Viewing means. Even within a single block, such as the Image Generation, and the Display Unit, there are multiple components. In most of the subsystems mentioned, they are an optical train and a TV camera, or a TV monitor, or a projection tube, and projection optics. Image Storage also has multiple components, the model, color, shading and lighting. This inter-relationship must be borne in mind at all times because a comparison of individual components can place you on the outer edge of a tree limb while you are cutting the limb.

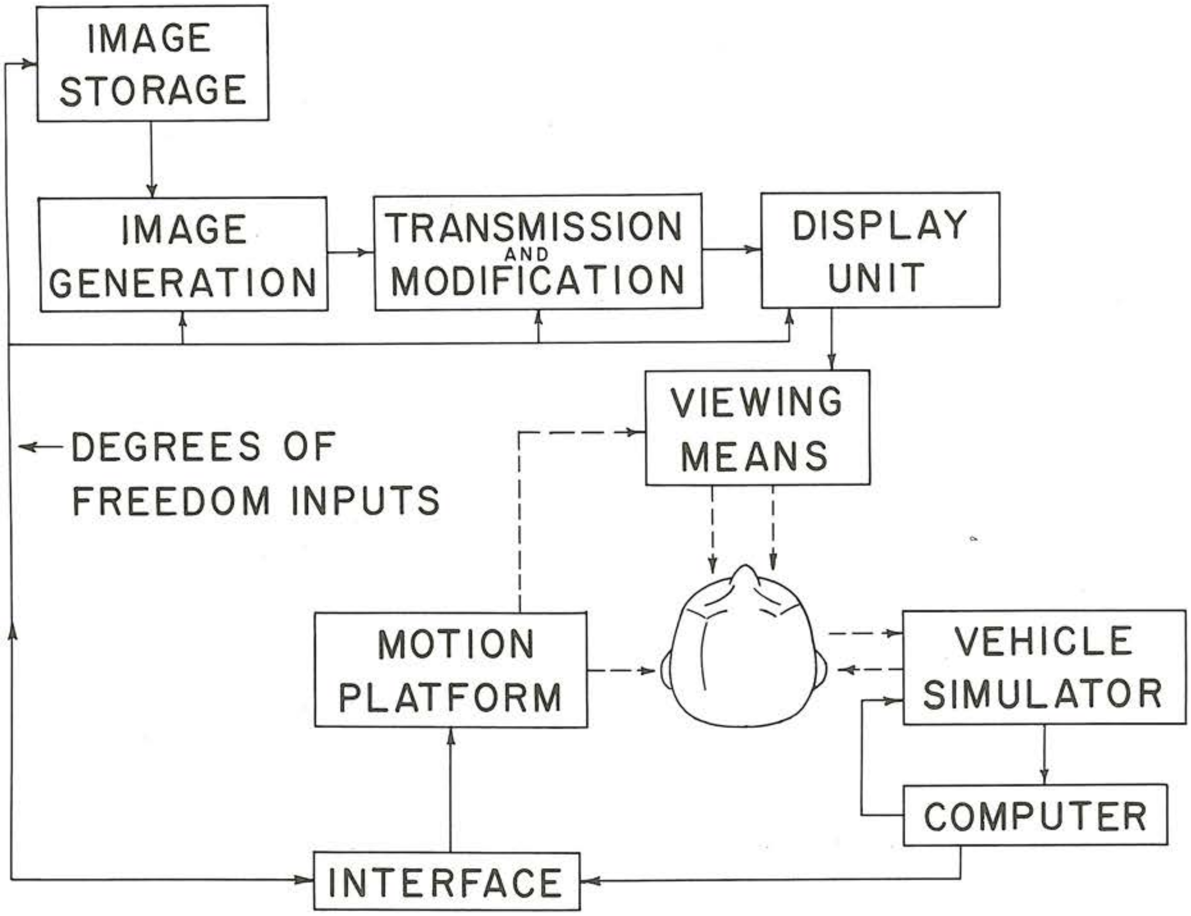

Figure 1. Block Diagram

IMAGE GENERATION. In two studies on wide-angle optics, Goodyear(8,9) identified three critical system design factors for optical probes in image generation subsystems. They are considered here as system parameters, not component parameters.

1. Depth of field or preferably the variation in optical resolution with near distance to object.

2. Working distance or the minimum distance between the entrance pupil and the model terrain.

3. The field of view both horizontal and vertical.

The depth of field characteristics are related to the human visual performance factors of:

a. Egocentric distance localization—that is the ability to judge absolute distance from observer.

b. Depth perception—the feeling that objects are not near you.

c. Depth discrimination—the determination of the relative distance of two objects from the observer.

The criticisms pilots have made of various approach and landing visual simulators may be due to deficiencies in the depth of field of the optical probe in addition to the system limiting resolution.

The depth of field mathematically is defined by the circle of confusion or the limiting resolution in the image plane, the distance from the focus plane to the lens, the focal length and the relative aperature.

Examination of figure 2 will show the difference between specifying a single number for the depth of field and the presentation of resolution as a function of range in the near field. Incidently, in the real-world of typical operating tasks, the ratio of object to image distance using the eyeball may be at a minimum of 400:1, however, with most image generation subsystems, it is about 40:1 or 1/10 real-world and here's where the problems lie.

The figure shows the performance, measured in-house, of some NAVTRADEVCEN devices having wide-angles, as well as other probes and a typical airline visual attachment for flight simulators (Redifon at NASA, Ames Research Center). The horizontal resolution values are system performance observed at the display unit for most systems, but the only independent variable is the object to lens distance. The object in this case was the USAF high resolution test target. Examination of the curve can answer for a specific optical probe what scale should be used for the model to match average trainee and atmospheric visual acuity requirements. Dust(10) described how pilot opinion of the resolution on their visual simulator improved when the model scale was reduced from 1200:1 to 600:1, however, this was at the expense of reduced approach distances as he did not increase the size of his model.

The vertical resolution can be improved by use of the Scheimflug principle in the optical train (8,9), as shown by a comparison of a curve marked "Farrand Tilt Lens," with that for the other Farrand probe. If the object plane (terrain) contains all the items to be used as visual cues, this becomes an acceptable solution. However, when the objects normal to an inclined imaginary object plane, used to provide some improvement, must be in focus and loom across the vertical field of view, this method also suffers a reduction in resolution. At this point, a pinhole becomes an attractive solution. The pinhole has a flatter increase in subtended angle of resolution with reduction in range. It can give a wide field of view and is distortionless. Use of a low light level camera tube compensates for the small aperature restriction and the faceplate light level (15,17). You will note that each visual simulation combination has a different shape for the resolution vs distance curve, thus permitting optimization at different ranges depending on mission. If the same scale factor was applied to all the systems shown, the point light source system would be superior for target acquisition, low altitude visual navigation and other visual tasks at long ranges whereas the 46° Redifon or the 160° Willey/NTDC lens system would give good performance for approach and landing and the Dalto Pinhole for land vehicle driving where extreme close ranges are needed. But don't make your selection yet as we have only discussed one design parameter so far.

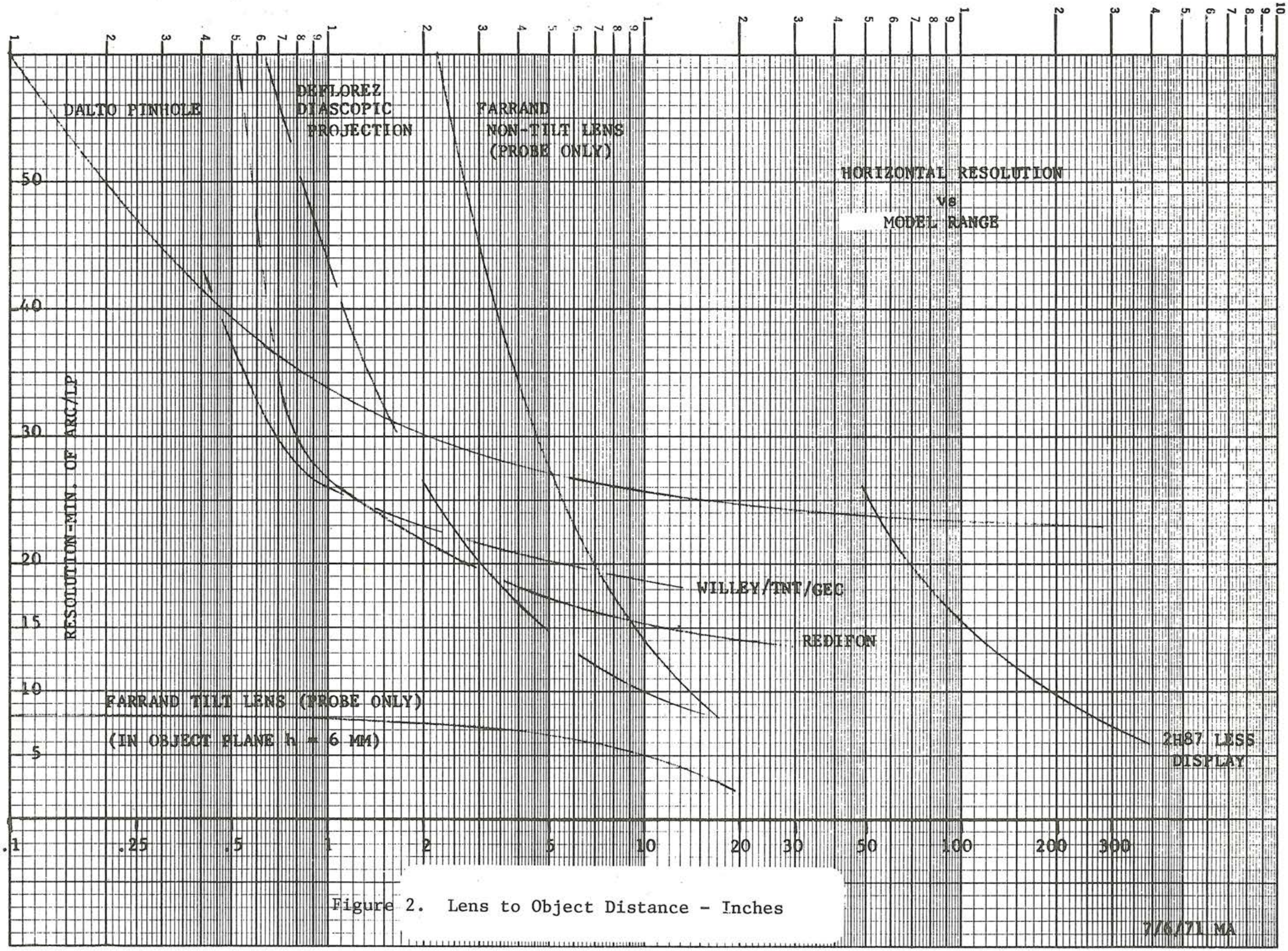

Figure 2. Lens to Object Distance - Inches

TABLE 1. IMAGE GENERATION

A, Optical Probe/TV Camera

Manufacturer	FOV, deg H V	No. of Channels	Distance Pupil to Model, mm	Aperature mm	f/No.	Camera Tube	Reference
Goodyear	210 60	3	5.0	-	6 (S)	-	NAS 8-20686
Willey	180 60	1	44.5	.91 x 1.19	5.6	1" Vidicon	16
GPL/NTDC	160 53	3	44.5	1.7 3.5	5.6 cent. 2.8 side	1" Vidicon	14,24
Farrand	140 Diag.	1	5.0	1.0	6.6 (S)	1" Vidicon	Comp. Brochure
Farrand	110 Diag.	1	6.3	1.0	5.0 (S)	1" Vidicon	Comp. Brochure
Dalto	100 84	1	45.7	.16	84.0	3" Isocon	17
Scanoptics	95 Diag.	1	12.7	1.3	8.0	1" Vidicon	8
Link AVST(1)	90 30	1	9.7	1.2	11-2/3(S)	1½"Vidicon	21
Goodyear	80 60	1	9.9	4	16	1" Vidicon	Dev. 2H87
Goodyear	80 Diag.	1	-	2.5	6(S)	1" Vidicon	18
Redifon	48 35	1	4.3	.93	18	3" Plumbicon	10, 13
			B. Diascopic Projection				
DeFlorez	220 90	1	5.0	7.9		-	11,12

(S) Scheimflug Correction
(1) Proposed Design

Let's look at the next factor mentioned—minimum working distance. This factor represents the pilot's eye when the aircraft is on the ground, the boat coxswain's eye above water level or the driver's eye above the ground. Table 1 lists the characteristics for a number of wide-angle optical probes including those in figure 2, such as field of view, working distance, aperature, f/no and the sensor or the light to electrical energy conversion unit. Working distances of 4 to 6mm for the entrance pupil are obtained by offset optical axes and inclusion of movable prisms and mirrors to provide angular degrees of freedom. The Willey lens is a straight optical axis design and would require rotation of the entire camera by means of a gimbal system to provide the angular degrees of freedom. The minimum working distance can also establish the model scale as it represents the minimum eye distance above terrain required. For example, for an eye height of 10', a field of view of 160^{o} and a minimum resolution of 8 min. at 3000', the proposed Link AVST system would require a scale of 312:1. For a scale range of 9.7' (116") and minimum resolution of 8 min., the only system meeting this requirement from figure 2 would be the point light source. However, if the same resolution was required at 60' (2.3" scale) then no system would satisfy. Examination of figure 2 shows that the point light source would just meet the 8 min. resolution at 16" scale range. The corresponding scale for 60' full scale would be 45:1.

A transparency size of 6' x 6' for the point light source would give a maneuver area of only 180' x 180'. The net result of this numerical exercise shows that there is still a need to compromise one or more of the stated requirements based on the current state-of-the-art.

The last design factor listed above was field of view. This is dictated by the mission requirements(4), however, compromises in the past were made such as accepting a 48° horizontal field of view for an aircraft approach and landing visual scene at a higher resolution at close range and a reasonable size terrain model. As seen from table 1, wide fields can be obtained with either multiple or single channels. The NAVTRADEVCEN destroyer docking visual display uses the GPL/NTDC system and necessitates a terrain model scale of 100:1 based mainly on the minimum working distance for the entrance pupil. When complexity and maintainability are also considered, a single channel TV system or the diascopic projection become prime candidates for larger than 140° horizontal field of view image generation elements. One additional system factor must be considered, that is, the mapping characteristics of both the pickup and projection lenses. To reduce the electronic circuit complexity in the TV camera, the pickup lens and the projection lens must have identical mapping characteristics and cancelling distortion characteristics. Farrand, Fairchild and Willey use the F-θ characteristics, where the height in the image plane h, is given by $h = F.\theta$ (F = Focal length and θ the semi-field angle). This gives more uniform illumination across the face of the camera tube than the F - tan θ mapping which results in the $\cos^4 \theta$ fall-off. In the Dalto pinhole camera, its extreme simplicity did create $\cos^4 \theta$ fall-off, and required an automatic gain control circuit in the TV camera to give fairly uniform relative illumination. Another solution is to add a relay lens after the probe objective to minimize distortion at the camera faceplate (image planes). As far as is known, only the Fairchild motion camera and projector lens set and the Willey wide-angle TV lenses are matched sets.

It seems that this discussion is leading to the other major component I want to cover, the display and viewing units.

DISPLAY AND VIEWING UNITS

As I define it, the display unit consists of the conversion element in the system. In CCTV, the electronic signals are converted to a visual scene by an electronic beam bombarding a phosphor or an oil film. The display unit may be viewed directly, or through an optical train or the image may be projected onto a screen. These additional items can be defined as the viewing unit. Table 2 lists a number of recent subsystems for comparison. In addition to the wide-angle and standard TV systems, a motion picture and a diascopic projection system are shown. The resolution and other characteristics are in some cases for the Display and Viewing Subsystem only and represent the contributions of the CRT, its electronics circuits, the optics and screen. Thus, resolution values shown here may be better than the system values shown in figure 2.

Altes and Chu(26) stated the following requirements for a wide-angle display:

"1. The observer should see an image which appears to be at optical infinity.

2. The field of view must be adequate to take care of head motion of a sitting person.

3. The brightness of the image must be five foot-lamberts or more.

4. The image should subtend an angle of 180° in the horizontal plane and 90° in the vertical plane."

The question of adequate resolution was not answered by Altes and Chu and they recommended experimentation to find the relation of resolution to field of view.

TABLE 2. DISPLAY/VIEWING SYSTEMS

A. CRT Type

Manufacturer	FOV (deg) H	FOV (deg) V	Type	Eye Relief (inches) or Throw Dist.	Exit Pupil (inches) H V	Subsystem Horizontal Resolution	Color	Brightness f-L	No. of Channels	Ref.
Goodyear	240	60	Refl. V.I.	60"	12 x 6	22.5 Min/lp	No	4.5	3	Dev. 2H87
Link AVST(1)	210	29	Refl. V.I.	∽ 35"	8 x 5.3	7'/lp	Yes	7	5	21
Willey/TNT	180	60	Refr. Proj.	10' Rad.	-	14.4'/lp	No	10	1	16
GPL	160	53	Refr. Proj.	10'Rad.	-	14'/lp @ (3)	No	1	3	25
GE (2)	144	36	Direct View	20"	-	7'/lp (3)	Yes	15	3	I-H Memo
Goodyear	120	45	Refl. V.I.	41"	12 x 8	6'/lp	No	15	2	20
Farrand	90	70	Refl. V.I.	30"	4	13.5'/lp	No	8-10	1	NTDC Head Set
Farrand	84 Diag.		Refl. V.I. Inline	29"	12 x 8	7'/lp (1)	No	3 (1)	1	23,33
Goodyear	50	41	Refl. V.I.	32"	12 x 8	6'/lp	No	6	1	19
Redifon	48	36	Refr. Proj.	10'	-	7'/lp (3)	Yes	6	1	13
NASA AMES #1	46	34.5	Refr. V.I.	29.5"	11.3" Dia.	13.5'/lp (3)	Yes	15	1	32
NASA AMES #2	40.6	30.4	Refr. V.I.	26.9"	12.91"Dia.	5.13'/lp (3)	Yes	20	1	13
B. Motion Picture										
Fairchild	160	60	Refr. Proj.	12½'R	-	3'/lp	Yes	26	1	6
C. Diascopic Projector										
DeFlorez	220	90	Direct	10' Rad	-	60-8'/lp (3)	Yes	.25	1	11,12

(1) Proposed
(2) Computer Generated Image
(3) Total System

Refr. = Refractive
Refl. = Reflective
V.I. = Virtual Image
Proj. = Projection

The factor of field of view is covered first. The first requirement in visual simulation is that objects subtend the same angle at the image generation end as they do at the display end. However, in CCTV, the total field of view at the input does not have to be identical to that at the viewing end. The Goodyear Device 2H87 and proposed Link AVST systems provide wide fields at the display by means of multiple channels. The Device 2H87 has included in the wide field of view picture a 80° field angle high detail scene (the carrier) which can be positioned in any channel. The Farrand 90° NAVTRADEVCEN Headset control, provided a 360° field by rotating the display/viewing unit in response to turning head movements. The Link AVST solution proposes electronic slewing of a 90° image across any of the five monitors. The objective in the three systems, was of course, to maximize the resolution along the line of sight. The Goodyear Device 2H87 assumed that the expected L.O.S. (Line of Sight) from the pilot would always be in the direction of the aircraft carrier. For the proposed Link AVST, the rationale has not been developed since the vehicles to be simulated here will not consider single "targets" to the exclusion of other visual cues. The Farrand solution was completely unprogramed in that the display field of view was always centered on the trainee whichever way he looked in azimuth, by head motion pick off.

The next factor covers the illusion of optical infinity. This stemmed from the requirements for aircraft approach and landing flight trainers. For the tank driver task objects 20' in front of the driver must be in focus and this is considerably less than "infinity." To date, no new experimentation has been performed to either verify or upset the assumption given in Altes and Chu and others in the late 1950's, that an image projected at 10' distance on a screen of sufficiently large field of view and with no connecting structures between the observer and the screen does not give distance cues. The only evaluations reported to date on infinity optics displays versus projected displays are those of Dust(10) and Chase(13). Based on pilots' opinions and performance, the collimated image of about 40-50° field of view, marked NASA AMES Number 2, was better than the projected image marked REDIFON because it was brighter and had more contrast, provided improvement in depth perception and minimized blinking. The depth perception was very strong near the ground such that everything stood out more realistically and could really be analyzed very similar to actual flight. However, the collimated optics actually produced an image plane 10.88' from the pilot's eye, whereas the projected picture had a 10' throw, thus, one may say that it was the means for forming the image rather than the "infinity" location of the image which gave the improvement.

Considering the highlight brightness requirement it would appear that all systems shown,except the GPL three channel,met the five foot-lamberts minimum, and about half achieved 10 foot-lamberts. An in-house evaluation, using the GPL/NTDC three channel yielded favorable comments despite the low light level and subjects were able to complete their tasks (ship docking) in approximately the same time as in the real-world. While the present goal of 10 foot-lamberts, based on equivalency with theater motion picture light levels still stands, values down to one foot-lamberts are usable. Planned experiments with the Diascopic Projection (Point Light Source) described by E. Swiatosz, at lower light levels and in color may finally set an experimental floor to this requirement, while experiments using the 160° Willey lens and Eidophor, described by E. Kashork, will cover the high brightness condition.

With regard to subsystem resolution and since the display CRT is larger than the pickup TV camera tube and the optics operate at a fixed distance— equal or better angular resolution is easier to obtain in the monochromatic mode. Dust(10) has pointed out a problem with the present shadow-mask color TV CRT's of the dot structure size limiting the resolution in a collimated lens virtual image system. It therefore appears that based on present components, wide-angle color displays will consist of multi-channel 60°-80° CRT's, motion pictures, or the diascopic projection. One final word on display/viewing systems. Besides the techniques listed, thought has been given to the use of lasers and rotating mirror systems to generate high resolution and wide-angle displays, though no complete system has been developed. (29)

DESIGN REQUIREMENTS STUDIES

Another way of checking on the course that wide-angle visual systems are taking is to look at the results of some design studies which are relatively unstructured. These studies generally ask for a description of a visual system, besides other components, to meet a broad spectrum of missions without dictating the solution. For example:

a. To provide visual cues to drivers/operators of an Army tank, an amphibious assault personnel carrier, a hydrofoil ship, and an air cushion vehicle. Link proposed, based on their analysis of the training requirements, a 3-D model and TV camera system with a multi-channel virtual image display. (21) This is identified as Link AVST in tables 1 and 2. In addition to the 3-D model, a 2-D model will be used to generate a picture of the waves, and this is inserted into the land imagery for the seagoing vehicles.

b. To provide visual cues for airplane pilot candidates training research, Link proposed four systems to cover all the flight phases. (30)

1. At station 1 on a T-37 flight simulator a Computer-Generated Image with 240°H x 165°V multiple window TV display for takeoff and landing, formation, airwork, and aerobatics flight.

2. At station 2 on a T-37 flight simulator a point light source image generation of sky and ground displayed on a wrap around screen similar to the F-151 Gunnery Trainer and the DMS for airwork and aerobatics.

3. At station 3 on a T-38 flight simulator a transparency or strip film image generation and wide-angle display or a 180° H x 60°V display for 3-D transparencies for navigation and low level flight.

4. At station 4 on a T-38 flight simulator, a 3-D model and TV camera pickup, and a wide-angle display or a computer-generated image and the wide-angle display for formation flying with another aircraft. If CGI, then takeoff and landing capabilities are added.

c. To provide visual cues in a very flexible system for conducting human factors experiments in the development of training device design across a broad spectrum of missions, the contractor proposed:

1. Stage I. A point light source projection using an orthophotographic transparency and a wrap around screen of 240°H x 165°V. The radius is 10' and available light level would be 1-2 foot-lamberts. The advantages are correct perspective and simplicity of construction and operation—no sophisticated electronic equipment.

2. Stage II. Computer-generated imagery with a full-color multi-channel display 100° x 130°. This would be by TV projection on a screen, or by use of inline reflective virtual image display units on a 15-foot radius.

Fifteen-hundred edges are required to provide three independent images on a background. Vertical resolution to be four arc minutes.

Lastly:

d. To provide visual cues for highway driving research using simulation techniques, UCLA, and General Electric Company proposed a computer-generated image and three channel display unit of $60^{\circ} \times 60^{\circ}$ flat screens 15' x 15' in a hexagon plan form.(31) The centers of the screen would be 13' from the subject's eye. The image brightness would be 20 foot-lamberts, using a rear projection screen, and a 3000 lumen Eidophor in color. The minimum resolution would be 3.95 min. of arc. Basic system would be sized for 10 independent coordinate systems. There would be a maximum of 1200 edges, 4 textured surfaces, and 500 point "light" sources in the scene portrayed during each image frame.

CONCLUSIONS

Five different techniques for wide-angle visual systems were described, and some data on four of the techniques was presented. Since none of these are universal or all encompassing as shown by the performance characteristics and the conceptual studies, all techniques must still be considered as active candidates for the near future depending on the visual and operator tasks to be performed and trained in. Where programed scenes are acceptable due to the nature of the operator's task, 160° motion pictures in color are tentatively acceptable. When using CCTV with physical image generation, the characteristics of resolution versus range, minimum working distance and field of view will determine the components. When using computer-generated imagery in CCTV, the number of edges and the number of independent images will govern the size of the digital computer. As far as CCTV displays are concerned, multiple channel units will be required for color display. From a reduced maintenance and simplicity of operation viewpoint, diascopic projection for color and the single channel wide-angle TV using a B&W Eidophor lead the other components. While most of the conclusions given are based on the facts presented, the others are derived from introspections, which anyone knowledgeable in the art can make.

RECOMMENDATIONS

What are my recommendations? In view of the number of prototype components and subsystems developed to date, it is recommended that further experimentation be in the area of applications to specific training problems to obtain quantitative measures for sorting out the better solutions. It should be similar to the work of Dust and Chase on the narrow field,of view aircraft approach and landing visual simulators and to a lesser extent on the GPL/NTDC system application to ship docking. As I pointed out before, Messrs Kashork and Swiatosz, whose papers are in these proceedings, will explore the Single Channel Wide-Angle TV and the Diascopic projection techniques within the next year. In addition to these, the pinhole TV will be applied to a specific training problem—tank driving. It is possible that next year's conference will have reports on the measures of acceptance of these new systems.

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SESSION III

Wednesday, 16 February 1972

Chairman: Mr. Edward H. Grace, Jr.
Head, Field Engineering and Support Department
Naval Training Device Center

CONFIGURATION MANAGEMENT AN ASSET TO TRAINING DEVICE PRODUCTION AND NAVY SUPPORT

MR. J. J. REGAN
Modification and Maintenance Engineering Department
Naval Training Device Center

INTRODUCTION

CONFIGURATION MANAGEMENT! The terminology in itself is enough to foster apprehension when found to be specified as a proposal requirement. Just what is this requirement that the Office of the Secretary of Defense has labeled: "A COMPLEX, MASSIVE and DETAILED UNDERTAKING"? Is it a revolutionary breakthough in the field of management?

The Navy has defined configuration management as:

> "A DISCIPLINE APPLYING TECHNICAL AND ADMINISTRATIVE DIRECTION AND SURVEILLANCE TO"
>
> 1. identify and document the physical characteristics of a configuration item
> 2. control changes to those characteristics, and
> 3. record and report change processing and implementation status.

Configuration Management new?! Eli Whitney in the early 1800s introduced techniques for the production of firearms with interchangeable parts. The technique! <u>Identify</u> in detail each part and hold manufacture to that identity. Of course, those were the days when life and weaponry were simpler.

1. No written contracts
2. Communications uncomplicated
3. Costs nearly constant, regardless of change
4. Very few acceptable design variations
5. Minimum documentation
6. Only a few people involved.

Both Government and Industry have practiced and improved the techniques introduced by Mr. Whitney and in a sense we might say, Configuration Management! Humbug! We've had it for years.

Let us examine today as compared to Mr. Whitney's time.

1. Written Contracts
2. Complex communication
3. Costs constantly rising

4. Limitless acceptable design variations

5. Monumental redundant documentation

6. Hundreds of people involved in equipment development.

With such problems, enormities and complexities, the task of management is extensive.

Configuration Management is an attempt to:

1. Simplify the task by reducing the elements involved to their simplest terms;

2. Equip each problem with a convenient handle and display the whole situation so that management can comprehend, analyze, and control it.

The Configuration Management concepts of today are basically what Eli Whitney introduced over a century ago.

1. Configuration Identification - it defines the products, its components and their interfaces

2. Configuration Control - restricts idle change

3. Configuration Status Accounting - provides records of changes that are authorized.

But! it does so in a MODERN, <u>DISCIPLINED</u> manner.

CONFIGURATION MANAGEMENT THROUGHOUT DOD

Credit for reviving interest in and for naming Configuration Management must go to the Air Force. The Air Force developed the first documented configuration management standard, AFSCM 375-1.

At the DOD Technical Documentation Conference in May of 1964, the Army and Navy expressed interest in the Air Force effort, and following the conference, The Office of the Secretary of Defense issued direction for development of uniform configuration management throughout DOD.

Subsequent to the direction of DOD, the following events took place:

1. June 1965: U. S. Army Material Command issued AMCR 11-26, Subject: Configuration Management

2. September 1965: U. S. Navy Material Command issued NAVMATINST 4130.1, Subject: Configuration Management. The basic policy cited was stated as follows:

"Configuration Management shall be applied in accordance with the provisions of this manual to all relevant Navy material items or configuration items (CI's) being newly procured for use by the Department of Defense (DOD). It will also be applied to those Navy material items already in operational use; on these items, case by case decisions shall be made, based on the availability of resources and the proven need for configuration management improvement. IN ANY CASE, ITS APPLICATION SHALL BE CAREFULLY TAILORED TO BE CONSISTENT WITH THE QUANTITY, SIZE, SCOPE, STAGE OF LIFE CYCLE, NATURE, AND COMPLEXITY OF THE ITEM INVOLVED."

DOD Standards subsequently issued, adding to those, which exist and apply to Configuration Management are:

MIL STD 480	Configuration Control - Engineering Changes, Deviations and Waivers - 30 October 1968.
MIL STD 481	Configuration Control - Engineering Changes, Deviations and Waivers (Short Form) - 30 October 1968.
MIL STD 482	Configuration Status Accounting Data, Elements and Related Features - 19 September 1968.
MIL STD 490	Specification Practices - 30 October 1968.

CONFIGURATION MANAGEMENT DURING DEVELOPMENT

The development of a major training device, as like any such equipment, is a complex web of processes, decisions, and interfaces between all individuals involved. The numbers of discrete elements of development form a myriad of virtually thousands of decisions and a proportionate amount of information flow. The management task of integrating all these elements and their efficient scheduling is a mastery of planning and organization.

Let us mentally picture this planning and organization as a well-oiled machine humming with development, fueled by $, and with a specified time limit of operation. Let us inject the element which can and does occur: "CHANGES" Change occurs in varied scope and at all points of a development interface network.

Now let us picture our well-oiled machine with gross numbers of changes occurring simultaneously and steps being retraced or development processes being recycled to that point where the last decision or interface involved is effected. This is analogous to a feedback function in an amplifier which, if not properly designed or controlled, can cause serious oscillation or instability.

Let us look at some examples of change.

Purchasing: The part called for cannot be delivered; request alternate.

Contracts: The customer wants two more and includes the duflop capability.

Product Engineering: Packaging problem; alternate design required.

Design: Hey, hold that release. We found a better way!

Manufacturing: The machinery can't produce it that way. Is this alternate O.K.?

Supply: Is anybody going to use up these 5,000 gidgets left over from the last job?

Test: Oh! Oh! It doesn't work!!

The effort, cost, and time involved to remanufacture, reorder, redesign, retest, or re (whatever) can be avoided in many cases through the basic configuration management elements of identification, control, and accountability.

CONFIGURATION MANAGEMENT AND NAVY SUPPORT

Intertwined with the complex development of a training device and totally dependent upon the flow of data reflecting the hardware is the development of SUPPORT for the long term use of the equipment. "CHANGE" Decisions made during the development phase regarding or affecting:

Maintainability
Reliability
Support data
Training
Facilities
Personnel
Parts
Support Equipment

have a far reaching effect into the life-cycle costs and availability of a training device.

It is because of this far reaching support impact, and its lack of immediate visibility, that an unconscious apathy tends to exist and, which causes support to be left out of many change decisions.

The major problems faced are;

1. Inaccuracy or lack of support data

2. Nonavailability of parts

3. Stocking, cataloging and managing parts made obsolete by change.

Once in operational use, the majority of these problems lose their visibility, and those that are identified require individual correction through a process which further compounds the problems of high cost and loss of availability. Configuration Management provides the discipline needed to assure that support receives its due consideration with every change decision. Navy devices, regardless of how sophisticated or expertly designed are not effective unless dependably available for use.

CONFIGURATION MANAGEMENT - WILL WORK!

Configuration Management will work — if it is understood, accepted and practiced consistently and habitually by both Government and industry personnel at all skill levels.

Configuration Management will work if there is an insistence on optimum uniform practices regardless of superficial argument of the advantages of shortcuts and innovations.

Configuration Management will work if:

WE DO NOT

1. Underestimate the task of configuration management.

WE DO

2. Establish policies, procedures, and documentation adequate to the identification, control and status determination of material items.

WE DO

3. Have management overview of the complete in-house product management function and documentation flow within engineering groups and between engineering and other functional areas.

WE DO NOT

4. Permit the existence of self governing design groups, each having independent design release authority.

WE DO

5. Have adequate design release and drawing control practices for integrated system design.

WE DO

6. Employ "packaged" configuration control with multiple engineering release capability.

WE DO

7. Establish detailed criteria for design change levels at which system analysis and review are mandatory.

WE DO NOT

8. Allow engineering group by-pass of formal change procedures as a result of lax discipline and control of drawings.

WE DO

9. Establish central configuration control with representation from all internal action organizations.

WE DO

10. Provide adequate documentation of changes during the manufacturing phase.

WE DO

11. Designate an individual responsible for Configuration Management.

CONTRACTUAL PROVISIONS

NAVMAT INSTRUCTION 4130.1 provides direction that appropriate provisions for configuration management shall be included in all contracts for the development, production, modification, and maintenance of Navy material items.

These provisions cover the contractor's responsibility for:

1. Development of a Configuration Management Plan that describes the methods and procedures for configuration identification control and status accounting to be used during the contract.
2. Maintaining records of any proposed changes to establish base lines.
3. Maintaining that part of the assigned technical data bank that is required for configuration identification and accounting.
4. Ensuring that all procedures and controls necessary to accomplish configuration management are implemented by his sub-contractors.
5. Change proposal initiation.
6. The preparation of equipment/component configuration listings is considered most important to configuration identification. Such documentation to be subject to appropriate contractor management and control to ensure its validity and suitability.
7. Numbering specification-type documents, engineering drawings and other related data composing configuration identification in accordance with appropriate Military Standards or other requirements documents.
8. Preparation of configuration status accounting records. Such status accounting to be subject to appropriate contractor management and control to ensure its validity and suitability.
9. The conduct of configuration audits.

SUMMARY

1. Configuration Management is not new, but merely a simplification, consolidation and modernization of existing management systems.
2. We live in a day and age of modern sophisticated equipment and our management techniques must parallel that sophistication.
3. Let us together understand, accept, and practice this modern management technique to the end of producing and supporting training equipment in the most effective manner.

THE UNIVERSAL DISPLAY PANEL

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INTRODUCTION

The purpose of this paper is to present the latest technology in the development of backlighted animated display panels. By using new industrial components, the design of animated display panels has produced a new breed of programmable training devices. The new Universal Display Panel provides a programmed animated panel with both flexibility and simplicity of operation, which has not been obtained before. The new Universal Panel actually increases training effectiveness, and provides student participation, at reduced training costs.

The Universal Display Panel is a backlighted vertical panel that can light up any section of an attached illustration (see figure 1). The attached illustration is made to appear to operate by an internal programmer that controls the lights behind the illustration. Almost any illustration can be presented on the face of the panel, such as, electrical, electronic, hydraulic, system block diagrams, and Pert charts. The internal programmer is removable and changeable (see figures 3 and 4). The programmer can be controlled from the device control panel, remote control, from the face of the illustration and from a cassette recorder.

A unique feature of the Universal Panel, is that the training illustration and the device operation program can be developed by the using activity, with minimum effort and cost. Another unique feature, is that the training illustration and device operational program can be changed in less than five minutes. As this device is a preprogrammed operating device, a cassette recorder can be used to control the Universal panel and at the same time provide complete lecture material.

The Universal Panel was conceived and designed at the Naval Training Device Center for the Bureau of Naval Personnel. The first Universal Display Panel is being used by the U.S. Mine Warfare School in Charleston South Carolina. The Mine School is presently using three overlay systems with the Universal Panel. Fifteen additional overlay systems will be delivered to the Mine school in September 1971.

PROBLEMS WITH THE NON-UNIVERSAL DISPLAY PANELS

A typical non-universal backlighted display panel is custom built. The illustration is painted on the permanently attached translucent plastic sheet. The background is painted opaque, and the illustration a transparent color. Behind each section of the illustration, such as, logic block or line segment, a light cell is constructed. Each light cell will have one or more lamps. Near each section of the illustration to be controlled is usually a control switch. This illustrates the specialized construction for each of these non-universal display panels.

The illustration usually represents operation equipment in the form of an electrical, electronic or hydraulic diagram. As the operational equipment is modified, so is the training device illustration in order to keep the training current.

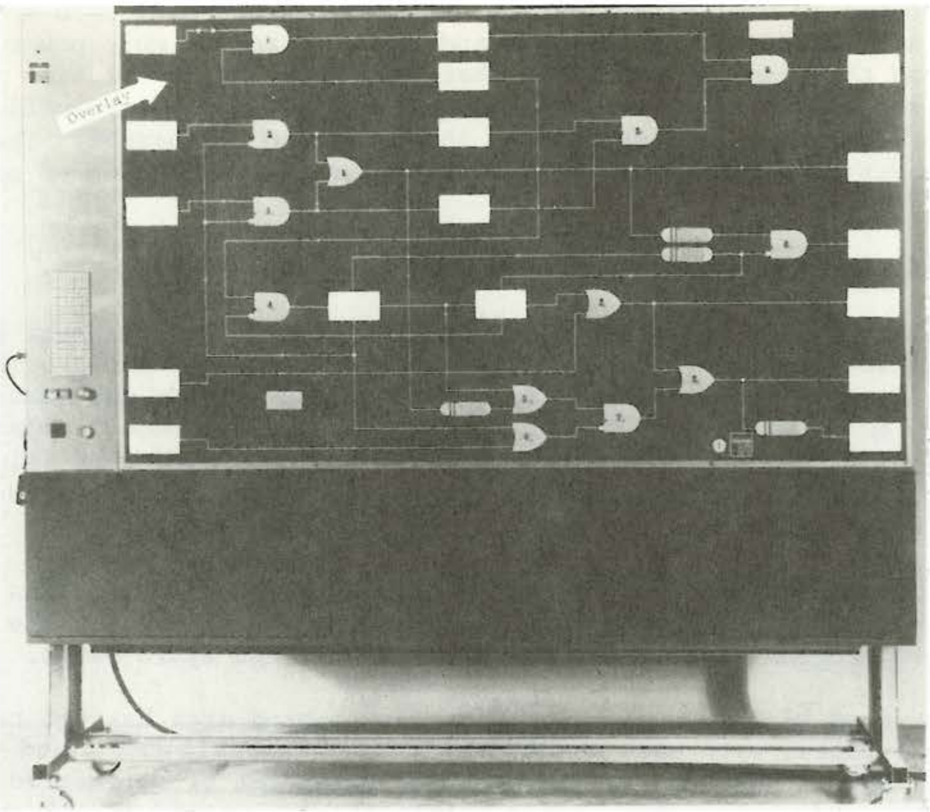

Figure 1. Universal Display Panel with Overlay

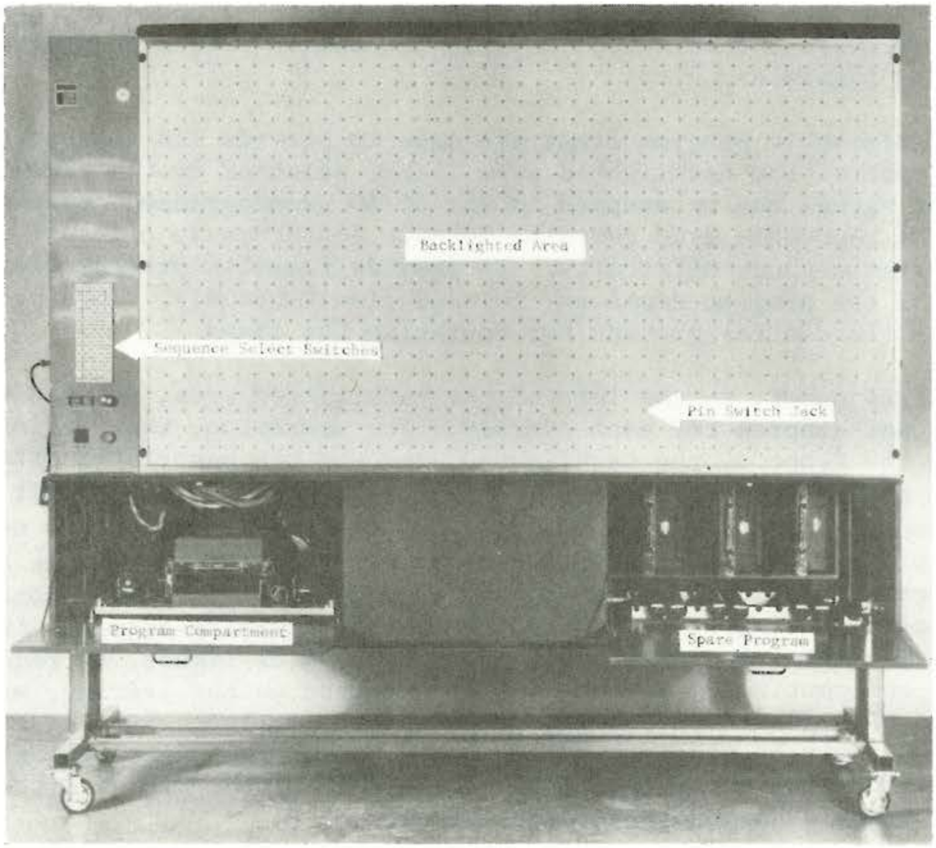

Figure 2. Universal Panel without Overlay

The problems in modifying a custom built device are many. To modify, new lamp cells are added, wiring of lamps and switches added, more power may be required, and the fixed illustration changed. The usual conclusion is that because of the custom fabrication technique, the device is not sufficiently flexible to permit easy and economical incorporation of changes. The end result is a device with a short usuage time, and the generation of another device.

DISCUSSION OF THE UNIVERSAL DISPLAY PANEL

The primary design objective was to provide the Bureau of Naval Personnel with a universal backlighted animated display panel that would provide flexibility for changing the displayed illustration, and provide the instructor and student with an automatic programmed presentation. A secondary objective was simplicity in design, operation, programming, and development of illustrated overlays. Simplicity in design, with reliable hardware, provides the user with a device he can understand and will use as intended.

The Universal Display Panel is adjustable in height and provides storage of three overlays. Compartments are provided for the storage of the program system, spare program components, the power supply and spare parts.

The four foot high by seven foot wide backlighted area has 966 two-inch square compartments, with each containing a lamp (see figures 2 and 4). The overlay can contain any type of illustration which can be delineated on a 23 by 42, 2-inch grid scale. The system capability is limited to 118 control grounds and simultaneous operation of 500 lamps, which has proven quite adequate. The programming of these lamps, as required for each overlay, is accomplished by use of a removable patchboard and two removable program drums (see figure 3). The patchboard selects the lamps to be operated, and the program drums activate the selected lamps in accordance with a preprogrammed sequence (see figure 4).

The two removable program drums are used to provide 118 separate switching grounds to control the backlighted area lamps, selected by the patchboard. The program drum system can be stepped to any of 60 preprogrammed training sequences. The removable drum contains movable actuators in order to change the desired program without difficulty. To provide flexible program capability, either one or two program drums may be used simultaneously. This provides either 59 or 118 control grounds for operating the lamps.

The control panel, to the left of the backlighted area, is used to control the operational program for each overlay. For operation, the overlay is attached to the front of the backlighted area and the associated patchboard and program drums are plugged into their receivers in the lower left compartment. By depressing any of the 60 sequence select switches on the control panel, the program drum will step to the selected training sequence and operate the programmed lamps to light up the overlay sections. The program system may also be single stepped to the desired training sequence from the control panel. The illumination of one or a group of lights, as required for progression and continuity of information depicted on the overlay, will then be indicated through the transparent area of the overlay. Flowing lights and blinking lights can be programmed for the overlay. The instructor also has the option to control the programming sequence remotely, from a distance up to 25 feet, using a hand held pendent switch.

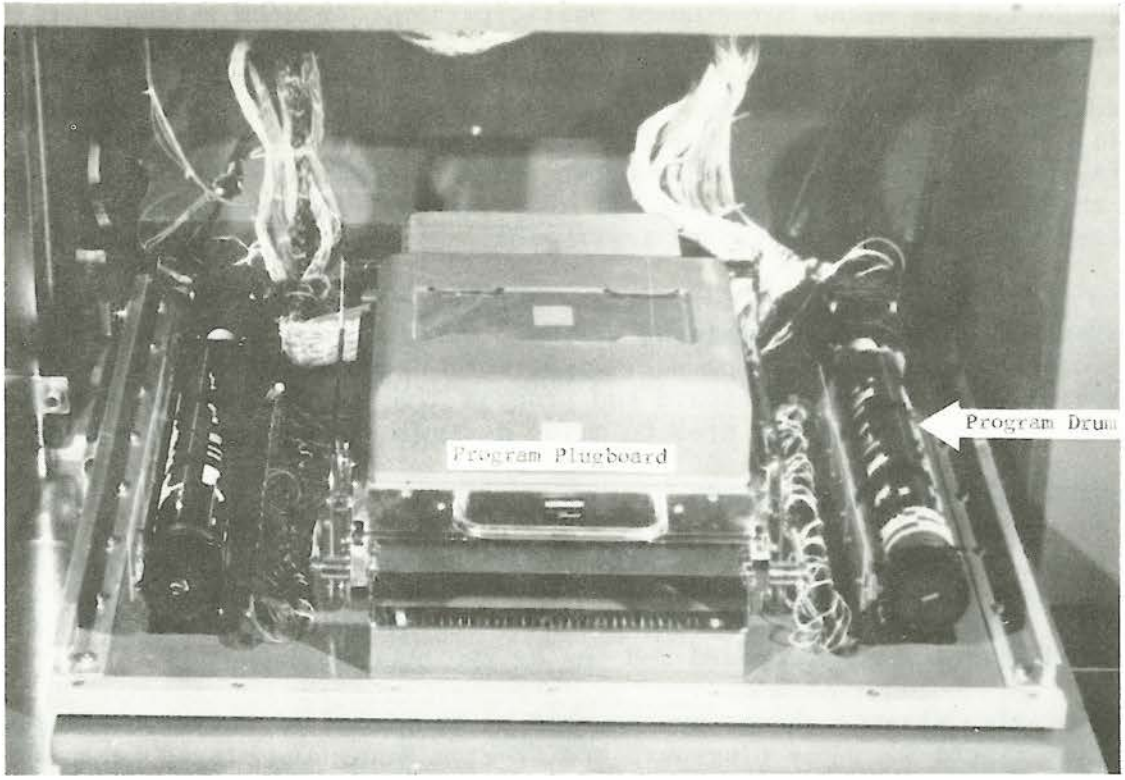

Figure 3. Program Plugboard and Program Drum

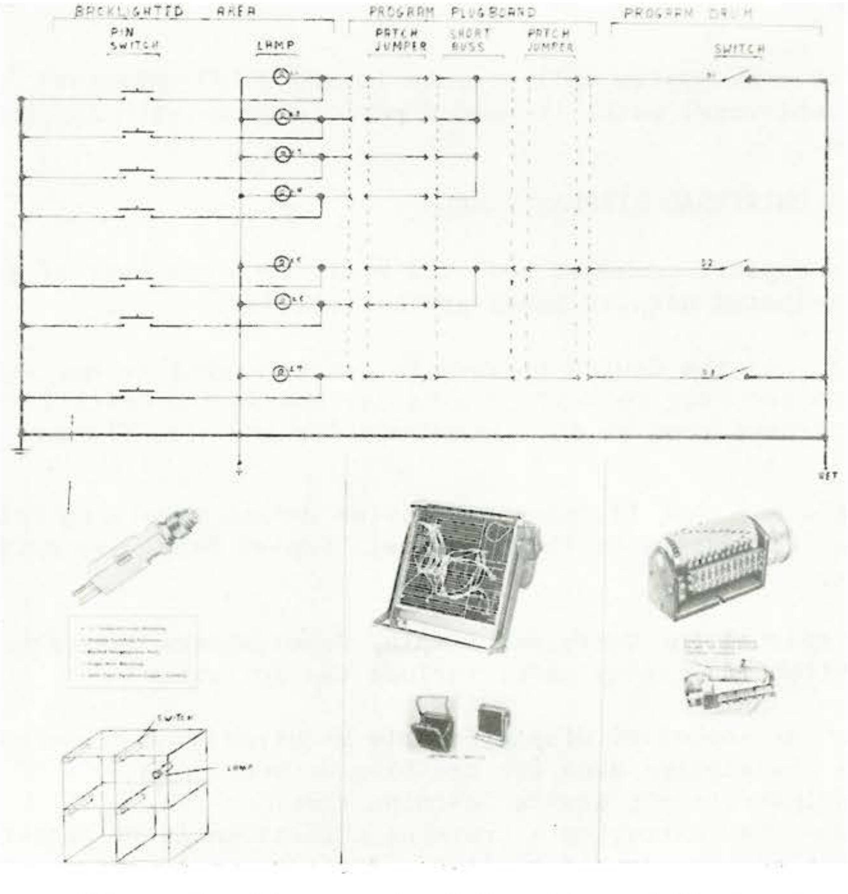

Figure 4. Programming Schematic and Hardware

The device has means for student participation. An open circuit two pole jack is placed in each window of the backlighted area, which will coincide, with a hole in the information area of the overlay (see figure 2). By placing an actuator pin through this hole into the two pole jack, the backlighted area will light (see figure 4). After the operation of the illustrated circuit has been taught, the instructor can have the student repeat the same operation by using the pin control from the face of the overlay. This method provides the important student feedback to the instructor.

The device has means for testing the operation circuits associated with each overlay prior to each training period. By activating sequence number 60 in the control panel, all lamps will light for any given illustration. In addition, a maintenance patchboard and program drum is used to activate all the lamps in the backlighted area to allow periodic testing of all circuits.

DISCUSSION OF THE OVERLAY SYSTEM

The overlay system, Device 3C128 series, consists of a four foot by seven foot transparent or translucent plastic sheet that is 1/8" thick. The illustration is transparent with the background being opaque. Each overlay has associated with it one plugboard and one or two program drums.

The overlay plastic sheets are mounted on the front of Universal Display Panel (See figure 1). The plugboard and program drums are placed in their respective receivers under the backlighted areas of the display panel (see figure 3). The holes, that are located at each backlighted section, allow a shorting pin to penetrate the overlay and mate with the required jack in the Universal Panel.

Any 3C128 overlay system will operate in any 3C127 Universal Display Panel. Thus, only one universal panel is needed per classroom with any number of overlay systems.

ADVANTAGES OF A UNIVERSAL DISPLAY PANEL

Some of the typical comments you will hear, from the user of a typical non-universal animated display panel are as follows:

a. "We don't use the device because it isn't current to our training."
b. "It takes too long to learn how to use the device effectively."
c. "We don't have room in our classrooms for any more display panels."

It becomes clear that training activities desire something better than they now have. The advent of the Universal Display Panel has solved many of these problems.

The advantages of the Universal Display Panel system over the typical non-universal backlighted display panel include the following:

a. Reduce the number of display panels required at a training activity.
b. Reduce the storage area for training devices.
c. Reduce instructor's device learning time.
d. Increase the instructor's training effectiveness by better understanding the device and by faster device operation.

e. Provide student feedback to instructor.
f. Reduce modification cost by permitting the school to modify illustration or make new illustrations and programs.
g. Reduce procurement time and costs per device, illustration and associated program equipment, due to commonality of design.

Specialized Universal Panels have been developed with almost all the advantages of the Universal Panel. For example, a Universal Panel with the addition of the actual equipment control panel. In this case, the backlighted panel will function from either the actual equipment control panel, or from the universal control panel.

CONCLUSION

The use of modern hardware in a unique manner has provided a training device, that can be used in many classrooms, for teaching a wide variety of technical subjects. Progress has been made in reducing training device obsolescence, thus reducing the overall training cost. Further improvements in cost reduction and improved devices are in the system now and will be seen in the classroom within a year.

REAL-TIME PROJECTED DISPLAYS

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INTRODUCTION

There has long been a need for a real-time dynamic projected display for large screen applications involving group viewing. The majority of the present systems utilize a form of slide projection or an oil film light valve. Slide projection makes use of silver film, Kalvar film, or a coated glass slide. These systems provide the brightness required and are near real-time. The film systems suffer from the problems associated with chemical development, film transport, and consumable costs if the system is frequently updated for real-time operation. Coated glass slides are utilized in a system where the image is scribed onto the slide in the projection gate. This provides the capability for continuously updating the current position on a given frame. A new frame must be generated when the viewer wishes to change the display content, for relocation of target tags, and when the historical data grows to the magnitude which tends to confuse rather than aid the viewing audience. Several modulated oil film light valve systems have been developed and are in use. Because of the nature of the modulation mechanism, it is necessary that these systems be operated in a scanned mode, thus limiting their application to those where scan or television type data is readily available, or can be made readily available. Most of the systems operate at a 525 line television standard, although a few of the older systems have been modified to operate at a 945 line standard. The resolution overall in either case falls in the 400-600 line range. The newer systems have the advantage of a considerably simplified tube not requiring continuous vacuum pumping.

The search for a technique has continued with considerable money being spent, both by government and private industry on the development of techniques which will overcome the shortcomings of the existing systems. Direct projection from a cathode ray tube was abandoned a number of years ago because of inadequate brightness and resolution. However, recent developments in this field have enabled General Dynamics to produce a real time projector which exceeds the capabilities of other systems and fills the needs of a large segment of the industry.

DEVELOPMENT

Late in 1969, General Dynamics undertook the development of a real-time projected display, based upon developments in the area of high brightness CRT's. Prior to this time, CRT's with adequate brightness and resolution were not available for comprehensive data projection. This projector utilizes a very high brightness, high resolution, 5" CRT mounted in a Schmidt optical system.

As a result of this development, equipment was produced and delivered to the Navy in late 1970. Figure 1 is a photograph of that projector. It has been in use in an ASW Tactical Analysis Center, where it presents an 8-foot square image on a rear projection screen. Figure 2 shows the optical system with the covers open. You will note that this is a classical Schmidt optical system. The image on the face of the tube is collected by the spherical mirror and directed towards the screen. A short distance from the mirror, an aspheric corrector plate corrects abberations in the system, and assists in imaging the data onto the screen. The CRT is specifically designed for projection in this type of an optical system. The radius of curvature of the faceplate is carefully chosen as it is a part of the optical system. General Dynamics choose the reflective optical system over a refractive system because of its simplicity, lower cost, larger aperture, and fewer elements. Refractive optical systems are available for projecting data from 5" tubes. These, however, require 9 optical elements with their associated air glass interfaces and precision mounting. These refractive lenses are approximately ½ of the optical speed of the Schmidt system and provide the same resolution.

SYSTEM IMPROVEMENTS

Late in 1970, advances in the state-of-the-CRT art produced an even higher resolution, higher brightness CRT, which we are now using in our projection systems. This CRT, also specifically designed for a reflective optical system, incorporates a ground and polished faceplate, and produces a very high resolution image (spot size .0035 inches) at a brightness level of 20,000 foot-lamberts when operated at 40,000 volts. This tube provides a significant improvement in the brightness and resolution available from the real-time projector.

Figure 1. Real-Time Projector

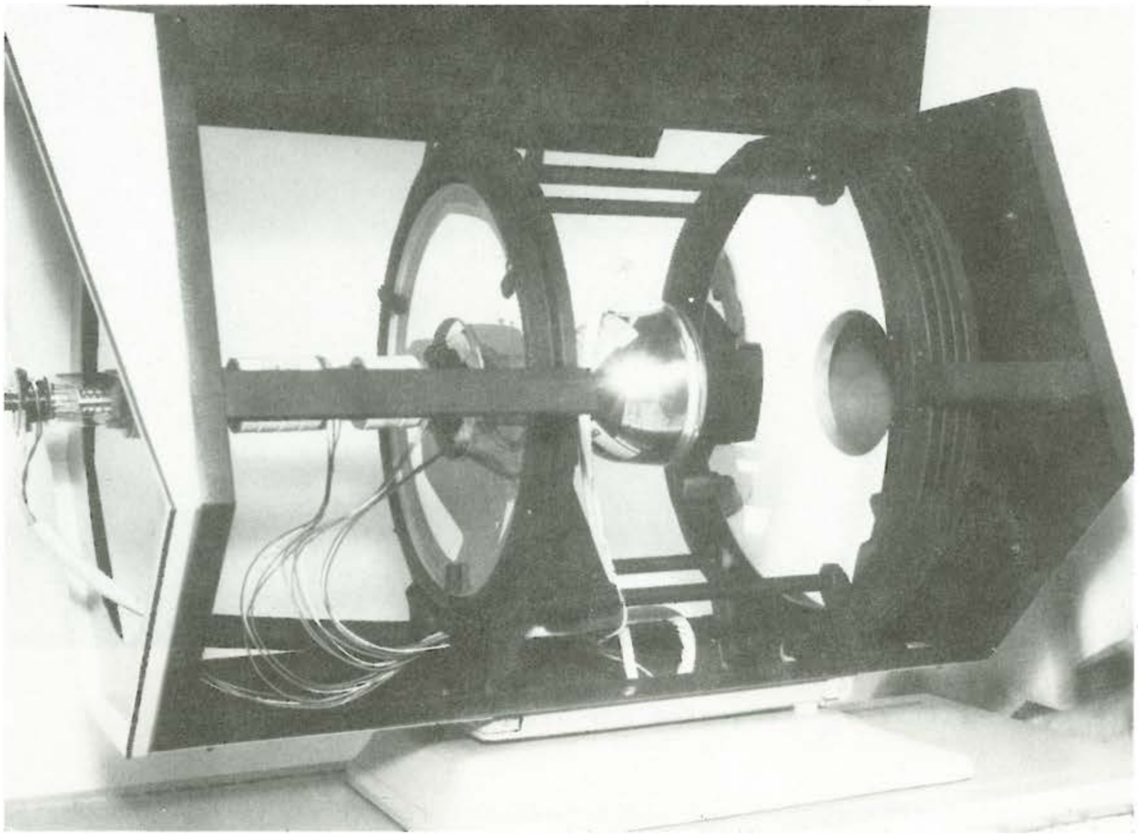

Figure 2. Real-Time Projector Optical System

Figure 3 is a photograph of a 5 x 5-foot air traffic control display on a rear projected screen utilizing the high resolution tube. The entire display is computer-generated, including the background data (range rings, fixes, holding patterns, approach paths, warning areas, obstacles, etc.) This particular display was programmed for two character sizes and two brightness levels. The number of character sizes and brightness levels used are not limited to two, but rather are defined by the system requirements. It is desirable to limit the number of character sizes and brightness levels to four or five each in order that the significance of this coding can be readily interpreted by all viewers.

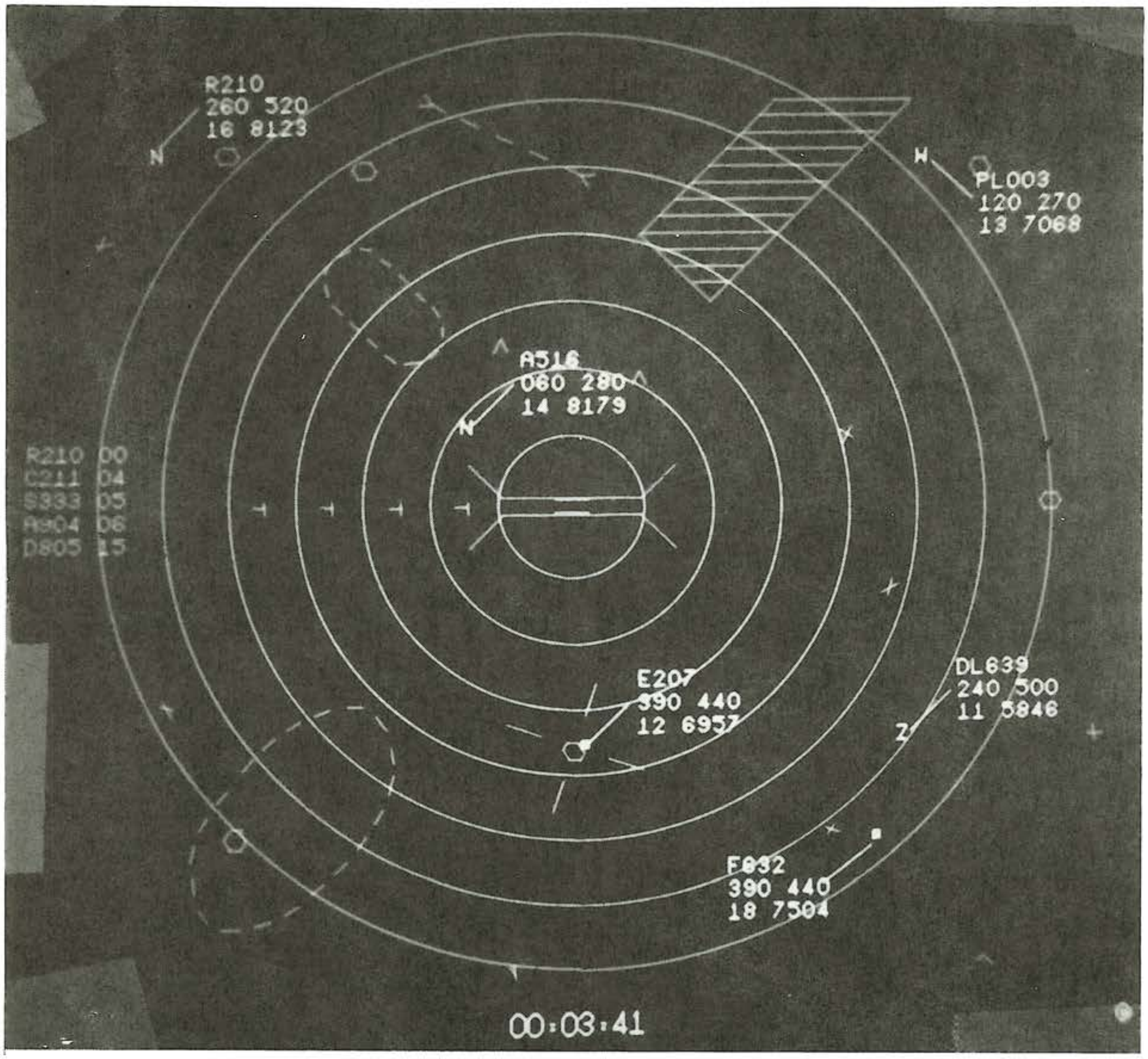

Figure 3. Projected Air Traffic Control Display

The target (aircraft) symbol and its associated tag shown in the photograph are typical of those used by the FAA in the Atlanta Center. It is obvious that any target symbology or format structure can be utilized. You will notice the clock at the bottom of the frame. This is a real-time clock which runs continuously. A specific symbol is used to identify the aircraft. These are "N" for northern arrival, "W" for a northern departure, and "Z" for southern departure. A box is used to indicate an aircraft transiting the area neither arriving nor departing from Atlanta. The airline and its flight number are on the first line of the format. The second line contains the altitude in hundreds of feet and the ground speed in knots. The third line is the computer track number and the aircraft's beacon code. Obviously, the formats could contain anything that is useful to the operators. These features could also be suppressed through operator keyboard actions, thus clearing the display when the data is not needed.

The system is a very flexible one and provides the capability to off-center to any given point. In addition to off-centering, there are expansion capabilities. Together these permit the operator to off-center to any point, and expand to any scale. You will note that the background features such as the runways, the extensions, warning area, are all contained in the dynamic data projected from the CRT. This background can be suppressed and the same information presented by projection of background slides. By reducing the amount of static data handled by the dynamic system, additional capability is provided for dynamic data. The overlay of static data by means of projected background slides is readily accomplished. Registration between the slide and the dynamic data is good. There are many slide projectors which provide a large background slide capacity. The standard Carousel has a capacity of 80 slides. Other units built for industrial purposes can extend this number to several hundred with a unit custom designed for a large program having a capacity of 1,000 slides. Background provided by means of slides can be in a contrasting color or in full-color, depending upon the requirements.

In addition to the improvement in the system resulting from advances in the tube art, advances have also been made in the optical system. The optical system shown in figure 2 was developed for television projection, and as such, does not have the edge resolution which is necessary for data presentation. These optics have a resolution of approximately 800 lines in the center and 350 lines at the edge. While this is adequate for entertainment material, it is inadequate for full-screen data presentation. For this reason, General Dynamics has developed an improved optical system. This optical system provides a minimum of 1500 line resolution at 60% modulation over the entire viewing area — a significant improvement. This development is complete and these optics are available for delivery in current systems. An improved set of driving electronics has also been developed. This set of electronics contains approximately 1/3 of the modules contained in the earlier version, further increasing the unit's reliability and decreasing the cost.

EQUIPMENT DESCRIPTION

Figure 4 is a block diagram of the equipment. The timing and control logic sorts the input data, and routes it to the appropriate points. Although, the electronic circuitry is straight-forward and is typical of that used in direct view CRT displays, certain portions deserve additional comment. The character generator, a proprietary item, is a 22-stroke character generator operating at a stroke rate of 8 MHz. This permits the typical alphanumeric character (10 strokes) to be generated in 1.4 microseconds. Separate deflection yokes are used for main positioning and for character generation. This permits the system to generate characters at this high rate. Vectors and ellipses are generated through the main deflection system. A full-screen vector is written in 40 microseconds. The distortion correction circuit is utilized to eliminate a small amount of pin cushion/barrel distortion which exists in the system when precision registration is desired. The protection circuitry controls the application of high voltage and unblank signals to the tube, thus preventing tube operation unless the proper deflection and power supply voltages are available. This safety feature prevents inadvertent burning of the phosphor.

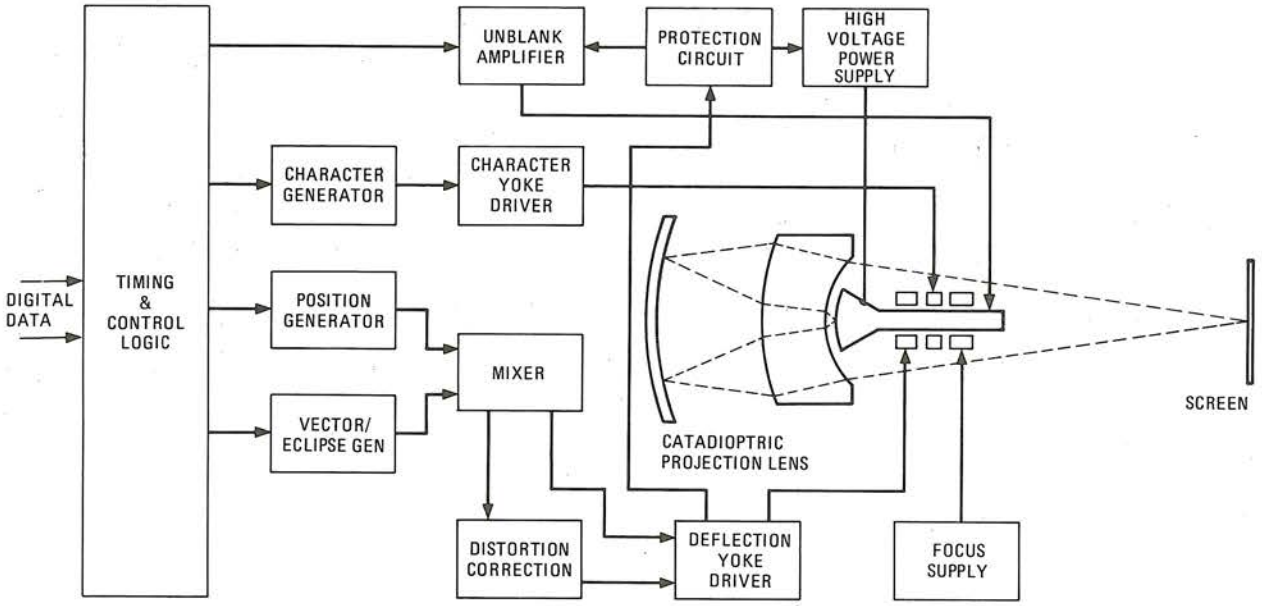

Figure 4. Real-Time Projector Block Diagram

You will note that the catadioptric projection lens is similar to the lens shown in figure 2 with certain important differences. A spherical lens element, placed between the tube face, and the mirror replaces the aspheric corrector. This improves the resolution while at the same time because of its location, does not captivate the tube within the optical system. The tube may be removed for maintenance purposes without optical system disassembly. Because the tube operates at 40 kilovolts, precautions are taken to prevent the soft x-rays generated by the beam impact on the phosphor from leaving the enclosure. Measurements confirm that the radiation external to the housing is less than 0.5 milliroentgens per hour. This level has been established by the Federal Government as a safe level for home television receivers.

While we have shown a computer-driven display in the block diagram, the projection system, since it is based upon a CRT, is capable of displaying and being driven from any of the information sources typically used in driving CRT displays. The unit can be readily configured to operate as a high resolution TV projector. It can also operate in a multi-purpose mode in which digital presentation is time-shared with analog signals such as television, scan converted radar, etc. For monochromatic applications, we have selected a green phosphor because of the sensitivity of the human eye to this color. A multi-color display can easily be generated. The simplest method to achieve this is through the use of multiple projectors with different color phosphor on the different projectors. A system is under development,which utilizes two projectors, one red and one green, displaying on a common screen. Friendly forces would be depicted in green with the hostile forces in red. Penetration phosphor techniques currently under development may produce the capability for multi-color display from a single tube. There are still some hurdles to be overcome in this program before it is a practical system.

The applications of the real-time display are limited only by the imagination of the systems designer. Applications include military command and control systems, tactical data systems, air traffic control, simulation, training, and management information systems. This system provides the highest resolution, real-time projection of display material available today.

The performance features of the real-time projector are summarized below:

Display Size	5' by 5' typical (2' x 2' to 8' x 8' available)
Projection Method	Front or Rear
Throw Distance	10 Feet
Screen Gain	1.5 nominal
Magnification Ratio	20X
Symbol Height	1"
Line Weight	.07"
CRT Diameter	5 3/8"
CRT Phosphor	PT-411 (green)
Accelerating Voltage	40KV
Refresh Rate	60 Hertz
Display Brightness	15 Foot-lamberts
Symbol Generation Time	1.4 microseconds (for average 10-stroke char.)
Vector Writing Time	40 microseconds full screen (proportional to length)
Deflection Settling Time Major Step	10 microseconds
Deflection Settling Time Minor Step	4 microseconds
Optical System	Reflective with f/0.7 aperture 1500 lines resolution with 60% modulation limiting resolution - 3,000 (nominal)
Tube Life	2,000 Hours

SUMMARY

In summary, the large screen real-time projector described is an advanced state-of-the-art equipment. Being a CRT, it can be utilized in all applications where CRT's are used today and it is compatible with the driving requirements of current displays. It can provide to group audiences, those displays and data formerly available only to operators of individual consoles on a real-time basis. It is very flexible in operation and does not limit the system designer to update cycles or history trails which may be undesirable. No chemicals are involved nor is there a continuous consumable requirement. The low cost, long life projection CRT is readily replaceable. This system is without equal for the display of dynamic data in real-time to a group audience.

BUILT-IN TEST (BIT) FOR TRAINING DEVICES

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Aerospace Engineer and Electronic Engineer, Respectively
Naval Training Device Center

As trainer electronics grows in scope and complexity, a similar growth is required in the equipment needed to check it out. The importance of speeding the repair of trainer systems is being accentuated by the increasing complexity of computer systems, microminiaturization, incorporation of operational equipment and GFE, and the demand for realistic, cost-effective training. Many approaches are being investigated, including sophisticated off-line test equipment, built-in test (BIT), and fault-analysis systems that isolate the fault to a single black box. For some applications, automatic test equipments (ATE) are being considered that can be used to isolate the fault within a black box, indicate the needed repair, and check out the required unit for proper operation and adjustment.

Little thought and time were devoted in the past to the design of test and checkout equipment. It is now evident that the same consideration should be given to the design of a test equipment system as we give to the design of the trainer system. A thorough analysis must be made of the training requirement and of the mission of the test system and its environment. Trade-offs must be made between the constraints of cost, time, operator skill levels, accuracy, repeatibility, and user confidence to arrive at an optimum test system.

Since most training devices are unique, or at least limited in number, the justification for using a fully automated test system from the standpoint of cost-effectiveness is questionable. There is justification, however, for utilizing Built-in-Test (BIT) on the more complex trainers and life-critical trainers such as environmental chambers.
Some of the more important factors to consider when deciding to incorporate BIT are:

a. It aids in achieving a more maintainable trainer by reducing the MTTR (mean-time-to-repair), which ultimately results in a higher operational availability factor. The high level of availability (98.5% or higher) required by most using commands is achievable only by using highly reliable equipment supported by efficient test and maintenance concepts.

b. It makes possible the diagnosis of failures in complex systems where manual methods of fault detection and fault isolation are impractical.

c. It reduces the maintenance manpower burden by reducing the overall maintenance man-hour and skill level requirements. The life-cycle cost of assigning three extra Navy TD's (TRADEVMEN) to a training device for 10 years is on the order of a million dollars. In addition to reducing manning requirements and costs, BIT can guarantee a consistent performance capability for failure diagnosis independent of the individuals assigned.

d. It reduces the requirements for general and standard manual test equipment and the associated requirements for calibration and repair.

e. Easily repeated consistency standard tests can be quickly run and rerun with a minimum personnel effort during engineering test and checkout to certify most of the interval hardware operations.

BIT costs are decided by the level of failure identification desired. With the modular construction techniques used in trainer design today, the most cost-effective repair level is failure identification to an LRU (line-replaceable unit). In most cases the LRU will be a replaceable module such as a printed circuit card, and on occasion the LRU may be a functional grouping of 2 or 3 cards or a small sub-assembly of a larger assembly. Specific fault isolation to a lower level and the repair/discard decision can best be accomplished off-line at a later time. With this maintenance concept, the trainer will be back on the line quickly with a minimum loss of training time.

Let's take a look at what some contractors have done with BIT for training devices. We'll be looking at various degrees of sophistication, all the way from simple monitoring systems to computer-controlled test programs. Some of the more basic types of BIT are panel meters and indicator lamps. One of the first orders of sophistication would be to add a manual scanning system, which consists of a standard rotary switch connected to selected test points. Even this simple example of BIT can be made elaborate by use of a test point scanner which automatically feeds information to the meters and lamps.

When a failure occurs in a system, one of the initial steps the technician will take is to verify the condition and the very existence of his power. This can be accomplished in a variety of ways, perhaps by using a combination of methods. Is the unit "plugged in"? Is a blown-fuse lamp lighted (basic BIT)? Perhaps the maintenance man has available a Power Supply Status Panel such as that used in Device 2B24. The panel consists of a matrix of lamps which gives instant Go, No-Go confirmation of the condition of the power. A test lamp feature precludes a burned-out bulb giving an erroneous indication. A very simple, yet useful example of BIT.

Most complex training devices already have the necessary equipment to perform extensive testing, particularly those with digital computers.

Another, more complex form of BIT is "introspective testing". "Introspection" is the utilization of one part of a system to test the entire system. Many contractors are now using the main trainer computer for testing in response to the requirements of MIL-T-23991C, General Specification for Military Training Devices. Device 15E22, EA-6B Team Tactics Trainer is a good example of this application. The maintenance and test programs for Device 15E22 consist of a variety of open-loop and closed-loop test routines. These routines not only detect faulty assemblies and modules, but they also indicate the nature of the failure. There are five basic categories of test programs:

a. Test Exercise Program - Checks the accuracy and flow of signals between the computer and all signal sources and terminal points in the trainer. The program is also used to calibrate the interface equipments and all displays and controls, and it is capable of exercising the equipment in both static and dynamic modes.

b. Daily Readiness Check - Determines visually that the trainer is ready for operation. This check uses automatic sequencing through a series of static outputs, utilizing the normal iteration rate of the main simulation program. A provision is also made for stepping through the programs or portions thereof, incrementally to verify the desired outputs. The type and nature of all failures are permanently recorded through the use of a teletypewriter.

c. Computer Diagnostic Programs - Commercially available diagnostic programs are used for the computer system.

d. Real-time Interface Equipment Diagnostics - Enables on-line program control checkout of the simulation interface equipment. These programs are automatic, requiring a minimum of operator intervention, and they provide a hard-copy of the test results. These diagnostics can be further broken down into two subprograms:

(1) Discrete input/output tests - Check the proper functioning of the discrete input/output channels of the trainer in a closed-loop fashion. All disconnection and reconnection are accomplished either under program control or by using a patchboard type device. Upon detection, the program indicates to the operator the faulty channel.

(2) Analog input/output tests - Exercise the analog devices through their full range of operation. This is accomplished in a closed-loop fashion using known calibrated digital-to-analog converters as a reference. The test is compiled so that the operator can specify the accuracy limits to which the equipment will be tested, and it readies the period and amplitudes of test signals via an on-line input device. All converters, multiplexers, and demultiplexers are tested, and all channels not functioning within specified limits are printed out on the teletypewriter.

e. Real-time Clock Test - Automatically checks the real-time clock for proper functioning and accuracy and automatically prints out the results on the teletypewriter.

Device 15E18, Tactical ECM Trainer, has a unique feature called a maintenance panel which is separate from the computer. The maintenance panel has various switches which enable the operator to take the computer off the line (when a problem is suspected in the computer), and step through the program manually, one word at a time. The panel can also be used to fault isolate to the LRU (line replaceable unit) level within the trainer. This concept of BIT is relatively simple and inexpensive to develop and is well-suited to smaller trainers in which elaborate software programs are not justified.

Another approach to BIT is the incorporation of off-the-shelf data logging equipment into the trainer design. Such a system built around a programmer comparator contains the following elements:

a. An operator's console, including control and display devices to present the evaluation of the tests to the operator.

b. Programming equipment that provides coordinated and precise control of the test equipment and the unit under test by using prepunched or magnetic tape.

c. A stimulation control unit that provides signals to be injected into the unit under test.

d. An adapter unit that is the link between the tester and the unit under test.

e. A test point switching unit that selects test points determined by the programmer and routes the signals to the test evaluator.

f. A comparator that accepts the information from the test points as ordered by the programmer and determines if the selected test results are within permitted tolerance.

g. A measurement unit which provides a standard for the comparator. Depending upon the encoded instructions and the results of the comparison, the test system may proceed to the next test, stop and allow the operator to make the next decision, or automatically search to a desired sub-routine for further evaluation of the malfunction.

Keep in mind,that so far, we have only discussed on-line testing. Once a module or assembly has been declared faulty and has been removed for off-line checkout, another type of BIT equipment comes into play. This particular equipment may or may not actually be built-in, but nevertheless, its importance can not be overemphasized. This is the assembly or module tester. Sophistication is definitely in order for the assembly tester. MIL-T-23991 specifies that all assemblies in the training device which are used more than five times must be checked on an automatic or semi-automatic test system, whereas assemblies which are used less than five times may be tested manually. A complete assembly tester will have power supplies, signal generators, oscilloscopes and other measuring equipment built into the tester. The tester should be capable of testing all cards and modules used in the trainer, including those used in the computer. It is desirable to have the tester programmable by means of a punch tape, punch card,or patch board. Special loads and other passive signal conditioning elements should also be included in the tester.

All that was discussed exists in training devices today. Where do we go tomorrow? We are always receptive to new ideas and breakthroughs in the field of testing as you submit proposals on new training devices. First, train your designers to be conscious of the maintenance problem and help them become familiar with the latest techniques in BIT. Then the bids will tend to be reasonable and trainer BIT capabilities will grow. One of the most outstanding sources of up-to-date information in the realm of BIT and automatic testing is PROJECT SETE which is conducted by New York University School of Engineering and Science. The project director's name is David M. Goodman. You can obtain a wealth of information from Mr. Goodman in the form of study reports, lecture papers, and actual instruction classes. You're missing a good source of information if some of your key people aren't on-board with Project SETE.

THE DRAGON ANTITANK MISSILE SYSTEM TRAINING EQUIPMENT AND GUNNER TRAINING

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The requirement for a medium range antitank/assault weapon that would provide the infantryman with an improved capability against tanks and hard targets over that provided by its predecessor, the 90MM recoilless rifle, was stated in a Qualitative Development Requirement Information document released by Ballistic Research Laboratories in October 1962. A United States Army Combat Developments Command Small Development Description, dated October 1968, identified the requirement for a Conduct-of-Fire Trainer to be used with this system. To meet these requirements, McDonnell Douglas Astronautics Company, TI-CO, developed the DRAGON Weapon System and its allied training equipment.

Prior to describing the training equipment, it is necessary to briefly describe the weapon system.

THE DRAGON WEAPON SYSTEM

The DRAGON is a one-man portable and operable, command to line of sight wire guided missile system. It consists of a tracker and a round.

ROUND. The DRAGON round consists of a launcher and a missile, packaged together, and is the expendable portion of the system.

1. The Launcher - The Launcher consists of a smooth bore fiberglass tube, breech, canister assembly, tracker mount, support stand, launcher wiring harness assembly and tracker battery, carrying strap, forward and aft shock absorbers. It is disposed of after the missile has been fired. The Launcher has an overall length of 44.10 inches and weighs approximately 8.9 pounds, without the missile. The high pressure canister and low pressure breech configuration supplies the required muzzle velocity without exceeding the permissable acceleration levels and with a minimum of recoil. The Launcher also serves as a storage and carrying case for the missile prior to launch.

2. The Missile - The Missile is the second item of the round. The missile consists of three major sections. The forward section contains the warhead and fuze system. The center section contains 30 pairs of side thrusters and their firing circuit boards. The aft section contains the electrical components assembly, control system electronics package, flare assembly, bobbin assembly, and three folding fins mounted on the sleeve assembly. The missile is approximately 28.5 inches in length, has a diameter of approximately 5 inches, and weighs approximately 14 pounds at launch.

TRACKER. The Tracker is the reusable component of the DRAGON Weapon System. It consists of an optical sight and infrared sensor, which are boresighted to each other, an electronics package, trigger, and a structure assembly. The tracker measures the displacement of the missile from the line of sight established by the gunner. Missile displacement measurements made by the tracker are converted to guidance commands which are transmitted to the missile by a wire link. The guidance commands produce horizontal and vertical missile control forces generated by small thrusting rockets which are mounted canted in the missile so that longitudinal thrust is also produced, thereby increasing the missile's forward velocity. The tracker determines missile position from the IR flare assembly at the aft end of the missile. A typical test launch is shown in figure 1.

Figure 1. Dragon Weapon System Firing

The simple but sophisticated DRAGON Weapon places the gunner in a new environment as compared to the 90MM recoilless rifle which it replaces. The gunner functions can be divided into four separate events:

1. The prefire function; i.e., the preparation of the weapon and the acquisition of the target.

2. The launch function; i.e., the trigger squeeze and control of launch reaction.

3. The post launch function; i.e., maintain a proper sight picture while tracking smoothly.

4. Post impact function; i.e., the removal of the tracker from the "spent" round and the preparation for refire if necessary.

The functions that occur in event one and four do not depart appreciably from the operation of other weapons. However, the functions which are required in events two and three are a radical departure from earlier systems. The student gunner must become accustomed to the time delay between trigger pull and launcher firing and must also learn to control his reactions to the large percentage of system weight loss during launch. After launch, function three, the gunner must suppress the natural reaction to put the weapon down, and continue to track the target with a smooth and steady motion regardless of the events which are taking place around him.

THE DRAGON TRAINING EQUIPMENT

The "Training Package," i.e., the training equipment and the training plan, is an important element of a weapon system development. The value of the training package is dependent upon proper assessment of two areas:

1. What is necessary to be learned by the trainee ?

2. What technological abilities; i.e. skill and knowledge does the prospective trainee possess which can be used during his training?

The training package should create a realistic environment for maximum effective learning to take place. Galileo said, "You cannot teach a man anything...you can only help him find it within himself." We are no longer satisfied just to teach a man something. If we are to have effective learning, we must use new and imaginative training equipment and techniques to help him find the skills within himself.

The DRAGON Training Equipment does create a realistic handling and launch environment. It also employs immediate feedback techniques in terms of gunner performance. The DRAGON Training Equipment provides the tools for developing and maintaining the gunner's proficiency, reduces the need for expending live missiles for training purposes, and evaluates the gunner's performance instantaneously.

The training equipment consists of the Launch Effects Trainer (LET), Infrared Transmitter, and the Monitoring Set as shown in figure 2. During training exercises the LET uses a tactical tracker for gunner sighting, and provides a launch recoil comparable to that of the weapon.

Figure 2. Dragon Training Equipment with Infrared Transmitter Mounted on Jeep

Launch Effects Trainer (LET). The Launch Effects Trainer simulates the Weapon Round in appearance, prefire weight and center of gravity and therefore can be used for handling and set-up exercises. The LET employs the energy of a 7.62 blank cartridge to produce an audible blast as well as the recoil and the weight shift effects of the tactical round. The internal arrangement of the LET is shown in figure 3.

For a training exercise, the student gunner executes the same prefire functions in using the LET as are required by the tactical weapon. These functions consist of the following:

1. Mount the tracker on the round
2. Lower the support stand
3. Assume firing position
4. Acquire target with tracker telescope.

A training assistant sets and locks the weight shift assembly into firing position and then opens the breech and inserts the cartridge. This requires removing the access portion of the aft shock absorber and opening the breech. Opening and closing of the breech cocks the firing mechanism and automatically sets the safety cam to the safe position. The complete sequence of events for LET firing is shown in figure 4.

LAUNCH EFFECTS TRAINER SUB-ASSEMBLY

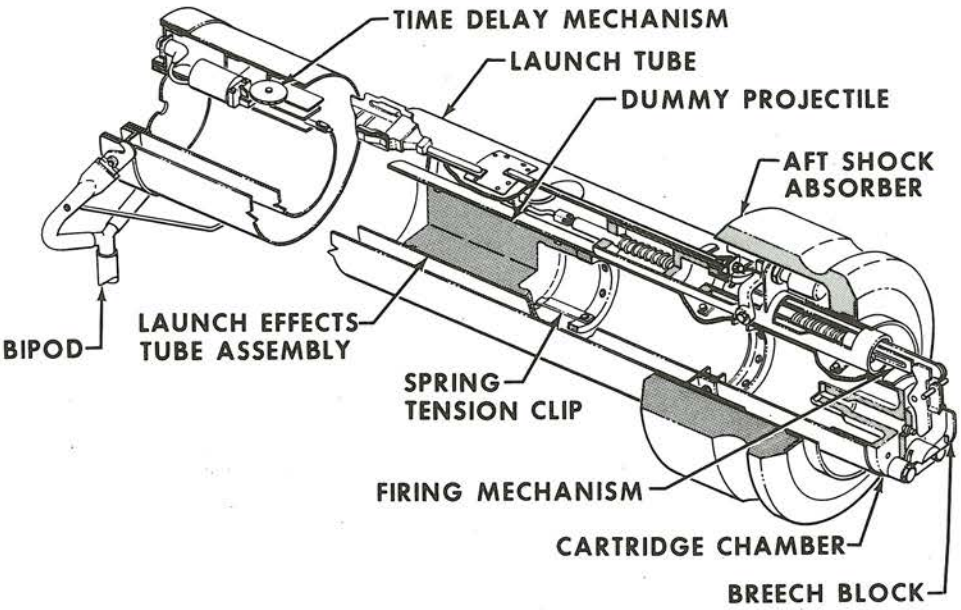
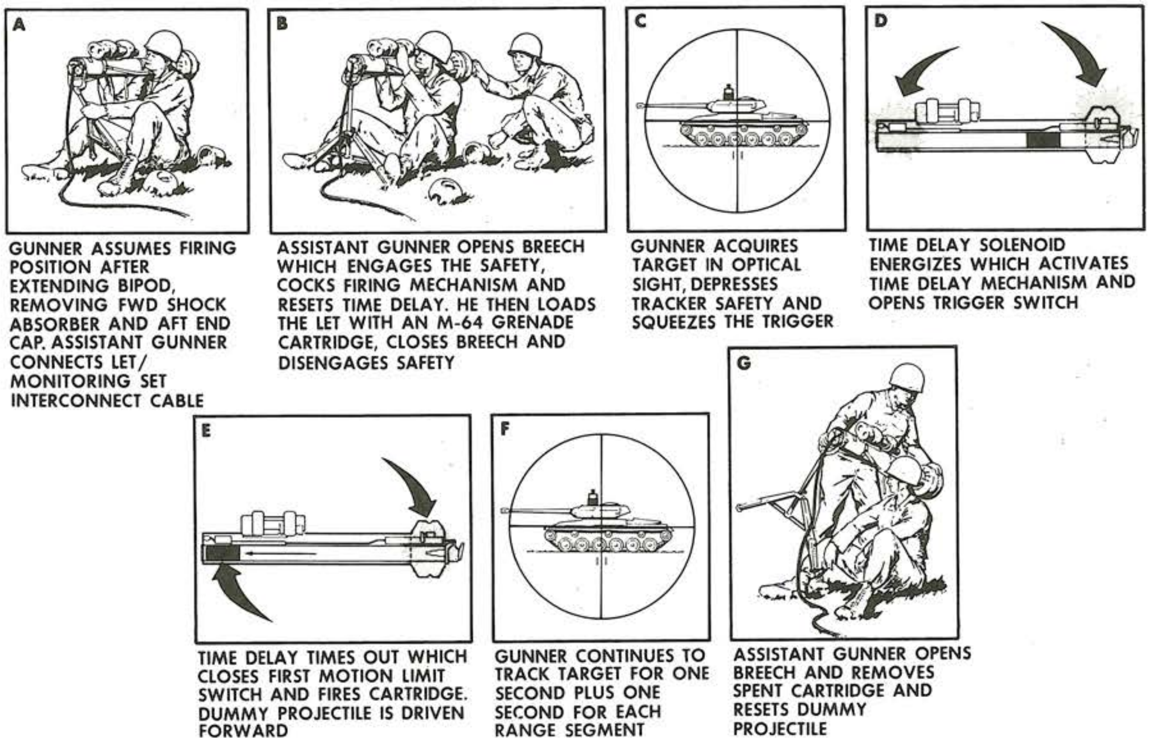


Figure 3. Launch Effects Trainer Subassembly

LET OPERATION



A GUNNER ASSUMES FIRING POSITION AFTER EXTENDING BIPOD, REMOVING FWD SHOCK ABSORBER AND AFT END CAP. ASSISTANT GUNNER CONNECTS LET/MONITORING SET INTERCONNECT CABLE

B ASSISTANT GUNNER OPENS BREECH WHICH ENGAGES THE SAFETY, COCKS FIRING MECHANISM AND RESETS TIME DELAY. HE THEN LOADS THE LET WITH AN M-64 GRENADE CARTRIDGE, CLOSES BREECH AND DISENGAGES SAFETY

C GUNNER ACQUIRES TARGET IN OPTICAL SIGHT, DEPRESSES TRACKER SAFETY AND SQUEEZES THE TRIGGER

D TIME DELAY SOLENOID ENERGIZES WHICH ACTIVATES TIME DELAY MECHANISM AND OPENS TRIGGER SWITCH

E TIME DELAY TIMES OUT WHICH CLOSES FIRST MOTION LIMIT SWITCH AND FIRES CARTRIDGE. DUMMY PROJECTILE IS DRIVEN FORWARD

F GUNNER CONTINUES TO TRACK TARGET FOR ONE SECOND PLUS ONE SECOND FOR EACH RANGE SEGMENT

G ASSISTANT GUNNER OPENS BREECH AND REMOVES SPENT CARTRIDGE AND RESETS DUMMY PROJECTILE

Figure 4. LET Operation

Infrared Transmitter. The Infrared Transmitter provides the necessary energy for establishing tracker sensor contact with the target. In so doing the Infrared Transmitter effectively simulates the missile flare. All visible wavelength infrared energy is filtered out to insure that the gunner tracks a target of realistic contrast and not the transmitter. Displacement of the transmitter beacon from the target aim point is compensated for at the Monitoring Set. Consequently, angular displacement between the sensor optics line of sight and the transmitter is detected as a gunner aiming error during a tracking exercise. The IR Transmitter can be vehicle mounted or stationary mounted to provide simulated stationary or moving targets.

Monitoring Set. The Monitoring Set consists of a control and indicator panel, control logic, error detector, function generator, battery and battery charger. A tracking indicator is provided to enable the instructor to instantaneously monitor the gunner's performance. A target range switch enables the instructor to compensate for target range and to review the various increments of the tracking period. An off target indicator, divided into four quadrants, indicates the direction of the error. Hit and miss indicators provide a readout at the end of a tracking period. Other controls are provided for recorder, target size, horizontal and vertical bias adjustments, an IR transmitter and trigger indicators. The bias adjustments are used during trainer set-up boresighting procedures to null error signals due to displacement of the aiming point from the Infrared Transmitter beacon.

Gunner tracking data is obtained from the tactical tracker, mounted on the LET, which measures the angular deviation from line-of-sight to the IR transmitter located on the target. The Monitoring Set processes, evaluates and displays the angular data received from the tracker. The instantaneous angular deviations from the correct aim point are evaluated by comparing these error signals to a programmed acceptance curve. When a gunner stays totally within the acceptance curve, in both horizontal and vertical throughout the tracking exercise, he is considered as having hit the target. If he exceeds the curve at any time, he is considered as having missed the target, with the approximate time and direction of the error being recorded and displayed at the end of the exercise. A score (0 to 100%), which is based on the gunner's average tracking error, is also displayed. These displays help the instructor evaluate the gunner's performance immediately and can be used to instruct the gunner on methods of improving his skill before his next firing.

THE DRAGON GUNNER TRAINING PROGRAM

The DRAGON Training Equipment has been integrated into and is being utilized in a gunner training program. The training program is divided into four phases of instruction which are presented in an order which reinforces the training objective.

The four phases consist of the following:

1. Technological Knowledge Development

2. Primary Skill Development

3. Instructional Firing

4. Marksmanship Skill Development.

During the development of the student gunners technological knowledge he learns the general characteristics of the DRAGON in terms of the requirement for the weapon, where it will be found in the Army TO&E as well as the DRAGON's physical characteristics and performance. The introduction to the training equipment, including assembly, disassembly, and malfunction immediate action, is also covered.

The Primary Skill Development phase begins with the identification of the motor skills which the gunner must employ to properly utilize the DRAGON System effectively. Each step required to prepare for an engagement of a target (target acquisition, range assessment, target tracking before and after fire) is demonstrated and then practiced to perfection by the student. The pros and cons of each of the firing positions are also discussed and demonstrated during this phase. The look alike, function alike features of the Launch Effects Trainer allows the student to practice in a realistic environment without the potential hazards of the tactical round.

During the Instructional Firing phase the student gunner begins to put into practice those safety procedures, which must be observed, with the tactical weapon when operating in the real launch environment. While serving as an assistant instructor the student becomes thoroughly familiar with the operation of the LET. That is, he learns those functions which are required to operate the LET, but are not gunner functions, when firing a tactical round. He also learns to operate the Monitoring Set.

During Marksmanship Skill Development which is the final phase of the training program, the gunner is scored on each of the simulated firings with the LET. The Monitoring Set provides the instructor with instantaneous indications of the gunner's performance in terms of the gunner's ability to recover from the launch environment, steady state tracking ability, and the instructor and student the ability to take the necessary corrective action on each shot. As a conclusion to this training program the last twenty firings are for a qualification score.

CONCLUSION

The simplicity of operation of the DRAGON Weapon System, excellent positive transfer characteristics of the DRAGON Training Equipment combined with a well developed training program have made it possible to demonstrate that more than 99 percent of the selected gunner candidates can qualify as Army "DRAGON" Gunners.

INNOVATIONS IN LAND COMBAT TRAINING

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INTRODUCTION

Since the last Industry Conference, we, at the Army Training Device Agency, have been getting a good deal of exposure throughout the Army. In the last 12 months we have had most of the CONARC Training Center Commanders visit us; in addition, General Westmoreland attended a demonstration of our Synthetic Flight Training System prior to its installation at Fort Rucker. On 1 July of last year, we changed our name to be more descriptive of what we do. (See figure 1.)

U.S. ARMY
TRAINING DEVICE AGENCY

Figure 1. Name Change

Getting General Haines and General Hunt here today is indicative of the command interest in training devices and simulators. Fortunately, I had some prior knowledge of General Haines' presentation so I intend that my paper be considered an extension of General Haines' remarks with emphasis on the need for training devices and simulation techniques for land combat training.

I have divided my paper into several parts. Initially, I would like to tell you a little about the Board for Dynamic Training; secondly, what I saw in Europe at several foreign training centers last September; thirdly, a discussion of cost-avoidance on a trainer in use in Europe; and lastly, what the future looks like for land combat training device developments.

ARMY TRAINING POLICY

In September of last year, General Westmoreland released a message on the subject of Army training policy. This message established a Board for Dynamic

Training to forge a new link between the managers of combat arms training, including both the Reserve and National Guard, and the Army's extensive training establishment. The short and long range goals of this link are to provide the unit training managers the expertise found within the training establishment to accomplish their training mission within the assets locally available. This Board is headed by General Paul F. Gorman, Deputy Commandant of the U.S. Army Infantry School, and responsive to the direction of the Commanding General, CONARC. The primary thrust of the Board for Dynamic Training will be to produce a catalog of idea-stimulating material on how to organize and conduct effective, stimulating, adventurous training and how to conduct training on tactics and weapons despite limitations on training areas or conditions of under-strength.

I think I can say without hesitation that if you have any innovative ideas about any area of training, whether it is in the area of devices, methods, or literature, you will find in General Gorman and his people, a receptive audience.

FOREIGN TRAINING

In September of last year I was fortunate to be a member of a Department of the Army team, which visited several German, French, and British Army training facilities to see what innovations they had that our Army might use. We saw some simple and very interesting training methods. I would like to show you some pictures taken during my travels. Figures 2 and 3 show subcaliber firing at the German Artillery School with miniature targets located approximately 100 yards away at the outer perimeter of a small field.

Figure 2.

Figure 3.

Figures 2 and 3. Subcaliber Firing at the German Artillery School

This next series, figures 4, 5, 6, 7, 8, 9, and 10, taken in the German Tank School, show a miniature range and some of the various targets in use. Tanks are driven up to this range and the crew goes through a gunnery exercise with subcaliber ammunition, as they would if they were firing full-size live ammunition. We know of no such range as this in use in the U.S. for tank gunnery.

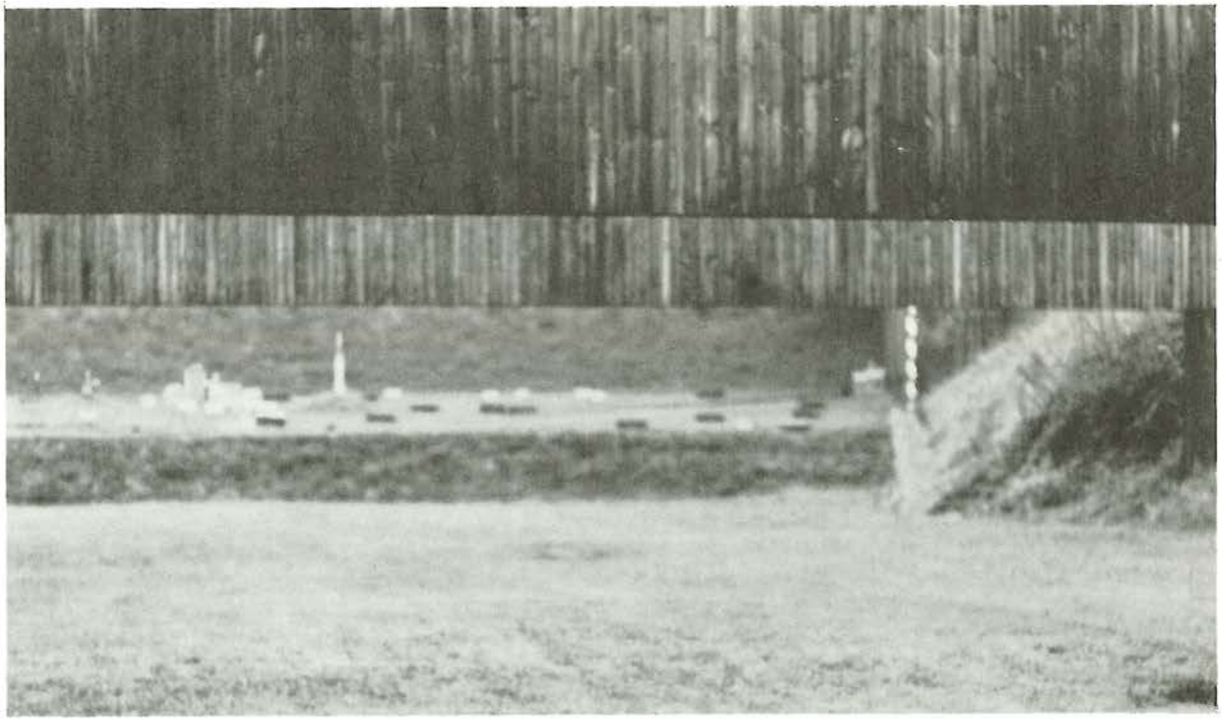

Figure 4.

Figure 5.

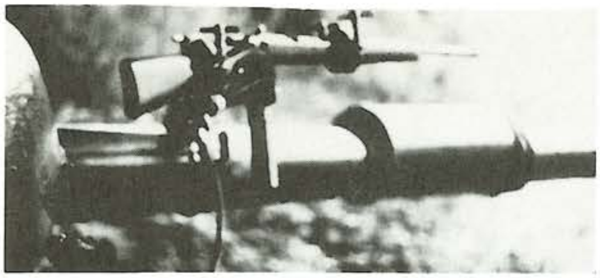

Figure 6.

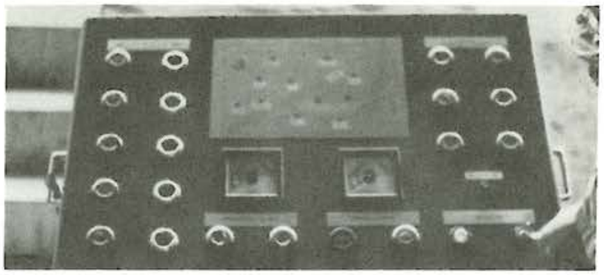

Figure 7.

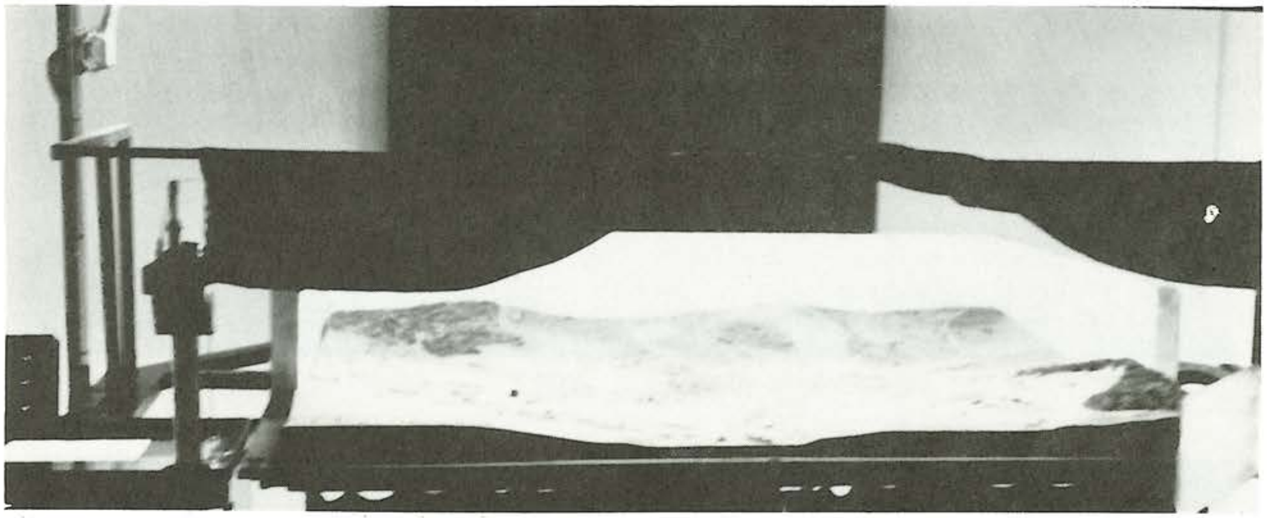

Figure 8.

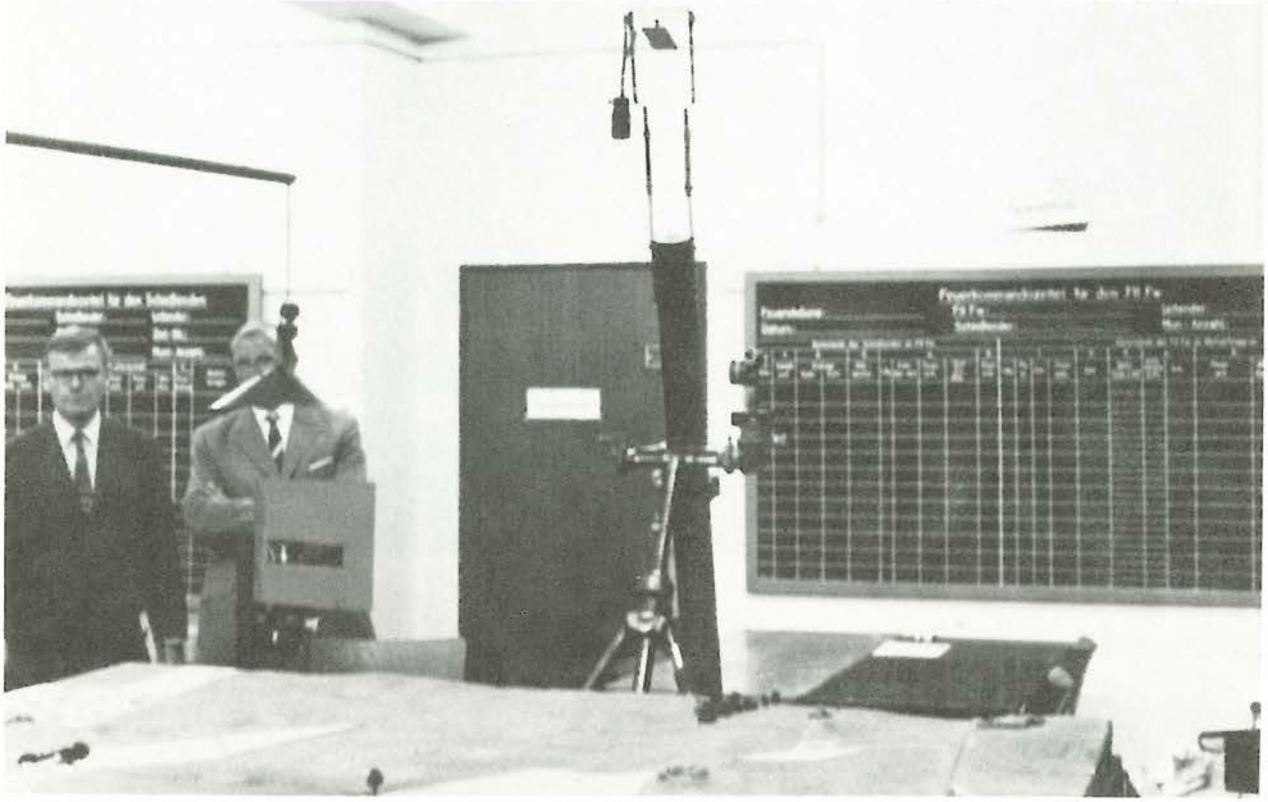

Figure 9.

Figure 10.

Figures 4 to 10. Miniature Range and Various Targets in Use at the German Tank School

The following figures 11, 12, 13, and 14 show a British method of training tank crews which is very similar to the methods in use in Germany. While we did not see the French Armor School, we were told they trained in a similar fashion.

Figure 11.

Figure 12.

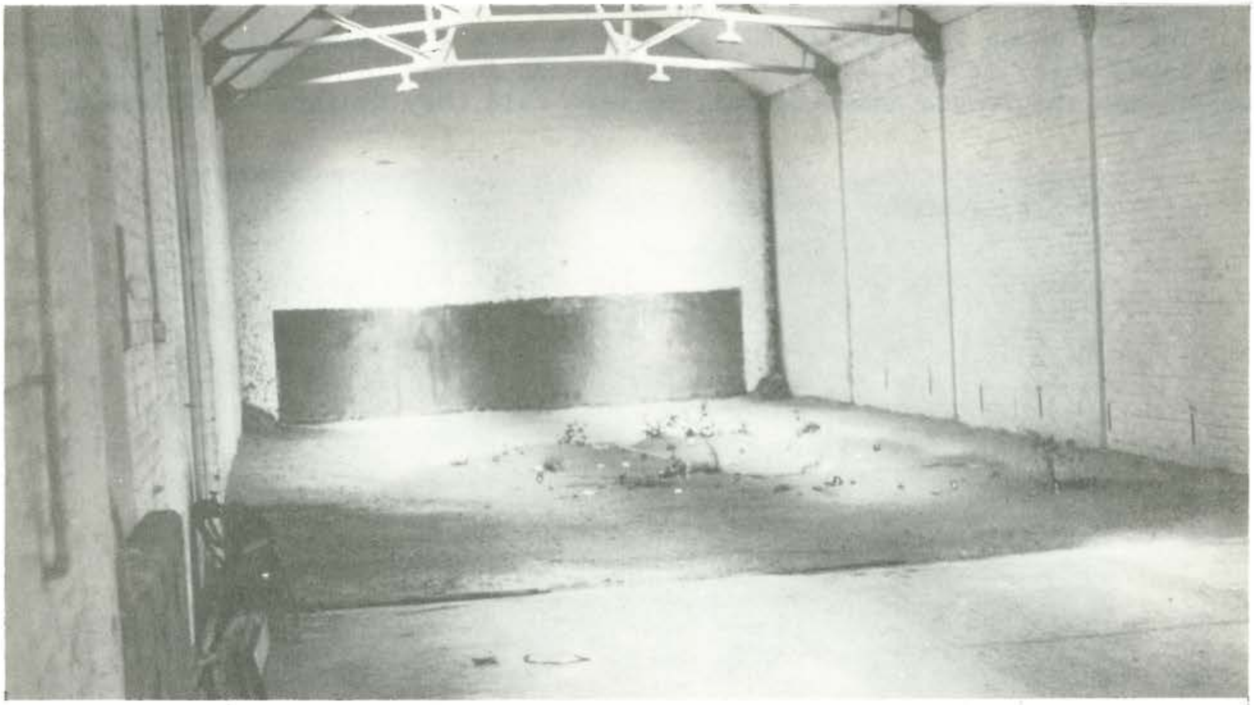

Figure 13.

Figure 14.

Figures 11 to 14. British Training Tank Crews

A French missile trainer is illustrated in figures 15 and 16. The gunner controls a spot of light which simulates wire-guided missiles. It appeared to be somewhat similar to what we had done in our Shillelagh trainer. The most sophisticated trainers were the driver trainers in use in both Germany, Belgium, and England, utilizing a terrain board 10' x 30' with a television pickup. The device is used to train tracked vehicle drivers. It simulates various types of terrain and is capable of training in emergency procedures. The driver's compartment contains a motion platform with either two or four degrees of freedom.

Figure 15. French Missile Trainer (Side View)

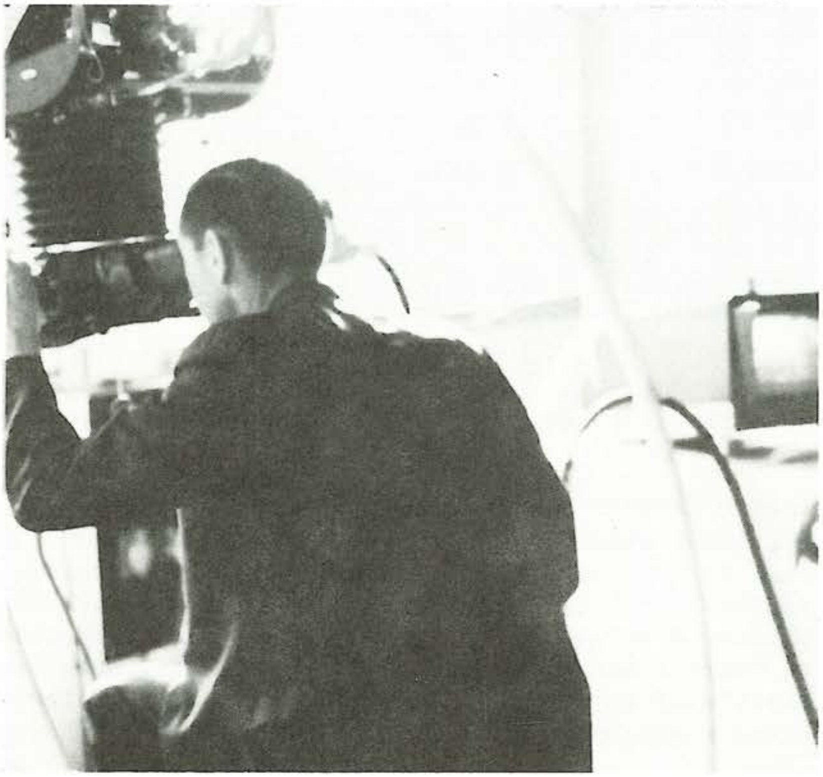

Figure 16. French Missile Trainer (Rear View)

COST-AVOIDANCE

Concerning this trainer, I would like to discuss an aspect of cost-avoidance, (figures 17a, b, and c), or cost savings, (figures 18a and b), which illustrates the economics of an effective trainer. The figures apply to the procurement of a driver trainer for the Leopard tanks which are used by both the German and Belgian armies. (See also figures 19 and 20.)

<u>COST-AVOIDANCE -- TANK DRIVER TRAINER</u>

COST STUDIES UNDERTAKEN INDEPENDENTLY BY THE FRENCH ARMY FOR THE AMX-30 TANK AND BY THE BELGIAN ARMY FOR THE LEOPARD TANK REVEAL THAT THE USE OF SIMULATORS FOR TRAINING TANK DRIVERS SAVES APPROXIMATELY 60% OF NORMAL TRAINING COSTS.

Figure 17a.

<u>EXAMPLE</u>

NUMBER OF TRAINEES: 600 DRIVERS PER YEAR.
TRAINING TIME PER DRIVER: 11 HOURS ON THE TANK - OR
7 HOURS ON THE SIMULATOR
+4 HOURS ON THE TANK

<u>AVAILABILITY OF TANKS FOR TRAINING</u>: 250 HOURS PER YEAR.

HOURLY COST OF TRAINING ON TANKS: $325.00 PER HOUR (INCLUDING DEPRECIATION COSTS OF TANK, MAINTENANCE, SPARE PARTS, FUEL, ETC.).

<u>AVAILABILITY OF A TANK SIMULATOR</u>: AT LEAST 160 HOURS PER MONTH, OR 1920 HOURS PER YEAR.

ACTUAL USE, DEPENDING ON TRAINING PROGRAM: 1500 HOURS PER YEAR.

HOURLY COST PER SIMULATOR: $40.00 PER HOUR (INCLUDING DEPCRECIATION COSTS OF SIMULATOR, MAINTENANCE, SPARE PARTS, ELECTRICAL POWER CONSUMPTION, ETC.).

Figure 17b.

COST OF TRAINING DRIVERS

600 DRIVERS, EACH SPENDING 11 HOURS ON THE TANK, REQUIRE A TOTAL OF 6600 HOURS PER YEAR.

THIS REQUIRES $\frac{6600}{250}$ = 27 TANKS - AT A COST OF $325.00 X 2400 = $780,000.

600 DRIVERS, EACH SPENDING 7 HOURS ON THE SIMULATOR, REQUIRE A TOTAL OF 4200 HOURS PER YEAR.

THIS REQUIRES $\frac{4200}{1500}$ = 3 SIMULATORS - AT A COST OF $40 X 4200 = $168,000.

TRAINING THEREFORE REQUIRES A TOTAL OF 10 TANKS + 3 SIMULATORS AT A COST OF: $780,000 + $168,000 = $948,000.

Figure 17c.

SAVINGS

THIS COST ANALYSIS SHOWS ANNUAL SAVINGS OF: \$2,745,000 - \$948,000 = \$1,197,000, OR APPROXIMATELY $\frac{\$1,197,000}{600} = \$1,995$ PER DRIVER, OR A PERCENTAGE SAVING OF 56%.

THE EQUIPMENT REQUIRED AMOUNTS TO: 10 TANKS + 3 SIMULATORS INSTEAD OF 27 TANKS.

Figure 18a.

ADVANTAGES

- -TRAINING CAN BE ACCOMPLISHED INDEPENDENTLY OF LOCAL WEATHER AND TOPOGRAPHICAL CONDITIONS.
- -TRAINEES CAN FAMILIARIZE THEMSELVES WITH ALL-WEATHER OPERATIONS, WITH COLD-WEATHER STARTING (-15°C), DRIVING ON ICY OR SNOW-COVERED SURFACES, ROUGH GROUND AND MOUNTAIN ROADS, FAST DRIVING ON DRY OR WET ROADS, ETC.
- -THE INSTRUCTOR CAN INTRODUCE MALFUNCTIONS WITHOUT DANGER AND REPEAT AN EXERCISE AS OFTEN AS NECESSARY.
- -THE INSTRUCTOR CAN MONITOR TRAINEE'S PERFORMANCE UNDER SIMULATED EMERGENCY CONDITIONS SUCH AS POWER FAILURE, BRAKE FAILURE, LOSS OF TRACK, ETC.
- -A SIMULATOR CAN BE USED AT LEAST 160 HOURS PER MONTH, WITH AN AVAILABILITY FACTOR ON THE ORDER OF 99%. THE TANK IS AVAILABLE FOR APPROXIMATELY 20 HOURS PER MONTH.
- -TRAINING IS NOT SUBJECT TO WEATHER CONDITIONS OR TANK MAINTENANCE SCHEDULES, ALLOWING FOR UNINTERRUPTED TRAINING PROGRAMS.
- -SIMULATOR UTILIZATION CAN BE INTENSIFIED DURING PERIODS OF EMERGENCY WHEN A LARGE STUDENT LOAD IS REQUIRED.

REDUCED TANK MAINTENANCE

BY STARTING TRAINEES ON THE SIMULATOR BEFORE ALLOWING THEM INTO REAL TANKS AVOIDS ELEMENTARY FAULTS WHICH CAN CAUSE VEHICLE DAMAGE (GEAR-BOXES, TRACKS, ETC.), WITH A RESULTING DECREASE IN MAINTENANCE.

Figure 18b.

Figure 19. Leopard Tanks Simulated Terrain

Figure 20. Driver Trainer-Leopard Tanks

These figures show how the Belgians reduced the number of tanks to be procured for the training of drivers from 27 to 10 by buying three simulators. I feel sure a similar case can be made for most major weapons; however, we must get into the picture at the earliest possible time. Whether or not trainers or simulators are bought is not important—what is important is that the alternatives are considered.

What I have shown you are just a few of the items we saw in Europe; however, of particular significance was how the training was accomplished. For example: In the British Armor Training Center at Bovington, the schools train instructors selected from units who, after completing their schooling, are reassigned to their units as instructors.

Secondly, it appears that the Europeans are satisfied with a lot less sophistication in their training than we are, because historically their land areas are limited and they have never had the quantities of ammunition nor the training areas that we have had in this country.

Lastly, both the French and the British mount trainers on both land combat vehicles, and helicopters, to simulate weapon firing. This is done even though it may require a reduction in the payload of the vehicle or aircraft. Both the British and French indicated that it was important for fighting vehicles to carry trainers to maintain gunner proficiency.

As I mentioned earlier, we have received a considerable amount of high-level interest in our business. We have conducted an intensified selling program, and the next two figures 21 and 22 show the result of that effort. Two years ago this list contained four or five items—today it is an indication of the added emphasis on training and training devices.

TRAINING DEVICE REQUIREMENTS

LASER TANK GUNNERY TRAINER, XM55 (3A110)
ARMED AIRCRAFT QUALIFICATION RANGE SYSTEM
SYNTHETIC FLIGHT TRAINING SYSTEM (SFTS)
AEROSCOUT AERO VISUAL TARGET ACQUISITION TRAINER
WEAPON STATION TRAINER, MICV-70
COMBINED ARMS TACTICAL TRAINING SIMULATOR
HIT-KILL INDICATOR FOR MBT
FLASH BANG SIMULATOR FOR MBT
XM803 WEAPONS SYSTEM TRAINER
XM803 DRIVER FAMILIARIZATION TRAINER
XM803 DRIVER POSITION TRAINER
XM803 GUNNER FAMILIARIZATION TRAINER
XM803 GUNNER POSITION TRAINER

Figure 21. List of Training Devices

TRAINING DEVICE REQUIREMENTS

XM803 TANK COMMANDER'S FAMILIARIZATION TRAINER
FIELD ARTILLERY FORWARD OBSERVER TRAINER
LARGE SCALE INDIRECT FIRE ADJUSTMENT SIMULATOR
AERIAL TARGET ENGAGEMENT RIFLE (ATER)
LASER RIFLE FIRE SIMULATOR
GROUND OBSERVER RECOGNITION (GOAR) KIT
SAM-D MISSILE TRAINING ROUND/HANDLING TRAINER
SAM-D ORGANIZATIONAL MAINTENANCE TRAINER
SAM-D SYNTHETIC TARGET SYSTEM
AN/PDR-60 RADIACMETER
SATELLITE COMMUNICATIONS EARTH TERMINAL REPAIR TRAINING DEVICE
SAM-D OPERATOR/TACTICS TRAINER

Figure 22. List of Training Devices

LAND COMBAT TRAINING

To begin any discussion of training device requirements for land combat training, the item that immediately comes to the forefront is the recently approved requirement for the Combined Arms Tactical Trainer.

This was alluded to very briefly by General Haines. This device will use a digital computer and a visual display to create simulated combat situations for the Battalion Commander trainee. Training programs will be designed to permit changes in friendly and enemy weapon systems, techniques and organizational structure with the objective of simulating an enemy on various terrains. The intent will be to generate problems and present situations from various perspectives from the Platoon Leader to the Brigade Commander. This device will be the most sophisticated and complex trainer ever undertaken for use by the land combat forces. If it is successful, similar items are envisioned for each of the combat arms schools. This program is a phased development schedule over a three to four year period.

We like to draw an analogy between CATTS (Combined Arms Tactical Training Simulator) for the Army and some of the Navy's sophisticated Fleet Tactics Trainers.

There is going to be a lot of high-level interest in this development and who knows, we may end up with a device which will enable us to be prepared for the next conflict, rather than the last one, which so often has been the case.

We, of the Army Training Device Agency, are in the process of writing memoranda of agreements with several of the Project Managers at the various AMC Commodity Commands. This is in addition to completed agreements with the MBT-70 Project Manager, and ARSV. We have had preliminary discussions with the SAM-D Project Manager, and we anticipate that we will be involved with training devices for SAM-D.

In FY 1973, and hopefully on a continuing basis, we will get funds for new initiatives which are to begin in FY 1972. For many years it appeared that our planning was in reverse. In FY 1972 and FY 1973 we are once more looking ahead.

SESSION IV

Wednesday, 16 February 1972

Chairman: Mr. Emerson J. Dobbs
Head, Sea Requirements and Plans Department
Naval Training Device Center

UNDERSEA WARFARE TRAINING DEVICE REQUIREMENTS FOR THE NEXT QUARTER CENTURY

MR. ALAN J. PESCH
Chief, Man/Machine Systems
Electric Boat division of General Dynamics

Reasonably accurate projections of the result of any multivariate, dynamic process are generally difficult to perform and are rarely made without recourse to large remnant terms. So it is with regard to forecasting training device requirements for the next twenty-five years. What is possible, and perhaps more meaningful, is the projection of current trends in naval missions, hardware, technology, training techniques, and personnel, and relating these trends to training device requirements.

NAVAL ROLES/UNDERSEA APPLICATIONS

Currently, the Navy has four major roles, each of which is being implemented in part through undersea applications. This relationship is described in figure 1. The major trend discerned from this figure is the scope of undersea warfare and the inference of impending increases in undersea applications in the areas of covert deterrence, control, and silent presence.

Naval Roles	Undersea Applications	
	Tasks	Elements
Strategic Deterrence	Secure Patrol	SSBN
Overseas Presence	Attrition	SSN
Sea Control	Denial, Protection	SS, SSN
Projection	Demolition	Swimmers

Figure 1. Undersea Warfare

NAVAL APPLICATION TRENDS

The newer ideas for future naval undersea systems, while difficult to project, will more probably follow the form of functionally specialized units as opposed to multifunction, multilevel command type ships. The role of the submarine as an application element is currently growing and will increasingly expand. The principal application will require greater unit specialization, which in turn drives the requirement for improved fleet integration and tactically coordinated operations.

The impact of these applications is obvious: a need for additional tactical commanders, highly skilled in specific mission areas such as ASW deployment, countermeasures, and anti-shipping missions. These will be similar to the requirements present in the current forms of ASW aircraft such as ANEW and the role of TACOS in those systems. Factors such as reduced manning, emphasis on the ability to select optimal hardware deployment modes in complex multivariate situations, increased individual control and responsibility, reduction in onboard maintenance through use of more modular systems, and the use of logistics managers instead of maintainers best typify these systems. The training device implications for these systems are shown in figure 2.

Future Naval Applications	Training Device Characteristics
o Larger numbers of tactical command billets.	o Increased trainee throughput
o Requirement for proficient career specialists in tactical deployment.	o In-depth, highly realistic simulations designed to develop individual skills and knowledge.
o Shift from requirements for analog maintenance to digital hardware/software maintenance skills.	o Extensive team training for many teams characterized by ease of availability, detailed performance measures, adaptive training, and secure interconnection of several remote team trainers.
o Small, close knit crews who remain a tactical team for long periods.	

Figure 2. Training Device Characteristics of Future Systems

Hardware Characteristics	Training Device Characteristics
o 1950's--Dedicated special purpose analog hardware.	o Original equipment.
o 1960's--Special purpose digital and dedicated analog.	o Original equipment. Digitally driven increase in simulation fidelity.
o 1970's--Within systems are multifunction digital processors, digital/analog displays.	o General purpose computer displays. Some built-in stimulation/training.
o 1980's--Complete general purpose digital hardware across systems. Adaptive logic, emphasis on software change.	o Major digital integration across various team, force, service trainers. Emphasis on tactical deployment, sophisticated environmental multivariate models, principal training in mental skills vs motor skills. Complete shift from hardware duplication to improving training technology.

Figure 3. Hardware and Training Trends

NAVAL HARDWARE TRENDS

A factor critical in projection of training requirements is the nature of hardware used in implementing the undersea applications listed in figure 1.

Naval hardware trends are shown in figure 3, along with their potential impact on training device characteristics. The major point is that dedicated analog equipment will be replaced by general purpose, multifunction digital processors and displays. This will, in turn, decrease the need for rote (knob and dial) skills and increase the need for in-depth, high-level mental abilities. Future operators will have to integrate the mental load of several watch stations, while rote skills will be performed automatically. In short, hardware will replace operators, per se, and the new systems will require highly knowledgeable decision makers.

Because future hardware will be general purpose, it will also be capable of self-stimulation for onboard training. Training device analysts and engineers will be increasingly required to participate in the design of the actual hardware systems because the systems themselves will be required to perform a significant portion of team and individual training at sea.

This trend also portends a requirement for a pronounced shift in emphasis from the development of training device hardware to the development of training device technology such as computer-aided instruction (CAI), computer adaptive training (CAT), and computer-managed instruction (CMI). Each involves improved measures of performance, training control, and training integration across systems, teams, task forces, and services.

TRAINING TRENDS

The trend to shift from at-sea training to shore facilities will increase in the 1970's. Principal reasons include cost of operation, reduced at-sea duty, and the reduced capability of conducting covert exercises.

This trend will require major increases in simulation fidelity with regard to models of environmental characteristics, sensors, cross-coupling, and multivarying tactical relationships. This same trend affords the opportunity for and, in fact, demands that behavioral scientists develop and apply improved training technology in such areas as CAI and CAT.

In the 1980's, some shore training will shift back to at-sea when complex team training capabilities will be resident in most digital military hardware. At that time the principal shore activity will consist of a continuing emphasis on individual training and preliminary team formulation training.

PERSONNEL TRENDS

Naval personnel will increasingly be forced to specialize in areas of expertise. General responsibilities such as management and tactical command of divisions and subdivisions will narrow down to functional areas such as ASW Tactical Command, Propulsion Systems, Strategic Systems, Sonar, etc. Training requirements will shift from on-the-job training to accelerated in-depth training in subsystem specialties ashore.

Subsystem specialists may require a two- to three-fold trainee output characteristic in comparison to the typical NEC descriptor of the 1960's. Similarly, pressures for improved trainee throughput rates to offset the effects of retention problems will demand improvements in basic instructional technology. Most of these improvements will be required in the form of individualized training devices for "A" schools.

SUMMARY OF PROJECTED TRAINING DEVICE DIRECTIONS

In summary, several major shifts should occur in the direction of training device development. Perhaps the two greatest areas of impact will be the expansion of the role played by behavioral scientists in the implementation of training, and in the development of complex computer simulation models and training executive control programs.

Behavioral scientists will be tasked to precisely define the key elements of training, and then develop accurate mission and behaviorally relatable performance measures and criteria for computer automation and control of training. These efforts must be performed to define the structure of complex executive programs.

Development of simulation models will include: environmental and hardware characteristics; accurate models of other operator inputs for individual training; models of functional teams such as sonar, fire control, etc., for total ship training; and multiple ship operative knowledge for multiforce operations.

Figure 4 lists the principal directions that training device design should take. The trend can be summarized this way: The greatest emphasis must be placed on developing advanced, behaviorally derived training technology as opposed to the past twenty-five years of hardware duplication.

- Stress training technology as opposed to hardware development
- Behavioral scientists should guide training implementation, not device design, for greatest potential payoff
- Improved models for simulation:

  Environment
  Integration across systems
  Sensors
  Operator interaction
  Interactive evaluation

- Shift from training rote skilled operators to complex multifunction decision makers
- General purpose hardware training devices
- Built-in training devices

Figure 4. Projected Training Device Directions

THE FARRAND GROUND EFFECTS PROJECTOR*

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Farrand Optical Co., Inc.

INTRODUCTION

The Farrand Ground Effects Projector is an outgrowth of the Mission Effects Projector which we designed and built for the Apollo Mission Simulators. Mission Effects Projectors were used to provide full color visual simulation for the NASA Apollo Simulators from the launch pad out to and including earth orbit, translunar trajectory and lunar orbit through the use of strip film. From lunar orbit to lunar touchdown a LEM Visual Simulator was used which the Farrand Optical Co., Inc. also designed and manufactured for NASA. The Ground Effects Projector, however, is specifically designed to provide real world views for aircraft flight simulation.

The Mission Effects Projector and the new Ground Effects Projector have very much in common in that they both utilize very wide full color strip film in multiple cassettes and their optical systems, as well as their functioning, bear a close resemblance to each other. The basic difference between the two systems lies in the fact that the Mission Effects Projector, in simulating orbital flights utilizes two-dimensional orthographic color strip film and distorts the imagery to provide a spherical earth view whereas the Ground Effects Projector utilizes continuous full color strip film to provide a full color presentation of simulated aircraft flight and rather than the generation of a spherical earth's view we now provide a perspective generation with vanishing points at the horizon.

One might ask why use strip film when one can utilize either cine-motion film or closed circuit television systems and map models. In the first place, film systems will always supply an inherently better view of the real world than any closed circuit television device can possibly achieve from the standpoint of color, resolution, and realism because films are actual photographs of the real world. Secondly, all film systems are far more compact than any model can ever be and aside from the increased realism, strip films in particular do provide wider operating margins. This last remark should be qualified. Visual simulators utilizing cine-motion projection systems are decidedly limited in translational excursions that can be provided to the simulator. It is the strip film system that provides latitudes and flight corridors far in excess of any model capability. Limits of a typical strip film are shown in figure 5. It is reasonable to ask at this point if film systems are so much better than television then why are closed circuit television systems still used? This question must be answered in several steps. First of all let us consider the cine-motion system. Cine-motion systems provide exceptional realism but there are certain compromises that one must accept.

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*Patents Pending

For example,

a. The variation in aircraft velocity cannot safely exceed a ratio of 2:1 with respect to the filming velocity.

b. Cine-motion systems cannot come to a complete stop or cannot make a standing start at any place other than the vicinity where starts and stops were actually filmed.

c. Even with 70mm film the full frame cannot be used for the instantaneous view since a residue surrounding that portion of the frame projected for the instantaneous view is necessary in order to allow for lateral and vertical translations as well as the angular degrees of freedom. These two parameters of instantaneous film projection size versus maneuvering freedom are interchangeable so that available resolution with respect to field of view must be traded against the maneuvering envelope.

d. Since the maneuvering volume is inherently limited by the frame size it is obvious that all maneuvers must be contained well within the filmed view of each frame and so fly-arounds and wide approaches cannot be simulated.

Alternatively, the full color strip film system not only provides all of the advantages of better resolution and realism to a greater degree than the cine-motion film system but it also avoids all of the disadvantages mentioned above.

OPERATING PRINCIPLES

Before we explain the overall system and its advantages, as well as some of its minor disadvantages, it is best to illustrate what we mean by a full color strip film image generator and the difficulties that had to be overcome in order to make such a system functional. In figure 1 it is evident that an aircraft flying a course at constant altitude may photograph a very thin lateral slice of the earth below continously with a strip film camera. At the end of such a mission the "frameless" strip film photography would represent a two-dimensional scale model in full color of the terrain that was flown over. Additionally, if the thin slice photographed were well ahead of the aircraft say at 20° to 30° below the horizon, the two-dimensional rectilinear map model would include the aspect of three-dimensional objects. The right half of figure 2 is a portion of a full color film strip just described which is completely devoid of perspective but which includes aspect. The left half of figure 2 shows the same view but with perspective regenerated. This particular view is confined to include an angle from 30 to 50 degrees below the horizon. At this point, we should say that the method described herein for making a strip film is purely descriptive and far too complex and therefore does not represent the manner in which such a film would be actually evolved.

In order to use this rectilinear two-dimensional model as an image source for flight simulation, one must be able to effectively locate the observer's eye at any altitude h above the film strip as shown in figure 3. The observer must be made to view this film strip out to a tremendous distance such that the angle of no detail below the horizon is minimal, say on the order of 20 minutes of arc. This means that a tremendous expanse of strip film must be used and it must be projected or viewed at such an acute angle that the perspective in the strip film is regenerated. Needless to say, use of any film in this manner is optically impossible and perhaps this is one of the reasons that such a system had not been devised up until the present time. We have been able to provide exactly the required view by the use of optical systems employed in the Apollo Visual Simulator together with a new optical device that regenerates perspective from a perspectiveless film strip.

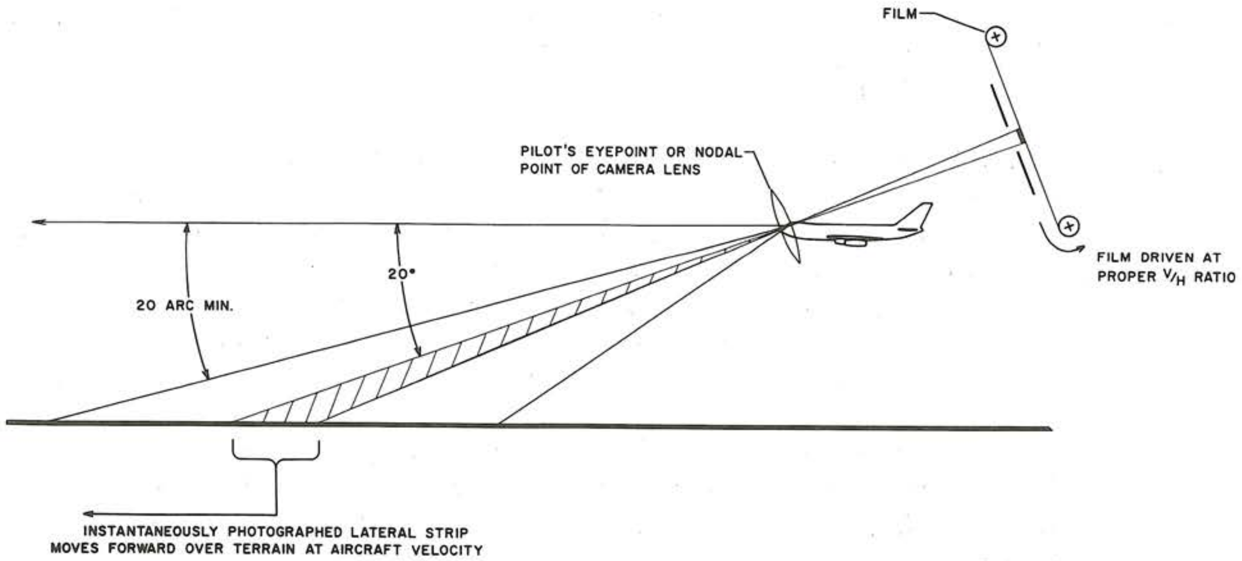


Figure 1. Forward Oblique Film Strip Fotography

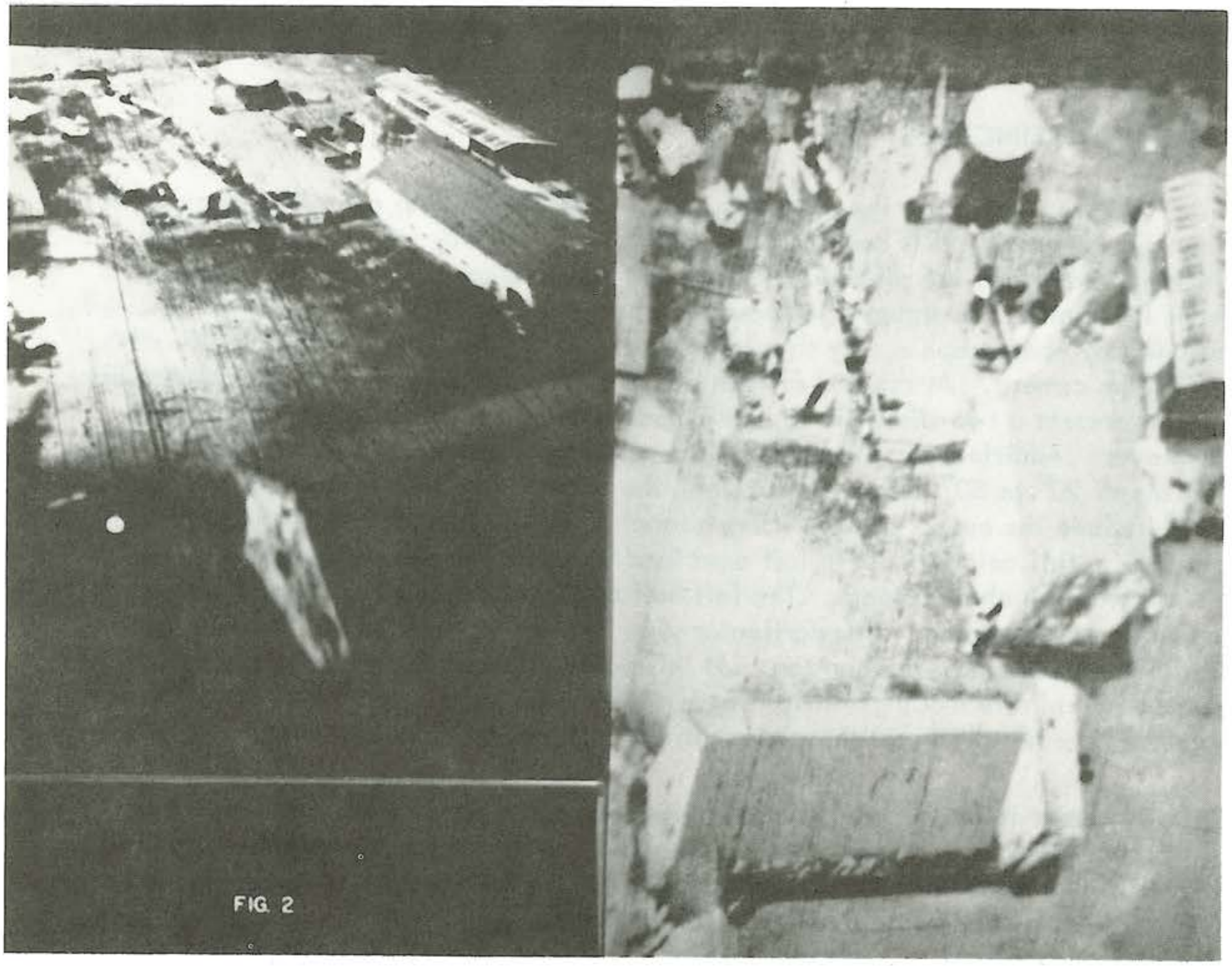


Figure 2. An Orthographic Strip Film View with Aspect is shown to the Right and the same View after Processing by the Perspective Regeneration System is shown to the left

Figure 3 illustrates the strip film principle used in achieving a reconstituted external world view. The system provides an instantaneous terrain view from 1.7h or 1.7 times the eye height forward of the nadir point to 150 h forward of the nadir point, an included vertical angle of approximately 54°. The Farrand Perspective Regeneration System permits the optical system to view the film in an orthogonal manner as shown, thereby avoiding illumination problems as well as shallow angle viewing problems. Note from figure 3 the angle at which the film would have to be viewed from an equivalent eyepoint in order to regenerate the proper perspective if the Perspective Regeneration System were not available -- an absolute impossibility!

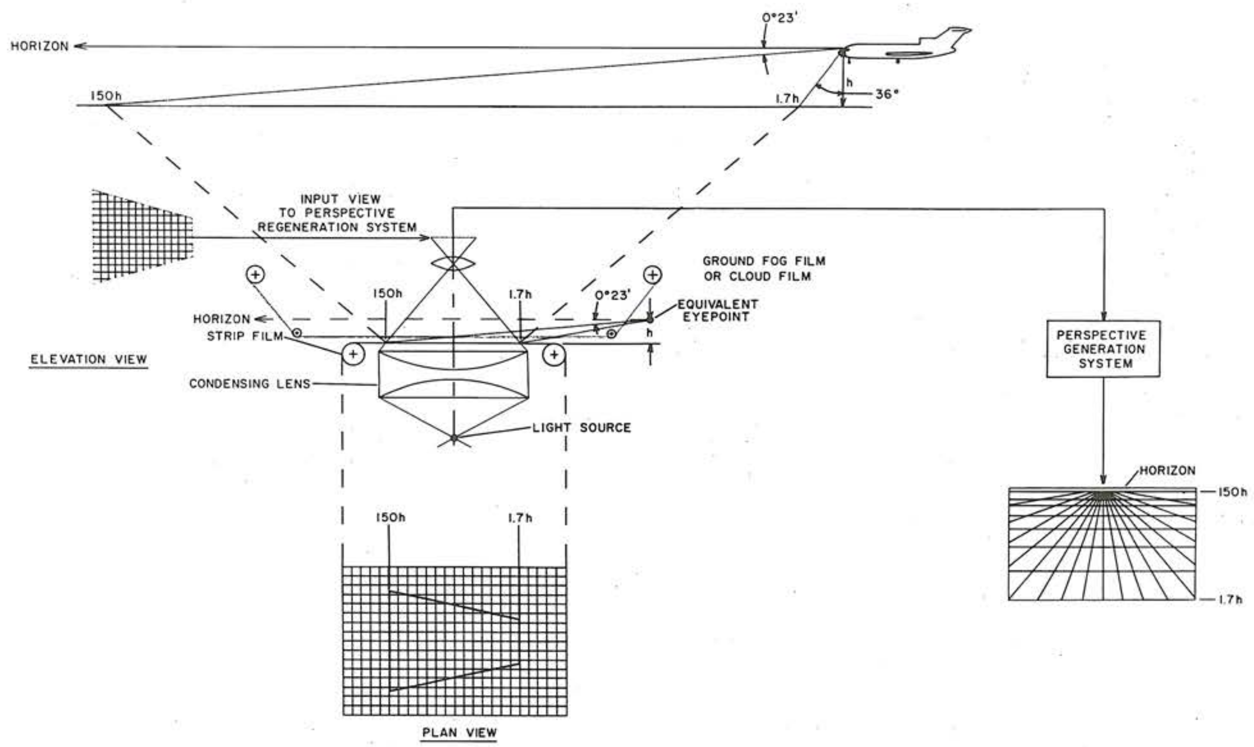
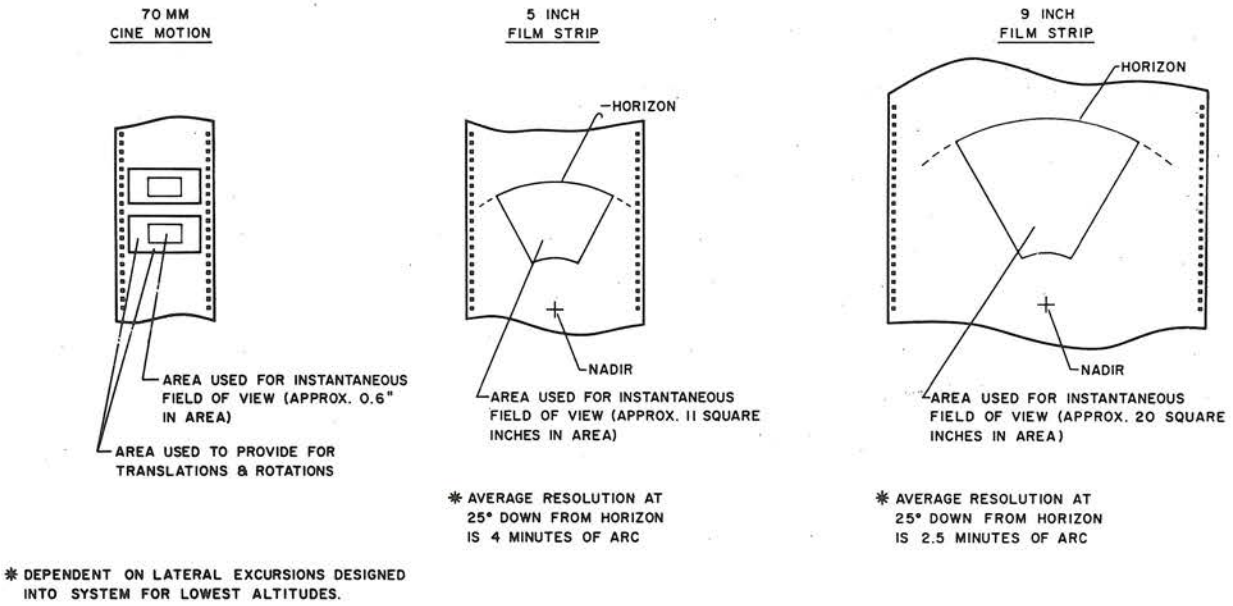


Figure 3. System Diagram

The rectilinear strip film is viewed in an orthogonal manner by a conventional optical system and the image is then processed by the Perspective Regeneration System, reconstituting the perspective out to 150 h or to within 23 arc minutes of the horizon.

Another noteworthy advantage of the strip film system employing a Perspective Regeneration System is the ease with which clouds or ground fog can be realistically simulated. The cloud or fog strip film shown in figure 3 is of linear density but becomes exactly analogous to the real world condition when the Perspective Regeneration System compresses the view vertically and laterally in accordance with elevation angle. This compression parallels true fog or clouds in the real world where the attenuation of visibility is a function of the angle of view through the fog. Because the fog source is of linear density, it is relatively simple to provide accurately repeatable RVR's (Runway Visual Ranges).

Resolution capability of any film system is directly related to the resolution capability of the film and the film patch size used to provide a given field of view. Considering a 136° field of view to provide 95° fields to both pilot and co-pilot with a 54° central overlap angle, the instantaneous patch size required of 5-inch and 9-inch strip films is shown in figure 4. The patches for both strip film sizes are compared to the instantaneous patch size of a 70 mm cine-motion system. When one considers the relative film areas used for projection, it is obvious that the resolution of either strip film system far exceeds the resolution that can be expected from the 70 mm cine-motion system. Additionally, the resolution increases as the angle of view approaches the horizon because of the compression or minification of the film area.



* AVERAGE RESOLUTION AT 25° DOWN FROM HORIZON IS 4 MINUTES OF ARC

* AVERAGE RESOLUTION AT 25° DOWN FROM HORIZON IS 2.5 MINUTES OF ARC

* DEPENDENT ON LATERAL EXCURSIONS DESIGNED INTO SYSTEM FOR LOWEST ALTITUDES.

Figure 4. Comparative Sizes of Image Source

PERFORMANCE CAPABILITY OF THE SYSTEM

Details of system operation will not be discussed at this point except for a few principles that will serve to explain the flexibility of the Ground Effects Projector. In order to achieve altitude variation, we employ a 2:1 varifocal lens system as well as a duplicate set of film cassettes. The reason for this duplication is so that when the varifocal lens in either cassette system approaches its limit of operation the adjoining varifocal lens and adjoining cassette system can be gradually brought into operation to replace the original system. In this manner one can leap-frog from one system to the other to almost any simulated altitude desired as long as different scale strip films are available. Switching from one set of cassettes to the other is accomplished by a cross dissolve system exactly in the same manner as was done in the Apollo Simulators. It must be noted at this point that the switching process from one system to the other is absolutely invisible to the observer.

The next point to be discussed concerns the lateral translational capability of a strip film system. Again referring to figure 4 it is seen that the patch sizes used for instantaneous projection do not extend to the edges of the film strip. To simulate lateral translation the film strip is merely translated laterally with respect to the optical system and when visual limits are reached, cloud banks and fog enter the scene so that no abrupt terminations are encountered. Translations are simply simulated because the perspective regeneration system is fixed with respect to the optical axis and, therefore, the horizon remains fixed with respect to the observer and only the film terrain input moves in accordance with the simulated motion of the observer.

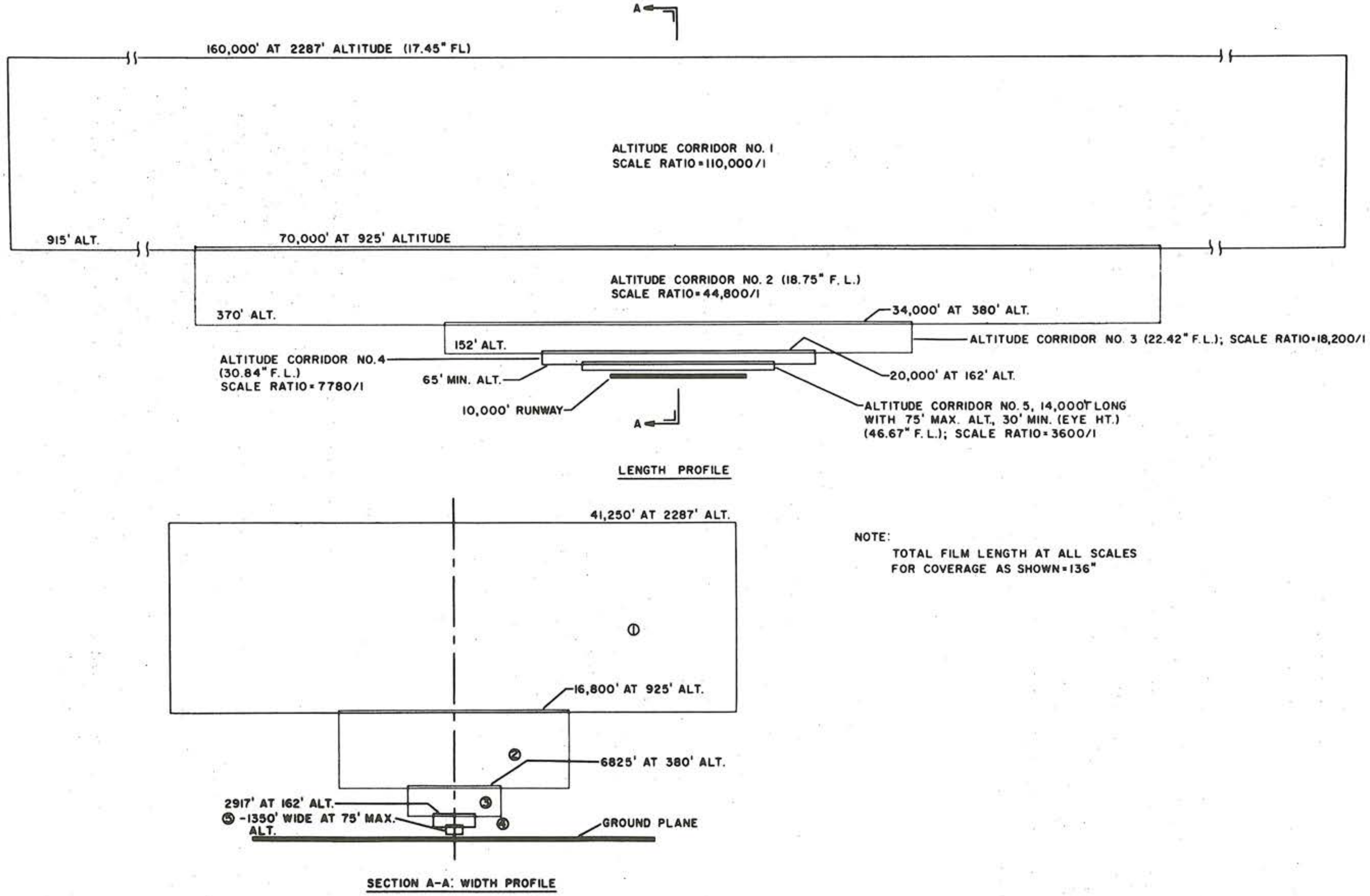
Longitudinal translations or forward velocity can actually vary from rearward motion to zero velocity or hovering simulation on up through simulated supersonic and hypersonic velocity since velocity is a direct function of linear film speed -- quite unlike a cine-motion film system where frame rate determines apparent velocity.

The angular degrees of freedom are easily simulated by well-known optical techniques employing scanning mirrors for pitch, cassette rotations for yaw and a derotating prism for roll.

As an example of the maneuvering volume of the Ground Effects System we may refer to figure 5. Each of the rectangles shown in the length profile and in the width profile represent strip films photographed and reproduced in the laboratory to different scales to simulate different mean altitudes. Using a 2:1 varifocal system and using five film strips of different scale we can simulate flight anywhere from touchdown up to a 2287 foot altitude where the aircraft can cross the film strip boundaries anywhere at any time with complete freedom. Note also the extensive width profile which is 42,250 feet at 2287 feet of altitude, 16,800 feet at 925 feet of altitude, and 1350 feet wide at 75 feet of altitude. A final observation on the compactness of such a film model is contained in the note on figure 5 where the total film length for all of the scales shown is only 136 inches.

At this point it would be well to mention that the film strip system so far described is used to generate only terrain views. The sky is separately injected by another projection system. The Ground Effects Projector System not only provides unusual realism for ground fog with exact repeatability of RVR in the manner described previously, but strobe lights are also generated in a unique manner so that frequency can be varied and the strobe effect will never appear to separate from the lamps themselves as very often is the case with cine-motion simulations. A final point to be considered is that the visibility of this system as far as runway lights and runway detail is concerned is too good and must be attenuated to simulate the real world view. The reason for this surprising characteristic is that runway and terrain detail are photographed at a relatively low altitude and all objects are therefore photographed at relatively close distances. This detail appears in absolute clarity on the strip film and when it appears just over the horizon it is generated by large scale film detail which is compressed by the optical system so that such detail appears unrealistically sharp and unrealistically too visible. We might add, however, it is far better to purposely degrade a view than to try to upgrade a scene where the detail is not present.

An additional advantage of the strip film system arises from the fact that the film is practically indestructible. The wear and tear associated with cine-motion systems does not occur with strip film because it is not an intermittent drive, rather it is run through a gate at a simulated aircraft speed which is inversely proportional to the real world scale. Furthermore, the cassettes are so designed that the film itself never comes into sliding contact with any other material; it is in fact supported on layers of cooling air while in the film gate. In addition to this cooling air flow, the strip film is never subjected to excessive heat because of the relatively low flux density of illumination required as a result of the large patch size used for projection. Should a film eventually deteriorate, the cost for replacement is minimal since it involves reproduction of a film length of approximately 12 feet.



NOTE:
TOTAL FILM LENGTH AT ALL SCALES
FOR COVERAGE AS SHOWN = 136"

Figure 5. Composite Coverage of Terrain for Five-Inch Strip Film System

LIMITATIONS OF STRIP FILM

Up to this point we have described the advantages of a film strip system without pointing out the limitations. So far as we know there are only three limitations associated with the Farrand Ground Effects Projector System. The primary limitation consists of an apparent lean of tall buildings, a defect which is introduced when regenerating perspective. Originally all detail is rectilinear, however, since buildings can only be represented in two-dimensions, when perspective is generated in the two-dimensional plane, the buildings are made to lean or point towards the vanishing point. For one or two-story buildings at reasonable simulated altitudes in excess of 500 feet the lean is not perceptible when flying at some forward velocity. This defect does not show up when landing on runways since runways are relatively flat with no vertical prominences visible.

The second minor defect concerns the appearance of buildings as we translate laterally in excessive amounts. Since building details are locked into the film we can never fly "around" them and so with large lateral displacements, buildings will always present the same face to the observer. Finally, the last limitation of a strip film system again derives from a two-dimensional film model where vertical prominences cannot be made to rise above the horizon. Fortunately, this limitation does not usually affect a commercial aircraft simulator.

CONCLUSION

In conclusion, it would be well to illustrate not only the size of a film strip system such as we have described but also the fields of view currently available. Figure 6 illustrates the fields of view that can be provided to both pilot and co-pilot using an L-1011 aircraft as an example. Figure 7 shows the film strip image generation or Ground Effects Projector feeding an Infinity Display System where both units are mounted to an L-1011 simulator cab.

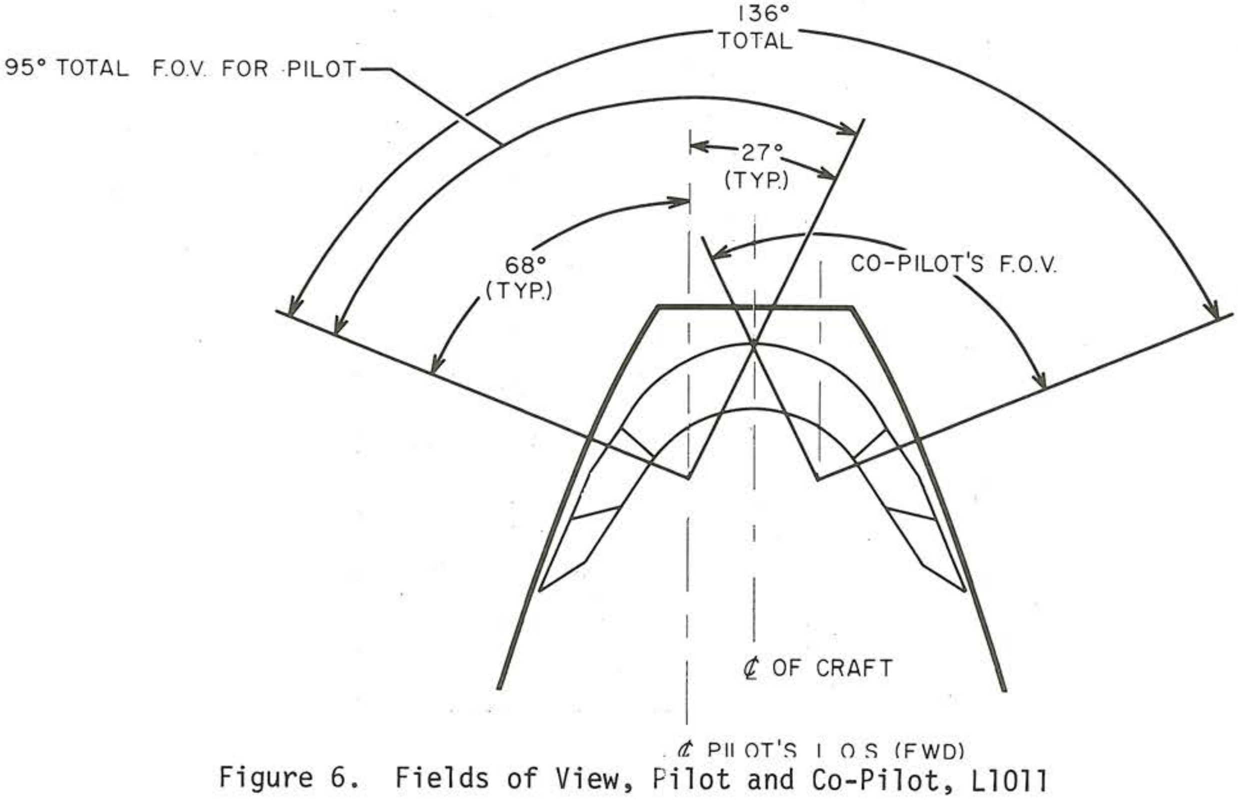


Figure 6. Fields of View, Pilot and Co-Pilot, L1011

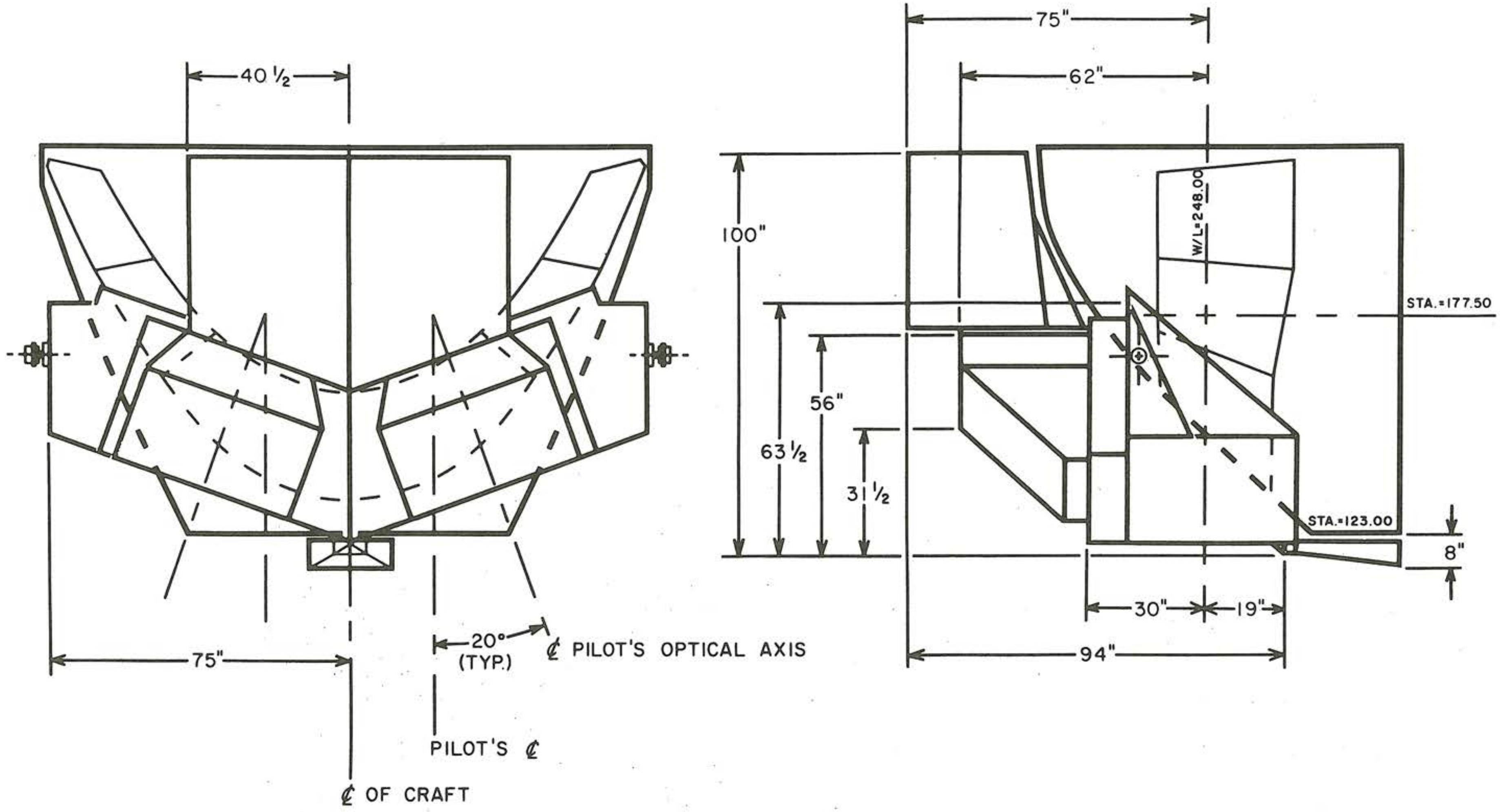


Figure 7. Visual Attachment Schematic, L1011

ADVANCES IN SONAR AUDIO SIMULATION

MR. E.J. WROBEL
Project Engineer, Naval Training Device Center

In order that students accept a training device, it is imperative that such a device provide realism, or else it will be merely treated as a sophisticated toy. This is particularly true when the training device patterns a specific operational equipment. Such things as the response to control movement, color of displays and readouts and the "feel" of the trainer contribute to the aesthetic relationship between the trainee and the device. This has manifested itself in the past, where because of the in-depth realism provided, enlisted Naval personnel were willing to sacrifice liberty hours in order to spend more time with the training device. What better index of favorable acceptance could one find?

One area of simulation, that has always posed problems, is that of audio sonar simulation. The human ear is an extremely sensitive sensor and very difficult to fool. The human ear is responsive to transients of very short durations, in the order of tens of milliseconds. Compound this with the wide variations in hearing response — both in amplitude and frequency — that occur between individuals by virtue of heredity, age, and history effects. Thus, if one generates an audio signal, that is not authentic, it will be evaluated as non-realistic by experienced listeners, but in-turn, differently by each individual. To rely on a collection of personnel in evaluation of sonar audio simulation realism can be an extremely frustrating experience.

Therefore, one of the fundamental problems associated with audio sonar simulation is a determination of what it is one has to simulate, and then a measure of the quantitative aspects of what it is that is being simulated. To rely on the query: "How does it sound to you?" is filled with danger. Perhaps a better way is to obtain at-sea recordings under calibrated conditions, then analyze these with an audio spectrum analyzer, and later use the same instrument to verify the authenticity of the simulated signals. Naturally, one must proceed with care, and limit himself to evaluating a limited number of signals at one time. For example, if the analyzer is used to ensure that the simulation equipment duplicates the aural response of an audio source taken singly, and then a similar procedure is employed to duplicate other audio sources, the probability that, when all sources are coupled together, the overall results; i.e., the sum of all aural contributors, will also be realistic and require relatively little adjustment. In this respect, it is imperative that the spectrum analyzer employed is not only adequate for the task, but that the operator of the analyzer be sufficiently knowledgeable of the limitations and virtues of this test equipment. The audio spectrum analyzer is an extremely valuable piece of test equipment in sonar audio simulation, when employed judiciously.

One frequently must consider the gains and losses associated with simulation versus stimulation in the audio sonar area. If one were to use portions of operational equipment in the training device, and inject simulated signals into such equipment, the question remains as to where in the system is it most advantageous to inject such signals. Obviously, a scheme where simulated signals are generated with the correct temporal and spatial relationships, and then fed into the "front-end" (hydrophones) of a sonar may require hundreds of audio channels. Such a scheme, while not necessarily unworkable, is somewhat impracticable.

In many cases, total simulation of the operational equipment audio processing channels is most desirable. After all, what is the ultimate goal? It is to realistically provide audio signals at some listening devices which appear to emanate from a real world. It is not important what means are used to generate these signals; only, the end result is of importance. Hence, in the ideal case, one simply requires a black box called audio simulation and a headset. This black box need not necessarily contain any components associated with the actual operational gear being simulated. Consider an audio channel where perhaps ten separate processing operations modify and act upon the signal between the hydrophones and the listening device. For training device purposes, the place to analyze the signals initially, is immediately before the listening device, as this may be where the desired signals require the least complexity in simulation.

Early attempts at training devices relied heavily upon the use of at-sea recordings, mostly on magnetic tape. While these were as realistic as the recording situation and equipment quality would allow, these techniques suffered from serious drawbacks, in that they were "canned" problems. For an initial and basic familiarization with sonar audio they may have been sufficient, however, the student generally could not exercise his controls, e.g., pulse width, operating mode, etc., as the recordings were unique to a specific set of sonar settings and environment. The student could at best simply listen.

Subsequent developments in audio sonar simulation involved analog techniques. A conglomeration of pulse generators, oscillators, noise generators and timing circuits would individually generate the various signals required for the particular bandpass characteristics of the sonar being simulated. Naturally, the broader the bandpass, the more complex the sonar and range of environmental conditions considered, the more outlandish the assortment of individual generators required. Figure 1 represents a typical simulation scheme of this type. Each line spectra of interest required a separate oscillator, sometimes variable in frequency. These were summed with various noise generators to provide the required signal at the earphones.

The audio simulation problem can become quite severe if one is concerned about obtaining realism. Effects such as own-ship noise, sea-state, target radiated noise, biological noise, diurnal effects, machinery noise, etc., may be significant, with associated requirements for simulation. Figure 2 shows the aural responses associated with a bottlenose porpoise within bandpass limitations of a particular sonar under consideration for a training device. It is apparent that this single object contributes heavily to the required simulation signals. Then, when one adds the requirements, resulting from additional noise contributors, the problem rapidly becomes monstrous.

Further progressive developments in sonar audio simulation involves using analog generators, as shown in figure 1. However, the timing circuitry responsible for synchronizing the signals to a real-life situation was replaced by digital signals from a central master processor. This technique was effectively used in the simulation of the AN/SQS-23 sonar in Device 14A2, Surface Ship ASW Attack Trainer.

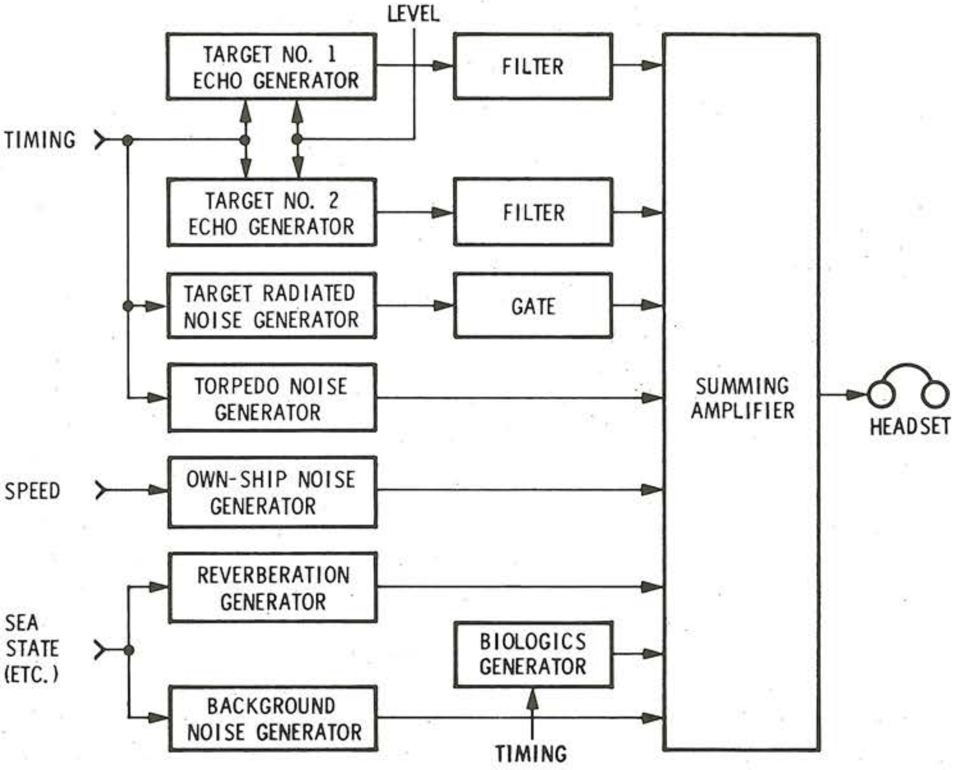


Figure 1. Analog Sonar Audio Simulation Block Diagram

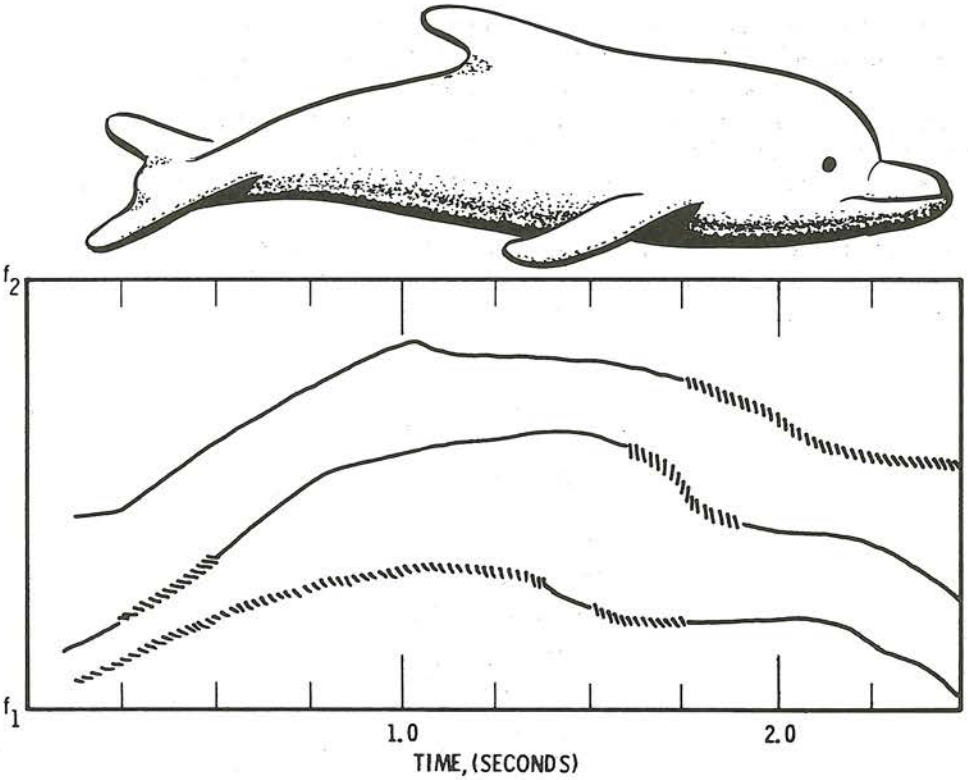


Figure 2. Aural Response of Bottlenose Porpoise

During the recent development of Device 14E19, Basic Operator/Team Trainer for the AN/SQS-26CX Sonar, additional breakthroughs in sonar audio simulation were successfully developed. This is the first system wherein sonar audio is generated by digital techniques. Figure 3 is a simplified block diagram of this approach. A sine-wave function is stored in computer memory in tabular form. Based upon the spectral sine components required at a particular time, this table is sampled at a rate corresponding to the frequency to be generated, and the results are held between sampling times in a register. Typically ten samples per cycle are obtained. Sampling times are in the order of approximately a microsecond. Additional spectral components are generated in the same fashion by time-sharing during the interval between sample times for other spectral components. In this particular training device, some 30 spectral components are generated simultaneously by such techniques. The sampled-and-stored output is then applied to a filter so as to remove higher order harmonics resulting from the sampling frequency. Audio signals of broad-band noise type character are also generated digitally by pseudo random techniques. A stepped sawtooth counter provides higher order harmonics associated with certain aural sources such as torpedoes and screws. The spectral line components and the noise signals are summed, filtered, and applied to headphones. The model employed for Device 14E19 considers audio signals resulting from own-ship, surface support units, submarines, torpedoes, sea-state, bottom, volume and surface reverberations, whales, porpoise, shrimp, pinnacles, ice and kelpbeds, which are of interest within the passband characteristics of the operational AN/SQS-26CX sonar. These signals are synchronized with their video counterparts in both time and space, resulting in extremely realistic simulation.

Generation of audio signals by purely digital techniques is not restricted to sonar simulation, but may be extended to other related disciplines. The beauty of such techniques is that the reliability is outstanding and the system is extremely flexible to future change within the constraints of the initial design, as virtually no hardware is involved. Also, accuracy problems resulting from drift and aging of analog circuitry are non-existent.

The art of audio sonar simulation has witnessed tremendous advances in the last decade. It is interesting to speculate about what technological advances the next decade will bring.

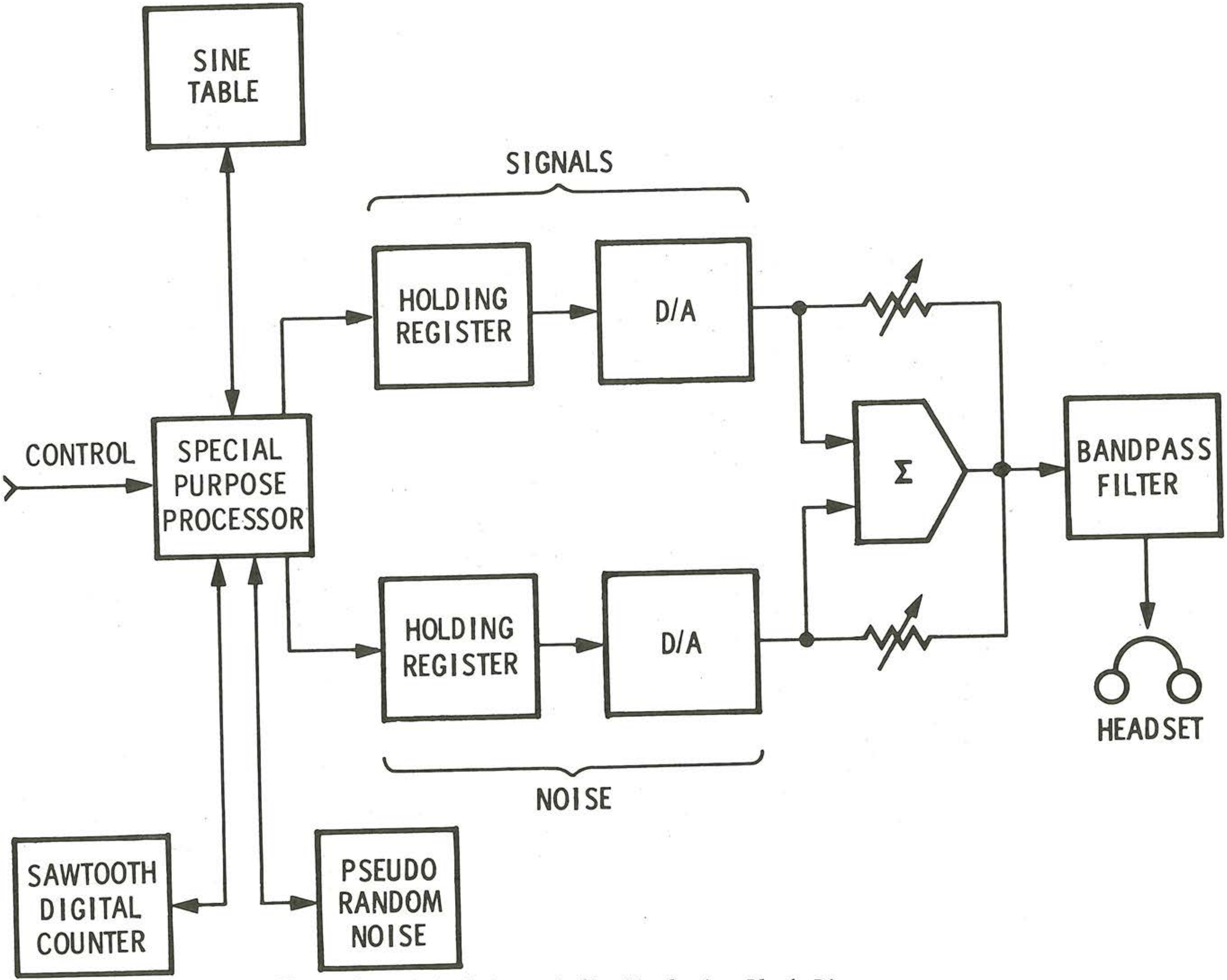


Figure 3. Digital Sonar Audio Simulation Block Diagram

MULTIPLE OSCILLOSCOPE TRACE GENERATION FOR ANALOG COMPUTERS

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and
PAUL E. SPEH, Senior Analog Computer Programer ,
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In many training and simulation situations, which utilize analog computers, it is desirable to have the option of viewing multiple, independent displays on a single cathode ray tube. However, most small analog computers are equipped only with a single trace capability oscilloscope and the added expense of purchasing a multitrace unit often cannot be justified. Furthermore, general purpose multitrace oscilloscopes are limited in the number of traces which can be produced and do not usually permit one to generate simultaneous X-Y and X-t displays.

At Florida Technological University the analog computer system consists of an Applied Dynamics Corp. model AD-5 computer equipped with four remote, time shared terminals, each of which is equipped with a single trace storage oscilloscope for display. While investigating a manual tracking problem we found that at least three independent traces were required at each of the four terminals. Therefore, a multitrace display system operating under computer control and utilizing the existing single trace oscilloscopes was designed. The main design requirements for the system were first, that it provide maximum applications flexibility since the computer is used by a number of individuals for research as well as instruction. Second, the tracking problem being studied called for a minimum of three traces, each to be independent of the others with respect to amplitude, position, and timing. Third, the limited computing power of the machine necessitated a design which would not decrease the machine's computing capability significantly. The figure depicts the system which was finally chosen. This system is completely under machine control and requires neither external circuitry nor machine integrators.

The six input signals, which can be either internally generated by the machine or externally generated, are brought to the inputs of six individual summing amplifiers, as shown in section 1 of figure 1. The potentiometer at the second input of each amplifier is used as a positioning control.

In section 2 the outputs of these amplifiers lead to a device peculiar to the AD-5 computer, the switching amplifer. The switching amplifier is a standard summer amplifier whose inputs can be switched off independently by a standard TTL logic signal. Such a signal can be generated elsewhere in the computer.

The switching amplifiers in section 3 merely collect the various switched inputs and route them to the appropriate oscilloscope axes.

In principle the amplifiers in sections 2 & 3 of the schematic could be consolidated into a single amplifier having four switched inputs.

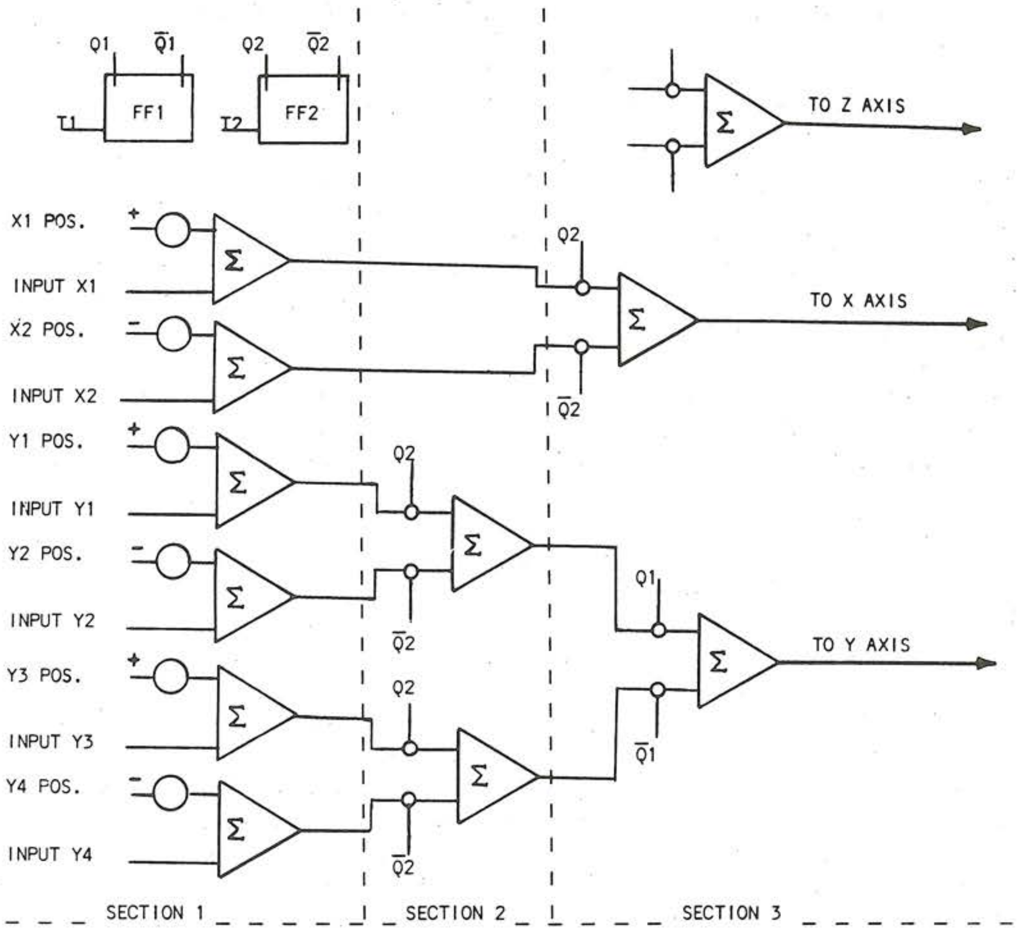

Figure 1. Schematic of the Multiple Trace Generating System

At present, the switching signals are derived from the timing generator of the computer, however, they could be externally generated or program controlled. The flip-flops shown in section 1 of the figure condition the timing signals to the required TTL levels.

It can be seen from the figure that the maximum number of signals that can be displayed depends only upon the number of available inputs on the switched amplifiers.

Now in use, the display control system has proved to be an invaluable aid in generating displays which were previously unattainable with the equipment on hand. At present it is possible to show simultaneously an X-Y plot, a waveform plotted versus time, and an illuminated spot showing the position of a joystick controller.

Although only three signals are presently being displayed, the system is capable of generating quite a few more. The two main limitations on the ultimate number of displays so generated are the number of switching amplifiers available and the resolution of the oscilloscope screen.

The possible applications of this system are only limited by the imagination of the user. Current applications at Florida Technological University include such diverse areas as speech sound analysis, ecological limit cycle simulations, and human operator performance studies.

ELECTROMAGNETIC COMPATIBILITY OF TRAINING DEVICES

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INTRODUCTION

Whenever a training device containing electronic equipments is operated in its intended operational environment, at designed levels, without degradation due to interference, it is called electromagnetically compatible. This paper will give some background history on interference specifications, their application to training devices, several problems that have occurred, present status of trainer EMC, and a forecast of what contractors may expect in the EMC (Electromagnetic Compatibility) area in the future.

BACKGROUND OF INTERFERENCE SPECIFICATIONS

The earliest electromagnetic interference specifications were written 25 years ago to control interference to voice communication receivers from aircraft electrical systems. In 1954, the Bureau of Ships, made revision to a draft of MIL-STD 225 and issued it as MIL-I-16910. The "C" version of this specification was dated 26 October 1964 and contained the radiated and conducted interference limits and test procedures to be used for Navy shore and shipboard electronic equipments. The Navy Bureau of Aeronautics generated another version of the proposed MIL-STD-225 which resulted in MIL-I-6181. In August of 1968, MIL-STD-461, "Electromagnetic Interference Characteristics Requirements for Equipment" was issued and superseded the general Army, Navy and Air Force interference specifications, including MIL-I-16910C which the Naval Training Device Center was using. The MIL-STD was a coordinated document containing interference test limits. The test procedures were documented in MIL-STD-462, "Electromagnetic Interference Characteristics, Measurement of," dated 31 July 1967. These Standards were meant to be used as a source for tailoring the interference requirements to meet the needs of the equipments being procured.

NAVTRADEVCEN INTERFERENCE CONTROL BACKGROUND

The Naval Training Device Center EMI philosophy prior to 1968 was to reference MIL-I-16910 directly in the trainer specification or indirectly through MIL-T-23991. Testing was occasionally performed. In 1968 MIL-STD-461 requirements began appearing in major training device specifications. The Electromagnetic Interference Control Plans became part of contractor submitted documentation. Some testing was required.

In an effort to avoid some of the less-than-desirable practices in cabling and grounding viewed in the field, MIL-T-23991C, dated October 1968, had new sections devoted to these areas. Additionally, the Air Force Handbook on Electromagnetic Compatibility was referenced as a design guide for meeting the electromagnetic interference suppression requirements appearing in the trainer specifications.

The detail specifications began having paragraphs requiring that elevated floor systems be incorporated into the overall grounding system, using MIL-STD-1310, "Shipboard Bonding and Grounding Requirements for Electromagnetic Compatibility" as a guide in the electrical bonding area. Crosstalk and signal-to-noise ratio requirements for audio communications systems were also included to eliminate these problems in future systems.

PAST PROBLEMS

A survey of recorded past interference problems revealed that trainers have not been a source of interference to other systems. Training devices also have been relatively free of being troubled by electromagnetic wave radiating systems (radar, TV). Interference that has been troublesome from external sources has usually entered the training device through the prime power leads. These have been of a transient nature such as large loads either going on or off the line and lightning effects.

It was revealing, however, to find that the majority of interference problems are self-induced. The following five cases are a small sampling of self-incompatibilities that have occurred:

Case 1 - An interference problem on a Sonar Tactics Trainer that required significant time and manpower to remedy was reported, with slight changes, as:
The 400 Hz and 60 Hz interference problems in the Sonar Systems have reached an unsatisfactory level. The major source interference appears to be topside in the cabling. One of the sonar receiving sets has 400 Hz interference internally as well. The interference problem from the cables appears in the audio circuits and also on the Scan Presentation. This interference appears at certain bearings only and these bearings can be made to change by rearranging the cables. It is felt that the following list of discrepancies have contributed to this problem:

Intermixing of signal cables and 400 Hz and 60 Hz power cables in the cable runs

Failure to shield signal cables and power cables sufficiently

Many of the cables are too long and have been doubled back or coiled rather than cut to the proper length.

The grounding system has in many cases been wired such that ground loops are possible.

After the installation of a Torpedo Modification, the interference seemed to increase. It is felt that the installation crew disturbed the cable runs under the Attack Center.

Case 2 - The following problem is associated with a Weapon System Trainer located in a van:

> At present there is an intolerable amount of feed-through from the pilot's ICS to the sonar ICS and vice versa. When independent hops are given, there is confusion when trainees start to talk on both ends at the same time. Maintenance intercom also feeds into the trainees' ICS system. Background noise when selector buttons are pushed is too loud.

Case 3 - Some discrepancies on a Flight Portion of a Weapon Systems Trainer read as follows:

a. ICS too noisy
b. UHF Comm (Main) noisy (intermittent)
c. Computer stops for unknown reason, requires master clear and start to resume operation
d. Computer stops, program is destroyed, requires re-load of program to resume operation.

Case 4 - Another problem on an Operational Flight Trainer:

> Random erroneous signals are inputed to the computer whenever the air compressor in the trainee station cycles on or off.

Case 5 - A problem on a Radar/MAD Trainer

> Interference from a 60 to 400 Hz frequency converter used in the system was causing noise to appear on the radar land-mass displays.

Most of the above problems have been taken care of, leading us to the present status of EMC at the Naval Training Device Center.

PRESENT STATUS

EMC field problems of the Case 1 magnitude do not currently exist. Field problems are becoming more scarce due to improved interference design practices and the contractor's awareness and ability to locate and rectify them prior to device acceptance. The "sore thumb" that needs medication now is the reduction of noise and crosstalk in the trainer audio systems.

GROUNDING, BONDING AND CABLING

Grounding systems are being improved. Elevated floors of the bolted stringer type are being used as an essential part of the trainer grounding systems.

In the area of electrical bonding practices, some contractors now have standard practices and procedures that are documented as company standards and have been found to be satisfactory. Not all contractors have had the opportunity to establish such practices and such matters are left to the individual expertise of the mechanical or electrical designers at the time of the particular trainer design.

An area which has been vastly improved in the past three years is cable categorization and separation. The planned routing and grouping of power and signal cables, according to interference producing capability and susceptibility to cable coupled interference in conjunction with improved grounding system, has probably done more for solving difficult problems than any other single item. Cabling installations are being designed in a fashion analogous to laying out the signal connections on a multilayer printed circuit board.

INSTALLATION SITES

Installation sites are studied in an effort to define risk areas to the local environment due to the probable emissions from the trainer and the risk areas of the environment to the trainer. As new buildings are planned to house training devices, electrical prints are reviewed to ensure that the grounding systems will be satisfactory for electronic equipment grounding and lightning protection.

MIL-STD-461 INPUTS

From a MIL-STD-461 viewpoint, the major training devices (that are closed systems (non-antenna type)) usually have three design requirements in the specification to control susceptibility due to transients on the prime power lines, conducted emissions being generated by the trainer and going out on the prime power lines and radiated emissions from the training system. Commercial off-the-shelf equipments such as computers are not required to be shielded. However, there is concern for the radiated emissions from the cables since they may become fairly efficient radiators and the location of many of the trainers are near operational equipments. The current specification input often has the following appearance:

> Electromagnetic Interference Suppression
> All electronic equipment other than off-the-shelf equipment to be furnished by the contractor shall be designed to meet the following requirements of Class 1C equipment listed in table 2 of Mil-Std-461: CE03, RE02, and CS06. Commercial off-the-shelf equipment shall be modified, if necessary, to meet the requirements of CS06 for power inputs and RE02 for cabling external to the equipment enclosures.

TESTING

Experience has indicated that the cost-effectiveness of testing to the electromagnetic interference suppression requirements is a variable determined by the installation environment. The current philosophy is to do as little testing as possible. Testing may be limited to checking the grounding system to ensure separation of the various categories of grounds and the electrical resistance across electrical bonding joints. Interference in the intercoms is and has been such a nuisance that it has been singled out for special attention. A general specification for communication systems for training devices (MIL-C-29025 TD) was issued 14 September 1971.

FORECAST FOR THE FUTURE

To extinguish the intercom interference fire, it is expected that intercom systems will be required, as a minimum, to meet the background noise, signal-to-noise and crosstalk levels prior to device acceptance. It is expected that a document on grounding and bonding will be written to standardize the techniques and the hardware for training device systems. The EMI Control Plan will be required to be submitted on major training devices. Its use is expected to diminish over the next five years as the Center's contractors become experienced in interference control design.

MIL-STD-461 is undergoing a change to make it more effective. It is expected that NAVTRADEVCEN specification will contain the "design to meet" requirement unless installation environment necessitates the "shall meet" requirement. When the "shall meet" clause is used, the specification will also have testing requirements.

Facility requirements will continue to be viewed with the purpose of ensuring that the training system and the facility will have a high probability of being compatible. Areas of interest will be existing cabling, grounding systems, power distribution and interference risk areas from transmitting systems.

SUMMARY

The Naval Training Device Center has had its share of interference problems, particularly in the area of self compatibility. Although the random type problems are being eliminated through improved electrical grounding and cabling techniques, power line transient and, particularly, audio communication interference problems continue to exist. Efforts are being directed to ensure their non-reoccurrence through improved specification requirements, design monitoring and contractor education.

SESSION V

Thursday, 17 February 1972

Chairman: Mr. Victor G. Hajek
Head, Air-Warfare Department (ASW/Environmental)
Naval Training Device Center

NEEDED: A STRATEGY FOR THE APPLICATION OF SIMULATION IN THE CURRICULA OF PROPOSED TRAINING SYSTEMS

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Naval Training Device Center

During the past year Naval Training Device Center personnel have been reviewing curricular materials which have established how the major Navy training simulators are used. This experience has convinced me that simulators are making a significant contribution to Navy training. Yet as I have studied simulator use patterns, it has become apparent that modern simulation technology has provided training capabilities that have yet to be absorbed into the working curricula of training activities. Tradition, rather than analysis, remains the prime rationale for designating which training objectives should be accomplished in simulators.

The study of simulator curricula is a part of a continuing device utilization measurement program, established under OPNAV Instruction 10171.4A. Within this program we are attempting to identify the purposes for which training devices are being used, the instructional methods being employed, and the relative cost of these various employment patterns.

There are various reasons for collecting and displaying historical data on how simulators are employed in Navy training. One of the reasons is to build a base of data and techniques for use in projecting future utilization patterns and cost on both existing simulators and proposed simulators - information that will be useful in trade-off studies for justifying the continued use of existing simulators and for justifying the development of major new simulators.

The curriculum, perhaps more than any other factor, determines the use pattern of a major device. This may be obvious to many people. But, when you are involved in the development of simulators, at the Naval Training Device Center, or as a contractor, you are aware of the important capabilities of the simulators, and frequently assume that because these capabilities exist, they will be used. This is not true. The configuration of the simulator sets certain limits on the use patterns, but it is the curriculum that determines how the simulator is actually employed.

Because of the importance of the curricula in establishing the utility of major simulators, certain individuals at the Naval Training Device Center are providing fleet training programs with technical assistance in the development of curricula materials. Either as in-house projects, or with the aid of contractors, Education Specialists, at the Center, are helping to develop detailed syllabi, and instructor handbooks containing exercise plans designed to meet fleet training objectives.

With a new awareness of factors, that determine how a simulator will actually be used, it has become evident that training devices should not be conceived merely as simulators of operational systems. Simulators should also be preceived as elements in the larger training system. In turn, the curricula for simulators must be viewed as elements in the curricula of larger training systems.

Figure 1, a simple system diagram, identifies major elements in a training system. It makes visible certain decisions that should be made during the design of a simulator and the development of the curriculum for the use of the simulator. This is a theoretical system concept. I am not suggesting that it is a model of what actually takes place in the design or functioning of training systems.

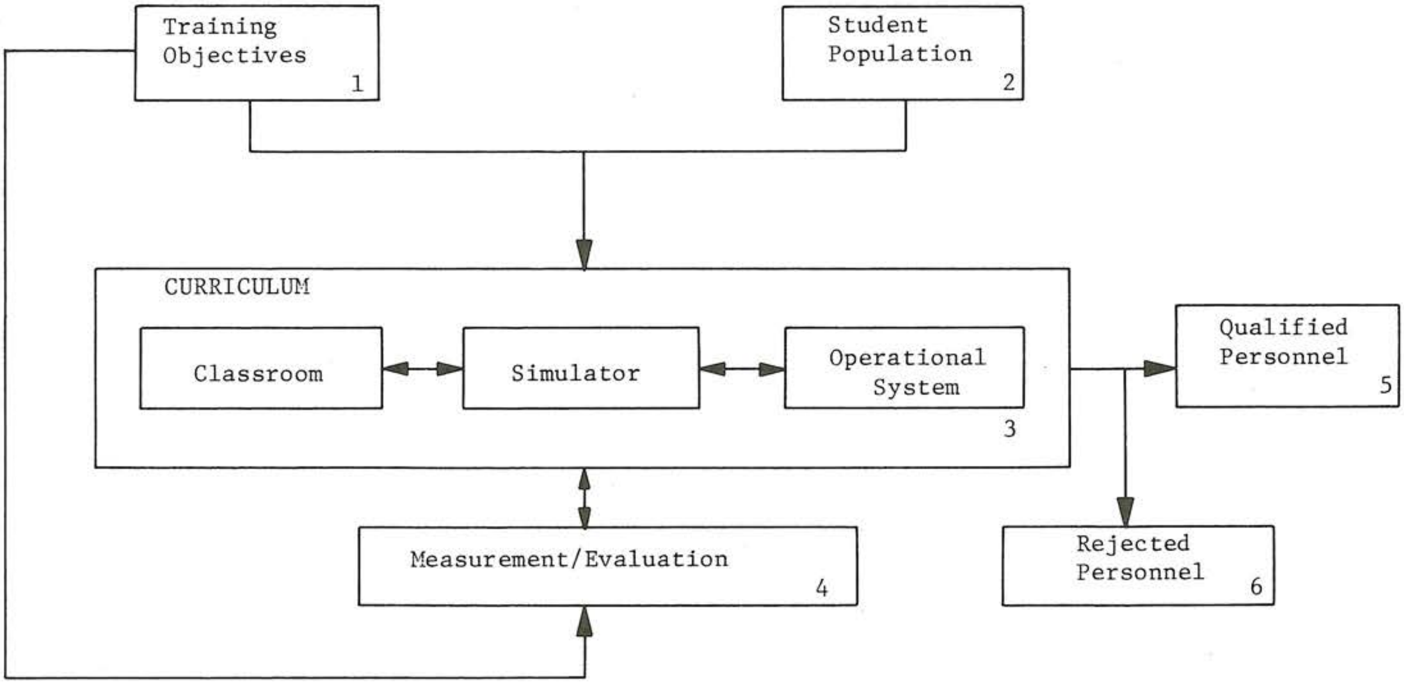

Figure 1. Training System

Based on an estimate of the individual and team skills required for the operation of a new weapon system, training objectives (element 1) are specified. Characteristics of personnel to be designated as operators of the system (element 2) are also designated. A curriculum (element 3) is planned, which is capable of training the specified personnel, to meet the training objectives. One of the critical functions of the curriculum is to designate a mix of training resources. The curriculum should designate which individual and team skills are to be achieved in the classroom, which are to be achieved in various forms of simulators, and which are to be learned in the operational system. It should also specify what level of skill in each instance is to be attained in the various instructional environments.

A measurement and evaluation program (element 4), should monitor student and team behavior, ensuring that prerequisite skills are learned before advanced skills are attempted. A student or team should be released from the system only after the training objectives (element 5) have been achieved or when it is projected that the students will not be able to meet the objectives within acceptable time or dollar limits established within the training system.

When the basic mix of resources within the curriculum of a new training system is specified, prior to the development of training hardware, the training devices or simulators can be configured to perform the specified role designated for simulators in the overall training system. This role would not be just something that happens without thought. It would be based on a set of carefully considered decisions concerning the role of simulation in the training system. The simulator would then be configured to ensure successful achievement of that role. The curriculum for the simulation would be responsive to that role. In addition, the utilization pattern of the simulator could be measured against that role.

A set of special competencies or techniques are required in designing a curriculum specifying the use of a training device as an element of a larger training system. Some of these techniques already exist in a usable form, others are in a primative state of development. See figure 2.

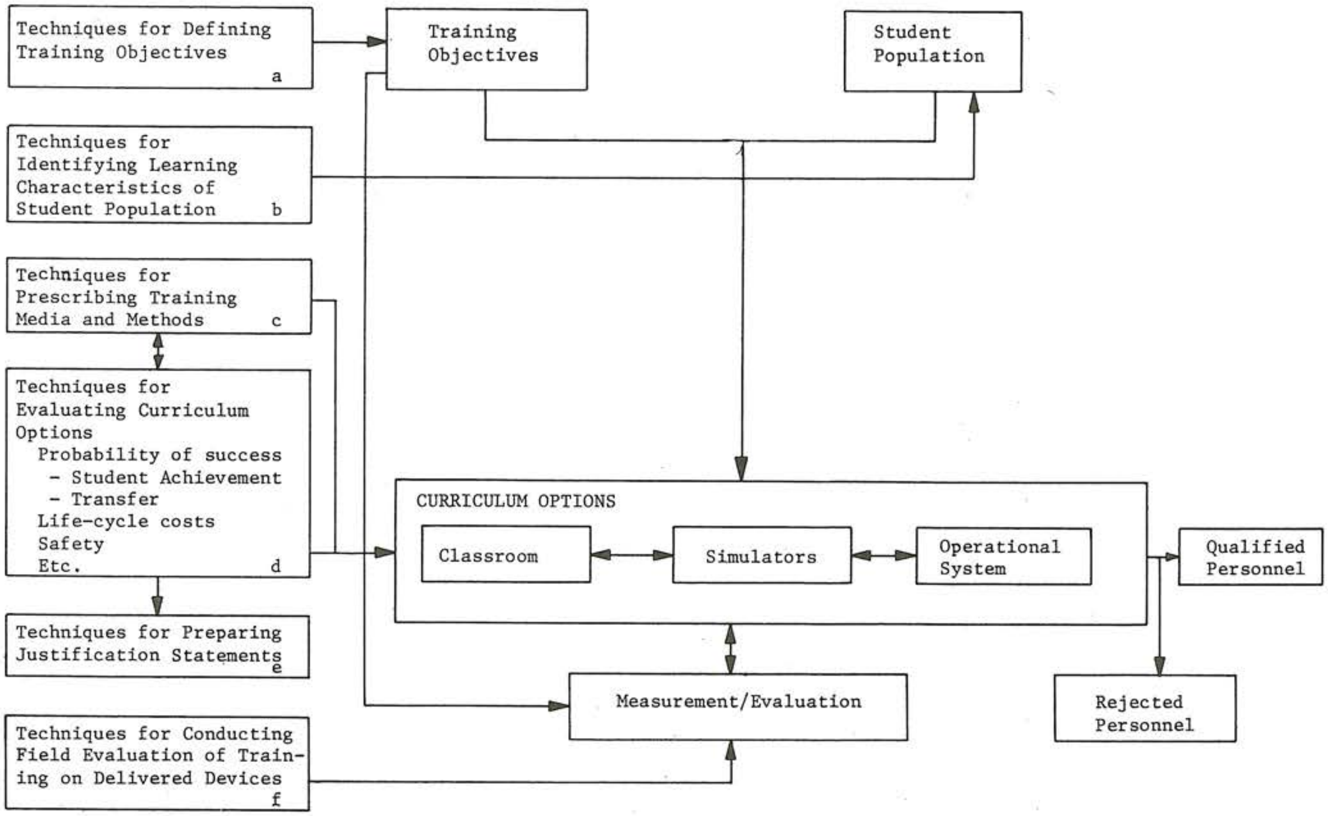

Figure 2. Techniques Required for Planning and Evaluating Training Systems

Techniques exist for defining training objectives (element a), as well as for identifying specific learning characteristics of a student population (element b).

However, we are a long way from having a set of strategies or methods for prescribing which forms of media, and which methods to use in achieving specified types of training objectives with various types of students (element c).

The curriculum designer has a role similar to a medical doctor in seeing a patient in his office. Just as the medical doctor diagnoses the condition of a sick patient and prescribes medication and therapy for the patient's recovery, the curriculum designer must diagnose the condition of a set of students, consider the skill building resources that can be brought to bear on the problem, and then prescribe one or more ways that the students can achieve the desired skills. Each prescription should contain a specified mix of learning experiences, the classroom, various forms of simulation, and the operational system. This mix of resources can only be considered in the context of the training system.

Once two or more curricular options with specified mixes of training resources have been identified, the next step is to evaluate them and select one for implementation. To do this we need information that does not exist, or at least is not organized for easy use. Evaluation techniques (element d) should include a way of estimating the probability of success for a proposed training system, success in terms of student achievement. We need usable and accepted guidelines for projecting the extent of transfer of learning that will take place, from a specified training system, to an operational system. These problems of measurement and the projection of achievement and transfer are receiving increased emphasis at the Naval Training Device Center.

Considerable effort at the Naval Training Device Center has been spent in developing techniques for projecting life-cycle costs on proposed simulators, and on collecting historical operating cost data on existing devices. Usable techniques are available. We also have techniques for comparing the relative cost of conducting an exercise in the operational system and in the simulators. Through the use of these projections, cost of ownership for proposed simulators can be one of the factors used in trade-off studies leading to a decision concerning which segments of a training program should be conducted in simulators and which in the operational systems.

The evaluation of a trainer and its curriculum in terms of projected student achievement, transfer and cost per student graduate can, in many instances, be useful in justifying the continued support or development of a simulator before budget and program analysts at the Department of Navy and Department of Defense levels (element e).

After a simulator and its exercise plans have been developed, as an element within a training system, a field evaluation should be conducted to determine if the training objectives for the simulator are being achieved (element f). At the present time, other types of demonstrations are required. We require the contractor to demonstrate that the simulator meets engineering specifications, including performance, maintainability and reliability. As a part of the maintenance training courses, students are required to demonstrate their ability to properly maintain the simulators by solving a series of carefully selected problems on the trainer - demonstrating that the maintenance course objectives have been met. We need, now, techniques for demonstrating that the training device is meeting the training objectives for which it was built.

As previously stated, at the heart of the problem of how to employ a simulator in a training system is the problem of selecting a mix of training resources. Which objectives can and should be accomplished in simulators, which in the operational system. A related question is what level of skill should be achieved in the simulators, before proceeding to the operational system?

Table 1 depicts six different mixes of training resources, ways that simulators are being employed in training systems.