AD617608

AMRL-TR-65-79

AN EXAMINATION OF THE FEASIBILITY OF MODULAR DESIGN FOR AUDIOVISUAL AUTOINSTRUCTIONAL EQUIPMENT

WILLIAM H. TROW

GRAFLEX, INC.

EDGAR A. SMITH, EdD

AEROSPACE MEDICAL RESEARCH LABORATORIES

MAY 1965

BEHAVIORAL SCIENCES LABORATORY
AEROSPACE MEDICAL RESEARCH LABORATORIES
AEROSPACE MEDICAL DIVISION
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

NOTICES

800 - June 1965 - 448-47-1001

AN EXAMINATION OF THE FEASIBILITY OF MODULAR DESIGN FOR AUDIOVISUAL AUTOINSTRUCTIONAL EQUIPMENT

WILLIAM H. TROW
EDGAR A. SMITH, EdD

FOREWORD

This study was initiated by the Behavioral Sciences Laboratory of the Aerospace Medical Research Laboratories, Aerospace Medical Division, Wright-Patterson Air Force Base, Ohio. The research was conducted in part by Graflex, Inc., Rochester, New York 14603, under Contract No. AF33 (657)-11339. Mr. William H. Trow, Project Engineer, was the principal investigator for Graflex, Inc. Dr. Edgar A. Smith of the Technical Training Branch, Training Research Division was the technical monitor. The research reported herein was begun in May, 1963 and was completed in March, 1964. The work was in support of Project 1710, "Training, Personnel and Psychological Stress Aspects of Bioastronautics," Task 171007 "Automated Training and Programed Instruction." Dr. Gordon A. Eckstrand was the Project Scientist, and Dr. Ross L. Morgan was the Task Scientist.

The authors extend their thanks to Mr. Christopher L. Faegre of the Programed Learning Department, Graflex, Inc., for his valuable assistance in detailing programed learning methods. They also thank Dr. Gordon A. Eckstrand and Dr. Ross L. Morgan for their review of and comments upon the manuscripts leading to this report.

This technical report has been reviewed and is approved.

WALTER F. GRETHER, PhD
Technical Director
Behavioral Sciences Laboratory

ABSTRACT

The increasing need for audiovisual autoinstructional equipment in a wide range of applications has created a major problem in development of satisfactory equipment to meet the varying demands. Each specific situation requires a certain combination of optical, mechanical and electronic functions which cannot necessarily be adapted to subsequent usages of the equipment. This results either in the costly acquisition of many similar pieces of equipment or in undesirable restrictions on the instructional techniques that might be used. This study examines existing and potential areas of application for audiovisual autoinstructional equipment and proposes a modular approach in the development of new equipment. Each module would embody a separable major function and would be interchangeable in the system. The proposed basic modules would include: (1) a slide-changer module, (2) a filmstrip module, (3) a family of screen modules, (4) a family of light source modules, (5) an audio record and playback module, (6) three signal pulsing modules, (7) a multiple-choice response module, and (8) a write-in response module. Many of these would allow operational alternatives or modification for specialized applications for maximum versatility.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

SECTION I

INTRODUCTION

Over the past several years, many articles have been written and much promotional literature has been distributed describing the many advantages of using audiovisual equipment in military and industrial applications. Particular emphasis has been placed on the use of such equipment in the performance of maintenance tasks. However, despite the demonstrated improvement in accuracy and thoroughness as well as the reduction of learning time, use of such equipment remains limited. Perhaps one reason for the limited use of audiovisual equipment is that many of the potential uses place special demands on the equipment. No one standard item can meet all needs, and most users find it prohibitively expensive to purchase and install custom-designed equipment. The same factors limit the demand for any given audiovisual device; therefore, mass production cannot be used to cut production costs.

From time to time, modular construction of audiovisual equipment has been considered as a potential solution to the problem of obtaining economical multipurpose equipment. The modular concept allows the user to select audiovisual components to satisfy his specific, immediate needs, with provision for future expansion and modification as required. The user need not be burdened with expensive features he cannot utilize simply because only complete units are available to him.

The modular concept has special promise for research and the development of instructional programs. With modules, the researcher could build whatever system he feels is the most suitable for each application. He would have the freedom to experiment with alternate modes of presentation and various methods of response. When the program is finalized, only the modules showing the most promise for that particular situation would be acquired in quantity. It is highly probable that equipment needed during development of an instructional program would be different from that used later. For example, it might be desirable to use slides during development but filmstrip after the program is finalized. Also, much of the data gathering and recording equipment required during development might not only be superfluous but actually detrimental during latter applications of the completed program.

This study explores the implications of modular design on audiovisual autoinstructional equipment. This will be accomplished in two phases, each developed within a section of this report. Section II will explore some of the functional requirements of audiovisual autoinstructional devices in terms of their utilization as (a) performance aids, (b) instructional aids, and (c) research vehicles. Section III considers the application of modular design concepts to obtain these functional requirements and presents a general description of a system of modules. A final section provides some conclusions drawn from the study. These may be summarized as indicating that a modular system would provide greater flexibility of equipment. While offering greater utilization potential, modulization also offers major economies. The combination could provide considerable impetus to expansion in the application of autoinstructional training techniques.

SECTION II

FUNCTIONAL REQUIREMENTS

Each automated instructional situation requires its own set of mechanical, optical and electronic functions. The applications where autoinstructional audiovisual equipment has been used vary from the quite standardized procedures in industry to experimental setups for research on learning and training. This section covers three major areas of application: (a) performance aids, (b) instructional aids, and (c) research and development.

The distinction between performance aids and instructional aids is arbitrary, yet convenient. It is not the intent here to attempt formal definition nor to indicate that such uses of audiovisual equipment can be neatly dichotomized into two mutually exclusive categories. Virtually all applications have some of the characteristics of both. However, for present purposes, it is convenient to consider the functional characteristics of audiovisual autoinstructional devices under varied conditions. In many applications, the aid is intended to be available for use each time the task is accomplished if the task is repeated at all. Success is measured in terms of completion of the task. Such applications will be referred to as performance aids.

In other applications, the aid is used initially, with the expectation that it will not be required continuously. Success is measured in terms of learning or retention. Applications of this type will be referred to as instructional aids. The directions for assembling a tricycle would be considered a performance aid if the tricycle were a Christmas gift for your child. The goal is to get it together. While some learning undoubtedly occurs, this is secondary. However, the same instruction sheet would be an instructional aid to the employee of a department store who will be assembling many tricycles. The learning and retention required for efficient performance of the subsequent repetitions may be more important than the rate or success of the first trial. In fact, the first trial may be accomplished on a replica that may enhance learning but never actually be used as a tricycle by a child.

Research and development applications would include both experimental investigations of the learning process or training techniques and the preliminary development of training programs.

PERFORMANCE AIDS

Perhaps the best way to approach the functional requirements of audiovisual performance aids is to describe two such devices and examine the functions involved. One of the first major ventures into the field of individualized audiovisual devices for use as performance aids was conducted at the Maintenance Laboratory, Air Force Personnel and Training Research Center, Lowry Air Force Base, Colorado. While several devices were developed, the Automatic-Loading Daylight Sound Film Viewer (Handy-Dandy) is particularly relevant here. The Handy-Dandy used magazines storing up to 200 feet of continuous-loop 16mm sound film. Inserting the magazine or cartridge accomplished all required threading. The device included a rear-projection screen to provide individual viewing. The projector had stop-frame capability controlled either by the viewer or by notches on the edge of the film. The device was developed to provide procedural demonstrations with an initial movie demonstration of the assembly of several parts followed by stop-frames viewed while the trainee imitated the demonstration by assembling actual parts.

Hughes Aircraft Corporation made an early application of a related performance aid during the fabrication of the Falcon air-to-air missile. The rather complex assembly operations involved in the production of this missile, especially the electronic wiring subassemblies, prompted Hughes to look into possible ways of providing accurate and flexible assembly instructions to the individual assembly operators. Adopting a method already developed by others, notably the Simplex Equipment Corporation which was then a division of General Precision Equipment, Hughes built a system consisting basically of a slide projector and a tape recorder. This equipment was set up at each work station. It was placed on the bench in front of the assembly operator, approximately at arm's length from him. The operator would listen through earphones to a verbal description of a single step in the assembly procedure while viewing a rear-projected color slide of that operation being performed.

After the operator had carried out those instructions, to the accompaniment of background music, a recorded signal on the tape actuated the slide changer. The next step would then be presented in the same manner. The entire cycle was repeated as each new subassembly was built. After some experience in the use of this method of instruction, it was decided that the fixed time allowed for each operation (machine pacing) was not necessarily beneficial. The equipment was modified to permit the recorded signal to stop the tape at the end of each step (block of information). When the operation was completed, the operator depressed a footswitch which changed the slide and restarted the tape.

This mode of operation is commonly referred to as the "demand" or "student-paced" mode, in contrast to the "timed," "machined-paced" or simply "paced" mode. Both modes of operation are in current use and should be available in a versatile system. (ref 1.)

FUNCTIONAL REQUIREMENTS

When procedures are subject to frequent change, the pictorial material may be presented on 2" x 2" (35mm) slides which can be replaced easily or rearranged in sequence in the slide tray. In an application of this type, use of fixed sequence filmstrips would be a costly inconvenience. Magnetic tape, being erasable and reuseable, allows similar flexibility in recording the audio portion; whereas an embossed phonograph disc or belt would not. Conversely, if the developed program were stable and if hundreds of copies of it were required, filmstrip and discs might be both more economical and more convenient.

Lighting leads to another major requirement. It is generally undesirable, if not impossible, to darken a work area sufficiently to provide adequate screen brightness with front projection, ie, with the projector on the same side of the screen as the viewer. As an additional problem with this arrangement, the viewer tends to obstruct the picture, or the projector interferes with the workspace of the viewer. For these reasons, projection from behind a translucent screen, usually referred to as rear-projection, has advantages. Combining the projector and screen into a single unit has additional advantages.

Performance aids are especially useful when complex work must be performed on an intermittent schedule. Under such circumstances, even experienced operators or maintenance personnel need guidance on the procedure. For maximum worker efficiency and minimum learning time, the equipment should be fully automatic except for a footswitch to control the timing. The operator should not be obliged to put aside tools or parts during the program to actuate anything on the control panel. Nor should the equipment allow the picture and taped message to get out of synchronization during normal sequencing of the program.

To meet the parameters described, the basic functions required for audiovisual performance aids are defined as follows:

(a) a rear-projection device
(b) remote-control slide changing capability
(c) a tape playback unit
(d) added circuitry for synchronized sequencing
(e) provision for recycling slide tray and tape
(f) auxiliary recording and photographic equipment

DETERRENTS TO EXPANDED USE

There seem to be three principal barriers which have been a deterrent to the more widespread use of this type of equipment:

(a) Instructional and supervisory personnel may not be familiar with such techniques as the writing of clear, concise scripts and the closeup photography of hand positions and metallic objects.

(b) Space allocation at the work station is often a difficult problem. The equipment must be arranged conveniently for a variety of situations which are often hampered by limited bench space and an array of other equipment.

(c) A large investment is involved in supplying versatile individualized equipment to a large number of personnel.

INSTRUCTIONAL AIDS

When the autoinstructional equipment is for instructional use in the classroom, rather than an aid to the on-the-job performance of a task, the equipment must take on the further function of providing a means for responding. The response forms fall into two general categories, selected responses and constructed responses. The common response forms (with the usual means for responding given in parentheses) are categorized below:

(1) Selected response

(a) True-False (two pushbuttons)
(b) Multiple Choice (three or more pushbuttons)

(2) Constructed response

(a) Written (pencil and paper)
(b) Spoken (recorded on tape)
(c) Manual (performance with objects)
(d) Typewritten (Alpha-numeric keyboard with computer)

SELECTED RESPONSE

Selected response has come into common use primarily because of advantages in grading tests objectively, even automatically. This same property has carried over into some teaching machines because of the relative simplicity of the electric circuitry involved. The use of true-false statements or multiple-choice questions was first advocated as a mechanized teaching method, adjunctive programming, by Sidney L. Pressey in 1926.

CONSTRUCTED RESPONSE - WRITTEN

Constructed response builds upon the classical Socratic method of learning. In modern programed learning, the questions or statements are carefully prepared so as to introduce material in small consecutive steps. The student is required to respond during each step. The advantage of this method, as postulated by B. F. Skinner in 1954, lies in the act of writing (or speaking or covertly forming) a response correctly, and immediately seeing (or hearing) that it is correct.

Written responses are accommodated in current teaching machines by providing a roll of paper which is mechanically transported under an opening for writing the response. As the correct answer on the printed program is revealed, the written response advances to a position under a transparent shield to prevent the changing of an incorrect response. It remains in view, however, so that it may be compared with the correct response.

CONSTRUCTED RESPONSE - SPOKEN

Another form of constructed response is the spoken response as typified by the language laboratory.

Here the vocalized response is recorded on tape and played back for aural comparison with an example or model. Many variations on this basic equipment concept have been tried successfully. In several installations, a student's progress can be monitored or his questions answered from a control center adjacent to the classroom.

The merging of filmed materials with language laboratory materials into integrated programs has potentialities that have barely begun to be realized. A very fitting application for such programs would be in combined language and culture training for personnel being readied for overseas duty. This would include military personnel, Peace Corpsmen and civilian technicians. Students could learn not only the basic foreign language but the expressions, gestures, cultural practices and taboos. The use of video tape to provide immediate visual and aural feedback is particularly promising at this time.

CONSTRUCTED RESPONSE - MANUAL

Manual responses, by our present definition, cover a variety of situations, the requirement being that equipment must be provided which requires specific overt responses, ie, performing actual activities as distinct from the vicarious experience of reading and/or writing verbal material.

As an illustrative, though not unique example, at the 3320 Retraining Group, Amarillo Air Force Base, Texas, audiovisual equipment is being utilized on an experimental basis in teaching the use of vacuum tube voltmeters. As in the performance aid applications described previously, the student is shown slides portraying the successive steps to be performed to the accompaniment of a taped narrative of each operation. Of crucial importance for present consideration is that he is furnished with an actual meter exactly like the one pictured and a series of electronic components. He uses the meter, in an individual laboratory situation, to determine whether or not each component possesses the prescribed resistance within accepted limits of tolerance or whether it is defective and in need of replacement. At Lackland Air Force Base, Folley et al (ref 2.) employed individual audiovisual devices for instruction on a manipulative task, the disassembly and assembly of the carbine. Each student was given step-by-step instruction while manipulating actual weapons.

These situations differ from those described previously as involving performance aids in that these instructional aids are used to contribute to learning. This being the case, factors such as transfer and retention become major considerations. The performance aids, by contrast, are at times referred to as nonlearning aids in that they enable the performance of a task without requiring the learning of sequences and details that have no relevance outside of that particular activity or situation.

Other, more sophisticated, devices react or adapt to the response. A recent commercial development applied to a recreational pastime, indicates the extent of potential applications in kinesthetic training and, more particularly, the alteration of responses to produce effects more closely approximating the desired effects (shaping of behaviour). This device, a simulated golf course, sets up a stimulus (a view of a golf course) and then reacts to the response (a golf stroke) by means of random access projection. Viewing the projected scene of a fairway from the tee stimulates the indoor golfer to hit the ball into the flexible projection screen. The resulting bulge in the screen is detected by a network of photoelectric cells, and the time interval between the two impacts is measured. The resulting data, describing the velocity and direction of the ball, are fed into a small computer which calculates the expected range and then selects, by random access, the scene most nearly corresponding to the new position on the fairway. This procedure is repeated over the entire simulated golf course. Provision has even been made for overshooting the green by including rearward facing scenes.

CONSTRUCTED RESPONSE - TYPEWRITTEN

The most sophisticated form of generalized (nonspecialized) response is a typewriter keyboard. This method has been pursued not to provide a typewritten response per se, but rather to permit automatic evaluation or scoring of a written response and, in many cases, to provide feedback impulses to the device. In this heuristic programming context, feedback refers to the on-the-spot use of incorrect responses to modify the sequence of the program, that is, to control the selection of the next stimulus to be displayed. The feedback must be provided by a program in some sort of logic device, such as a computer. The audio and/or visual material must be available on a random access basis. Swets et al have described such a computer controlled system (ref 3).

Related efforts on the design of adaptive teaching systems with a capability of selecting and altering criteria are being performed by Gordon Pask of System Research, Limited in London, England.

Some degree of feedback is required in any program where alternative routes are provided for remedial steps or to "skip ahead." Such programs are referred to as "branching" or "intrinsic." Their principal proponent has been Norman A. Crowder. A very simple embodiment of the branching concept is the "scrambled book" where the student does the response evaluation and random access searching himself.

Because of the high cost of computers and the associated input and output equipment, keyboard response is not proposed generally for normal classroom use. However, investigations by O. K. Moore suggest that preschool-age children can be trained to read, typewrite and compose stories before they are old enough to manipulate a pencil. This may hasten the day of the special keyboard-computer-equipped schoolrooms for the teaching of many subjects.

RESEARCH AND DEVELOPMENT APPLICATIONS

Our third area of application, research and development, embraces many of the same functions as the performance aid and learning aid areas but with addition of some further requirements such as:

(a) data-collecting (scorekeeping) capability
(b) flexibility for experimental manipulation
(c) augmented performance requirements.

The probability that a training course will be of optimum effectiveness increases with the extent to which it has been validated. Program validation includes repeated study, on an item-by-item basis, of responses obtained in actual use.

In the development of new programs for training in specialized skills, the primary concern is the capability of mocking up any combination of the functions. The particular arrangement needed may be subject to frequent modification or integration of additional functions as development progresses.

At times, uncommon limitations may have to be imposed on the performance of some of these functions. For example, picture change may have to be nearly instantaneous, or the time interval between pictures may have to be variable but very accurately controlled. Probably there will be more frequent demand for high speed random access for use in training research, not only for the visual materials but for the audio messages as well.

SYNCHRONIZATION AND RANDOM ACCESS

The maintenance of synchronization between the visual and the audio frames with high-speed, random access creates a sizeable problem. The usual technique of using a recorded signal to trigger the slide change or filmstrip advance is not easily adapted to these requirements. One method of synchronization is to physically join the audio and visual media. The Audioslide, developed by the Gray Manufacturing Company, Hartford, Conn., is an example. The transparency is mounted in the center of a large slide (approximately 4 inches square) on which a spiral groove is embossed. The audio signal can be both recorded and played by means of a revolving cartridge in the projector. Revere Camera Co., Chicago, Ill., and Kalart Co., Plainville, Conn., also provide equipment with the audio and visual material physically joined. The Lectron Corporation of America, Milwaukee, Wis., provides an interesting system with confirming and remedial material keyed to associated parallel tape channels. At present, none of these machines provide random access for selecting the slides.

Another method of synchronization which could be developed for use with a multichannel tape system, such as a message repeater, would be to key the channel selector mechanically to the frame or slide selector. Such a mechanism was developed at Graflex Inc., Rochester, N. Y., early in 1963. The number of parallel tape channels that can be accommodated in one machine is relatively limited. Selection of any specified frame on a long filmstrip by entering the frame number on a desk calculator type of keyboard has been accomplished in the Behavioral Sciences Laboratory at Wright Patterson Air Force Base, based largely on equipment developed by U. S. Industries, Goleta, Calif. It is conceivable that a similar method could be used to select any specified block of audio information on a tape moving at high speed by counting sustained (long duration) signals.

Although the specialized capabilities described in this section are, for the most part, outside the scope of this study, they have been mentioned to illustrate the degree of flexibility which may be required of the research equipment system.

RESPONSE EVALUATION AND FEEDBACK

At the present time, multiple-choice and keyboard-computer responses can be processed automatically. Recent developments in machine recognition of written symbols and speech sound wave forms are promising. The advent of computer controlled cathode ray tubes offers intriguing possibilities for the very near future. However, written or spoken responses, for practical purposes, are generally processed at the present with human assistance. The response is self-scored on a subjective basis. Another alternative, not requiring exotic equipment, is a written or spoken response followed by a confirming multiple-choice response. This input (if correct) can be used to advance the program or (if incorrect) to present remedial branches. It can also be recorded on a counter, magnetic tape, punched cards or the like to compile error rate data automatically for program evaluation. An arrangement similar to this has been devised by a British firm, Associated Electrical Industries. Two buttons, labelled "correct" and "?" either proceed with the program or present remedial information not directed at any specific response. This results in simpler mechanics and simpler programming. (ref 4.)

On the other hand, the programmer may wish to increase the complexity of his program by requiring two or more correct responses to a given stimulus. This would allow him greater freedom in the use of remedial branches. If the response panel had $\underline{n}$ pushbuttons, then the use of all possible combinations would provide up to $2^n - 1$ different responses. For example, if 1 = yes and 0 = no, and the first and third of four statements were the correct ones, then the pushbutton input would be "1010." The control function must be able to discriminate the pattern of this binary input and, according to a predetermined program, select the proper feedback.

SECTION III

MODULIZATION

From a review of the various functions served by audiovisual equipment, it is clear that requirements to be fulfilled by a piece of autoinstructional equipment may vary in type or complexity from time to time. Especially in the area of program development for specialized skills is the complexity apt to be great and the equipment subject to frequent and drastic modification. A survey of available equipment would indicate that no available device can fulfill all functions, nor can components be interchanged among a few devices to satisfy a larger variety of purposes.

Many instructional program developers have found that their equipment, some of it quite expensive, that has satisfactorily served its originally intended purpose, has become obsolete when additional requirements are placed on it. Or, perhaps, the requirements of one setup may have been simplified, so that a major function representing a large percentage of the cost of the equipment, is no longer required. It frequently happens that when a program is under development, much elaborate timing and recording apparatus is required that is neither required nor desired in later classroom or on-the-job use.

For individualized audiovisual equipment, a very attractive possibility is to develop a number of interchangeable packages, or modules, each embodying a single major function. These modules could be designed and constructed to permit their being combined into various configurations. The program developer may build up whatever system he feels is the most suitable for each application. He would have the freedom to experiment with various configurations to attain the maximum effectiveness of his program. When the program is finalized, only the modules necessary to meet the specific training situation would be acquired in quantity.

The remainder of this report is devoted to a discussion of some of the considerations that enter into the modulization of various separable functions and some of the characteristics of the modules comprising one basic system.

MODULIZATION OF VISUAL DISPLAY

We shall first investigate the feasibility of separating the visual display functions into two or more modules. The basic functional areas with which we are concerned are as follows:

(a) Rear-projection screen, with mirror(s) and enclosure, or screen box.
(b) Projection lens
(c) Film transport mechanisms for various film formats
(d) Light source, including lamp and condensing system
(e) Blower for cooling.

A determination must be made as to which of these functional areas should be combined into a single module and which should remain separate. To do this, one must first estimate the extent to which the various alternatives might be used in major applications. We shall assume that the basic system would be designed for individual use and, hence, would have the smallest screen. A larger screen for group instruction would be the exceptional requirement, carrying along with it the need for a more powerful light source and blower. This will be discussed in greater detail later.

Closely tied to this major usage consideration is the desirability of designing with a potentiality for maximum versatility.

The visual display equipment should be designed to accommodate both slide and filmstrip modules (ref 5). Further, it should be possible to project either moving pictures or still pictures on the same screen by interchanging the projection mechanisms. However, the ultimate in versatility would be to be able to switch from one visual medium to another instantaneously by remote control. To accomplish this, the projection mechanisms must be spatially arranged to permit simultaneous operation, each feeding into a common, unobstructed light path. Yet it is also desirable, for simpler setups, that the still projection module form a compact and unified configuration with the screen module. To arrive at a completely satisfactory arrangement for every possible combination of the modules while keeping costs within reason is difficult. Such an accomplishment would undoubtedly require a certain amount of compromise in compactness and appearance.

It will be assumed for the present that a motion picture module would consist of any of several commercially available projectors equipped with an appropriate projection lens. Due to the specialized lamp requirements of motion picture projectors (ref 6) and also the greater complexity of their film handling mechanisms, only the still projection functions will be subject to modular treatment. The question now arises whether the film transport module should have both slide and filmstrip mechanisms built in, or whether separate modules should be provided for each. Although most still projectors designed for classroom use are convertible from filmstrip to slide operation by the interchanging of manual film transport mechanisms, the fact that autoinstructional applications almost invariably require remote control motorized operation indicates that each basic mechanism should be self-contained. Also, the possible substitution of more complex mechanisms such as random access capability, and the fact that the two film formats require different projection lenses in a rear-projection application, as will be shown in following paragraphs, add to the argument that the slide and filmstrip mechanisms should be designed as separate modules. The film transport modules are discussed further elsewhere in this section.

EQUALIZATION OF PICTURE SIZE

When accommodating various sizes of film format with a screen of a given size, it is desirable to have the picture fill the screen, or nearly so. For interchangeability, it is also desirable to maintain approximately the same projection distance to the screen. These two requirements can only be met by matching the focal length of the projection lens to the film frame size. Thus a set of projection lenses must be selected, preferably having standard focal lengths so as to make use of existing lens designs. All members of the set must project about the same picture size at a common projection distance. The wider the field coverage required of a projection lens, the more difficult and expensive it becomes to cover the maximum frame size without darkened corners. Hence, for any film format there is a practical low limit on focal length.

Table I lists two sets of lenses, designated A and B, which are presently available and would be suitable for compact configurations. Also shown are a few moving picture projection lenses which might be used, depending on the selected light path configuration. We have, for purposes of comparison, selected an 8-inch square screen as standard for individual instruction. Set A, using the shortest standard focal lengths available and practicable, gives a film to screen distance of about 16 inches, which would provide a very compact design. Set B, using the next higher increment of focal lengths, results in a distance of around 22 inches, which would require more folding of the light path for compactness.

In any case, it can be seen that, for fully modulized visual display equipment, the projection lens must be regarded as part of the film transport module. As an alternative, the use of a zoom lens might be practicable under certain circumstances. However, it would have to be justified on the basis of a combination module and the acceptability of higher unit cost, not only for the more expensive lens system and zoom mechanism, but also for the zoom control. Furthermore, corner resolution of a low-cost zoom lens design would probably fall below the requirements of this application.

TABLE I

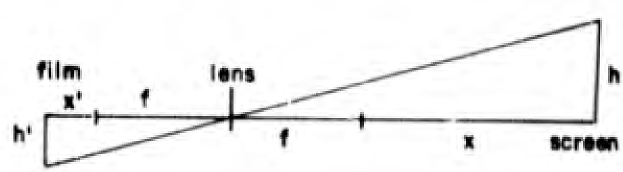
PROJECTION LENSES SUITABLE FOR COMPACT DESIGNS

(Dimensions in inches unless otherwise indicated)

Set	Format	Frame width	Focal length	Film-to-screen distance *	Picture width **	Picture height
A.	35mm slide	1.344	2.0	16.25	8.0	5.4
	35mm strip	.906	1.5	15.6	7.5	5.63
B.	35mm slide	1.344	3.0	22.6	7.2	4.85
	35mm strip	.906	2.0	21.95	8.0	6.0
	16mm movie	.380	.625	14.4	8.0	6.0
			.750	17.3	8.0	6.0
			1.0	23.0	8.0	6.0
	8mm movie	.172	0.5	24.2	8.0	6.0
			15mm	28.4	8.0	6.0

* To make optimum use of illumination from the common light source module, the position of the single-frame filmstrip was moved forward on the light cone 0.65 inch from the double-frame slide position. This difference shows up in the film-to-screen distances.

** The film-to-screen distances for 8-inch picture width were calculated by simultaneous solution of the simple lens formula $xx' = f^2$ and the magnification formula $h/h' = (x+f)/(x'+f)$. These quantities are defined in the following diagram:



The picture widths less than 8 inches were calculated in reverse from the film-to-screen distances which were determined as stated in the preceding footnote.

THE SCREEN BOX MODULE

An important difference between front and rear projection is that the image is reversed right for left. Correcting this by reversing the slides or filmstrips is generally inconvenient. Reversing most movie film is impossible. Thus it is preferable to accomplish this correction by using an odd number of mirrors.

The positioning of auxilliary projection systems, such as a moving picture projector, is most convenient if the entire optical axis is horizontal. Based on the conventional placement of controls on standard projection equipment, the logical arrangement would be to use a one-mirror system with the projector to the left of the screen box. (See Fig 1.) The projector and screen box modules would then have interface openings which would coincide when the modules are attached. With this arrangement the projector could be used alone for front projection, and the screen box could be used with any auxilliary projector.

Some applications require motion sequences interspersed in a slide or filmstrip presentation. The separate projection systems could be made available interchangeably on one screen in either of two ways. One is to mount the large 45° mirror rotatably so as to clear the path for projection from a smaller 45° mirror at the back of the screen box, for example as shown in figure 1(D). (Note that the rotatable mirror must be swung so as to face away from the straight-through light path to avoid grazing incidence reflections at the edge of the screen.) This method virtually requires a manual shifting operation, if the expense of a drive motor and a clamping mechanism is not justifiable. These problems can be avoided by going to the alternative method of using a fixed partial mirror, or beam splitter. The disadvantage here, however, is the loss of light by reflection when using the transmitted beam and by transmission when using the reflected beam. However, if one of the projection systems can supply abundant lumen output, the losses of the other system can be minimized by using a reflectance-transmittance ratio of, say, 70 to 30 instead of 50 to 50.

The arrangement illustrated in figure 1(D) indicates that a basic screen box module could be provided with a removable panel at the rear of the box which could be replaced by a small mirror extension for specialized use with a second projector.

Two additional features which might be provided in the screen box module will be described in a later section. These are the "answer mask" and the "photoelectric code detector."

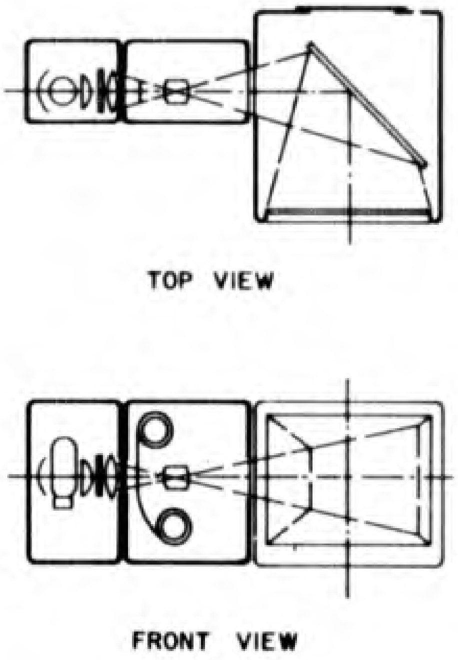
Finally, for the instruction of groups of various sizes, rather than individuals, larger screen boxes must be substituted for the 8-inch screen box. The maximum audience size that can view a given screen satisfactorily can be calculated from recommended values of distance and off-axis angle (ref 6). Using those values and an area of six square feet per person, an audience of $P=6W^2$ persons (where W equals screen width in feet) is possible with rear projection in a normally lighted room. By contrast, for front projection in a semidarkened room, $P=2.2W^2$ is recommended. (The derivation of these formulae is given in the Appendix.) Table II shows the audience that can be accommodated if the screen width is successively doubled. Of course, it may be advisable to select some intermediate size as the best compromise for common class sizes.

TABLE II

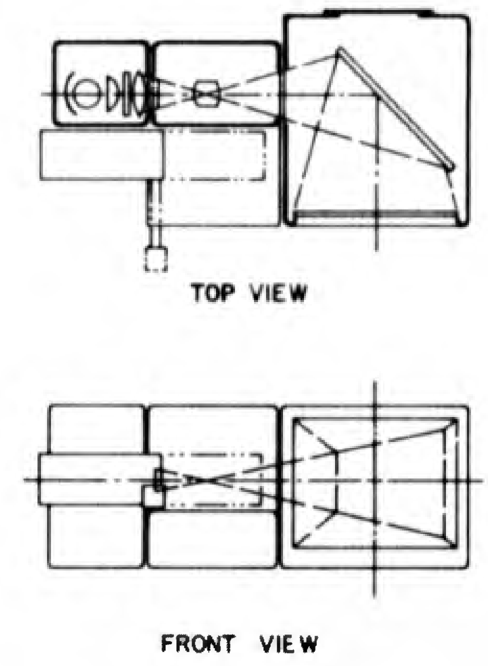
AUDIENCE SIZE (P) VS SCREEN WIDTH (W)

Screen Width		Rear projection	Front projection
inches	feet	$P = 6W^2$	$P = 2.2W^2$
8	2/3	3	2
16	1-1/3	10	4
32	2-2/3	42	15
64	5-1/3	170	62

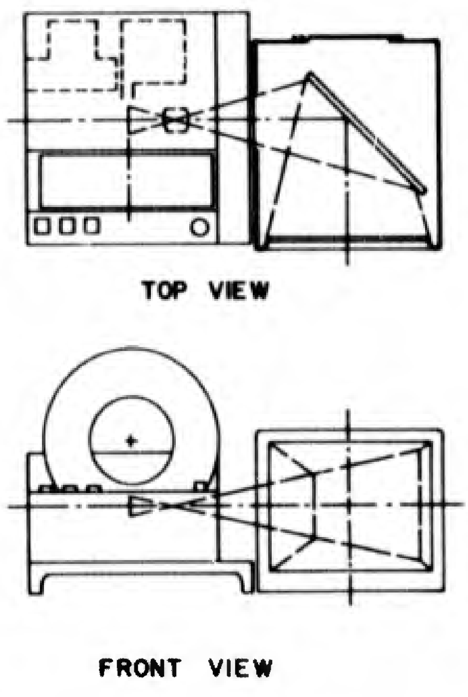
(Note: Large screens are subject to limitations of light output and film resolution.)



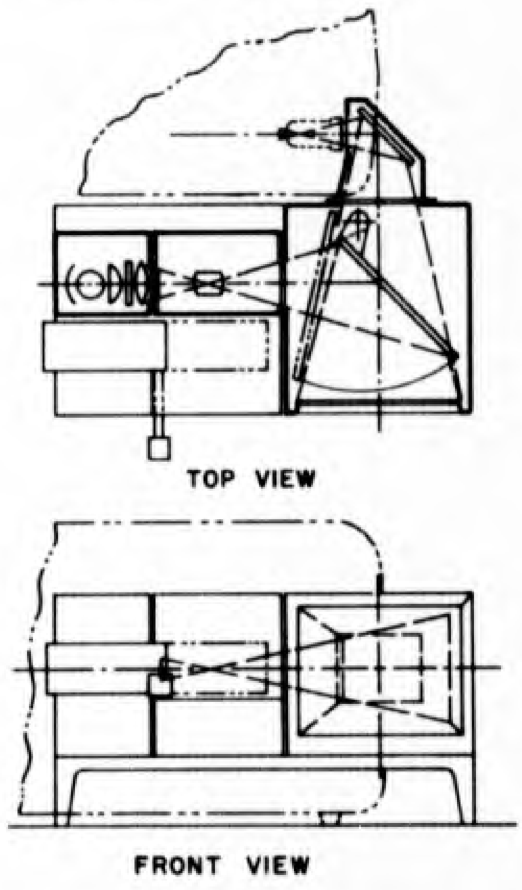
A. SYSTEM MADE UP OF LIGHT SOURCE, FILMSTRIP AND SCREEN BOX MODULES.



B. SAME AS A, EXCEPT WITH AIREQUIPT SLIDE CHANGER.



C. SCREEN BOX MODULE USED WITH SAWYER'S ROTOMATIC PROJECTOR (2" LENS AND BASE ADDED).



D. SAME AS B, EXCEPT WITH SWINGING MIRROR AND EXTENSION FOR INTERMIX WITH 16MM MOVIE PROJECTOR.

FIG. 1. SUGGESTED MODULIZATION OF VISUAL DISPLAY
(Sections Through Cases Indicated By Heavy Lines. All Views 1/8 Scale.)

THE LIGHT SOURCE MODULE

There are two environmental variables which strongly affect the brightness requirements of the visual display.

(a) audience size - a larger audience necessitates more screen area, as shown in table II. The required lumen output of the light source increases directly with the square of the screen width, assuming equally efficient condensing systems.

(b) ambient light level - this can be expected to vary at least tenfold from one situation to another, and likewise affects the required lumen output (ref 6).

To accommodate these independent variables, provision should be made to allow for the substitution of more powerful light sources for the basic low-wattage unit. Since the base-to-filament dimension of high-wattage lamps is greater than that of low-wattage lamps, the vertical position of the socket must differ for each source, yet the precise relationship between the lamp and the condenser system must be maintained. For these reasons, it appears advisable to design a family of complete light source modules, separable from both the film transport and screen box modules. Each member of this family could be designed so as to supply power to the film transport module through a case-mounted plug and socket.

The higher wattage modules would require higher capacity blowers for adequate cooling. Conversely, low-wattage lamps (100 watts or less) can be convection-cooled without the aid of a blower.

If a smaller still-picture format should come into common use in audiovisual materials, such as the 8mm or 16mm filmstrip, the integration of the light source with this film module would probably be the best choice. In this case, a lamp with an internal condensing reflector, such as the Sylvania Tru-Flector, which is now commonly used in both 8mm and 16mm projectors, could be mounted in more precise relationship to the film gate in an integrated module.

Finally, three design considerations should be mentioned with regard to the light source module:

(a) The condensing lens system should be specifically designed to be compatible with the short focal length projection lenses in order to achieve optimum efficiency.

(b) The modular construction is especially well suited for employing a very efficient cooling system. This would consist of an impeller which exhausts the air directly from around the lamp. With an enclosed box, the air intake can be restricted to the front aperture, thus drawing cool air in from the film gate area toward the lamp. The alternative is to force air at the film which is necessary with high-wattage motion picture projectors, but may allow heat to accumulate in the lamphouse.

(c) It is desirable to increase the rated lamp life beyond the usual 25 hours when the equipment is to be used several hours every day. This can be done either by reducing the operating voltage or, preferably, by using a lamp at normal voltage that is designed to operate at a higher voltage. In either case, the light output is reduced and reddened. For example, the rated life of both a 115-volt lamp operating at 106 volts and a 125-volt lamp operating at 115 volts will be increased 300% while the lumen output will be reduced by only 25%.

THE FILM TRANSPORT MODULES

It should be emphasized at this point that the anticipated use of these modular equipment systems differs from normal classroom use, where slides and filmstrips may often be intermixed from one showing to the next. For the broad autoinstructional field envisioned here, the use of slides and filmstrips would be more distinct. We can summarize from Section II that slides are and will continue to be used almost exclusively in research, in program development, and in low quantity or flexible programs in any area. Conversely, filmstrips are and will continue to be employed primarily for "published" classroom programs and training courses (ref 5). (Random access filmstrip usage is not included in this discussion.) This distinction results from the fact that quantity reproduction costs of filmstrips are lower and also from their compact, one-piece nature.

The design of a transport module for filmstrips would be fairly straightforward, inasmuch as the motor-actuated advance mechanism could be adapted from current designs. Possible modifications might include the addition of remote reverse operation or provision for handling a continuous loop of filmstrip for repetitive applications. The latter modification would necessitate side-loading capability, as well as some sort of support for the loop. In any case, the film gate should be designed to pass film splices without catching. Another possible modification might be provision for half-frame (or quater-frame) indexing of the filmstrip in the gate to suit the format of the program frames, as will be discussed later. Of course, manual operation should also be provided.

The module for 2 x 2 (35mm) slides could make use of any commercial automatic slide changer mechanism that is dimensionally feasible. However, one important restriction is that for the compact arrangement under consideration, any slide magazine (or tray) longer than the commonly used Airequipt design (about 5-3/4 inches) would run into the screen module. (The Airequipt magazine is limited to a capacity of 36 cardboard-mounted slides.) Also there is the problem occuring in industrial production applications of recycling the linear travel of the magazine if it is not easily accessible to the operator. Both of the above problems would be solved by using a circular magazine, such as the Kodak Carousel® (Eastman Kodak Co., Rochester, N. Y.) or the Sawyer's Rototray (Sawyer's Inc., Portland, Ore.), even though this type takes up considerably more storage space than a straight tray. (For a comparison of cost and storage space per slide of various slide trays, see Table III.) The circular magazine would also lend itself to a more sophisticated random access module. The Sawyer's Rotomatic changer has the further advantage of accommodating several types of straight trays, as well as a stack changer for loose slides.

TABLE III

COST AND STORAGE SPACE PER SLIDE FOR VARIOUS SLIDE TRAYS

Type	Capacity	¢ /slide (retail)	cu. in./slide (as boxed)
Airequipt	36	6.2	0.95
Kodak Carousel	80	3.7	2.5
Sawyer's Rototray	100	3.0	2.1
Sawyer's Easy-Edit	36	4.0	1.3

MODULIZATION OF AUDIO FUNCTIONS

As with the visual display functions, it may be feasible to separate some of the audio functions into modules. However, the separability of audio functions, as we shall see, is not so much for the accommodation of interchangeable media or of various sized audiences as it is for the attainment of specialized and more complicated systems. The problem will be to define a basic audio sub-system, complete in itself for common usage, but which will accept add-on modules for more complex systems. The complete audio sub-system must provide three fundamental functions, namely, program recording, program playback and automatic sequencing control. Before taking up the electronics of modular audio systems, we should review the various audio recording media.

AUDIO MEDIA

There are currently three recording processes in common audiovisual use. The playback of these recording processes all involve relative motion between (a) a record material carrying variations, in the direction of motion, of one of its physical properties, and (b) a detector of these variations. The relative motion causes a voltage to be generated in the detector. (The recording process itself is roughly the reverse operation.) The three processes (with the material, the nature of the variations, and the detector) are as follows:

(a) Phonographic (a groove embossed in plastic with transverse ripples causing vibrations in a tracking stylus)

(b) Magnetic (variations in field strength of a magnetized material passing an extremely narrow gap between two pole pieces)

(c) Optical (variations in density or clear area of photographic film passing a narrow illuminated slit over a photoelectric cell).

There are also three configurations of the recording material in common use:

(a) Discs (rotated on a turntable, with the detector moving slowly from edge to center)
(b) Tape or film (transferred from reel to reel past the detector)
(c) Belts (turned on parallel rollers with the detector usually moving slowly from edge to edge).

Of the nine possible audio media resulting from combinations of any one process and any configuration, six have been used extensively. Examples of commercial equipment using these media are given in table IV.

As stated previously, the choice between the phonographic (or optical) process and the magnetic process, like the choice between filmstrips and slides, is primarily a matter of the need for revision of the program and the cost factor, based on the quantity of reproductions involved in the particular application. There are several other important considerations which might indicate, in some cases, that some medium other than the usual magnetic tape would be the most feasible.

TABLE IV

EQUIPMENT USING VARIOUS AUDIO MEDIA

MATERIAL CONFIGURATION

AUDIO PROCESS	Disc	Tape or Film	Belt
Phonographic	All Phonographs Edison (30^m) Gray (20^m, 1^h) Soundscriber (15, 30^m) Gray Audioslide	Not Used	Dictaphone (15, 30^m)
Magnetic	Telefunken (10^m) Concord Magnedisc Revere Soundslide	All Tape Recorders 8MM and 16MM Sound Movies Edison, Dictaphone, and Others (40^m To 10^h)	IBM (14^m) Nord (15^m) Stenocord (8, 12^m) Victor Comptometer (12^m)
Optical	Not Used	16MM & 35MM Sound Movies Kalart Filmstrip (18^s)	Not Used

NOTE: Dictating machines are underlined.
Maximum playing times in parentheses. (ref 7.)

PHONOGRAPH DISCS AND BELTS

For high quantity audiovisual applications the familiar pressed phonograph record is employed, usually in combination with filmstrips, primarily because of its durability and the great availability of record players. In the area of dictating machines, a smaller, thinner, semiflexible disc is used by several manufacturers. These discs (and belts) are soft enough to be embossed by a stylus, rather than being hot pressed from a master, which accounts for the difference in durability. These discs are low in cost and excellent for mailing and filing, but the sound quality, though adequate initially, deteriorates with repeated playing. Without specifying quantitatively the drop in frequency response, it could be said that, for reasonably good reproduction of music, the limit is around ten plays, while for understandable voice reproduction, the limit is roughly 50 to 100 plays. Furthermore, in contrast to magnetic recordings, the phonographic groove cannot be erased. In case of change, a new disc must be cut. (An audiovisual product using this medium is the Gray Audioslide described earlier.

MAGNETIC TAPE, BELTS AND DISCS

Generally speaking, the shortcomings of the phonographic media are the advantages of the magnetic media, and vice versa. The quality of reproduction does not deteriorate with repeated playing, and it is common practice to erase and re-record with the magnetic process. However, for equivalent playing time, magnetic tape is more expensive and bulkier than vinyl discs. Magnetic discs and belts also have shorter playing times than their phonographic counterparts because of the wider recording track. The great advantage that magnetic tape has over other audio media for many audiovisual applications is the fact that two, or even four, channels can be recorded simultaneously, allowing the use of inaudible stop-and-go signals or other information.

There are at least six different ways that magnetic tape can be handled, depending on the degree of convenience and repeatability desired:

(a) Two separate reels - the standard tape recorder and dictating machine method.

(b) One-reel pull-out cartridge - developed early for commercial tapes to reduce the danger of spilling.

(c) Two-reel cartridge - current designs by RCA and Bell Sound Division, Thompson Wooldridge Inc., Columbus, O., who also make the tape decks to operate these cartridges.

(d) Continuous loop cartridge - non-reversible, in which the tape is pulled off the inside of the reel while being rewound loosely on the outside. Examples are the Cousino Echomatic and the Fidelipac® (Conley Electronics Corp., Evanston, Ill.), both of which are used by Pentron Electronics Corp., Chicago, Ill., and other recorder manufacturers.

(e) Stack-changer cartridge - designed for automatic changing, recently developed by both KRS Electronics, Palo Alto, Calif., and Revere-Wollensak Division, 3M Co., St. Paul, Minn.

(f) Random storage - a reel-less cartridge in which the tape folds freely back and forth in random fashion; still in experimental stages.

The magnetic stripe on motion picture film is analogous to tape and can be used where 8mm or 16mm sound films are the controlling program medium. A recent proposal by M. A. Kerr (U. S. Pat. 3,017,466) would permit stereo (2-channel) magnetic recording to be superimposed on an optical sound track without disrupting the latter.

Magnetic belts resulted from an adaptation of the magnetic coating process used on mylar tape to the Dictabelt® configuration, which in turn evolved from the early Dictaphone wax cylinders. Although their playing time is shorter than that of the phonographic belts, the magnetic belts can be reused many times even after being pressed flat, the creases having little effect on playback quality. Two tracking patterns are possible: (a) helical, for continuous play of the entire belt, as in the dictating machines, and (b) parallel, for short period multi-channel operation, such as the example described previously.

To complete our survey of audio media, we shall mention three other products making use of two of these media. The first is the Concord® Magnedisc, (Concord Electronics Corp., Los Angeles, Calif.) a magnetic disc with a spiral groove molded into it for the purpose of tracking the narrow pole pieces of the magnetic head, which is mounted in a conventional tone arm. The machine can be converted to standard phonograph operation by merely replacing the magnetic head with a plug-in phono cartridge. The magnetic disc (without a groove) is also used in the Revere Sound Slide, (Revere Camera Co., Chicago, Ill.) a counterpart of the Gray Audioslide.

The third product is the Kalart Soundstrip projector (Kalart Co., Inc., Plainville, Conn.) which scans, line by line, an optical sound track contained on alternate frames of the filmstrip. The rotating scanner covers a full double frame of sound in 18 seconds. As with other optical sound films, large quantity reproduction is required for economic justification.

Thus we see after examining several audio media, each of which has certain advantages in appropriate applications, the most versatile medium for the low quantity programing applications with which we are primarily concerned here is magnetic tape. Further discussion will be in terms of tape, although in many cases other media may be substituted.

PROGRAM SEQUENCING

In addition to recording and playing back the audio portion of a program, an audio module should provide automatic sequencing by means of signals. This is the control function of the system and may involve any of several operations:

(a) Stop audio - must be restarted manually or by some other input.

(b) Film advance - changes frame of visual display in continuous operation.

(c) Repeat - on manual command, returns to the signal at the beginning of a block of information for replay without film advance.

(d) Timed stop - delay of the audio message a predetermined number of seconds, followed by automatic restart.

(e) Multiple choice response coding - pre-recorded signals set up correct response number, against which student response is compared.

(f) Switching to alternate visual media - for example, shutting off a slide projector and turning on a moving picture projector.

(g) Independent control of stop audio and film advance - if several pictures accompany one audio message, or if several tape stops are required with one picture.

SIGNALING METHODS

The first signaling method used in audiovisual systems was the audible tone, telling the operator to advance the film manually or by remote control. Later, an automatic control signal detector was developed by Simplex Corp., using a signal frequency of 12 kilocycles per second to be compatible with the Cinemascope equipment for which it was being developed. A similar 10 kcps system was later used for the Graflex PM tape recorder. The electronics for this method are economical and compact, but if an audible "beep" is not wanted, a signal in the audible range should not be used unless a second channel is available. This thinking prompted DuKane Corp. to develop a low frequency system using 30 cps, which is inaudible. However, when this frequency is used with phonograph equipment, a specially designed tone arm is required for maximum reliability. A signaling method based on an old amateur radio device has been used by Pentron Corp. After a certain number of seconds of silence on the recording, a time-constant circuit shuts off the machine.

If two or more functions are to be controlled by signals, a means of differentiating them is necessary. The method used in the Graflex Audio-Graphic, for instance, is by timed pulses of the signal frequency, in this case 400 cps. Up to nine pulses may be recorded by means of a telephone dial and read out by means of a stepping relay. The pulse method has been found to be more economical than generating nine different frequencies. However, generating and differentiating only two or three frequencies would appear to be more economical than two or three pulses.

Whatever signaling method is used, synchronization of audio message with visual display must be maintained, regardless of other functions performed by the signals. The choice of signal pattern used and their assignment to various interchangeable functions in alternative modular systems can only be worked out in detail in a thorough product development study.

AUDIO MODULES

The first question to be answered regarding the modulization of the audio functions is whether the recording function should be separate from or combined with the playback function. Again, the decision must be based on the economics of quantity production. The additional electronic components required for recording, exclusive of the microphone, amount to about 50% of the cost of the playback components, exclusive of the tape deck. If the majority of applications require relatively few playback-only units compared to the number of combination units, the added cost of manufacturing small quantities of the playback-only units would probably be greater than if they were all produced as combination units. It should be kept in mind that in experimental set-ups especially, it might be an inconvenience not to be able to record at a playback station. Of course, the "record" switch should have a safety device to prevent accidental erasure.

FUNCTIONS OF THE BASIC MODULE

We may also specify in a general way the features to be recommended in a basic tape module for autoinstructional applications.

(a) Tape handling - a two-reel system for reversing capability. Where handling by students is involved, a two-reel cartridge of the RCA type would be considered.

(b) Tape speed - for reasonably good quality of reproduction of background music and to avoid difficulties of filtering out an unsteady (wowing) pulse frequency, a tape speed of 3-3/4 inches per second.

(c) Sound heads - for optimum versatility, two-channel quarter-track configuration with separate erase heads.

(d) Controls - the usual play, stop, fast forward and rewind buttons, on-off-volume knob, record-playback switch with red panel light and recording level indicator.

(e) Speaker - for normal operation, a jack for a headset. Contrary to common practice, the built-in speaker may be omitted for cost savings and replaced by an optional good quality external speaker, attached at the headset jack.

For most applications anticipated for this equipment, program sequencing signals are a necessity. Therefore, it seems logical that the basic audio module should have single-pulse recording and read-out capability, as distinguished from coded pulses which can be made to perform several functions without altering the system. A single pulse, however, can be made to perform two (or possibly more) different functions on an either/or basis, i. e., by altering the system by means of a multi-contact control switch. The two principal functions are those which differentiate the student-paced mode from the machine-paced mode. In machine-paced mode, the pulse closes a relay to remotely advance the film. In student-paced mode, the pulse stops the tape drive, to be restarted by a footswitch or panel button, which also advances the film.

Another switching arrangement which would be highly advantageous in some applications would be the transfer of audio recording and playback to the second (signal) channel head for audio response (language laboratory) use. Perhaps simpler would be playback only of the pre-recorded program on the second channel, while retaining the first channel for student recording. It is advisable that all intermodal switching be accomplished by a single multi-position switch so as to avoid any difficulties resulting from incorrect setting of the controls.

OPTIONAL FUNCTIONS

A feature that is essential on dictation machines is the ability to back up and repeat short passages of the audio message. This is also a very desirable feature for instructional equipment, for often the meaning cannot be grasped in one hearing, or one's attention may be momentarily diverted. However, remote actuation of the rewind drive on a tape deck adds about 20% to the manufacturing cost of the deck, or about as much as all the electronic components in a playback unit. Although the reversible motor and cam which operate the forward-reverse shift mechanism may be omitted and replaced by a knob, a design permitting the addition of this function by the customer would not be feasible. Thus, the repeat function cannot be a separate module and would have to be either built in or omitted by the manufacturer.

Actuation of the remote repeat function, if present, would be by means of a dual footswitch or pushbuttons. Ordinarily, the dual footswitch would be used only for stop and start. With the repeat function, a momentary tap on the stop pedal can be made to stop the tape mechanism, while sustained pressure causes rewind for as long as the pedal is depressed, or until a stop signal on the tape is reached. The tape can then be restarted by depressing the start pedal, or, at greater expense, automatically on release of the repeat pedal. It is important, when rewinding to a stop signal, that it be impossible to rewind further into the previous block of information and thus lose synchronization with the visual display. Also, the start pedal must trigger the film advance only when progressing to the next block of information and not when restarting after a repeat. It can be seen from the foregoing requirements and restrictions that the switching circuits can become quite complicated in order for the equipment to operate properly under all circumstances.

Another useful feature which adds cost, since it cannot be modularized but must be either built in or omitted, is the tape footage counter. This is an invaluable aid when searching for a specific block of information.

The external control and operating features discussed up to this point are listed below. Those features which may be omitted in the basic module are marked with an asterisk.

Pushbuttons:	play stop fast forward } (may be manual control) rewind } *signal record
Switches:	on - off - volume mode (2 or 3 positions) *record - playback
Jacks:	*for microphone or mixer } or headset for external speaker } for film advance (remote control cable)
Sockets:	for footswitch for multiple signal modules (see next section)
Indicators:	*recording level *footage counter

The approximate relative manufacturing costs attached to each of the major audio module functions are illustrated in the circle graph (fig 2).

MULTIPLE SIGNAL MODULES

When two or more simple control functions are to be programed or a complex function, such as (d), (e), (f), or (g) listed on page 18 is to be programed, a means of generating coded pulses and a means of differentiating between them (read-out) is required.

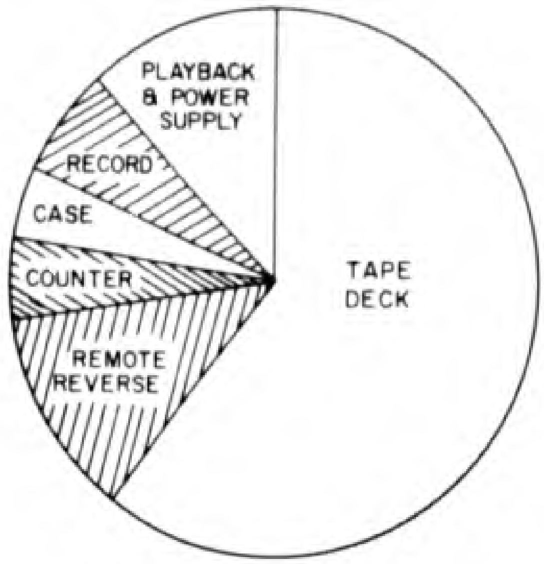


Fig. 2. Relative Cost of Major Audio Functions

The cost of the additional electronic and mechanical components for generating these pulses, which might make up a pulse-record module, would be roughly twice that of the basic record-playback electronics, excluding the tape deck. The same would be true of the read-out module. Obviously, the basic unit should not be burdened with these costs. In addition, these two modules would draw much more current from the basic module and thereby affect the operating voltage. To accommodate this extra load (for only occasional use) would double or triple the cost of the power supply in the basic module. Thus, for increased wattage requirements and voltage regulation, an auxiliary power supply is needed for multiple signal operation. It would therefore be preferable to omit these functions from the basic module and provide them instead as independent modules. These functions, packaged separately, would be integrated into the system by means of cables or flush-mounted connectors.

A complete modulized audio system is illustrated by the block diagram in Fig. 3. The modules making up the suggested basic system are connected by solid arrows. The remaining modules, connected by dashed arrows, would be optional.

MODULIZATION OF RESPONSE FUNCTIONS

Many, perhaps most, applications of audiovisual autoinstructional equipment do not require a response module as such. Both the Air Force and the Hughes applications described in Section I are examples in which the trainee responds on actual equipment rather than on a response panel. There are some situations, however, in which the autoinstructional system would require the inclusion of special provisions for responding and for the confirmation of responses. This would be particularly true if programmed instruction techniques were to be utilized.

In Skinnerian programs, reinforcement of a correct response results from immediate confirmation. If the program is of the multiple choice type, confirmation is usually accomplished by the act of making a correct response which advances the program to the next stimulus frame. In the case of written responses, means must be provided for the student to compare his written response with the one desired. In certain applications it may be desirable to use aural confirmation, but generally the confirmation is presented visually.

Visual presentation of the answer frame may be accomplished by any of several methods, each having certain advantages (A) and disadvantages (D) as listed below:

(a) Answer on next frame (slide or filmstrip) -

A: An unmodified projector can be used.
A: The program can be rearranged easily (on slides).
D: Film usage is twice that of other methods.
D: A second advance actuation is required after the response is compared.
D: Unless repeated, the stimulus can no longer be seen when the answer appears.

(b) Answer with next stimulus (slide or filmstrip) -

A: An unmodified projector can be used.
A: A second advance actuation is not required.
D: A program on slides cannot be rearranged without disturbing adjacent frames.
D: The stimulus is no longer visible.

(c) Half-frame advance (filmstrip only - the stimulus moves to the top half of the screen as the answer appears in the lower half) -

A: The stimulus remains visible when the answer appears.
D: A simple modification of the projector is required.
D: A second advance actuation is required.
D: The program cannot be rearranged.

(d) Answer mask (slide or filmstrip - the answer, in a standardized location in the lower portion of each stimulus frame, is obscured by a manually or electrically operated mask adjacent to the film or the screen) -

A: The stimulus remains visible when the answer appears.
A: A program on slides can be rearranged easily.
D: An additional built-in mechanism is required.
D: Advance actuation is required after mask actuation.

If, in a finalized filmstrip program, stimulus retention is mandatory, method (c) appears to be the best choice. (It is assumed that all program frames can be fitted into the half-frame format - a

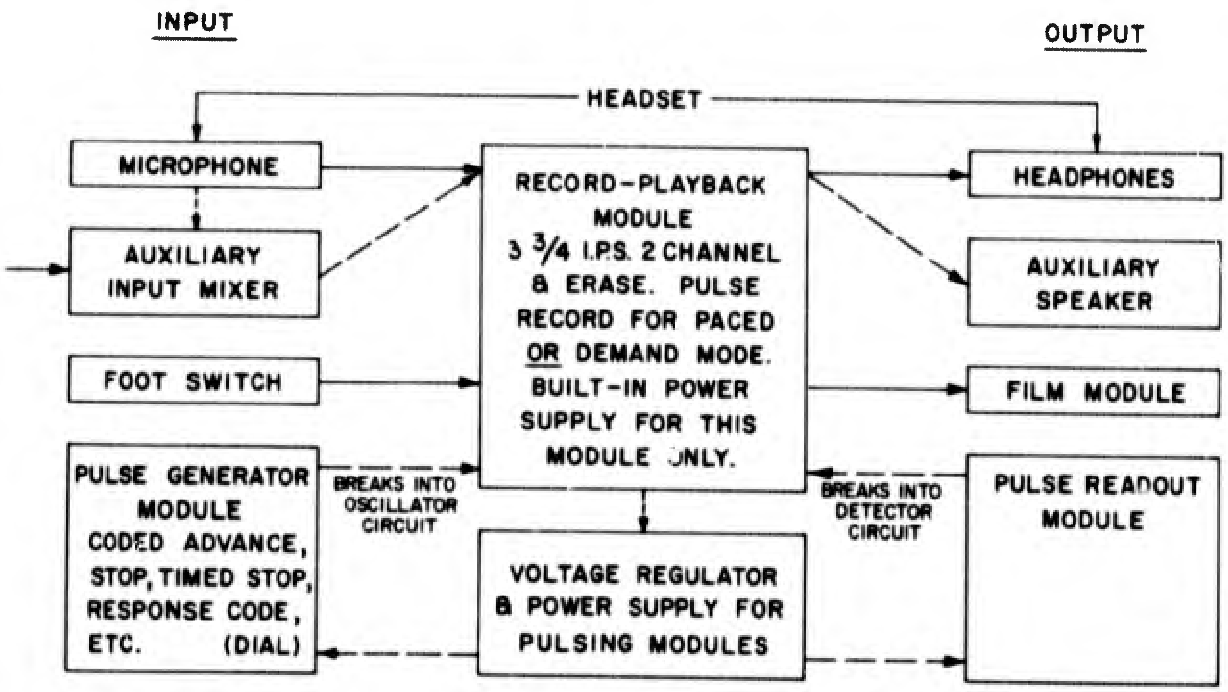


FIG. 3. SUGGESTED MODULIZATION OF AUDIO FUNCTIONS

single frame divided in half horizontally, or the amount of 35mm film transported by two sprocket holes.) If stimulus retention is not mandatory, method (b) would be preferable. For a slide program in the experimental stages not requiring stimulus retention, method (a) would be adequate. However, for stimulus retention in a slide program which is to be transferred directly to filmstrips, only method (d) is satisfactory. The extra equipment cost could probably be justified by the importance of these conditions.

For proper utilization of the answer mask method, it would be advisable to have the alternating sequence of stimulus - answer - next stimulus - etc. maintained and enforced by locking out each operation until the other has been completed. The written-response module would have to have two switch-closing functions with mutual lock-out: the first to withdraw the answer mask as the response is transported under the transparent shield, and the second, a pushbutton perhaps, to return the mask and advance the program.

The following sections discuss some of the more specific characteristics that would be desirable in three types of response modules.

THE BASIC MULTIPLE-CHOICE MODULE

The basic requirements of a multiple-choice module are that a correct response advances the program and an incorrect response in some way indicates an error.

If the program is sequenced by an audio module with pulsed signal capability, as described in the preceding section, this information can be set up in a simple memory device, such as a stepping relay. The output of the module, either program advance or error indication, depends on whether or not the student's response agrees with the position of the stepping relay.

With a visual-only program, or if the audio module does not have pulsed signal capability, the program slide or filmstrip frame can carry the key information. Bright or dark spots can be photographed in specific positions at the sides or bottom of each frame (masked from view on the screen) and their position detected photoelectrically. The coding of spot patterns, in conjunction with the response input, causes the filmstrip to advance, to proceed to a remedial branch or to skip ahead to the "main line", depending on the correctness of the response.

Provision for external use of erroneous responses might also be included for error tabulation. This function, being primarily for the purpose of program validation, might best be treated as an accessory module.

THE BASIC WRITTEN RESPONSE MODULE

The basic requirements of a written response module are as follows:

(a) The response tape should be locally procurable for replacement, easy to install and inexpensive. Adding machine tape, for example, meets these requirements. Except during validation, most response tapes are disposed of soon after use.

(b) The writing aperture should not be more than about 3/4 inch high, to avoid excessive use of paper. However, for flexibility in programing certain subjects, it should be possible to increase the aperture height when responses require several lines of writing or sketches. In either case, the response should, if desired, advance fully under the transparent shield before the correct response is revealed.

(c) The configuration of the module should permit comfortable hand positions for not only right- and left-handed writers but also for the overhand position. The writing area should be close to desk-top level and tilted up slightly. Additional writing comfort can be obtained if the module can be moved about freely, being connected to other modules by no more than an electric cable.

(d) The possibility exists of using this module with a nonelectric teaching machine, which might easily result in reduced costs from increased production quantities. Advance of the paper roll would be manual rather than by means of an electromechanical device powered from the central visual or audio module. The manual input would be unidirectional and could be used to actuate a remote switch for advancing the program. In the case of an audio-only program, this control would replace the footswitch.

(e) To provide for the alternating sequence option, the manual input (response tape advance) could actuate the mask withdrawal switch, while an extra button, inoperative except after mask withdrawal, could be provided for program advance. Multiple-choice follow-up of a written response, discussed in section II can be accommodated by the combined use of the two modules described here.

AUDIO RESPONSE

An audio response adaptation of the modular autoinstructional equipment described in this report would not be economical for ordinary language laboratory use without an integrated visual portion of the program. The value of such a combined program has been cited previously. For other course material it would allow the programmer the freedom to call for a spoken response when this might be more advantageous than the usual written or multiple choice response.

The possibility of recording on either the program channel or the signal channel has been discussed, and also the desirability of having a single control switch. The response module itself would consist of a standard headset - a microphone suspended from a set of earphones. The connection with the audio module could be by means of the microphone and external speaker jacks.

SECTION IV

SUMMARY AND CONCLUSIONS

This report is intended to contribute to the development of modular audiovisual instructional systems. Primary attention has been given to equipment for individual instruction and secondary attention to adaptation of this equipment for group use.

An audio-visual autoinstructional system involves a light source, transport mechanism, projection lenses, screens, audio system(s), control and sequencing unit, and unit(s) to accept student responses. At the present time, these elements cannot, as a rule, be interchanged among systems designed to meet rather specific requirements. If an autoinstructional system could be assembled from basic modules, it might be possible to fulfill many requirements by different configurations of the same modules. This would allow greater flexibility than presently possible. Such greater flexibility would be especially valuable in conducting research, developing instructional programs, and providing for highly specialized individual instruction.

It is perhaps true that modular construction would make any one system more expensive than the equivalent integrated design, primarily because of the individual case construction and attachment devices. Likewise, modular construction generally would not allow as much compactness. However, the flexibility gained with modulization in many cases allows a considerably smaller total expenditure for multiple applications. The modular design would appear to lead to more system capability per dollar cost than is presently possible.

The modular design of autoinstructional equipment seems feasible. The design of a specific set of modules would have to be based on a more detailed design study with special attention to the specific functions to be fulfilled, product criteria such as size, weight and other economic and production factors. Many decisions must be made in the course of a design study as to which, if any, of various alternatives represents the best compromise between use value and cost. However, the general outlines of a basic system are clear. The complete modular system must be designed to attain:

(1) the greatest convenience and lowest cost for the most commonly used setups, and

(2) the accommodation of less commonly used accessory modules. Some of these might be of such infrequent application as to be manufactured only on special order.

The modules from which any one of several systems may be built up could be as follows:

(1) SLIDE MODULE - An automatic 35mm slide changer, preferably of a type which would permit the construction of special models featuring remote answer mask actuation and random access selection. The basic module would include an appropriate projection lens, means for manual operation and a connector for remote actuation.

(2) FILMSTRIP MODULE - An automatic 35mm filmstrip transport mechanism, convertible from single-frame to half-frame advance, and designed for use with cartridge-loaded filmstrips. A special model might be developed featuring high-speed random access selection. This basic module would likewise include an appropriate projection lens, means for manual operation and a connector for remote actuation.

(3) SCREEN MODULE - A rear-projection screen of sufficient size for individual use mounted, along with a single mirror, in a box which could be positively attached to either the Slide Module or the Filmstrip Module. Provision would be made for the addition of a small-mirror extension (and replacement of the large mirror with a beam-splitter or swinging mirror) for auxilliary moving picture input. Provision would also be made for the addition of a photoelectric code detector compatible, if possible, with an existing coding system. This module could be replaced by

larger modules suitable for group or lecture room instruction.

(4) LIGHT SOURCE MODULE - A light source, consisting of a lamp, condenser lenses, heat filter and blower (if required), with a lumen output suitable for use with the individual-size Screen Module in a normally lighted room. This module could be positively attached to, and would supply power to, either the Slide or Filmstrip Module. It could also be replaced by a more powerful source for use with larger screens.

(5) AUDIO MODULE - A two-channel tape recorder-playback unit (less speaker) using twin reels or an RCA-type cartridge, and having the capability of recording and reading out single-pulse signals. Provision would be made for omitting the recording feature for playback only use, and also for adding a remote reverse mechanism. Manual controls for fast forward and rewind would be present. This module would include connectors for these accessories: microphone or auxilliary input mixer; footswitch or remote cord; headphones or external speaker; cable for remote actuation of film advance. In addition, the pulse record and readout circuits could be interrupted by the insertion of connectors from the Pulsing Modules.

(6) PULSING MODULES - Accessory modules for generating and reading out multiple-pulse codes for scoring, timing, stopping of tape, etc. These modules would require a supplementary power supply and voltage regulator.

(7) MULTIPLE-CHOICE - A four-button unit which compares the student response with the answer set up in a simple memory device within the module by either coded audio pulses or photoelectric input. Correct responses would actuate program advance, while incorrect responses would be indicated by an error light. Provision would be made for the attachment of an accessory error tabulating device.

(8) WRITE-IN MODULE - A paper roll advance mechanism of low contour and comfortable for writing. Manual input, such as a knob, would advance the written response under a transparent shield and then actuate answer mask withdrawal. A pushbutton for program advance would then be operable.

In the execution of the production design of these modules, the usual characteristics of high-quality product design should be present:

(1) Durable construction, for shipment as well as hard use.

(2) Reliable operation with minimum need for servicing.

(3) Compact and attractive design.

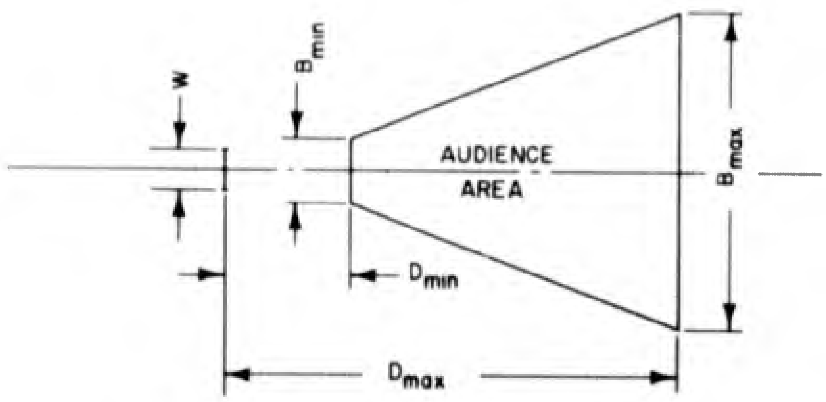
(4) Minimal controls around screen to avoid distraction.

(5) Quiet operation.

(6) Convenient for system setup and maintenance, including trouble-shooting and lamp replacement.

APPENDIX

AUDIENCE SIZE (P) VS SCREEN WIDTH (W)



Using	D_{max} =	10W (rear) or	5.5W (front)
	D_{min} =	2W	2W
	B_{max} =	7.5W	5.5W
	B_{min} =	1.5W	2W

Assume 6 sq. ft./person

$$P = \frac{A}{6} = \frac{1}{6}\left(\frac{1}{2} B_{max} D_{max} - \frac{1}{2} B_{min} D_{min}\right) = \frac{1}{12} \quad (75W^2 - 3W^2)$$

For Rear Projection, $P = \frac{1}{12} \quad (7.5 \times 10W^2 - 1.5 \times 2W^2) = 6W^2$

For Front Projection, $P = \frac{1}{12} \quad (5.5 \times 5.5W^2 - 2 \times 2W^2) = 2.2W^2$

NOTE: The 2.2 value for front projection is in agreement with the table of audience capacity given in the Audio-Visual Equipment Directory, 1964, p. 322 (ref 8).

REFERENCES

1. Goldman, Jay, and Eisenberg, Hyman, "On the Job Learning," Electronic Production, November-December 1963, pp 18-21.

2. Folley, John D. Jr., Bouch, Aubrey J., and Foley, John P. Jr., A Field Experimental Study of Programmed Instruction on a Manipulative Task, AMRL TR 64-90, Aerospace Medical Research Laboratories, Wright-Patterson AFB, Ohio, October 1964. (AD 608 296)

3. Swets, John A. et al, The Socratic System: A Computer System to Aid Teaching Complex Concepts, AMRL Memorandum P-43, Aerospace Medical Research Laboratories, Wright-Patterson AFB, Ohio, June 1963. (AD 421 792)

4. Rigg, Robinson P., "Teaching Machines," Film User, February 1963, p 69.

5. Trow, William H., and Smith, Edgar A., Filmstrip Techniques for Individualized Instruction, AMRL TR 65-78, Aerospace Medical Research Laboratories, Wright-Patterson AFB, Ohio, May 1965.

6. Trow, William H., and Smith, Edgar A., Design Considerations Influencing the Size and Cost of Optical Components in Auto-Instructional Devices, AMRL TR 65-80, Aerospace Medical Research Laboratories, Wright-Patterson AFB, Ohio, May 1965.

7. "Dictation Equipment Specifications Chart," Modern Office Procedures, August 1963, pp 22-23.

8. Audio-Visual Equipment Directory, 10th Edition, National Audio-Visual Association, Inc., Fairfax, Va., January 1964.