COMPUTER

MANAGED LEARNING SYSTEM

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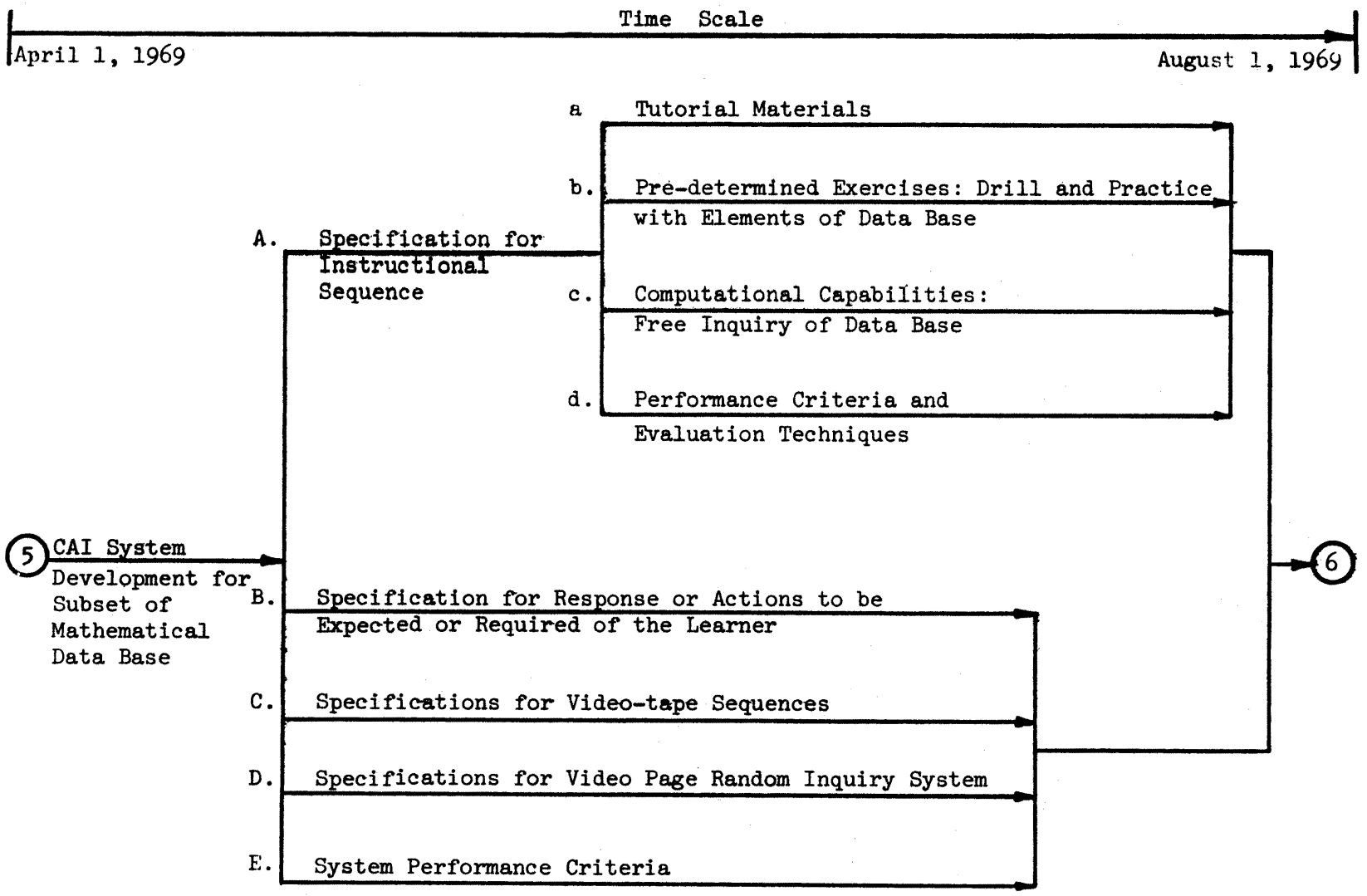
I. PROJECT STATUS AND THE YEAR AHEAD

During its first year of operation, the Project has assembled its staff, constructed its facilities, installed a first version of its multi-media communications system, devised the computer software for operating the communications equipment, devised a computer-managed instructional system, and continues to make progress in the development of instructional materials.

Figures 1.1 through 1.4 are the program control charts presented in the original Project Proposal and are included here as an assistance for evaluation of the general progress of the program. To date, substantial progress has been made toward the completion of all activities shown in Figures 1.1 and 1.2, which accounts for Phase I of the originally proposed program. Some progress has been made in vital activities of Phase II, represented in Figure 1.3.

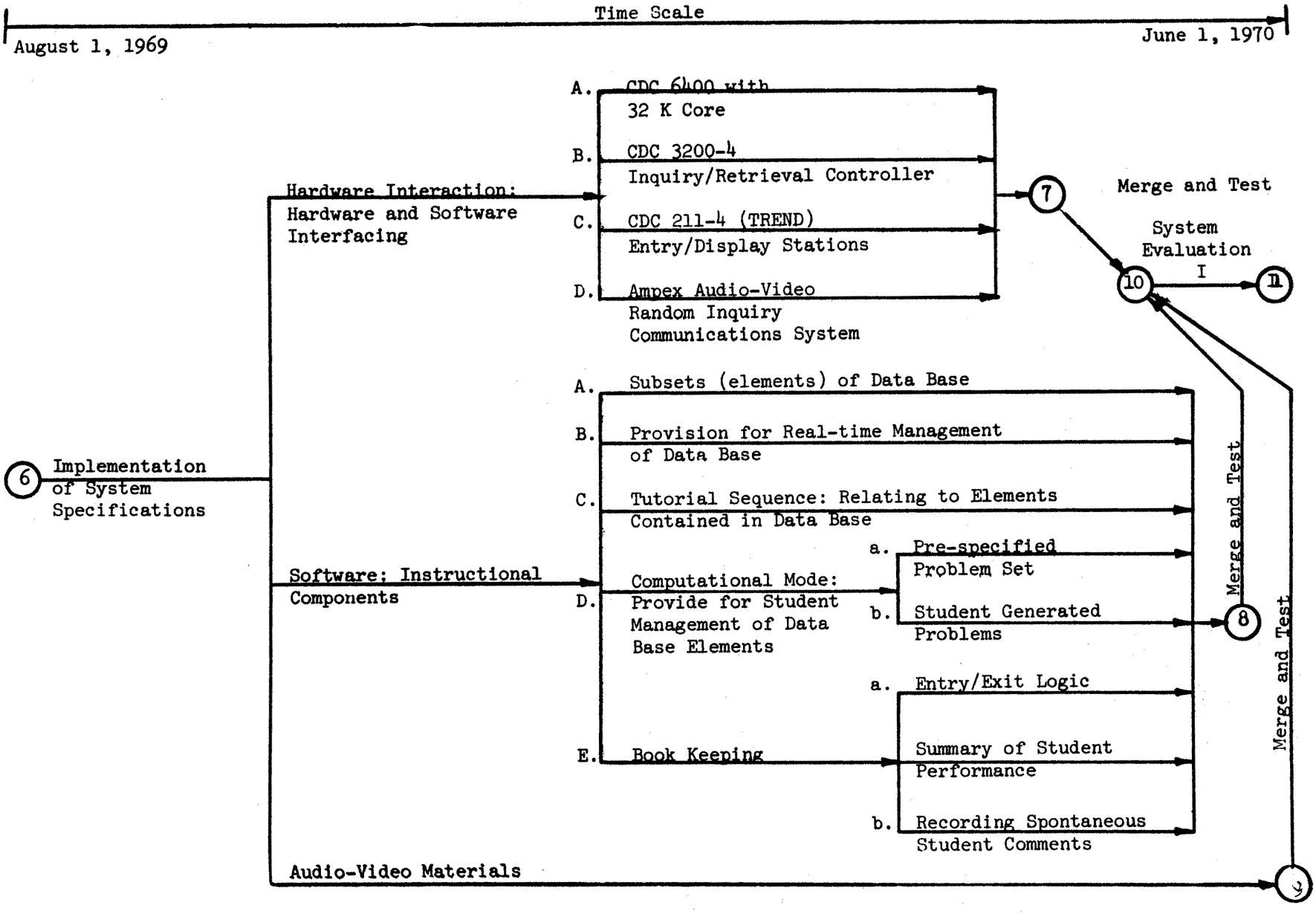
The single major difficulty which has been encountered concerns the random access audio-video communication equipment. The timing for introduction of this equipment into the program is shown in Figure 1.2 - Activity 6-7(D). This equipment was delivered approximately three months behind schedule, as a first complication. The significant difficulty, however, has been in failure of the interface logic unit to execute its required functions. At this time, the major problems with the interface appear to have been solved, but not without considerable effort on the part of Project staff.

The audio-video equipment, aside from the computer interface, has been performing in a satisfactory manner. Some instructional materials have



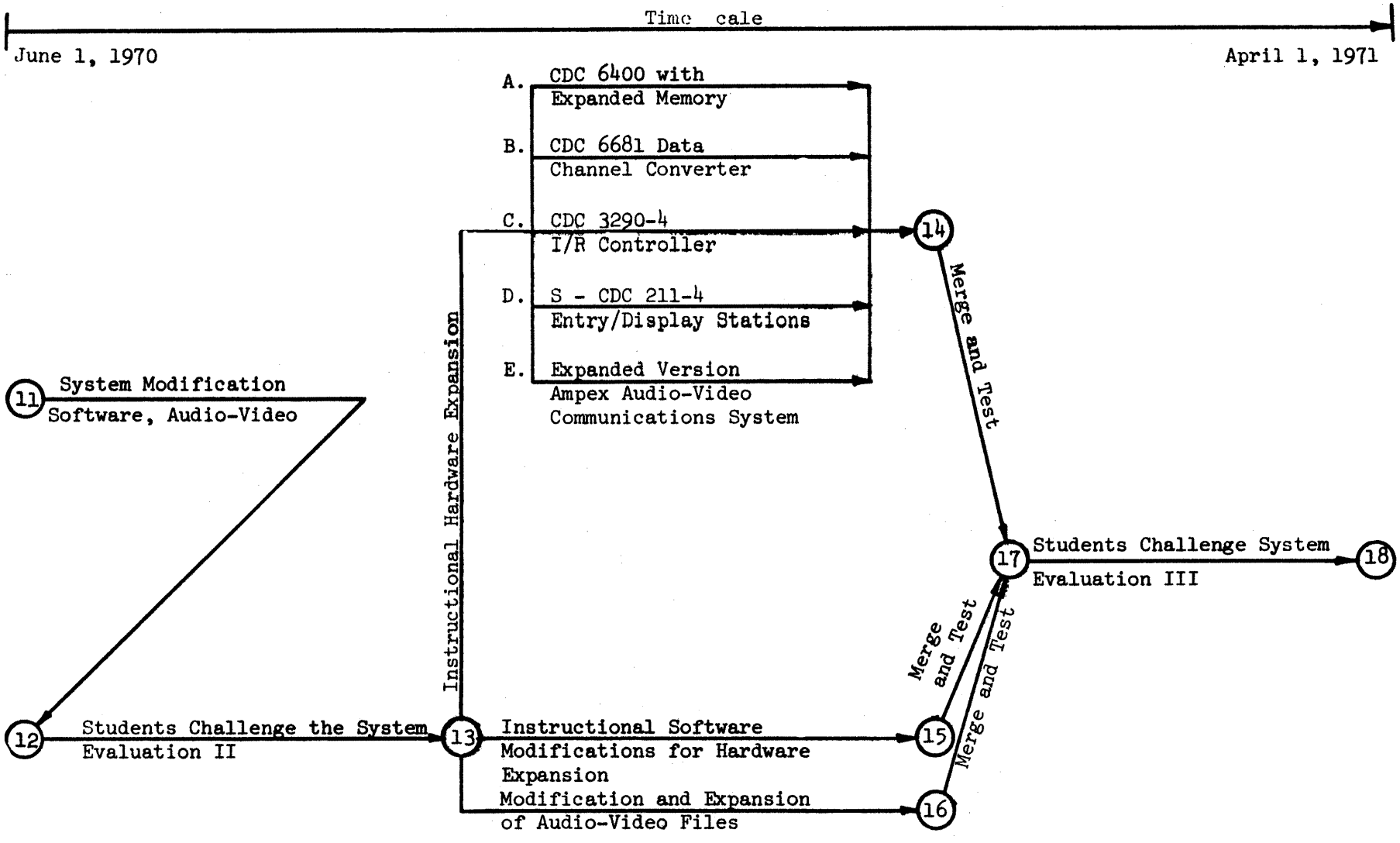
PROPOSED CAI PROJECT: PHASE I-A

FIGURE 1.1



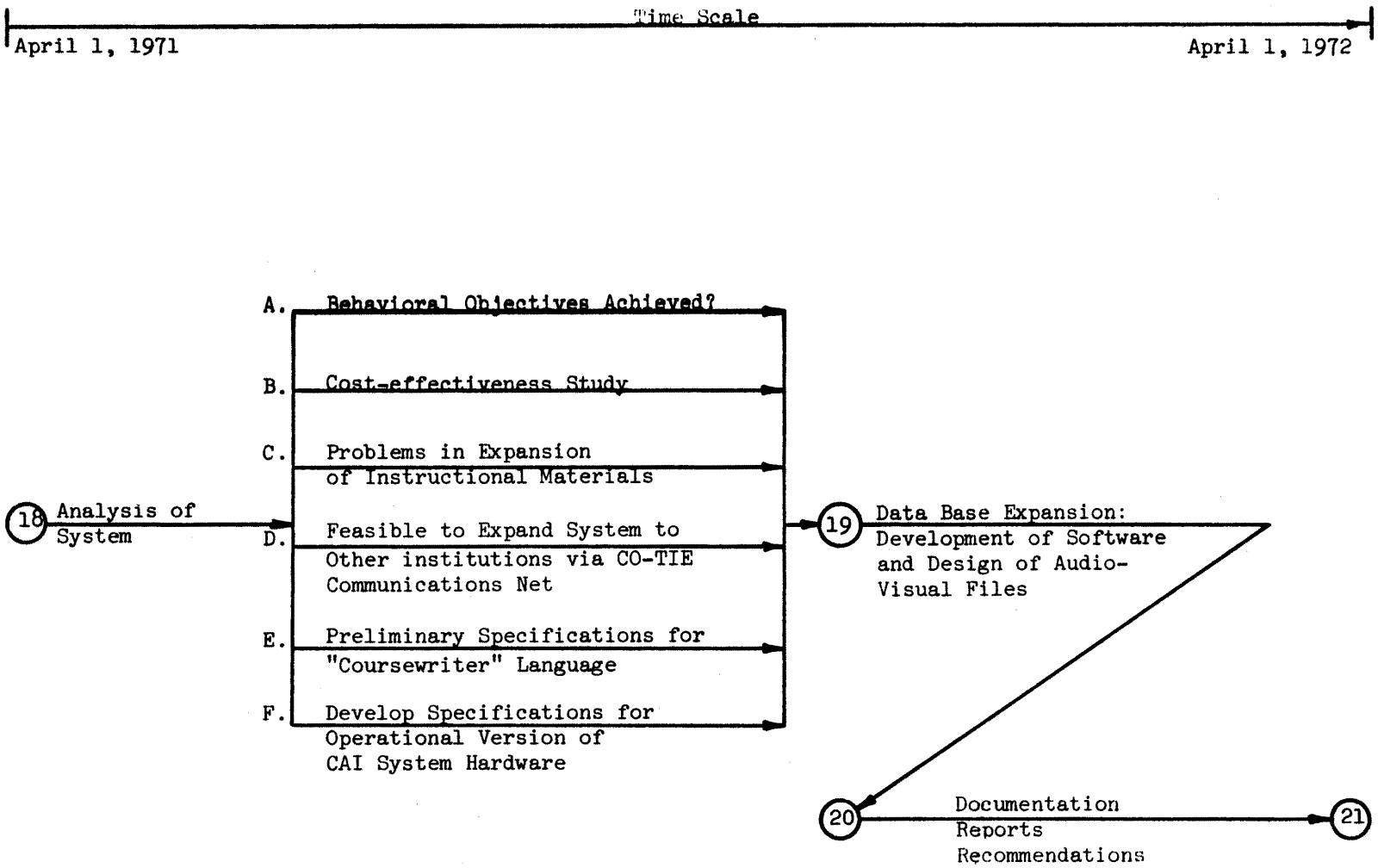
PROPOSED CAI PROJECT PHASE I-B

FIGURE 1.2



PROPOSED CAI PROJECT: PHASE II

FIGURE 1.3



PROPOSED CAI PROJECT: PHASE III

FIGURE 1.4

been stored on video tapes and on the video disk. Even though the units must be operated manually, they have been useful in working toward the design and improvement of instructional material.

The summary effect of the problem with the communications equipment is to delay the first real student use of the total system. This activity has been rescheduled to begin in late June, 1970.

It is hoped that, as a result of the equipment problem discussed above, no real time will have been lost to the ultimate project objective. Work has proceeded ahead of schedule on the development of the multi-terminal configuration planned for Phase II (re Figure 1.3). Computer software has been developed to the condition which is theoretically required to operate a large number of terminals simultaneously. The additional TREND terminals called for in Phase II, together with a dedicated 6681 Data Channel Converter, have been delivered to the Project and will be put into operation immediately. No problems are anticipated in stabilizing the multi-terminal computer software by June of this year. The equipment required to update the video disk to accommodate the several student stations has been ordered and is scheduled for delivery by the middle part of June, 1970.

The decision has been made to limit the multi-station configuration to five student stations (the original proposal was eight). The only justification for this change is an effort to conserve Project funds. It is felt that this change should have no deteriorating effect on Project objectives. There are two fundamental reasons for the requirement of several terminals: first, to provide facilities for a good amount of student exposure to the

computer-managed instructional program; and, second, to insure that program software is capable of proper response in a multi-terminal environment. As it happens, the requirement for central computer memory is quite low (re Section 3.5); therefore, the instructional system can be made available for student work at various hours throughout the day. Accordingly, sufficient testing may be accomplished with but a few terminals. It is hoped that the major software problems will be identified as well through the simultaneous operation of five terminals as with the eight originally planned for.

During the year to come, attention will focus on evaluation of the total Computer-Managed Learning System (CMLS) and on correction of the various problems that will be revealed through the evaluation process. Formal evaluation will revolve around two separate periods of student use of the system. The first period of student use is scheduled to begin in late June, 1970, and will be approximately one month in duration. The objective of this activity is to reveal mechanical problems in the system and to identify major problems in the instructional materials and pedagogical strategy.

Allowing a three-to-four month period for problem correction, a second program of student use will be conducted. This last activity is most critical to the Project objectives. As a consequence of this event, Project investigators hope to establish the contribution which the CMLS may make to the process of engineering education. An evaluation of the instructional system will in fact be an evaluation of the students, themselves. Students representing a wide variety of educational background will be exposed to the CMLS in an effort to determine its

adaptability to diverse equipment. Resources of the Human Factors Research Laboratory at Colorado State University will be used in designing evaluation procedures and in providing objective interpretation. It is likely, through the evaluation period, that the Project will support a graduate student, from the Human Factors Research Laboratory, as a means of providing continuous attention to this important activity.

Details of work accomplished by the Project during the past year are discussed in the following report sections.

II. PEDAGOGICAL DESIGN

One of the major considerations of the CMLS Project is that of design and implementation of a capable instructional strategy. The method of approach to this problem was first to define a complete educational strategy without regard for the manner in which it was to be implemented. Review of the literature of educational psychology was directed at those notions thought to be particularly applicable to scientific education. The strategy having been defined as a working hypothesis, the next step was a first estimate of how much of the instructional strategy could actually be implemented as an interactive computer system. In this latter determination, little thought has been given to the question of advisability of computer implementation from a psychological point of view. The Project is committed to analysis of psychological problems associated with the system after implementation - Version I.

A review of those notions just described is presented in the following sections.

2.1 The Fundamental Premises

Bloom[1] describes one who is knowledgeable of a certain subject as being able to perform six discrete functions with the subject material. These functions, or conditions of learning, are called *Cognitive Levels* and are defined as:

Level 1 - Recall Information About A Concept (Knowledge)

1. Bloom, B., et al., *Taxonomy of Educational Objectives: Cognitive Domain*, McKay, New York, 1963.

Each student should be able to recall and state, write, or identify specific terminology, facts, relationships, methods, principles and theories related to a given concept.

Level 2 - Use the Concept (Comprehension)

When given the necessary information and specifically asked to do so, each student should be able to restate the concept in his own words, identify an example of the concept, translate the concept from one form to another, use the concept to reach a conclusion, predict a trend or determine an answer.

Level 3 - Choose the Correct Concept and Use it Correctly (Application)

Given a problem which is new to him, each student should be able to choose the appropriate concept and use it correctly to solve the problem. This is a closed or single answer problem. Some analysis may be involved.

Level 4 - Problem Analysis

Each student should be able to decompose a given problem into meaningful elements, determine the relationship between these elements and identify the organizing principles for the elements.

Level 5 - Synthesis

Each student should be able to combine the elements required to form a pattern or structure not clearly there before. The synthesis process may result in the production of a unique communication, a plan, a design, a proposed set of operations or a set of abstract relations.

Level 6 - Evaluation of a Design

Each student should be able to make purposeful judgment about the *value* of ideas, works, solutions, methods, materials, designs, etc., using stated criteria and standards in his appraisal.

It is theorized that, throughout the learning process, the mind most naturally works in a hierarchical fashion in accordance with the

Cognitive Levels defined by Bloom. It was, therefore, decided that the Computer Managed Learning System (CMLS) should be modeled after Bloom's *Cognitive Levels*. The instructional strategy should seek to develop the student at each of these levels, in an ordered manner.

The ideal instructional strategy should address all six of the *Cognitive Levels*. It was decided, however, that treatment of the *Synthesis Level* would present difficulties which could not be effectively treated by the computer-managed instructional program. Accordingly, no formal attempts will be made to incorporate the *Synthesis Level* into the CMLS.

The intuition of any educator would indicate that the learning process must deal with many fundamental and discrete units of information. The cognitive level definitions provide for this intuition and, more important, describe the different treatments which these units should receive. Recognition of these levels as distinct from one another provides a clear pattern of instructional treatment and for establishing an ordered sequence of behavioral objectives.

Following these broad guidelines, the components and behavior of the CMLS were organized as follows:

a. Decompose the instructional topic into fundamental elements (call these concepts).

b. Define the hierarchical arrangement among the concepts.

c. Provide for organization of the concepts at each of the *Cognitive Levels*.

d. Define behavioral objectives to be used by the system and its user in the determination of learner capability at each of the *Cognitive Levels*.

e. Provide evaluation of user performance against the behavioral objectives. Such evaluation is to be made available to the student so that he may emphasize (or rework) areas of weakness.

f. Provide computational support to the system user. This support will be adaptive in the sense that having demonstrated competence with any particular concept, the user is provided with automatic processing of all associated computational details. For example, once the user is determined to be capable with the concept of quadratic equations, he should be provided, from that point forward, with a computational *macro* for extracting the roots of the equation.

g. The interactions between the student and the CMLS is to provide for different degrees of ignorance of the user. That is, the student should be required to concentrate only on those portions of a given topic which are unfamiliar to him or are particularly difficult for him.

h. Presuming, in the extreme case, that the user of the system is totally familiar with a given topic, the CMLS should be capable of providing computational support, summary equations, tables, etc., as a general service.

As a final general premise, it is presumed that the user of the CMLS wants to learn and therefore that performance evaluations are made only for the purpose of deciding on a course of action at any point in time. The notion of *failure to pass* is alien to the system.

Presumably, a wide variety of topics could be organized and treated in the manner just described. As a demonstration of this

instructional program, the Project is in the process of implementing the topic of Vector Algebra. The contents of the CMLS version of this topic, including the various treatments of its components, are shown in Figure 2.1.

2.2 The Instructional Program

The manner in which the various subject components are treated in an interactive computer system is described in this section. The various pieces of equipment required to execute the program will be described in Chapter IV. At this point, however, it is necessary to establish the manner in which information is processed and to recognize the nature of the communications system.

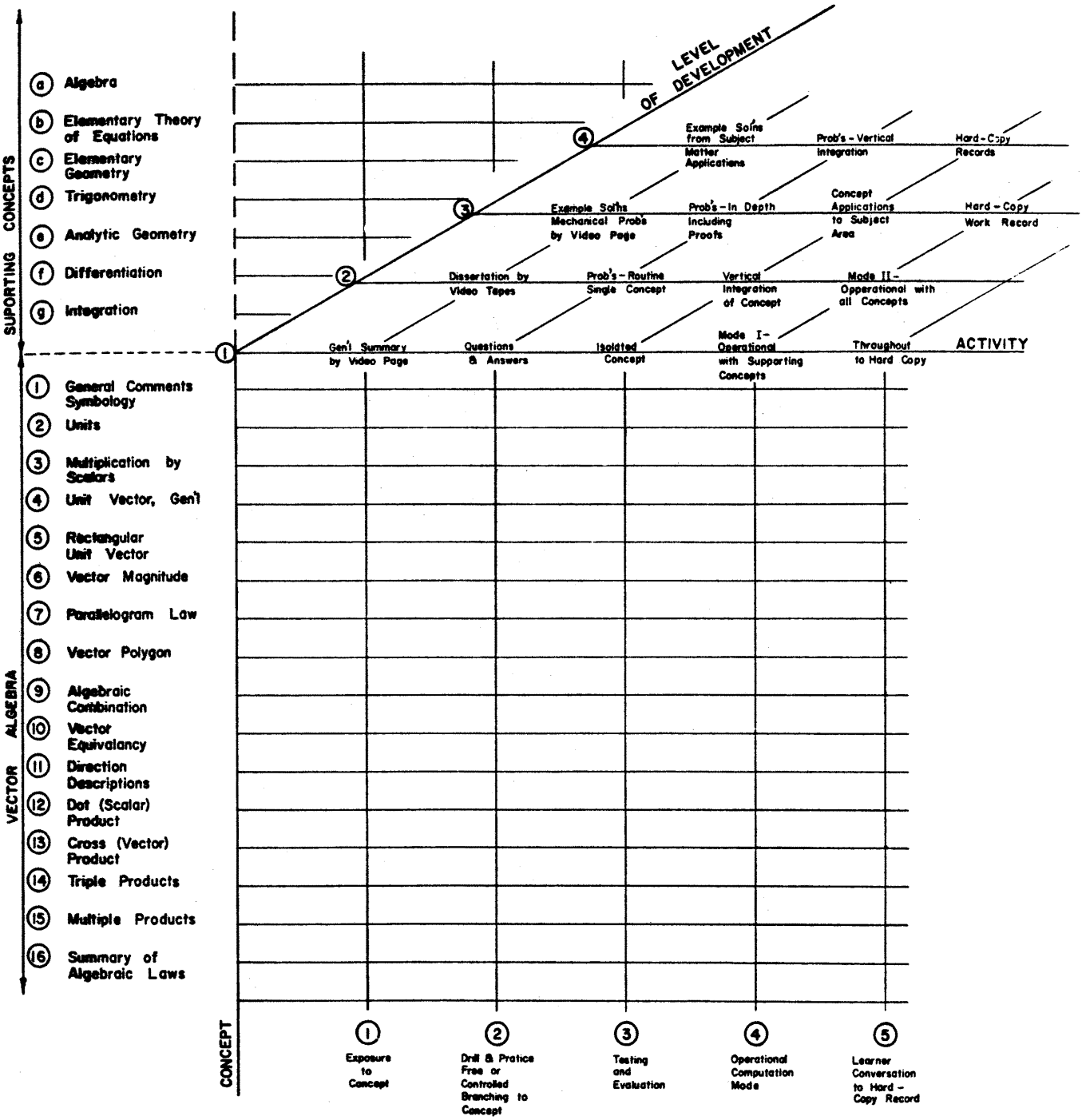
The CMLS user maintains communication directly to a CDC 6400 computer system, via a CDC 211-4 TREND terminal. The system response may fall into any of four categories:

- Response produced uniquely by the central processor, e.g., the results of some computation.

- Response composed of prepared message segments stored on a mass memory device.

- Response prepared and stored on video tape. The comptulter searches out the proper Video Tape Record (VTR), activates the proper playback unit and directs the VTR to the proper student station.

  Response prepared and stored on a single image (graph, table, photograph, etc.) on a random access video disk. Any record, called a Video Page (VIP) may be accessed by the computer and delivered to the



COMPUTER MANAGED LEARNING SYSTEM MATRIX

FIGURE 2.1

proper student station, as activity of the moment may require.

The net objective of the computer-communications system is to provide an instructional network which can be entered and left at will; which can be followed largely at the discretion of the system user or under predominant computer control; and which will automatically adapt to the requirements and interests of a particular user. The organization of this network is defined in the following outline. It is important to note that the definitions and behavior described do not refer to any particular instructional topic. In this respect, the network and its management are applicable to a wide range of subject matter.

CMLS - INSTRUCTIONAL NETWORK

1. Establish Communication

1.1 Machine Dialogue

System establishes its own identity and addresses itself personally to the user.

1.2 Assembly of Background Information on Student

This information will be used to condition the system in such a way that it is able to select the various routes through the network to best fit the situation of the individual. Information collected here is abstracted and stored as counters in a *Status Record*. The counters may be added to or altered as the user proceeds through the instructional network. At various points of progress, the counters

in the *Status Record* will establish the most appropriate subsequent routing through the network.

1.2.1 Student Name

1.2.2 Academic Major

1.2.3 Year in School

1.2.4 Grade Point Average

1.2.5 Has student had previous formal exposure to vector concepts in a math course?

1.2.6 Has student used vector concepts in courses other than math courses?

1.2.7 Is student using CMLS as part of a formal course assignment?

Assign appropriate priority codes as a result of 2.1 through 2.7.

1.3 Set up student file with above information.

1.4 Presentation to familiarize the student with the CMLS operation and brief outline of the instructional network approach.

2. Formal Presentation of Concepts

The first branch in the network will be a formal presentation of vector concepts. This will be accomplished on a concept-by-concept basis. A given concept, as defined by the various rows in the learning matrix (Figure 2.1), will be presented as a combination of one Video Tape Record (VTR) followed immediately by a series of Video Pages (VIP's). The Video Page *Chapter* will present material in the following order: pertinent questions which the student should be able to answer as a consequence of the VTR presentation; a handbook-type summary of appropriate definitions, formulas, constants, etc.; a set of mechanical problems, together with their solutions,

which represent the computational manifestations of the concept; and a set of problems which relates the use of the concept to the student's own field of interest. The student may wish to skip over the example problems sections and should be given the opportunity to do so at the beginning of each set. While examining any problem set, the student should be able to step through the series as rapidly as he may wish.

The individual Video Tape Records will be two-to-four minute presentations. The complete VTR package will be limited to one hour video tape for the first version of the system. Allowing for two or three utility VTR's, there will be no more than 50 - 52 minutes of total tape available for subject matter presentation.

2.1 Concept 1 - Scalars, Vectors, Definition of Vector Algebra, General Symbology.

2.1.1 VTR - 1. Two-to-four minute audio/video presentation.

2.1.2 VIP presentation of critical questions relating to the first CMLS concept. This may be one or more video pages.

2.1.3 VIP presentation of concept summary: definitions, formulas, etc. Every effort should be made to confine this to one VIP.

2.1.4 VIP presentation of operational (computational) features of the concept. This presentation may be a series of VIP's. Student may step through series at will, or may skip the series entirely, at his own discretion.

2.1.5 VIP presentation of examples of application of the concept to student's particular field. It will be required to

assemble alternative presentations here. Each alternative emphasizes the different academic disciplines; i.e., Mechanical Engineering, Electrical Engineering, Civil Engineering. The appropriate presentation will be determined by consulting a counter in the status record. Subject matter applications should be sequentially graded in terms of the student's academic level.

2.2 Concept 2 - Unit Vector, Zero Vector, Special Definitions.

2.2.1 VTR - 2

2.2.2 VIP questions

2.2.3 VIP Capsule Summary

2.2.4 Mechanical Operations

2.2.5 Subject Matter Applications

2.3 Concept 3 -

.

.

2.17

NOTE: Timers will be set on the events following the VTR presentations to determine the length of time which the student is spending with each VIP series. Such times would be entered in the student's Status Record. This will provide interpretive and conditioning information.

Through the first branch in the instructional network, we are attempting to provide for student development at *Cognitive Levels* 1 and 2 (after Bloom).

3. Review of Concept Summaries

3.1 User is shown a VIP which explains that he is about to be delivered a review of the Concept Summaries. He is shown how to bypass this step, if he desires. If he elects to bypass, he is sent to the next point in the CMLS, which consists of general instructions for recalling any of the presentations he has seen to date.

3.2 Student steps through VIP Concept Summaries at his own rate. This corresponds to Nodes 1.1.1 through 17.1.1 in the learning matrix (Figure 2.1). The student will be timed through this activity. While the student is on a particular VIP, he should be able to recall the corresponding VTR or associated VIP problem presentations. Following any recall, the user is automatically returned to the VIP Summary Page from which the original exit was effected. The user is able to backspace through the VIP summary list.

At any point in time, the student is able to sign off on the 211-4. On resuming activity, the student will be given only two alternatives: (1) start over, essentially at the beginning of the Presentation of Concepts, or (2) he may return to a program flag position most recently passed during his previous session.

The student will be able to arrest his sequence and "backspace" at any time to the most previous instructional element.

4. System Recall Procedure

On user demand for review of materials which have been passed previously,

he will receive a VIP of the learning matrix (Figure 2.1). From this, he is able to address the desired review materials.

4.1 VTR presentation of procedure for accessing any of the following:

4.1.1 Any one of the VTR's Node n. 1.2, where the "n" is the number of the concept desired.

4.1.2 Any single VIP in the Concept Summary list. Node n. 1.1 where "n" is the concept number.

4.1.3 Beginning of example solution sequence. Node n. 1.3 - Computational details involving isolated concept. User specifies "n" the concept number. At any point in the sequence, the student should be able to request a return to his point of embarkation.

4.2 User experimentation with recall procedure. User requests "RECALL." VIP Catalog of summary names is presented. User types name or code number and specifies VTR or VIP. Improper (not interpretable) user action must result in a message display to alert the user of a problem with his request. A second improper user action will automatically reference the original presentation of "RECALL" procedure. This again leaves the user in an experimental position with the recall procedure.

5. Example Problem Solutions

This presentation will concentrate on the computational manifestations of each of the "fundamental" vector concepts. The examples will be presented by a VIP Chapter of problems. This corresponds to learning matrix nodes

1.1.3 through 17.1.3. There may be more than one VIP at each node. Each problem is carefully designed to emphasize a single concept although there may have to be some compounding of concepts when dealing with the higher order ideas. Each page in this sequence should be individually addressed so that it may be summoned by the internal logic of the CMLS. The system user should be able to access the beginning of this file; from this point he can step sequentially through the various pages. Upon completion of this examination, the user will automatically be returned to his original point of embarkation. All computations involved in this problem set will be accomplished in terms of fundamental computational procedures; i.e., simple addition, subtraction, multiplication, etc.

6. Instruction for Real-Time Computational Capability

6.1 VTR presentation of basic computational capability. The CMLS user is informed of his capability to use the system as a calculator. At this point in the instructional network, the user will be limited to execution of:

- Addition
- Subtraction
- Multiplication
- Division
- Exponentiation, including fractional
- Exponents
- Evaluation of:

  Trigonometric functions
  Definite Integrals
  Roots of the Quadratic Equation
  Simultaneous Equations (n x x)
  Determinants (3 x 3)

A VIP handbook page lists the integrals which the system is capable of handling directly. Instructions are provided for accessing this catalog page.

The user may place the system in computation mode at any point in time by depressing one of the four special function buttons at the top of the 211 terminal keyboard. Release of the function button returns the user to his previous activity. The user may assign values to alpha-numeric names of his own choice. Once a value has been assigned to a variable name, the student may use the variable name in place of its value in any subsequent computational stage. At the request of the system user, the computational results may be accumulated to produce a hard-copy record which will be made available after the user signs off the system.

6.2 Experimentation with Computational Capabilities

At this point, it would be possible to present a VIP display with some suggested computational exercises. Particular attention is provided for system reaction to improper (undefined) user activity.

6.3 Instructions for recall of VIP Catalog of computational functions.

7. Drill and Practice

The objective here is to develop the student at *Cognitive Levels* 1 and 2. The mechanism corresponds to learning matrix nodes 1.2.1 and 1.2.2 through 17.2.1 and 17.2.2. This section of the CMLS is characterized by two features:

> The student is able to use the computational capability of CMLS, in whatever way he chooses, in seeking an answer to a question or problem. For this particular drill-and-practice routine, the user may employ only the primary computational routines identified in Section 6.
>
> The student may present his answer in any form he wishes via the 211-4 teletypewriter. No effort will be made for the CMLS to interpret the student's answer. In fact, the answer, as well as the process used to derive it, may be totally inappropriate.

Following the student's presentation of his own answer, the CMLS will respond with its stored version of the correct answer or problem solution. It will be the responsibility of the student to evaluate the quality of his response compared to the standard established by the CMLS response. This technique would, hopefully, begin to develop the student at *Cognitive Level* 6.

During the Drill and Practice phase, a hard-copy record will be developed to contain for each problem or question:

- statement of the problem or question;
- all computational activity;
- the student's answer or response; and
- the correct answer or response.

Much evaluation will be required concerning what is to be expected of the student before the CMLS solution is provided to him. Some obvious possibilities are that the student may:

- type in a simple request for the answer;
- make three (?) computations; or
- type in something he considers to be an answer.

The system user is able to skip around any question or problem at will. However, the user will only be shown answers or solutions for those questions which he actually attempts. The premise here is that a student will have to be very confident of a question or problem before he elects not to attempt it and thus be deprived of seeing a correct answer or a correct response. Thus, further reinforcement at *Cognitive Level* 6 should be attained. At any point in time, during the drill and practice activity, the student may request a help sequence. In general, the signal for computer response will be a HELP message from the 211-4 typewriter. The first HELP request results in a VIP display of appropriate summary concepts. a third HELP request results in a VTR presentation of the appropriate concept. A fourth HELP request results in a message from the computer which advises the student to pick up his hard-copy work record and see his instructor.

Having activated all of his allowable HELP routines for a given problem or question, the student may still elect to continue with his drill and practice activity, although he does so against the most current evaluation of his condition.

8. Testing Routine I

The objective of the first testing activity is to establish that the student has *knowledge* of individual concepts. This includes recall or recognition of concept definition and capability to execute a computational process.

The interpreted student responses will be limited to key words and numerical data. The quiz will be computer-evaluated and the student is made aware of

his score immediately on completion of the exam. The student is expected to perform at some minimal level before being allowed to advance to any consideration of higher-ordered materials. Much evaluation work remains to be done in order to set minimum performance standards and to provide for proper evaluation of performance. The CMLS system will react in one of the following ways at the conclusion of a given quiz:

8.1 Student performance satisfactory.

In this event, the student is simply informed of his score on the exam, given a list of the questions which were missed on the exam, and informed of the particular concepts which were stressed in the questions or problems which he missed. The student is allowed to pass on to the next activity in the instructional network. Of course, he may always request review or drill and practice - which he may elect on the basis of his test evaluation.

8.2 Student performance unsatisfactory.

8.2.1 VIP Sequence consisting of summaries of the critical concepts.

8.2.2 Drill and practice with critical concepts but should contain a random injection of concepts not covered during the remedial review.

8.2.3 Second Quiz - concentrates on the critical concepts but should contain a random injection of concepts not covered during the remedial review. If the student's performance is considered to be satisfactory, he is allowed to pass on to the next branch in the instructional network. Before moving on, the student is warned of concepts in which he still may be

weak. If results of the remedial quiz are unsatisfactory, the student is informed he must restart the program. In reworking the program, the CMLS will use all of the evaluation information, collected to this point, in determining a new route through the instructional network.

9. Example Problem Solutions

This branch corresponds to nodes 1.1.4 through 17.1.4 in the learning matrix (Figure 2.1). The objective of this activity is to begin the development of the student at *Cognitive Level* 3. The problems would be rather mechanical and each problem should involve only one or two concepts. The concepts are not treated in any particular order. The problems are kept as simple as possible without being obvious as to which concept is being involved. Analysis is to be minimized, although it will not be possible to avoid it entirely. Problems and their solutions are presented by VIP.

10. Drill and Practice

The problems will be presented by VIP. The VIP problem will remain displayed until the user specifically requests the next problem. The user may make any computation he desires, use any verbage he wishes in constructing his solution to the problem. All work records are throughput to hard copy. The student record receives a note that the student has encountered the problem and keeps track of the time spent on the problem, but the details of the work are not stored in the student's permanent file. As the student works his problem, he may request a series of HELP routines. The first HELP request will produce a VIP display of some similar problem extracted from the file of example solutions. The problem presented will be the one which most clearly emphasizes the concept being stressed at the time of the HELP request. A second request

for HELP produces a second VIP problem which relates the current Drill and Practice problem situation. A third request for HELP produces a VIP summary or summaries of the concepts involved in the present problem situation. A fourth request for HELP produces a presentation of the VTR concepts involved in the current problem. The fifth request for HELP provides the suggestion that the user pass on to the next problem in the current Drill and Practice series.

At the conclusion of any HELP sequence, program control is returned to the point from which the first HELP call was initiated. In addition to activating the several HELP activities outlined above, the user may, himself, access any of the CMLS's materials to which he has been exposed to this point in time.

Continued evaluation will be given to the behavioral criteria which the user must have satisfied before being entitled to see the problem solution or answer to the particular exercise on which he is working. After display of the problem solution, the user is passed directly to the next drill and practice problem in the prepared series.

11. Testing Routines II.

The test routines emphasize the requirement of correct choice of concept and the ability to perform with a given concept. The emphasis should not be on analysis, but some must necessarily be involved. The nature of the test questions and problems will be such that any question or problem may involve two or three concepts. Effort should be made to keep compounding of concepts to a minimum. Problem statement will be by VIP. The problem statement

should include instructions on the required form and order of the answers. Answer evaluations will be made on the basis of key words and numerical comparisons. The problems and questions should be laid out such that all of the primary concepts are involved systematically. This will assist in assembling an evaluation which will include a course of remedial action for each individual student. This may be better explained by the assistance of the following table:

QUESTION or PROBLEM	CONCEPT (S) EMPHASIZED . . .	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1		1	1	1														
2		1			1													
3		1			1	1												
4		1	1				1											
5		1	1				1	1										
6		1			1	1	1	1										
7		1			1	1	1	1										
8								1	1									
9							1	1	1									
10										1								
.																		
.																		
.																		
.																		
N		1															1	1

CONCEPT CORRELATION MATRIX

TABLE I

If the patterns of concept involvement are carefully designed, it should be possible to determine several remedial routines for each student on a statistical basis. For example, if a student were to miss only questions 4 and 5 from Table I, we might conclude that he was weak in concepts 1 and/or 2 and/or 6 and/or 7. However, concept 1 occurs in all other problems; concepts 6 and 7 occur frequently in other problems. The conclusion would be that concept 2 requires additional attention. Alternatively, it may be the manner in which concept 2 combines with 6 and/or 7. At any rate, the proposed method of evaluation is explained through this hypothetical example.

A numerical score, as well as limited commentary on the evaluation, will be made available immediately following the completion of the exam. These results will be output on the CRT of the 211-4. The student's complete quiz work is throughput to a hard-copy record, which he may pick up at the conclusion of the exam.

12. Remedial Activity

As a result of the previous examination activity, the CMLS student file will contain a performance record which will include a suggested remedial sequence. The student may elect to follow the system recommendation or to conduct a review of his own choosing.

In general, the prescribed review will take on the following form:

presentation of the VIP summaries for those concepts which are considered to be questionable;

presentation of drill and practice problems constructed according to the same concept

pattern as the quiz problems which gave difficulty; and

administration of another complete examination which covers the total subject matter.

13. Real Time Computational Capability - All Concepts

The system user is to be acquainted with the various computational macros which are now available to him. These macros would allow the following operations, for example:

- vector addition and subtraction;
- vector multiplication by a scalar;
- resolution of a vector into scalar components;
- computation of vector magnitude;
- dot product
- cross product;
- scalar triple product
- vector triple product
- given rectangular components--produce vector magnitude, direction numbers, and direction angles; and
- projection of a vector in a given direction.

13.1 User Experimentation with computational capability.

Any failure to execute at this point gives an error message on the CRT and presents a VIP computation "catalog" on the student TV monitor.

14. Example problem Solutions.

Problems are quite broad and are designed to integrate a maximum number of vector concepts into a single problem objective. The problem should be of a general nature although some tailoring may be done to suit the student's

major and educational level. The intent here would be to relate to the student's development at *Cognitive Level* 4. Problems will be presented by VIP. The user may step through the problems at his own pace.

15. Drill and Practice - In Depth Problems

At this point, the user has computational capability with all vector algebra concepts. The user also has total recall of any Video Tape Record, VIP concept summary and VIP example problem chapter. As in the previous Drill and Practice series, the total work record for any given problem is produced onto a hard-copy record for the student. The work record will not be stored in the student's permanent file. The status record file will contain a note of the problem attempted and the time which the student has spent on each problem. Any HELP sequences at this point will be constructed for each individual problem.

2.3 Current Status of Development of the Instructional Network

The design of the instructional network has been described in the previous two sections. Three components of the network have been coded for the computer at this time. These are: initial dialogue and collection of user status information; the computation mode; and an interactive graphical display package which plots any vector quantity against a three dimensional perspective. These packages were selected for first preparation because of their representation of the varities of problems expected in the total coding process. The actual interest, to this point, has been in design rather than the implementation of the instructional packages themselves. Accordingly, the preliminary instructional

packages were developed largely for the purpose of testing the operating system and for evaluating the magnitude of the work associated with coding the instructional program.

It is anticipated that the remaining instructional packages will be placed on the system with an additional five man-months effort, in actual coding.

The preparation of the Video Tape Records and Video Pages was begun in October, 1969. Development of these materials was intensified at the beginning of this year and should be concluded by June of this year. Alternative versions of these materials are being developed with the plan of experimentation against student reaction. As most of these materials are accessed by an address code, materials may be easily interchanged with little or no alterations required in the computer coding.

It is planned that a limited number of students will be exposed (by human application) to these materials through the months of April through June of this year. The purpose in this is, of course, testing of subject matter presentation rather than students.

III. SOFTWARE FOR COMPUTER MANAGED LEARNING SYSTEM

The software for the Computer-Managed Learning System is being implemented on a Control Data Corporation 6400 computer system. This computer is maintained as a University facility; special access to the computer has been provided to the Project for the purpose of implementation and operation of CMLS. The software may be considered in four categories:

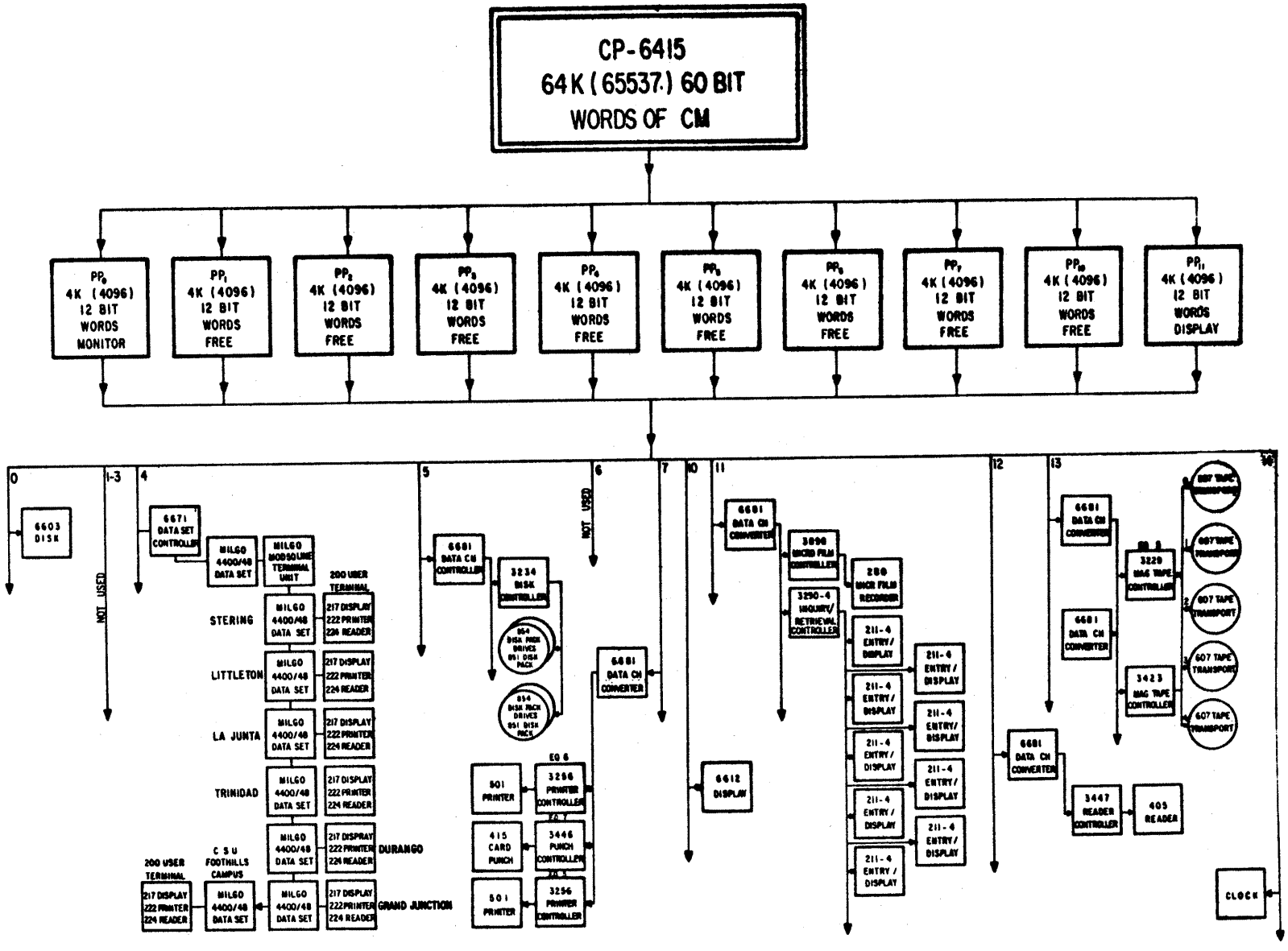
- The System Control Program
- Instructional Programs
- Data Base and Utilities
- Peripheral Equipment Control Programs

3.1 System Control Program (SCP)

The computer hardware available to the Project is of standard configuration. Figure 3.1 shows the relationship of the special hardware required by the Project to the remainder of the facility.

The standard hardware has the capacity of serving only one user at a time. In order to accommodate numerous student terminals, it is necessary to provide a scheme for sharing the resources of the system among the users of the CMLS in an equitable manner. Such is the function of SCP.

It might be considered normal for the SCP to involve complex interaction with the operating system provided by the computer manufacturer, if not to replace it entirely. Either of these approaches could prove to be very costly and difficult to



CDC 6400 COMPUTER SYSTEM AT COLORADO STATE UNIVERSITY

FIGURE 3.1

implement, especially in considering the problem of disruption of normal computer operations. The approach adopted in the implementation of SCP has been to minimize both interaction with the computer operating system and intrusion on computer operations in general. The result of this approach has been to provide a system which was inexpensive to implement (six man-months) and which promises to be inexpensive to operate. The principal features of SCP are:

- User Management
- Data Base Management
- Communications
- Utility Functions

3.1.1 User Management

Since the CMLS must provide for numerous users to be active at any given time, a mechanism to switch from one user to another is of paramount importance because the computer resources can be made available only to one individual at any instant. When a CMLS user indicates his readiness to communicate with the computer, he enters his name on the CRT and depresses the transmit key at the terminal. SCP thereupon retrieves his status record from the data base and, based on the information contained in the record, the appropriate instructional program is summoned. The SCP provides uninterrupted attention to a particular user until one of two events occur: either the instructional program completes the processing of the user's initial input and

requests further information from him, or a predetermined section of the instructional program has been completed. In either case, the user is placed at the end of a queue to await further service. Any user who requests service or who is waiting in the queue while another user is being serviced must, of course, be delayed. It is intended that the average delay to any one user not exceed two seconds. There are numerous design trade-offs which must be examined in order to provide this type of service. These trade-offs usually center on the question of rapid processing at the expense of large central memory requirements versus the access to bulk storage with an associated deterioration in service time. These problems will be the subject of continual evaluation and redesign.

3.1.2 Data Base Management

The instructional programs do not access the data base directly. Rather, they provide SCP with the relative address of any particular data base record that is required. If the SCP monitor determines that the request is valid and that the requested record is not already in central memory, the transfer is made to a predetermined buffer shared by all programs. Only the user status record is altered by instructional programs. SCP provides all bookkeeping required for updating the status record and restoring it to rotating memory before a new record is brought in.

3.1.3 Communications

Communication with the user terminal requires that input messages be brought into central memory and formatted in a manner that facilitates processing by an instructional program. Output messages to the user must be provided with appropriate control codes and routed to the correct terminal. In addition, there is the necessity of activating information packages stored on the Video Tape and Video Disk units. The routines for realizing a particular display from a coded request are part of SCP.

3.1.4 Utility Functions

In order to avoid duplication of effort in coding the instructional programs, SCP provides several utility functions to the designer of the instructional program. By requiring that the program designer make use of the facilities (suitably modified or extended as necessary), the over-all size of the system has been kept within reasonable bounds. (See Section 3.5 for software specifications). Utilities include interpretation of input against command lists; string manipulation routines; and conversion of numerics to and from internal binary storage.

3.2 Instructional Programs

The actual control of student activity at a terminal is accomplished through extensions to SCP. These programs, written in a subset of FORTRAN IV, share a region of central memory

immediately beyond SCP. Only one area of central memory is allocated to them; whenever a new program is brought into memory, it necessarily destroys the previous one. The programs are, however, reentrant so that it is not necessary to reinitialize a program already in memory for each new user. Instructional programs communicate with the student user through SCP so that at all times the system may monitor its own activity.

The library of instructional programs is stored on rotating memory. When fully developed, this library will constitute the largest single component of the CMLS package. The three instructional programs implemented to date are the programs for user identification and initialization of status record, the computation code, and the vector display package.

3.3 Data Base and Utilities

The data base is stored on random access rotating memory. As all records are of the same length, the software required to manage the data base is minimal in size and simple in concept. The data base consists of three types of records.

3.3.1 User Status Record

This record contains all information relative to the current operations of a student user, as well as the record of his past activities. The historical information contains a list of all activities experienced by the student since his beginning with the CMLS; the amount of time spent with each of the activities; performance evaluations, including test

scores; and a record of problems successfully attempted. The user status record is resident in central memory whenever the user is active and it is the only information saved when the system is passed on to another user.

3.3.2 Command Record

This record consists of commands that constitute the valid communication language by which the student communicates with the computer. These commands are stored, one per word, in the record in display coded format.

3.3.3 Message Record

The message record is a formatted response to the user that has been anticipated by the designer of an instructional program. It contains all required control codes and so may be displayed with a minimum of coding effort.

3.3.4 Utilities

The system makes use of off-line storage on magnetic tape for the data base. Because the formats of records for tape and rotating storage are different, a certain amount of processing is required to load the data base. Moreover, SCP programs are used to effect the transfer of contents of the data base to the system printer and for dumping diagnostic information in student work records onto hard copy.

3.4 Peripheral Equipment Control Programs

The CMLS requires the use of two special peripheral processor

programs. One of these controls communications with the 211-4 student terminals; the other controls the operation of the video tape recorder and video disk equipment is of particular interest for it is the first time that this particular equipment has been controlled by a digital computer.

The driver package for the 211-4 terminals was prepared by CDC systems engineers. The Project wishes to acknowledge Mr. Robert Hedges and Mr. Rick Renz for their preparation of this package. Mr. Hedges is resident analyst assigned to the CDC 6400 installation at the University of Colorado, Boulder, Colorado, and Mr. Renz has a similar position at Colorado State University. The video equipment driver was prepared by Mr. Mike Adler, who is on the systems staff in the Computer Center at Colorado State University.

The TREND terminals are driven through a CDC 6681 Data Channel Converter and a CDC 3290 Inquiry/Retrieval Controller. The interface logic for the video equipment is hard-wired directly to a 6681 Data Channel Converter.

3.5 Software Specifications

In its present condition, the operating program for CMLS requires $1,700_{10}$ words of central memory. The program composition is as follows:

- Data Storage - 450_{10} words
- SCP - 725_{10} words

- Operating System Interface - 320_{10} words
- Instructional Utility - 175_{10} words

The SCP package consists of FORTRAN routines with an average size of 32_{10} words each. There are also 48 COMPASS routines having an average size of 9_{10} words.

IV. SYSTEM HARDWARE

A typical student learning station will consist of:

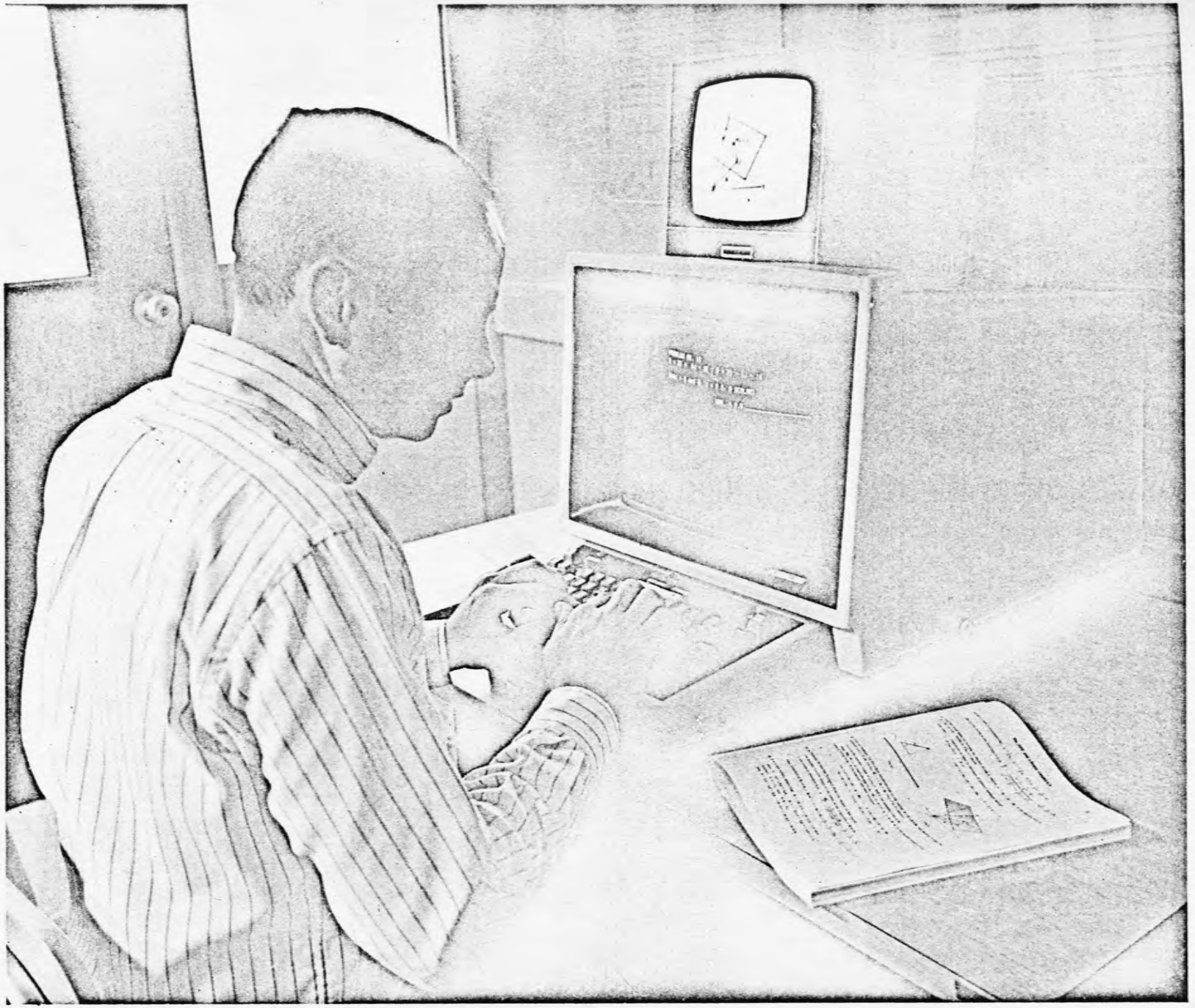
- One Standard CDC 211-4 (TREND) communications terminal
- One Video Monitor
- One Audio Receiver (headphones in the operating version)

This equipment, configured for program development purposes, is shown in Figure 4.1. The TREND terminal is connected, through a 235 foot service line, to a CDC 3290-4 Inquiry/Retrieval Computer. The video and audio receivers are connected to logic interfacing which is housed in the video disk cabinet.

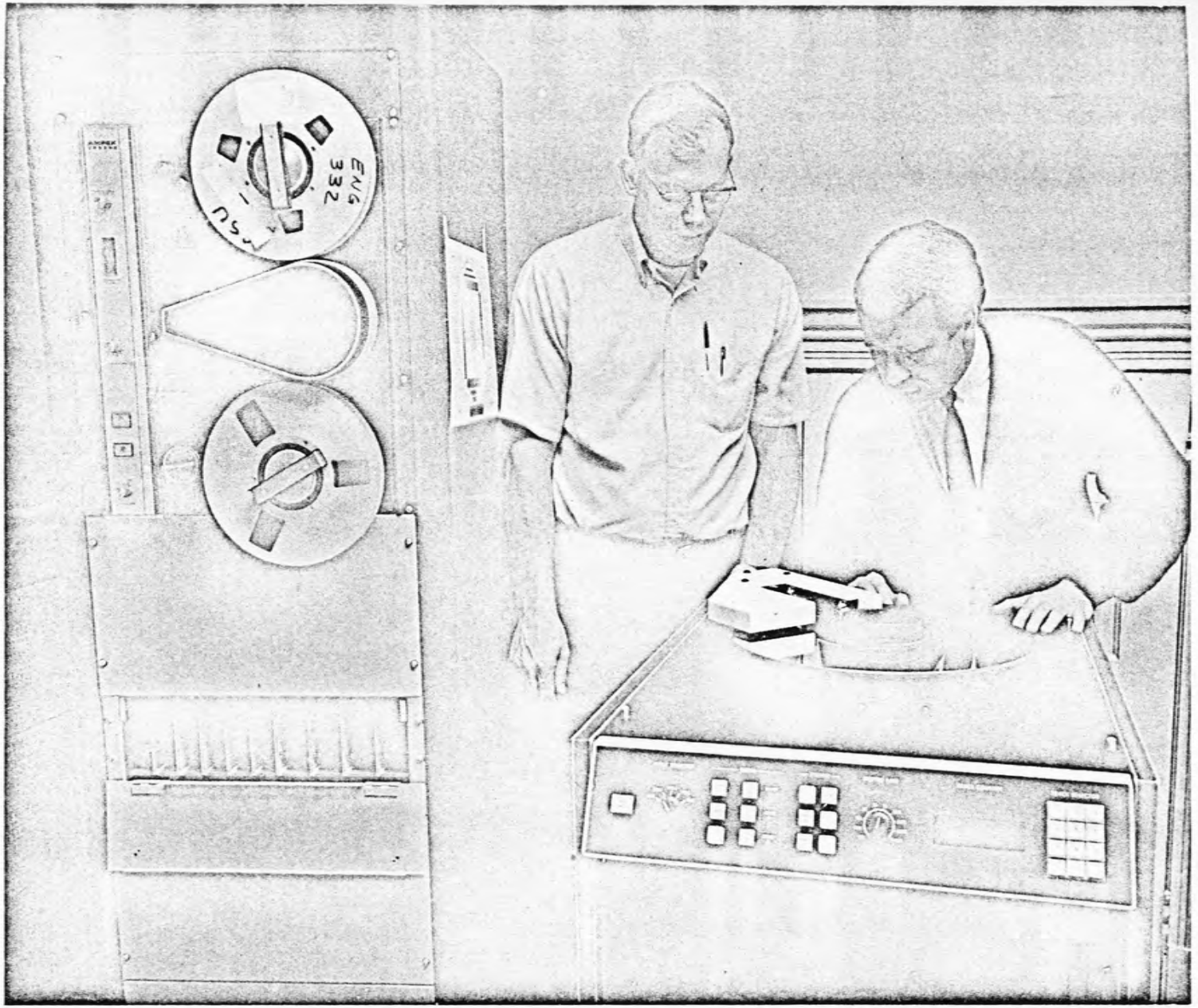
At the present time, two TREND terminals are being used. During actual student testing phases, the number of terminals will be increased to five.

4.1 Video Disk Unit

The various fixed images, which provide a wide variety of visual reinforcement for the operation of the CMLS, are stored on a rotating video memory disk. This unit was designed specifically for the Project by the Ampex Corporation. The unit is configured to provide rapid random access to any one of the stored images. Control of the disk is provided by the computer. Disk and computer are linked by a 250 foot service line - attached, at the computer end, to a CDC 6681 Data Channel Converter; the logic interfacing is located in the disk cabinet. The disk unit is pictured in the right-hand portion of Figure 4.2. At present, permanent storage is provided for 450 video images.



STUDENT LEARNING STATION
FIGURE 4.1



VIDEO TAPE AND DISC UNITS

FIGURE 4.2

Once a particular video image is accessed on the top surface of the disk, it is immediately transferred to an assigned track on the bottom surface. A fixed buffer head provides readout to a given student monitor. The monitor display may be held for an indefinite period without requiring further attention from the computer or preventing access to some other image required at another student station. The video screen is automatically and continuously refreshed from its own buffer. The unit may accommodate, in its present condition, up to 21 buffer heads. One buffer head is required for each student terminal.

The original video images are easily and quickly imposed on the top side of the disk from input provided by an inexpensive TV camera. Images may be altered, rearranged or replaced on the disk at will and at negligible cost.

At the present time, the disk is equipped with two buffer heads; expansion to five will be effected by June of 1970.

4.2 Video Tape Deck

The CMLS instructional network employs numerous audio/video presentations, each of two-to-three minute duration. These visual presentations are stored on an Ampex Model VP-5900, one-inch helical scan videotape system. The standard unit has been reconfigured to allow for random-access-remote-control. Access and monitoring of a particular video program is provided by the computer, which is connected to the unit through the same logic interfacing which serves the Video Disck (Section 4.1).

There is no provision for buffering the video program. This means that any student station requiring a video segment demands the entire resource of the video tape unit. Furthermore, access to any particular video program may require one to three minutes. These characteristics are, in general, unacceptable for an operating instructional system. The real interest in this pilot project is, however, in evaluating the contribution of this type of instructional reinforcement and this should be possible, even considering the mechanical deficiencies.

During actual student testing of the CMLS concept, the number of video tape recorders will be increased to three. This will minimize conflict and delay in servicing the five student stations.

Figure 4.2 pictures, on the left, the video tape deck currently in operation. A schematic of the total hardware system is shown in Figure 4.3.

To summarize, the present equipment configuration consists of:

- one CDC 6400 Computer System (provided by the University);
- one 3290-4 Inquiry/Retrieval Computer;
- one Central Logic Interface (originally built by Ampex Corp. and modified by Project personnel);
- one Ampex (modified) Model VP-5900 Videotape Unit;
- one Ampex (custom-designed) Video Disk Unit;

COMPUTER-MANAGED LEARNING SYSTEM

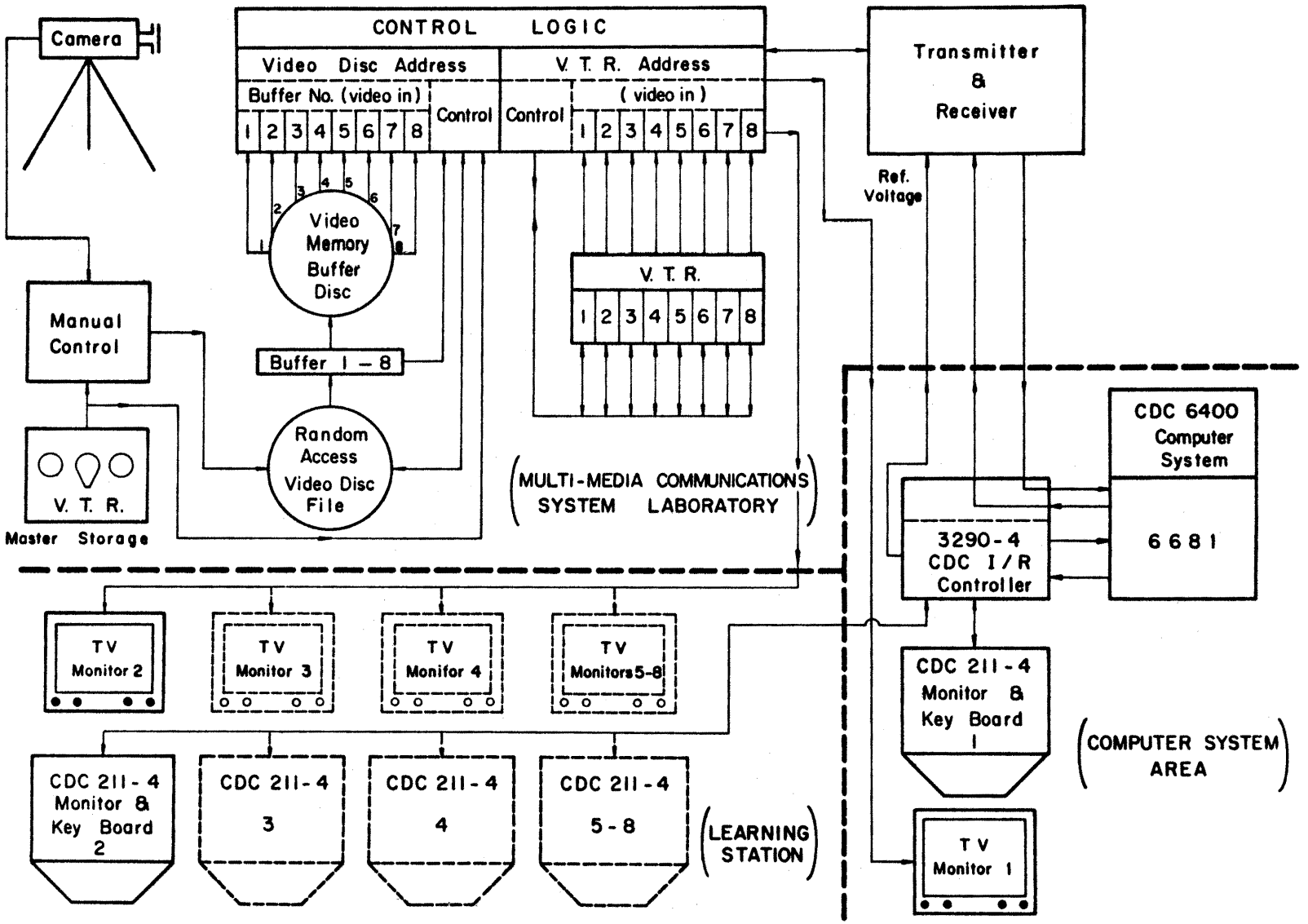


FIGURE 4.3

- three Conrac 9-inch general purpose video monitors; and
- two CDC 211-4 (TREND) terminals.

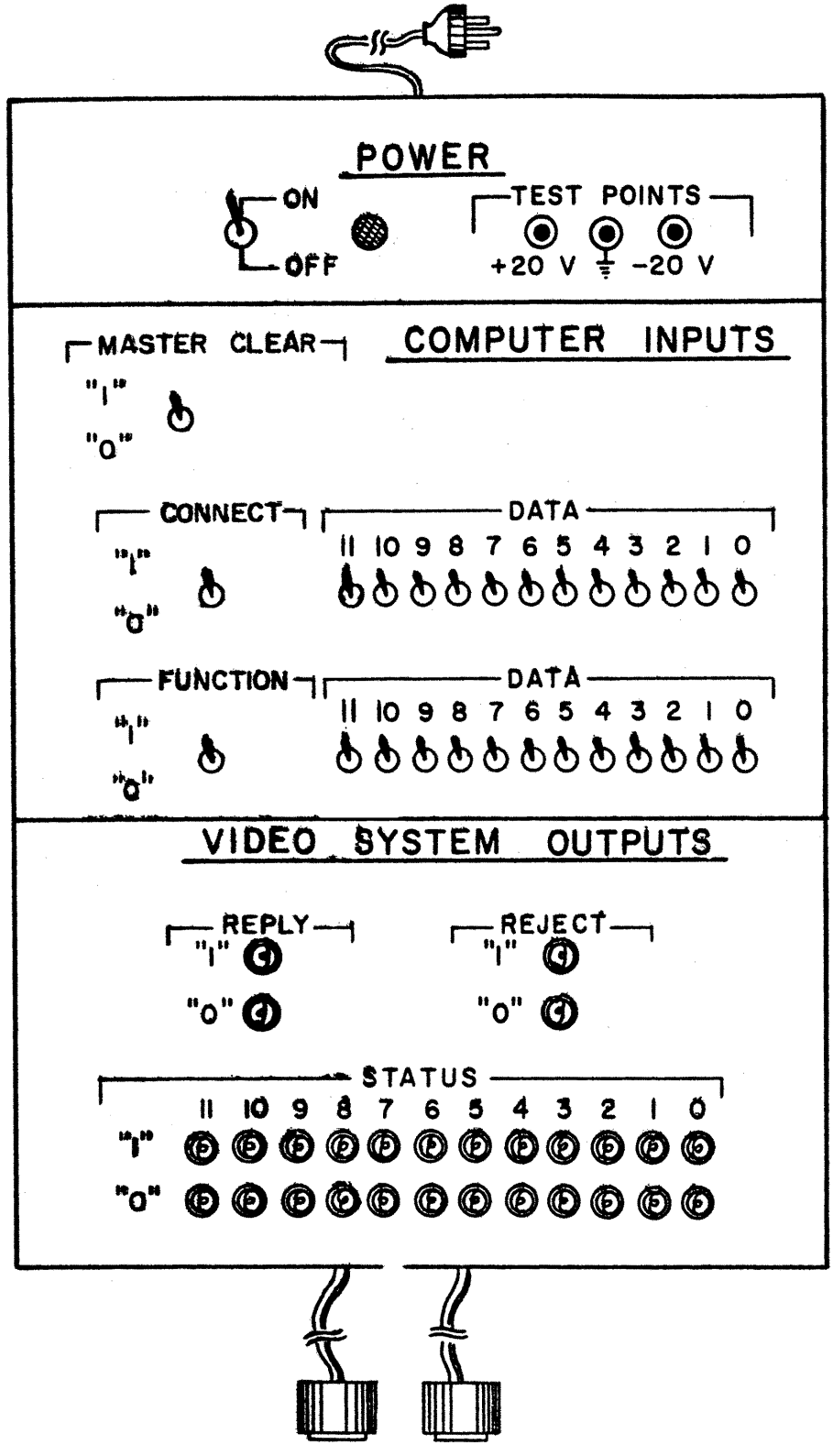
This configuration is the minimal requirement for program development work. During student testing phases, the configuration will be increased by:

- one 6681 Data Channel Converter (dedicated);
- three CDC 211-4 terminals;
- three Video Disk Buffer Channels; and
- two remote-control random access videotape units.

4.3 Computer Simulator

Of peripheral interest to the original Project objectives has been the design and construction of a computer simulator. This unit emulates the data communications provided by the CDC 6681 Channel Converter. The simulator has proven to be a requirement in stabilizing the custom-designed Ampex logic interface. Many difficulties have been encountered with the interface portion of the system, and these have been systematically identified and corrected through the use of the simulator. This unit, designed and constructed by Project personnel, has also proven to be invaluable in the development of the computer packages required to drive the video tape and disk.

The simulator has been mounted in the videotape rack; the control words are shown in Figure 4.4.



VIDEO SYSTEM / COMPUTER INTERFACE
TEST & SIMULATION UNIT

PANEL CONFIGURATION
FIGURE 4.4

V. SPECIAL FEATURES

Two activities of the Project merit individual discussion because of their general applicability to man-machine communications. These are: the development of real-time computational processing capability via a CDC 211-4 terminal and an "Aural System for Communications."

5.1 Real-Time Computational Processing

It was originally thought that the real-time processing of random data would be accomplished in fixed format on a computation-at-a-time basis, using an interpretive program. The inflexibility of this approach, together with an excessive communications requirement, led to the decision to develop a free-format, computation string processor. The standard algebraic operator set was to be expanded to include a capability to process number sets (in this case, three-dimensional vectors).

To date, this program has been developed and is operational as a FORTRAN IV subset. The program is operating in simulation mode through standard I/O devices. Adaptation of the processor to operate under the System Control Program (Section 3.1) is now underway. Completion of conversion activity is expected by the end of April, 1970. The adaptation will include several COMPASS routines, to keep the program size to a minimum. The arithmetic is floating point and the operator set consists of :

- The Unary Operator: -1,
- Addition: +,
- Subtraction: -,
- Multiplication: *,
- Division: /,

(recieve dual interpretation as either scalar or vector operators)

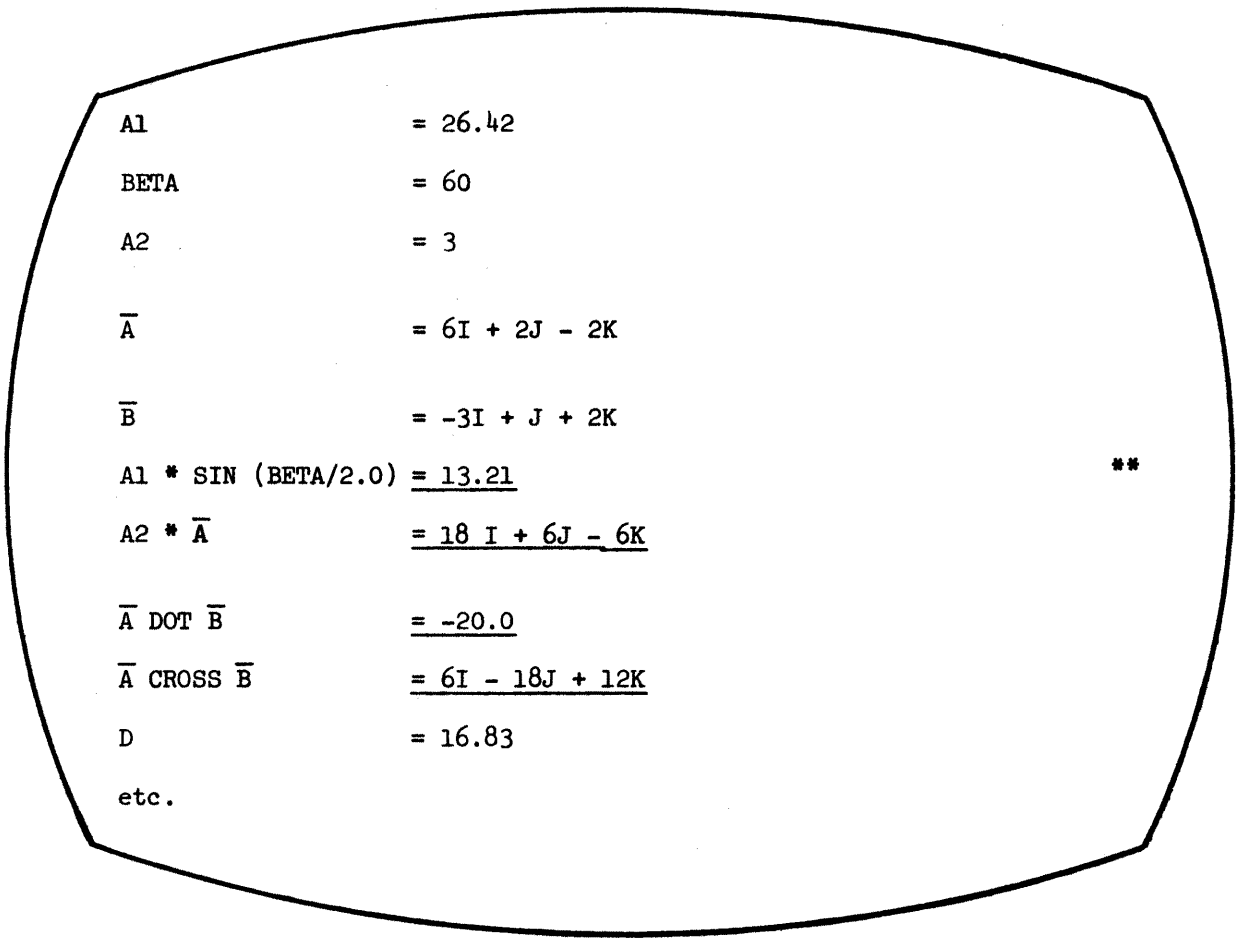
- Exponentiation: ↑,
- Vector Cross Product: Cross,
- Vector Dot Product: Dot,
- Vector Magnitude: MAG,
- Vector Directions: DIR, and
- Grouping: (,).

Utility routines are also provided for:

- evaluation of trigonometric functions,
- solution to simultaneous equations,
- evaluation of determinants, and
- evaluation of definite integrals.

Additional utilities may be developed with little or no associated increase in central computer core.

Each CMLS user is provided with (at present) 20 buffer words for data assignment, which he may label as he wishes, at execution time. Data may be mixed vector and scalar quantities. The CRT at the student terminal will appear as in Figure 5.1, for some hypothetical computation sequence. Computational activity may be dumped onto hard copy if the user desires.



** Underlined portion of display is computed computer response.

HYPOTHETICAL CRT DISPLAY - COMPUTATION MODE
FIGURE 5.1

5.2 Aural System for Communications

At the present time, good progress has been made in the development of a fundamental system which will enable the CMLS user to communicate aurally with the computer. This work has been a spin-off from originally planned developments. The effort is a contribution to the Project from the Department of Electrical Engineering at Colorado State University. The concepts involved in the Aural System for Communications (ASC), as well as ongoing development, are attributed to Mr. Herman Levin, a Ph.D. candidate in the Department of Electrical Engineering (re: Section 6.3). The initial Progress Report on the Development of ASC is included as Appendix A of this report.

The CMLS Project has a special reason for interest in the development of the ASC concept which may not be so obvious, and is explained as follows. It should be recalled that one of the fundamental objectives of the Project is the development of an instructional system that is responsive (adaptive) to pertinent specific conditions of each user. It would be ideal if, in addition to considerations of a factual nature, the CMLS could respond to the psychological condition of the user during the time of his learning activity. It appears to be possible, using the ASC technique, to determine certain fundamental information concerning the psychological condition of the CMLS user at any given instant of his involvement with the instructional system.

Having contrived to secure a "base-line" recording of a limited number of control words, it appears to be possible, through subsequent comparisons, to interpret small differences in signal patterns as being indicators of some condition of the communicator's temperament of the moment. Thus, a logical addition has been made to the list of conditions which are used to select the most appropriate reaction to the student activity in progress.

Having the capability to distinguish the temperament of the CMLS user, at any point in time, does not guarantee that appropriate use can be made of the information. The potential appears to exist, however, and the Project will attempt to make every possible use of this new opportunity. The most critical factor involving the use of this important tool is the time required for the full implementation of the Aural System for Communications. An instant application of ASC would, of course, be to provide for fundamental communications with the computer that otherwise would have been provided by manual entry through the TREND terminal keyboard.

VI. PROJECT PERSONNEL

In addition to the principal investigators, the Project staff consists of:

Charles C. Britton, Assistant Professor of Electrical Engineering. Professor Britton's services are being provided by the Department of Electrical Engineering. He is working on evaluation and formulation of the instructional network. Professor Britton is a particularly well qualified instructor and is responsible for design and operation of a newly established interdisciplinary program for freshman engineering students at Colorado State University.

Geoffrey C. Leach, a graduate student in Computer Sciences. Mr. Leach's considerable experience in system applications to large-scale computers makes him a most valuable asset to the CMLS Project. Mr. Leach has had the primary responsibility for the implementation of the System Control Program, provision for the Data Base Management and Utilities (re: Chapter III). Mr. Leach will continue to work on these aspects of the program as he continues his work on a graduate degree in Computer Sciences. He is supported, through Project funds, as a Graduate Research Assistant.

Herman Levin, a graduate student in Electrical Engineering. Section 5.2 of this report gave a brief discussion of Mr. Levin's work in developing the Aural System for Communications. In addition to this activity, he has contributed heavily in stabilizing the performance of the logic interface for the video

communications equipment. He conceived the logic design for the computer simulator (Section 4.3) and has supervised its construction and check-out. His work with instructional products at Bell and Howell Co. represents a background in instructional psychology which will prove to be a continuing asset to the Project. He has an appointment as a Graduate Research Assistant with the Department of Electrical Engineering.

Melvin Nieberger, Chief Electronics Technician. Mr. Nieberger is employed by the Project on a full-time basis. His work background in electronic systems has been invaluable in the implementation of the multi-media communications system. As a result of Mr. Nieberger's experience, the Project is quickly becoming independent of electronic equipment manufacturers. This capability will become even more important as the communications system is expanded to serve several student stations.

Brief resumes are given in the following sections for the individuals discussed above.

6.1 BRITTON, CHARLES C. Associate Professor of Electrical Engineering, holds a B.S. degree from Texas Technological College, Lubbock Texas; a M.S. degree from Iowa State College, Ames, Iowa; and further study has been done at the University of Colorado, Boulder, Colorado. Professor Britton was a consultant for the Army Signal Corps, Radio Officer and Instrumentation Consultant, Engineering Research Center, Colorado State University; General Electric Research Laboratories, Test Engineer.

Professor Britton has been teaching at Colorado State University since 1950. He previously taught at Iowa State College, Ames, Iowa.

Professor Britton is a member of Instrument Society of America, Institute of Electrical and Electronics Engineers, American Society for Engineering Education, Eta Kappa Nu, Tau Beta Pi, Phi Kappa Phi, Sigma Tau, Alpha Chi, Kappa Mu Epsilon, and Sigma Xi.

6.2 LEACH, GEOFFREY CAMPBELL. Received his B.S. (chemistry) and did postgraduate work in economics at McGill University, Montreal, Canada. His Systems training includes Burrough B-5500 and B-6500, IBM System 360/65 and IBM 1130 and 2250, and UNIVAC 1108. His software training includes ALGOL, COBOL, FORTRAN and PL-1; machine language - B-5500, 1130, 2250, 360/65 and 1108. Geoff's experience has been with Mahasco Industries, Amsterdam, New York (computer evaluation, systems programming support, display programs for IBM 2250, operating system/compiler program for 1130 and B5500, on-line business applications), and Realtime Systems, Inc., New York, New York (application programming, customer programming support, and technical sales for B-5500 timesharing service).

6.3 LEVIN, HERMAN. In obtaining his B.S.E.E., he attended Illinois Institute of Technology (1954), Naval Aviation Training Command (1956), and Loyola University (Nuclear Physics, 1959), and obtained his M.S.E.E. at the Illinois Institute of Technology (1969). Past experience has been that of a consultant, Corporate Research & Development at Bell

and Howell Co.; Manager, Electronic Design Department, Photo Products Group at Bell and Howell Co.; Manager, Data Handling and Recording Systems, Elgin Research and Development Division at Elgin National Watch Company; Sneior Engineer, Aerospace and Instrumentation Section, Cook Research Laboratories Division at Cook Electric Company; Naval Aviator and Engineering Officer, Naval Air Commands with the U.S. Navy; Design Engineer, Electro-optical Laboratory at Schneider-Cogswell, Inc.; and Tool and Diemaker at H. Laidman and Co. As Manager, Electronic Design, at Bell and Howell, he had the prime responsibility for all electrical and electronic design and concepts in present and future division products. Projects directly conceived and designed include both novel and sophisticated systems of electro-optical and electronic control of photographic instruments and electronic systems for audio-visual devices. He contributed to, and managed, programs involving special and proprietary schemes of electronic displays. He introduced the use of computer technology in electronic design and analysis, including personal instruction, and established a training and updating program for this group. He has been engaged in projects primarily under government and military contracts that involved state-of-the-art development and systems. He is the author of *Introduction to Computer Analysis: ECAP for Electronic Technicians and Engineers*, Prentice-Hall, Inc., 1970.

6.4 NIEBERGER, MELVIN. Mr. Nieberger is the Chief Electronics Technician with the Project. He has had two years in Electrical

Engineering and Instrumentation, two years in instrumentation and build-up with Atmospheric Science, and two-and-a-half years of schooling in Electrical Engineering at Colorado State University. Other experience has been as a Test Engineer with Hewlett-Packard, Loveland, Colorado; Electronic Technician in primary and secondary standard laboratory with Martin Company; Electronic Technician in Radar with the U.S. Air Force, and as an independent technical consultant on electronic systems. He is in charge of supervision, maintenance and operation of all CMLS equipment.

VII. INTEREST FROM THE ACADEMIC COMMUNITY

The College of Engineering continues to show interest in the development of the CMLS Project. Individual faculty members actively seek progress information and engage Project investigators in conversation relating to various potential uses of the CMLS.

From across the Campus, several specific centers of interest are developing. The most notable of these are:

- Department of Mathematics and Statistics, particularly the statistics group;
- Department of Agronomy -- the geneticists have shown the most active interest;
- College of Business -- interest has been particularly high among the management sciences group; and
- the Department of Fishery and Wildlife Biology.

Most of the individuals interested in CMLS express disappointment that the system is not yet in condition for implementation, and it is for this reason that no effort is being made to advertise the work. It is the firm belief of the Project investigators that too much of CAI has been sold on potential rather than accomplishment. Every effort is being made to avoid this pitfall.

VIII. CONTRIBUTIONS BY COLORADO STATE UNIVERSITY

During its first year of existence, the Project has received much support from the University community. This support should be accepted by the Sponsor as evidence of the sincere interest shown in the potential value of the computer as an active element in the instructional process. Project investigators gratefully acknowledge:

The University Computer Center - B. W. Marschner, Director. The Center has provided special privileges of access to the CDC 6400 Computer System and has allocated a small section of Central Memory to Project use. Systems personnel have been provided for the purpose of writing the software package required to drive the Ampex video equipment. Space has been provided for the special equipment required by the Project.

The Department of Electrical Engineering - R. J. Churchill, Head. The Department has provided invaluable support of Project personnel. These include: Professor Charles Britton, Mr. Herman Levin, Ph.D. candidate, and two undergraduate students who have contributed a great deal in the assembly of the video communications equipment.

The University Administration has remodeled space for the Project laboratory and has provided the services of Mr. D. R. Garfield, Administrative Officer for the Engineering Research Center. Dr. A. R. Chamberlain, President, and Dr. L. V. Baldwin, Dean of the College of Engineering, have offered

generously of their time and have provided continuous encouragement.

The Office of Educational Media - Mr. Preston Davis, Director. This office continues to offer important assistance in the preparation of video-tape materials.

APPENDIX A

Progress Report

Special Project:

AURAL SYSTEM FOR COMMUNICATIONS

(ASC)

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December 12, 1969

Department of Electrical Engineering
Colorado State University

I. INTRODUCTION

The system outlined in this initial report pertains to a method of communicating with computer-managed systems. We must differentiate methods of communicating with large scale computer systems on the basis of such categories as (1) batch-processing, (2) time-sharing, (3) real-time operation, and (4) managing modes. The usual method of "conversing" for batch-processing is the punched card and the printer output. For the slow-speed remote time-sharing terminal, the teletype keyboard is prime. For hihg-speed terminals, the batch-processing means apply. In real-time operation, the rigorous definition implies a dedicated computer system that obtains inputs and provides outputs directly with associated equipment; usually no human link is required.

Category (4) represents unique situations that can combine the first three categories plus the very interesting addition of a human link that is an essential part of a closed system cycle.

Specifically, we may note that in computer-managed systems, we can provide a group of inputs that are batch-processed, with outputs stored and on call. Generally, we are also in direct contact with the computer in a time-shared mode. The direct contact is also used to control or manage the system equipment in an effective real-time mode (although actually time-shared). In the first two categories, the computer is used as a tool for the solution of a problem that does not generally involve human interaction; i.e., a problem is submitted, at some time later (from seconds to hours) the individual receives an output. Conversational modes in time-sharing are an exception, but not a profound exception in that submitting a program in its

entirety or a statement at a time is significant only if there is strong justification for the statement at a time procedure. For the sake of simplicity, we will lump batch-processing and time-sharing as both being concerned with the input of a predetermined program. With these considerations, the first three categories do not represent a closed-loop with a human link as part of the loop. Therefore, there is not a pressing need for a natural conversational mode between human and system.

The situation is much different for the computer-managed mode. In this case the computer, the system equipment, and the human operate on an interrelated basis, definitely a closed-loop system. Further, and of marked significance, the degree of success of a managed system is inherently related to the conversational means used between subsystems and the human link. The significance is paramount in computer-managed learning systems. In this case, the human serves not only as a system component, but is also the final output. Regardless of how smoothly the mechanism works, if the operator cannot effectively receive, comprehend, and retain the outputs, regardless of their subtlety, the system cannot be considered a success.

It is with these considerations in mind that a method for enhancing communications in a computer-managed systems was proposed. Specific application background was based on the Computer-Assisted-Instruction (CAI) project underway in the College of Engineering. The CAI system will consist of cathode ray tube display consoles with keyboards that permit time-shared communication with a large general-purpose computing system (CDC 6400 Series). Video-recording subsystems are part of the operator station inputs and are controlled by the computer. Therefore, the sensory modes to the operator are

visual and audio in the static mode of operation (video tape recordings). Visual and dexterous in an active mode of operation (random-access video disk, CRT computer display, and input keyboard). What is denied to the user is an active aural mode. It is the intent of this Project to investigate the feasibility of implementing such a mode by the design of a limited, and hopefully, simple system that may be used in connection with CAI applications. In keeping with contemporary practice, we will name the system, even before its birgh, and attach a suitable acronym. Therefore, we shall speak hereafter of the Aural System for Communications (ASC).

II. SYSTEM CONCEPT

The system approach will have a limited aural communications mode incorporated in a Visual Output/Key Input Computer Communication Console. The purpose of such a communications is to provide a conversational introductory mode to enable the user to operate the console without prior instruction.

This aural mode would inform the user as to procedure, significance of controls, availability of material. Further, inherent in the term "conversational" is the significance of two-way verbal communication. The system must therefore be capable of recognizing a limited set of personalized spoken words.

All prime controls are to be digital in nature. Analog-to-digital conversion of audio inputs is implied.

The heart of the specific concept outlined in this report is that the word recognition process will be personalized. Therefore, the recognition process involves comparison of an individual's verbal input with his own pronunciation of the same words. As an indication of the difficulty of having a generalized reference for even a single word, the music composer, Leos Janacek, claimed to have recorded (in musical notation) 60 distinct ways in which the word "yes" could be pronounced. In the ASC concept, a person's input of the word "yes" is processed and compared to a previously processed record of his pronunciation of the same word.

The ASC system will be confined to a small set of personalized words which it will understand and to which it will react.

We will illustrate s system cycle commencing from a user's first encounter with the computer-managed learning system. Further, a specific ASC system configuration will be assumed to provide examples of possible implementation.

2.1 The first-time user sits down at the ASC console. The act of sitting turns the console on.

2.2 The pre-recorded magnetic-drum or tape subsystem responds with "Good Morning" (or "Afternoon" or "Evening" dependent upon its daily clock). "If this is your first use of the console, please take a magnetic cassette out of the center drawer and place it in the slot labeled cassette." "The control words that are part of the aural vocabulary will appear, one at a time, on your console video screen. Please say each word distinctly, and in your normal tone of voice."

2.3 This procedure records and indexes the set of control words personalized as to the individual user. It really doesn't matter what the user says as long as it is possible to associate a control word with a distinct aural signal pattern. The basis of this discrimination is shown in Figure 1.

2.4 The control word vocabulary is now recorded on the individual's personal cassette. On subsequent uses of the console, he need not repeat this recording procedure. He merely inserts his cassette and begins the conversational mode. The console "voice" begins in the same manner as in paragraph 2.2, except that the console senses the "playback only" slot of the

cassetts and does not request a recording nor displays the vocabulary. The "voice" proceeds to explain the next operation, with the facility to "ask questions" that can be answered by one or more of the control words.

2.5 To outline this two-way conversational operation, first assume ideal conditions; i.e., the user always states the control words precisely as has been done on his original personal cassette. Further, assume a set of control words consisting of Yes; No; Turn; Repeat.

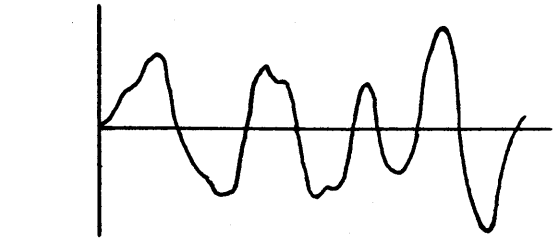
2.6 We now continue the communications with the "voice" explaining the console operation. At the conclusion, the "voice" asks "Did you understand the explanation?" Assume the user answers "Yes." The response is recorded. The recording is processed as previously shown in Figure 1. The resulting digitized word is now compared for coincidence of logic levels with each word in the control vocabulary as recorded on the user's personal cassette. When a match is made, the file number associated with that control word pattern indicates that the response was a "Yes." Therefore, the operation is continued. If a "No" was detected, the instructional sequence would be repeated. A block diagram of the mechanics of the system is shown in Figure 2.

2.7 The simple four word vocabulary would be sufficient for a large number of applications. "Yes" and "No" are self-explanatory. The "Turn" and "Repeat" words are intended for the operations of "Turn the (video) page" and "Repeat the (video or audio) instructional or dissertation sequence."

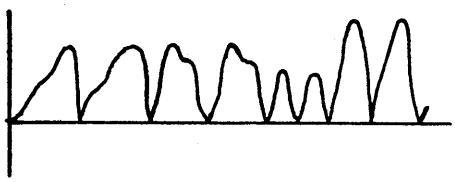
2.8 The example conversational statements above contain words extraneous to the required control functions. The basic system takes care of this case simply by not recognizing them. The word scanning process would be such that each digitized word on Loop 2 (the individual words are made distinct by the pauses between them) is compared to the total vocabulary on the personal tape. If no match is found, the process is repeated for the next word. If no word is found, the "voice" responds with a "I do not understand" message.

2.9 Less than ideal conditions occur when the user's aural input differs slightly from his original personal cassette recording in both time and tone. For the time discrepancy, this can be compensated by playing back Loop 1 at speeds faster and slower than normal. The word comparison would be made upon each playback to seek a match. To compensate for both time and tonal discrepancies, a weighted judgment must be made. This requires an added circuit that, in essence, counts the incremental matches made for each word. The judgment can then be made on a percentage basis; i.e., if 60 percent of the segments match, consider it a valid control word.

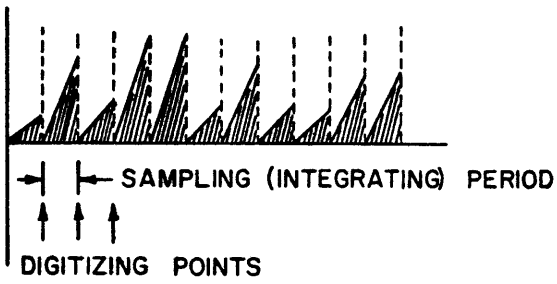
2.10 The scanning and processing procedures outlined would be relatively lengthy if actually implemented by simple reel-to-reel cassette transports. These are depicted for illustrative purposes only. A practical time response can be effected by use of magnetic disk and/or drum transports.



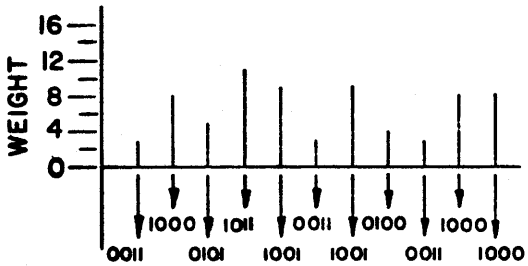
a) Audio input signal



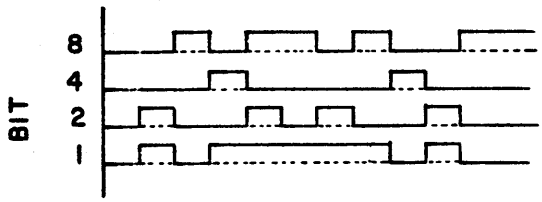
b) Absolute value of audio input



c) Audio input summed by increments



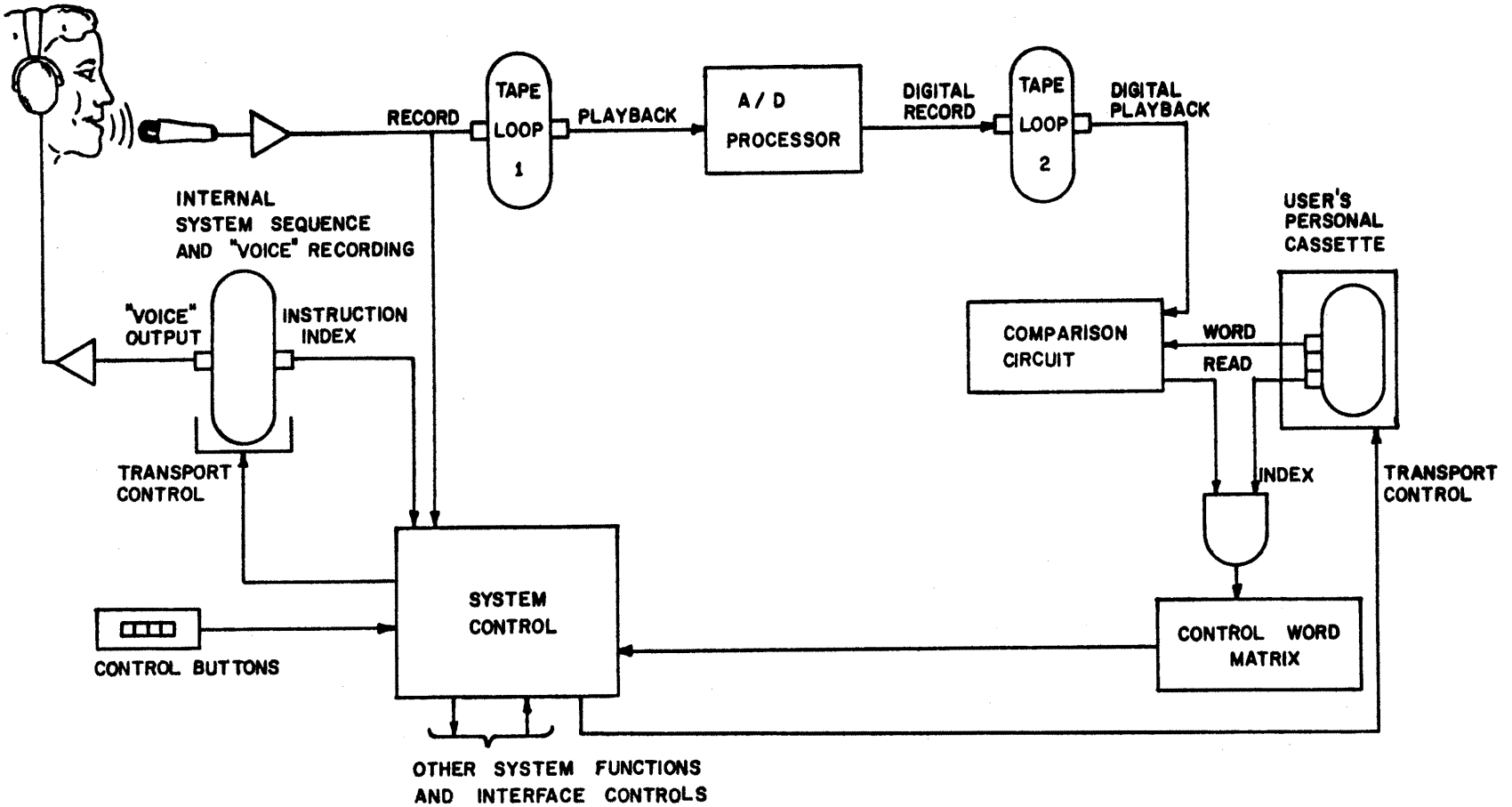
d) Analog level to digit conversion



e) Digitized output recorded

PROCESSING OF AN AURAL CONTROL WORD

FIGURE 1



A BASIC ASC SYSTEM CONFIGERATION

FIGURE 2

The details of the specific processing scheme depicted in Figure 1 are as follows:

Figure 1a - This is a simplified representation of a single word audio input.

Figure 1b - We are seeking the energy content per time increment. Therefore, the absolute value of the input signal is obtained by full-wave rectification.

Figure 1c - This is the first step of the information discrimination process. The analog signal is divided into fixed sampling periods. It is then summed by integration over this period.

Figure 1d - The final incremental values of the summed signal are digitized.

Figure 13 - The control word is now represented as a 4-bit parallel binary word. Further, a file number is recorded to sequentially index the word. Therefore, for example, the control word represented by this specific digital word may be designated control word number 4.

A review of the system sequence with respect to Figure 2 is as follows:

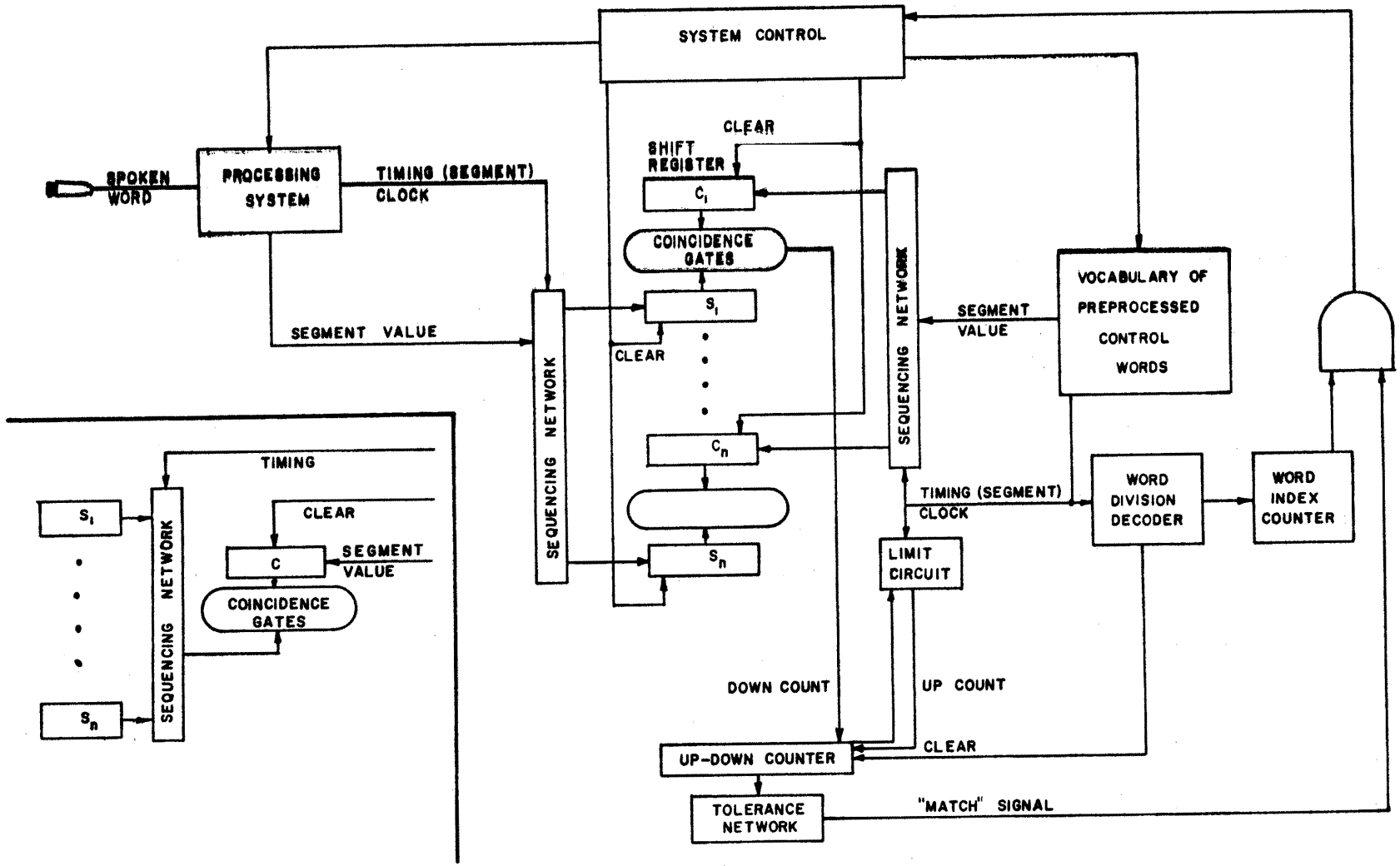
2.11 Control Button starts Internal Sequence transport via System Control. "Voice" provides instructions, then asks if instructions are understood.

2.12 User's answer is recorded on Loop 1. Loop is simultaneously played back into A/D Processor. The digitized output is recorded on Loop 2.

2.13 Loop 2 is played back continuously. With each pass, the user's digitized control word is compared to a control word on his previously recorded personal tape.

2.14 When a match is found, the index number of the control word is entered into the Control Word Matrix. The proper

(appropriate) signal is fed to the System Control. This elicites the proper response from the interal system sequencing tape, the "voice" output, and other system functions.



CONTROL WORD RECOGNITION SYSTEM

FIGURE 3

III. CONTROL WORD RECOGNITION

Graphical recordings have been made of the proposed initial set of control words. The set consists of "Yes," "No," "Turn," and "Repeat." We still seek the best methods to process and to recognize the spoken control words. The basis for processing may consist of one or more of the properties of the audio signal, namely: spectral content, temporal length, and natural increments (syllables). The original proposal suggested operation on the energy content of the word by digitizing the integrated energy level over equal time increments. Study of the voice graphs leads to the belief that this procedure may yield some success if accompanied by an appropriate recognition (comparison) system.

Figure 3 illustrates an approach to the recognition system outlined in Figure 2. The bases for the system are counting procedures that register the number of matches of segment levels. The operation is as follows:

3.1 Assume a word or sentence has been spoken by the user. The word is processed and the digitized result is recorded.

3.2 The system control causes the value of the first segment of the processed spoken word to be shifted into the first register S_1, the second into register S_2, etc., until the word is contained fully in the register bank. We note here that a finite number of segments is implied for this direct implementation. The alternative of having an undefined number of processed segments, but a limited number of registers merely

dictates that it is possible to lose trailing information.

3.3 Upon completion of this loading, the register C_1 is filled with the value of the first segment of the first control word. The sequence continues until the numbered registers are filled.

3.4 The number of segment of the control is counted up to the limit determined by the number of registers.

3.5 Coincidence gates then compare each bit in each register. If a match is made in any register, it counts down the up-down segment counter. On this basis, a perfect match would leave a zero in the counter. This null count would result in the production of a match signal. A relative match may be permitted by combinational logic that would discount one or more of the lower order bits. (A division process can also be used to determine percentage of match, but this would involve a separate arithmetic unit.)

3.6 The match signal would permit the exit of the word index to the external system; i.e., an indication that control word number X was spoken.

3.7 An alternative to the paired bank of registers would be a single register for the control word and an associating sequencing network that would connect the register bits to succeeding spoken word registers.

3.8 Upon completion of a coincidence test, whether a match was made or not, the up-down counter and the control word

register(s) would be cleared. If a match was made, the spoken word registers would be cleared.

3.9 If the awaited response was a single word, the proper system action would occur. If it was to be a multiple word, the next spoken word would be loaded.

The recognition system outlined above operates on the basis of comparison of the digitized levels of time incremented energy content. It has the stated shortcoming of lack of incremented synchronization. This simply means that if the same word is stated at a different rate than the originally processed reference word, then the corresponding parts of the word will not line up with regard to a fixed time base. The recommended means of accommodating this discrepancy was to shift the timing base of either the incoming word or of the reference word. The procedure may be implemented as follows: Consider the incoming word to be stored in the registers S_i as shown in Figure 5. The reference control word would be recorded and processed, not with reference to a single fixed incremental time length, but to a series of increment lengths. For example, we may determine from a sampling study that there is a reasonable range involved in rate of speech under circumstances pertaining to our ASC console operation. We may then process our reference word considering the slowest rate, the fastest, the mean rate, and perhaps the first and third quartiles as well. This would mean that the spoken word in registers S_i sould be scanned five times for level matches. This can be done quite rapidly, and, while not a particularly elegant scheme, does have the advantage of simplicity of system.

However, there are statistical methods that are not so totally dependent upon incremental synchronization for comparison of two such samples. Since one of the ground rules for the ASC system is that it should be self-contained, we must avoid relations that result in complex mathematical operations. The method that appears most appropriate is determination of the coefficient of correlation. We note that we will be dealing with the correlation of discrete numerical values. Therefore, the measure of coincidence we seek may be given by the relation:

$$R = \frac{N\Sigma(SC) - \Sigma S \Sigma C}{\{[N\Sigma S^2 - (\Sigma S)^2]\ [N\Sigma C^2 - (\Sigma C)^2]\}^{1/2}}$$

Where: N = number of level increments
S = digitized value of the Spoken word
C = digitized value of the reference Control word.

We note that even with this relatively simple correlation criteria we must include an arithmetic unit into the ASC console that is capable of all the arithmetic operations of addition, subtraction, multiplication, division, and exponentiation.

To begin tangible investigations into the recognition phase it is proposed that the following assumptions be made at this time. (1) The processing method will be the digitizing of the integrated energy levels between equal time divisions. (2) The recognition methods will be either time base variation or measure of the correlation coefficient; i.e., both will be investigated.

IV. INTERFACE REQUIREMENTS

The ASC system may serve in two modes. Primarily, it is used as a means of providing introductory information with regard to communications console operation. A secondary function can be as a aural substitute for such sequencing buttons, or typed controls, as "Repeat video dissertation" and "Sequence to next video page." Both modes require interface with the video system. The initial system shall be construed to have the latter independence. This separation from the computer interface controls is not a system limitation, but a chosen design parameter to permit a more definitive initial description. In keeping with this philosophy, the implied association of the ASC system with Computer-Assisted-Instruction (CAI) equipment will be considered explicitely.

Interface requirements consist of the output of appropriately formatted control words to control both the Video Tape Recorder (VTR) and the Random Access Video Disk File (VDF) subsystems. As it presently exists, the required 12 bit words for the Ampex system are shown in Figures 4a and 4b.

The ASC system would interpose itself between the Computer System and the Video System. Activation of the ASC would provide a fixed Status word to the Computer indicating both VTR and VDF are in Local Control. The Reject line would be raised to reject incoming (to video system) control words. The ASC control word output to the video system simulates the 12 bit Computer system word, but with a limited set of words. These are illustrated in Figure 5. It may be noted that while 12 bits are transmitted, only a few are variable. The general form of the words are:

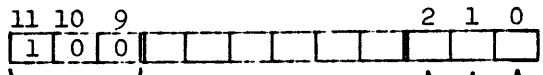
Connect:	100, 000, 000, VV0 (V = variable 0, 1)
Function:	000, 000, 000, V0V
Status:	000, 000, 00V, 00V

Therefore the implementation may be accomplished with very few elements.

Because the interface of the ASC system with both the Video and Computer systems requires only compatible Logical word transmissions, the ASC may be designed as a separate entity. There would be no requirement for internal connection to either of the prime systems; nor would there be operational differences to be considered.

CONTROL WORDS: TO VIDEO SYSTEM

Function:



Fixed Equipment No.

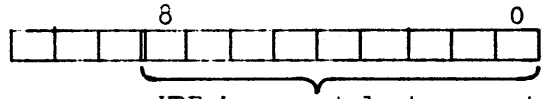
Connect VTR

Connect VDF to count UP the number of steps indicated in the Function Control word.

Connect VDF to count DOWN the number of steps indicated in the Function Control word.

Word Group Set: (((100), (010), (001)))

Function: VDF:

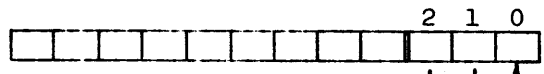


VDF incremental step count. Number of steps (listed in binary 2's complement) desired. Count is either UP or DOWN dependent upon CONNECTION word.

Word Group Set: (((000000000), ..., (001000000)*, (111111111)**))

[* 2's complement of 448_{10}]
[** Octal 777, Index Code]

Function: VTR:



Start/Stop

Fast Forward/Play

Fast Reverse/ Undesignated

Word Group Set: (((000), (100), (010), (001)))

INTERFACE CONTROL WORDS

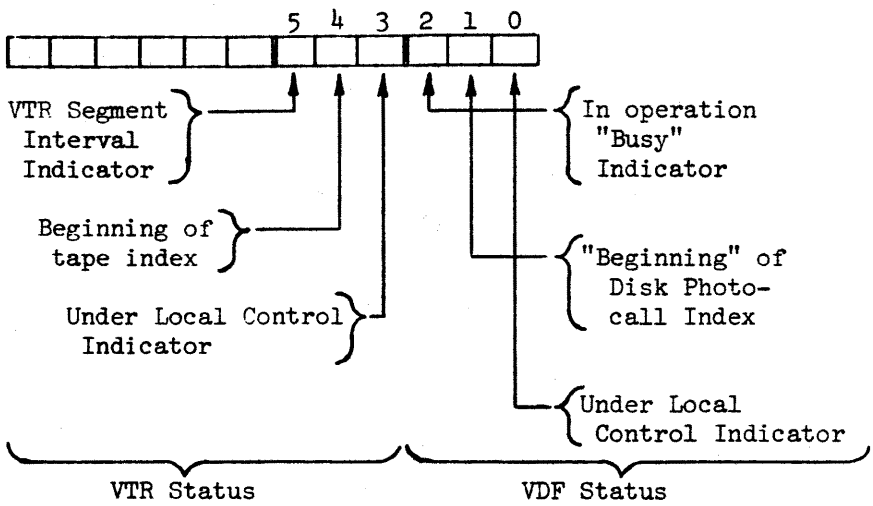
FIGURE 4a

CONTROL WORDS: TO COMPUTER SYSTEM

Status:

Discrete Control Bits:

Reject: (Device is in Local Mode)
Reply: (Control word received)



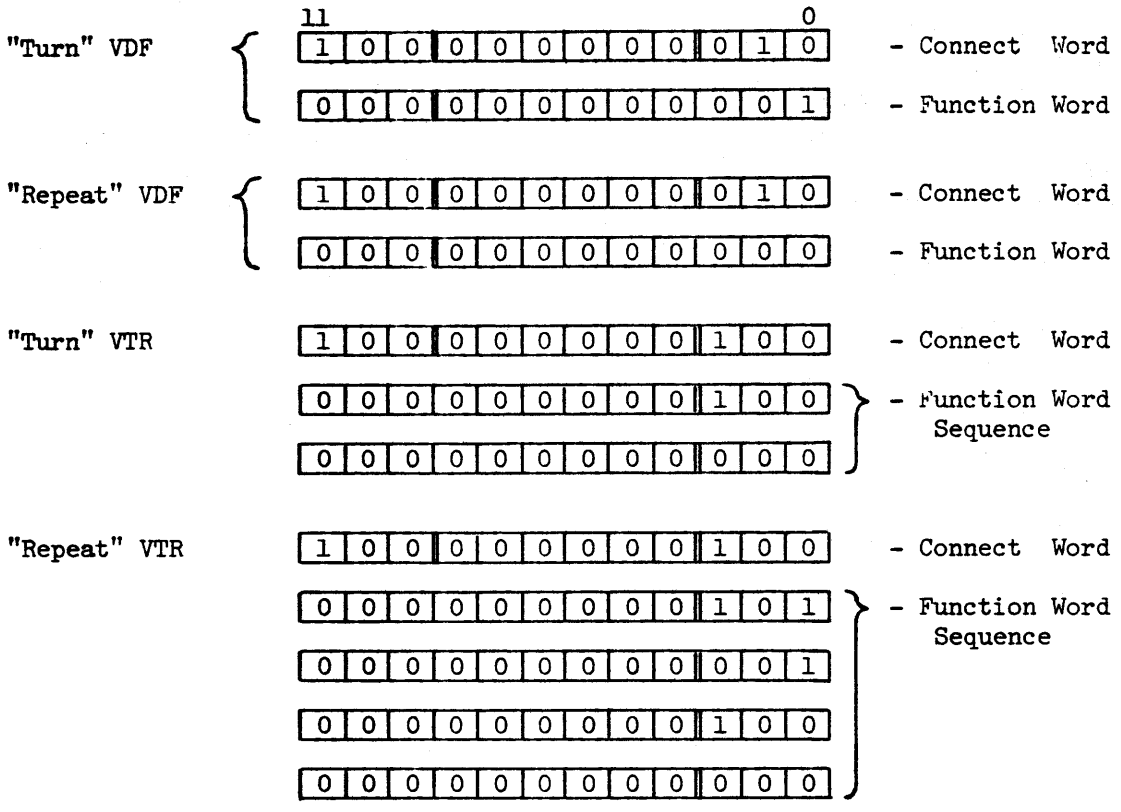
Word Group Set: (((000), (101), (011), (001), ([(100), (010)]*))

[*Subset of (000)]

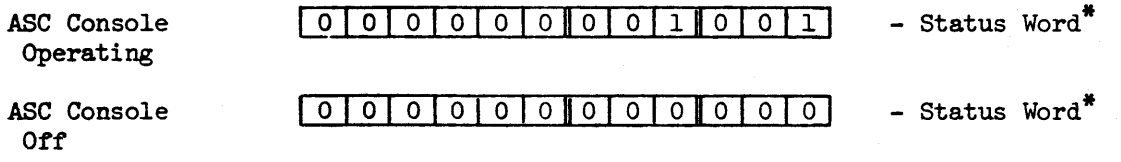
INTERFACE CONTROL WORDS

FIGURE 4b

OPERATION



STATUS:



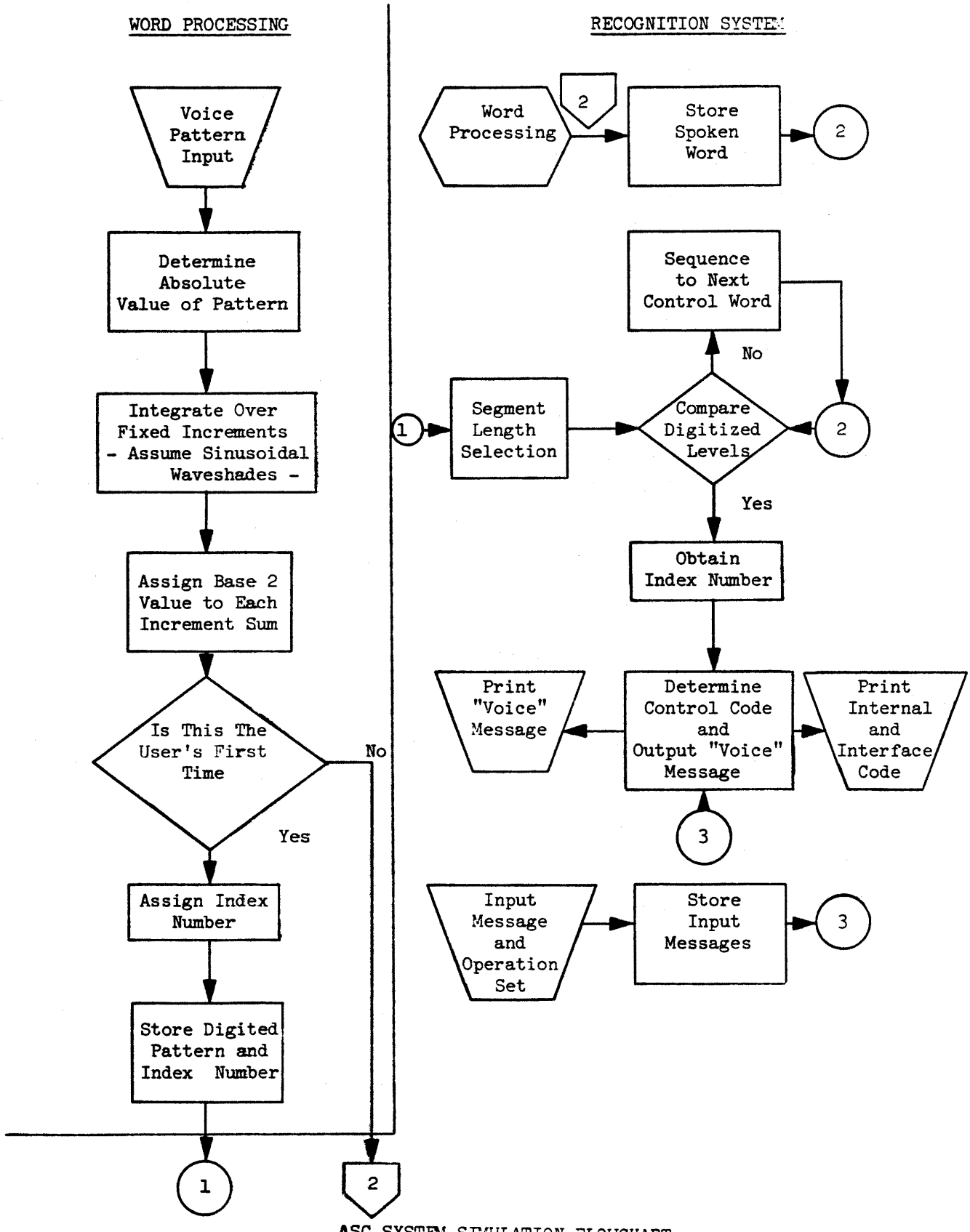
(*ASC Status Words are "or'd" with Video Status Words)

ASC CONTROL WORDS

FIGURE 5

V. SUMMARY

The basis for the operation and implementation of a basic system for aural communication with computer-managed systems has been described. The apparatus for the investigations will be computer-simulation of the processing and recognition systems. With this in mind, the next period of endeavor will be concerned with programming the system. The system Flow Chart is shown in Figure 6. The input data will be determined from actual voice recordings. It is hoped at some later date to make arrangements for direct digitizing by use of laboratory analog-digital converters.



ASC SYSTEM SIMULATION FLOWCHART

FIGURE 6