-B-

BRANCH. (Branching) A point of choice at which students are sent to alternative items depending on their responses to the particular item. A common use of branching is in intrinsic programs, where the branch (or loop) consists of a single item explaining why a particular answer is incorrect and returning the student to the original item for another try. A criterion item may be inserted in a linear program and, if the student passes it, he is sent forward several items (Forward Branching); if he fails the criterion item he takes an intervening sequence of review or remedial items. A student may, at a criterion item, be sent backward in the program to repeat items he has already seen but has inadequately mastered (Backward Branching or Wash-Back). Students may be branched on the basis of either constructed responses or multiple-choice responses, although the latter predominate.

CARTESIAN METHOD. An approach to handling complex problems which may be useful in programming subject matter. It involves essentially two activities: (a) analyzing the problem into its smallest parts, and (b) proceeding from the simple to the complex.

CHAINING. The linking together of a series of discriminating responses in a particular order. The completion of the first response provides the stimulus for the second response. In typical laboratory examples, reinforcement is given at the end of the chain of responses. A classroom parallel can be seen in the solution of a long-division problem: each step in the procedure could be separately taught, even in a random order, but the final performance requires a prescribed order to achieve the solution. To provide a student knowledge of results at the end of the solution sequence parallels the provision of reinforcement following the final response in a chain.

CLASS-DESCRIPTIVE METHODS. A method of sequencing material in a program, in which the common and significant characteristics of a set of objects are simultaneously presented to the learner. (This is in contrast to the object-descriptive method.) Example: The heads of three different coins are presented side by side as one display - the tails of the coins as another display.

COMPUTER-ASSISTED INSTRUCTION. An extension of programmed instruction which allows presentation of concepts to the student and evaluation of student responses by the computer, while utilizing the capabilities peculiar to the computer.

COMPUTATIONAL MODE. The mode of operation which the computer is used as a computing or data processing device.

CONCEPT. A specific idea class of information presented within the curriculum, e.g., fundamentals of pulse code modulation.

CONVERSATIONAL CHAINING. A programming technique in which the correct answer to an item is not presented by itself but is rather embedded in the text of the following item. Consecutive items are thus closely linked by the necessity of repeating in the new item the word or words that were elicited in the previous item. The response to one item becomes part of the stimulus in the next.

COURSE MATERIAL. The contents of a course prepared by the author and presented to the student. May also be called text or course statements.

CRITERION. See TERMINAL BEHAVIOR.

CRITERION PROGRAMMING. The subject matter is not programmed; instead, programmed instructions direct the student to resource materials from which he returns for a test of the material (criterion test) and his next instructions.

CUE STIMULUS. The material (problem, statement) which precedes the blank in a frame. The task of the learner is to make the correct response to the cue-stimulus. Also see PROMPT.

CURSOR. A specially indicated area on the face of the instructional display to indicate the point on the screen where the next character will be displayed.

-D-

DELIMITER. A special character to designate the limits of arguments in a course instruction.

DENSITY. The rate at which new material is introduced. It is the ration of the number of different responses required of the learner to the total number of responses required. Density is independent for a single set of frames and cumulative for a sequence of sets. If all the responses are different, the density is 1.00.

DICTIONARY. A special area of core storage used as a table of character patterns that can be displayed by means of the instructional display screen.

DIFFERENTIAL PROGRAMMING. (Intrinsic Programming) In differential programming, variation in the program is a function of pupil characteristics.

DIALOGUE SYSTEM. See INQUIRY SYSTEM.

DOVETAILING. A technique used in programming which involves the interlacing of associations into a pattern consistent with that required when the information concept or skill is put to use. Example: "If $5 \times 5 = 5^2$, and $7 \times 7 \times 7 = 7^3$, $N \times N =$ ____?"

DRILL AND PRACTICE SYSTEM. A system strictly supplementary to regular curriculum, which consists of practice and drills beginning at a mid-level of difficulty and proceeding up or down every drill period as dictated by the previous period's performance.

ECLECTIC PROGRAMMING. Programmers not committed to a particular school of programming. The resulting programs may contain ruleg and egrul sequences, multiple-choice and constructed response items, branches and linear sequences.

ELECTRONIC BOOK. A bank of slides prestored in an electronic slide selector which is controlled by the computer. Information on slide is similar to that normally found in a textbook and is displayed on a CRT monitor.

ELECTRONIC BLACKBOARD. Computer controlled storage tube which allows information that cannot be predetermined to be presented to the student via TV display.

EXTRINSIC PROGRAM. A term usually applied to Skinnerian (linear) programs. The program proceeds in small steps from simple levels to complex levels in a predetermined order of frames.

FADING. The gradual removal of the prompts in a sequence of items teaching a particular topic. Sequences typically begin with highly prompted items and end with unprompted terminal items. The work is sometimes used as a synonym of vanishing.

FEEDBACK. A term borrowed from communication theory, it describes an occurrence resulting from or contingent upon the student's response. It is not necessarily synonymous with reinforcement, since it is not defined by its effect on the recurrence of the response. In a trouble-shooting program for instance, the response might be, "I choose to measure A." Feedback would be, "The value of A is X." The feedback does not indicate necessarily the rightness or wrongness of measuring A.

FORCING. The presentation of subject matter in such small steps as to assure a correct response by the learner.

FRAME (ITEM). A unit of a program; the segment displayed at each step in the sequence. Usually the unit that requires a response.

FRAME, FORCED. A stimulus frame presented to the student forcing him to respond correctly by making the answer obvious.

FRAME, TERMINAL. A frame having no prompts, located at the end of a sequence, designed to test whether the student has reached "terminal behavior."

-G-

GRAPHIC. User defined picture symbols, which have been previously loaded on a table, that can be presented on the instructional display.

-I-

INQUIRY SYSTEM (DIALOGUE SYSTEM). A system permitting dialogues between student and computer. General problems are presented to the student. To solve them, he must request and organize appropriate information from the computer. He may be asked to demonstrate his achievement by answering questions, but he may also seek information within a given range of possibilities in order to answer such questions.

INSTRUCTIONAL HOUR. A group paced definition of instructional time. The length of time a course is presented to a class of students is given in instructional hours.

INTRINSIC PROGRAMMING. A programming technique developed by Norman Crowder, characterized by relatively lengthy items, multiple-choice responses, and consistent use of branching. If, after reading the information section of each item, the student selects the correct response to the question based on the material, he is sent to an item presenting new information. If he selects an incorrect alternative, he is sent to an item which provides information as to why his choice was incorrect. To the extent that the programmer has correctly predicted the possible response that the student population will make, the program taken by each student is under the control of his own responses, and will differ for students of differing abilities.

ITEM (FRAME). A segment of material which the student handles at one time. An item may vary in size from a single incomplete sentence, question, or instruction to perform some response, up to a sizable paragraph. In almost all programming methods, it will require at least one response and will provide for knowledge of results before the student proceeds to the next item.

-L-

LATENCY. The time that elapses between student reception of control of an input device and student indication of completion of his entry.

LESSON DESIGNER. One who prepares course material for input to the computer and subsequent presentation to the student (see AUTHOR).

LINEAR PROGRAM. A program which has a single, predetermined sequence of steps. Error responses are not corrected or immediately repeated. A drop-out device can be incorporated into the machine whereby errors may be reviewed at the end of the set sequence.

LINEAR PROGRAMMING. A programming technique developed by B. F. Skinner. Set sequences of items present information in small units and required a response from the student at each step. The steps are so designed that errors will be minimal for even the slower students in the target population. Every student does each item in the program, his progress differing only in the rate at which he proceeds through the sequence. Constructed responses are demanded of the student most of the time.

LIST PROCESSING LANGUAGES. A language specifically designed for the efficient processing of verbal or English information; for example, COURSEWRITER and INFORM are list processing languages.

-M-

MATHETICS. An approach to programming designed by T. F. Gilbert. It is an attempt to establish a set of rules or guidelines for analyzing and writing programs. Basically, an example is given and solved. Another example is given and the student is "forced" to participate in the solution and, finally, the student is free to solve a similar problem.'

MEDIA. The means by which instructional material is presented to the student; e.g., slides, audio, television.

MODIFIER. A function of an author language which changes the action to be taken by certain operation codes.

-O-

OBJECT-DESCRIPTIVE METHOD. A method of sequencing material in a program in which a complete object is presented and the different components of interest are pointed out or identified. (This is in contrast to the class-descriptive method.) Example: The word "dime" and the tail, head, and side view of a dime are presented in one display.

OBJECTIVE. An objectively defined goal toward which instruction is directed. The student is expected to reach this goal by the end of the instructional unit. Also see TERMINAL BEHAVIOR.

ON-LINE PROGRAMMING. The programming techniques which allow processing of data as rapidly as the information is generated by the source.

OVERPROMPTING. An undesirable feature of some programs in which a text of frames has an excessive number of prompts. The student is likely to become overly "dependent" on program-supplied responses, making weaning more difficult.

PACE. The rate at which the subject is permitted to work through the programmed material. (The pace may be determined by the learner or by a pacer.) Time intervals in instruction. Two crucial intervals are: (a) between presentation of a cue or question and presentation of the correct information or answer, and (b) between one cue or question and the next.

PACER. 1. Component of a teaching machine which limits the time intervals (a) between presentation of a cue or question and the presentation of the correct information or answer and/or (b) between one cue or question and the next. 2. A type of stimulus-response device which presents stimulus materials for a given interval of time and then provides the appropriate response, whether or not the learner has attempted to answer.

PACING. In programmed instruction, the rate at which the student proceeds through a given number of items. The usual procedure is self-pacing: the student reads and responds at his own rate. A stimulus device such as a film may be adapted to perform stimulus-response functions. If materials are presented by such a device to a group, the time allowed for input and for response must be standardized (through) group-pacing. A few devices, such as reading accelerators, control the individual student's pace by machine-pacing, moving on to the next item irrespective of the student's behavior.

PARAMETERIZED MACRO. A routine which contains several instructions and is general in nature. It can be used repeatedly in a course with very little modification. Parameters are the data required to tailor a macro routine to a specific problem.

PEDAGOGIC LOGIC. That strategy or approach used to present course material to a student.

POPULATION. The number of students to which a particular program is presented.

PROCTOR. One who administers and operates the computer system used for CAI.

PROGRAM (CURRICULUM PROGRAM). A sequence of carefully constructed items leading the student to mastery of a subject with minimal error. The distinguishing characteristic of programmed materials is the testing procedure to which they are subjected. Empirical evidence of the effectiveness of each teaching sequence is obtainable from the performance records of students.

PROGRAMMED BOOK. A special book in which the subject matter to be learned has been arranged into a series of sequential steps leading from familiar concepts to new materials. Differs from a "scrambled text" in that the content is arranged so that the student proceeds directly from one step to the next, or one succeeding page to the next, rather than skipping around. The student generally is asked to construct a response as opposed to making a choice among alternatives.

PROGRAMMED INSTRUCTION. The utilization of programmed materials to achieve educational objectives. Synonymous with auto-instruction, automated teaching, etc.

PROGRAMMED TEXTBOOK. A book in which a program is printed in one of two typical formats: page-to-page or down-the-page. In the first type, the student turns the page after each item, finding the answer and the next item on the following page. Generally, items are arranged in levels. The student goes through the book doing all the items on one level, then repeats the process for each successive level. A down-the-page format requires the student to mask the answer column and in some cases everything but the item he is working on as he reads down the page. A programmed text almost always presents a linear program.

PROGRAMMER. The person responsible for the design of items and sequences in a program. The programmer may be a psychologist working with a subject-matter expert who delineates the content, or he may be a subject-matter specialist trained in programming techniques.

PROGRAMMING. The process of arranging the material to be learned into a series of sequential steps; usually moves the student from a familiar background into a complex and new set of concepts, principles, and understandings.

PROMPT. A stimulus added to the terminal stimulus to make the correct response more likely while the student is learning. It may be pictorial or verbal. Prompts vary in strength, i.e., in the probability with which they will evoke the correct response from a given population. The term is used synonymously with cue and is generally synonymous with the non-technical term hint. Prompts were classified by Skinner into two major types: Formal prompts provide knowledge about the form of the expected response, such as the number of letters, the initial letter, or the sound pattern (prompted by a rhyme); thematic prompts depend on meaningful associations which make the student likely to give the expected response.

A distinction between prompt and cue is made by some writers. Prompt describes the function of a model of the response which the student copies, while a cue is a hint of a weaker sort. (Skinner specifically excluded from the category stimuli to be imitated.) This usage of the term parallels the laboratory technique of response prompting, in which a student is given a stimulus (a word or picture), is told the correct response (prompted), and repeats the response after the prompter. (NOTE: Since one use of the term specifically excludes that which the other use of the term includes, readers must determine which sense the author intends before interpreting one set of results as being in conflict with another.)

PROMPT, EMPHASIS. One of the cues or stimuli employed for insuring correct responses. An emphasis prompt is usually an underlined word or phrase written in capital letters to give it emphasis. Example: (a) PARIS is the capital of France. The capital of France is_______.

PROMPT, FORMAL. A prompt which provides the pupil with cues to the appearance of the required response; i.e., the way the response "looks." Example: "The capital of France is P---S." The "P," the number of dashes, and the "S" are formal prompts.

PROMPT, SEQUENCE. One of the cues employed for insuring correct responses. The sequence prompt may be one of two formats: (a) If a pupil reads a text in one item and gives one of the words in the next item, the sequence prompt is a function of what the student had just read or seen. (b) If a student copies a model in one item, and repeats the response without a model in the next item, the sequence prompt is a function of what the student had just written or produced.

PROMPT, THEMATIC. A prompt which depends for effect upon previous associations in the pupil's repertoire. Example: Canis Familiaris is man's best friend. Canis Familiaris is the technical name for the animal commonly called a ___. The phrase "man's best friend" means "dog" to most people. The phrase "man's best friend" is the thematic prompt.

PROMPTING. The method or sequence or providing verbal and symbolic cues to encourage responses. Can be visual, verbal, symbolic, or auditory.

-Q-

QUINTAIN. A medieval teaching machine used to train knights. The appropriate response was to strike a shield directly in the center with a lance. If the lance struck off center, the device would deliver feedback by striking the horseman a blow as he rode by.

-R-

RATE. See PACING.

RECYCLING. A machine function which returns the student to a previous part of the program.

REINFORCEMENT. A technical psychological term that denotes a process in which some stimulus, presented immediately following a response, increases the rate at which the response is emitted in a standard situation or which increases the probability that the response will recur when the situation recurs. A stimulus having such an effect is "reinforcing" or is a "reinforcer." Knowledge of results (feedback or confirmation) has been shown to reinforce correct responses of students in many learning tasks. When the student's correct response is followed by presentation of the correct answer, the probability that the correct response will recur is increased. When correct responses are not followed by knowledge of results, and when the student has no other way of determining what is correct, learning may not occur . . . The correct answer is a reinforcer. Considerable confusion has arisen because stimuli such as food, praise, or money are sometimes called reinforcers even in situations where they are not effective; i.e., no learning occurs when they are present or the same learning occurs even when they are not present. Experimental findings suggest that presentation of the correct answer may not be operating as a reinforcer in programmed instruction. Learning has been shown to occur without confirmation of correct responses. The extent to which the correct answer may truly be called a reinforcer remains to be demonstrated. (NOTE: Educators should be aware that the psychological use of the term reinforcement does not parallel their own use of it. The two definitions are quite distinct. In both cases, a response is strengthened, but the procedures differ. In educational parlance, repetition or rehearsal is the procedure denoted by reinforcement.)

REINFORCEMENT, MECHANISM. Some type of reward for responding correctly to the items in the display. A motivational factor causing the individual to keep working at the set of materials. Sometimes considered as an integral part of the confirming mechanism.

REINFORCERS, PRIMARY. A class of stimuli which will, without any prior history of training, reinforce operant behavior.

REMEDIAL LOOP. The portion of a program which provides additional information to a student in need of assistance.

RESPONSE. A technical psychological term that designates a wide variety of behavior. It may involve the production of anything from a single phoneme or letter, word or phrase, to the solution of a problem requiring an hour or more. It may involve selection among alternatives (multiple-choice) in which case the response often includes the non-verbal manipulation of buttons, keys, etc.

RESPONSE, CONSTRUCTED. (Response, Composed) A student's effort to complete a sentence, solve a problem or to answer a question. A model of the response may be provided for the student to copy, but as long as he writes, says, or thinks it, rather than selecting it from a set of alternatives, the response is constructed.

RESPONSE, COVERT. (Response, Passive) An internalized response which the student presumably makes but which is neither recorded nor otherwise available to an observer. A student who is producing an oral or written response must think of the response (i.e., respond covertly) before producing it. Experimentation is underway to determine the relative contributions of the covert and the overt components of responses in varied programs and with students of various ability levels, etc.

RESPONSE MODE. The kind of response the pupil makes while working on a program. Examples: writing the answer, pushing a button, pressing a panel, etc.

RESPONSE, MULTIPLE-CHOICE. The student's selection of one out of two or more alternatives . . . . The provision of the correct answer among the alternatives prevent him from responding in his own words but does not necessarily produce a smaller step nor an easier item than some constructed-response items. The provision of incorrect alternatives, Skinner argues, may "strengthen unwanted forms of behavior," i.e., the student may retain the erroneous information despite the provision of knowledge of results (q.v.). Where the desired behavior is a selection of or a discrimination between alternatives, the multiple-choice item seems the more efficient training and testing technique.

RESPONSE, OVERT. A student's oral, written or manipulative act which is, or can be recorded by an observer. Whether such responses contribute significantly to learning or not, they provide the data on the basis of which programs are revised.

ROTE REVIEW. Repetition of a frame presented earlier in the program. This type of presentation is useful mainly where sheer memorization of verbal material is desired. Such items are usually presented out of sequence.

RULEG. The systematic technique for construction of programmed sequences developed by Evans, Glaser and Homme: All verbal subject matter is classified into (1) RU's, a class including definitions, formulae, laws, etc.; and (2) EG's, a class including descriptions of physical events, theorems, statements of relationships between specific objects, etc. The latter provide examples (EG's) of the former class of statements. With this classification scheme, the authors recommend that programmers introduce new information according to the formula "RU, EG, incomplete EG," the student's response being the completion of the incomplete example; for instance, the student could be given a spelling rule and a correctly spelled example of it, and be required to spell a second such word. The advice has caused controversy. Some programmers prefer an inductive approach, leading the student through a series of examples (EG's) before having him formulate the RU himself. This approach has been tagged EGRUL.

-S-

SEGMENT. That portion of a program which presents several related concepts. The program is divided by logical breaking points into segments.

SCRAMBLED BOOK. See SCRAMBLED TEXTBOOK.

SCRAMBLED TEXTBOOK. A programmed textbook arranged according to the branching method of programming. If a correct response is made to a question, the learner is referred to a page in the book which confirms his response and moves him on in the program. If the response is incorrect, he is referred to another page which gives him remedial attention. Eventually he is returned to the question that he missed, and he tries again. Since the pages are not taken in order, it is called a "scrambled textbook." Each frame presents a multiple choice question; each of the several answers directs the student to a different page.

SEQUENCING. Arranging the frames of a program in an order that provides the most efficient situation for learning.

SIGN ON AND SIGN OFF. The procedure used by the author, proctor, or student to signal the computer that he wishes to begin or end work with the CAI program.

SOCRATIC METHOD. A method of instruction which consists of a conversational quiz in which a tutor asks questions, the student replies, and the tutor leads the student by a series of questions to the correct response.

STEP. The increment in subject-matter level to be learned with each succeeding item or frame in the program.

STEP SIZE. Average amount of difference between successive frames. A function which is inversely proportional to the number of frames in an instructional unit.

STIMULUS. A technical term in psychology, it designates a class of events which impinge on an organism's sensory equipment and which experimenters can manipulate, describe, or hypothesize to exist. Stimuli are linked as observable (or hypothesized) antecedents to specific responses. In S-R (stimulus-response) psychology, the stimulus is a necessary antecedent to a response. Skinner's position places more emphasis on the consequent reinforcing stimuli than on the antecedents. In a program, the content of the item is the stimulus. This includes the terminal stimulus (the bare b bones of the question or statement), any additional stimuli operating as prompts or models, and any external material such as panels.

STIMULUS, TERMINAL. The unprompted question, incomplete statement, or problem to which the student is taught to respond. This stimulus may occur as part of a prompted item which is not, therefore, a terminal idea.

STUDENT HOUR. The mean time required for a group of students to complete a programmed instruction course.

-T-

TEACHING AIDS. Devices useful in the teaching process which do not assure learning either because they do not necessarily require any action on the part of the learner when he is presented with the subject matter, or they permit him to practice some activity but do not necessarily provide him with subject matter on which to practice.

TEACHING MACHINE. A device that presents a program. Most machines control the material to which the student has access at any moment, preventing him from looking ahead or reviewing old items. Many machines contain a response mechanism: a tape on which the student writes, a keyboard, or selection buttons. Some provision is made for knowledge of results, either by revealing the correct answer after the student responds or by advancing to the next item, thereby signaling correct completion of the previous item.

A few machines score the student's response and tabulate errors. Machines are being developed which will select the next step on the basis of the student's response. This type of machine, in combination with a branched program, comprises what Stolurow calls an adaptive teaching machine.

In Porter's terminology, a teaching machine is a stimulus-response device providing immediate reinforcement. Such machines are distinguished from (1) stimulus devices, such as films, phonographs, etc., which present information but make no provision for responses from the student, and likewise from (2) response devices such as typewriters, which provide for practice but not for controlled input of information. A teacher may provide the missing half of either a stimulus device or a response device.

TERMINAL. The assortment of devices by which information is presented to and received from the student.

TERMINAL BEHAVIOR. The behavior the student is expected to have acquired at the end of a program or programmed sequence. Evidence that such behavior has indeed been acquired is provided by successful responses to terminal items and/or by performance on a criterion test. The terminal items contain no prompts, and are placed far enough from the training sequences to measure more than immediate memory. Criteria vary in testing of programs as they do in any other learning situation. Criterion tests may involve multiple-choice terms, fill-in items, essays, or performance of some other task. If given immediately after the learning sequence, it is a test of acquisition; if given considerably later, it is a retention test. Such tests may involve only the actual material explicitly covered in the learning sequence, or they may involve extension, generalization, or application of the learned material, generally called transfer.

TIMED OUT. Denotes that a student response is not made within the maximum allowable time specified for the student to complete his entry.

TUTORIAL SYSTEM. A system which presents nearly complete instructional sequence in a given subject. Leads the student through a fixed sequence of topics, but provides for branching between problems (under student control, voluntary or involuntary). It first presents facts and examples and then asks questions covering the material presented. After the student answers, a judgment is made by system. The student may request a branch to easier questions voluntarily. If evaluations of student performance are included in the lesson program, involuntary branching may occur when predetermined criteria are met by the student.

-V-

<u>VALIDATION CRITERIA</u>. Criteria used to define effectiveness of an educational program in terms of the portion of students making a certain grade; e.g., 80/80 signifies 80 percent of the students made grades greater than 80 percent on the examination.

<u>VANISHING</u>. A term originally designating the removal of more and more of the components of a specific <u>chain</u> of responses. In an example, a student might be asked in the first frame to fill in a few obvious letters in a poem, then more letters, then words, phrases, and whole lines. When all the components had been vanished, the student would be reciting the whole poem. The term is often used synonymous with <u>fading</u>, although the process of withdrawing <u>prompts</u> is not strictly parallel to the above process.

-W-

<u>WASHBACK</u>. See BRANCHING.

<u>WEANING</u>. Behavioral goal of the fading technique. Training of the pupil to make "independent" responses to stimuli which were previously accompanied by <u>prompts</u>.

APPENDIX B

ACRONYMS

ALGOL	Algorithnic Language
ASR	Automatic Send-Reveive
ATS	Automated Teaching System
BASIC	Beginners All-purpose Symbolic Instruction Code
BBN	Bolt Beraneh and Newman Inc.
BR	Branch
CA	Correct Answer
CAI	Computer Assisted Instruction
CAL	Course Author Language
CATO	Compiler for Automatic Teaching Operations
CB	Alternate Correct Answers
CBE	Computer Based Education
CBI	Computer Based Instruction
CCTV	Closed-Circuit Television
CDC	Control Data Corporation
CDT	Computer Directed Teaching
C/I	Characters per Instruction
CLASS	Computer-based Laboratory for Automation of School Systems
COBOL	Common Business Oriented Language
CPU	Central Processing Unit
CRT	Cathode-Ray Tube
EOB	End-of-Block
FN	Function
FORTRAN	Formula Translation

G&N	Guidance and Navigation
GE	General Electric
GPDS	General Purpose Display System
GR	Group
GROW	Germantown, Roosevelt, Overbrook, and Wanamaker
IBM	International Business Machines
ID	Identification
I/F	Instruction per frame
IH	Instructional hours
JOSS	Johnniac Open Shop System
JOVIAL	Jules Own Version of International Algebraic Language
KWT	Keyword Test
LD	Lesson Designer
LUCID	Language Used to Communicate Internal Design
M&O	Maintenance and Operations
MAT	Mathematical Algouthmic Translator
MSFN	Manned Space Flight Network
NSF	National Science Foundation
NX	Next
OP	Operation
PAS	Program Assembly Language
PAT	Partial Answer Test
PI	Programmed Instruction

PISD	Philadelphia Independent School District
PK	Printer Keyboard
PL	Programmed Learning
PLANIT	Programming Language for Interactive Teaching
PLATO	Programmed Logic for Automatic Teaching Operations
PR	Present
QU	Question
R/S	Remote Site
SDC	System Development Corporation
SIRS	Salary Information Retrieval System
SMCVG	Simulation Memory Character Vector Generator
TSA	Teacher-Student ALGOL
TSS	Time-Sharing System
TY	Type
UCI	University of California at Irvine
UN	Unanticipated Response
WA	Wrong Answer
WB	Alternate Wrong Answer

NASA-Langley, 1967 —— 8 CR-917

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