

## USE OF CATHODE-RAY TUBES AT INSTRUCTOR STATIONS

DR. E. A. STARK AND MR. J. A. PUIG  
The Singer Company, Simulation Products Division  
and Naval Training Equipment Center, Respectively

The incorporation of cathode-ray tube displays in flight simulator instructor stations will permit the masses of data available in the simulator to be organized for more rapid, meaningful interpretation. The CRT can display relevant data, when needed, in any format appropriate to each instructional task. Experience with current CRT instructor stations is reviewed, together with the instructional tasks accomplished in flight simulators. Recommendations are made for the further definition of the simulator instructor's tasks, and for the extended application of CRT'S. Emphasis is placed on the analysis of requirements for the display and formatting of instructional information.

### 1. INTRODUCTION

Although flight simulators are sometimes thought of and used as substitutes for aircraft, they are in fact unique tools having unique capabilities and limitations. They can not only be effectively practiced in flight training, but can also support training in a variety of skills and under circumstances which cannot be safely and/or economically approached in the aircraft. In addition, they have inherent capabilities for optimizing learning, which are currently unavailable in the flight environment.

The aircraft, its environment and its interactions with the crew are represented in the simulator by means of a computer. Because the computer deals with all of the parameters defining the state of the aircraft, the characteristics of the environment and the performance of the crew, it contains the basic data required to support a highly flexible and effective interface between the student and the instructor. The quality and efficiency of training is largely a function of how well the simulator/instructor interface is implemented. The quality of the interface, in turn, depends heavily on the relevance of the displays and controls at the interface, for the tasks performed in the conduct of training. Many simulator instructor tasks are closely analogous to those performed by the flight instructor, but some are unique to the simulator. In each case, data are available to the simulator instructor which are not available to the flight instructor, and unusual capabilities are available for the control of simulator training conditions. Properly mediated, these data can be used to greatly enhance teaching.

### 2. INSTRUCTOR TASKS

Simulator instructors and flight instructors perform six basic tasks in the promotion of flight crew training. Optimization of training in both ground and airborne settings requires efficient task-relevant information exchange and training control in each of these tasks.

a) Briefing. Effective student practice requires preparation immediately prior to the practice session. The instructor's briefing covers the procedures to be used in that particular lesson—e. g., the maneuvers to be practiced, likely sources of error, performance standards and grading criteria, and appropriate communications procedures. It may also include special instructions based on the needs of individual students.

b) Demonstration. Both in flight and in the simulator, demonstration is used extensively to familiarize the student with the sequence of events, the peculiar problems, and the performance standards associated with each flight task. Demonstrations give the student an overall impression of the maneuver or task to be practiced, and help him to associate required procedures and significant maneuver events with that impression.

c) Performance Monitoring and Diagnosis. During student practice, the instructor monitors the performance of the student (in the aircraft or simulator) to identify deviations from prescribed performance and to diagnose possible causes of these deviations. In the aircraft, the instructor is exposed to essentially the same stimuli as the student, and performance monitoring involves a continuous comparison of observed performance with the standards defined for the task.

Where performance standards are ill-defined, and where the practice conditions tend to vary, instructor flight experience is valuable in making meaningful diagnoses of learning problems.

Where performance standards are well-established and clearly defined, and where the conditions of practice can be thoroughly controlled, instructor flight experience is less critical.

d) Coaching and Guidance. The instructor must occasionally make inputs to the student to remind him of procedural steps and performance standards, and to anticipate potential errors. These functions are based on the information collected in the monitoring process, as it is compared with known or displayed standards, and with previous experience with performance trends in that task or maneuver. Much of the guidance task depends also on knowledge of individual student capabilities and response tendencies. Typically, guidance is more effective when the instructor knows something of the student's past history and his approach to learning.

e) Evaluation. Continuously throughout training, the instructor must evaluate progress to identify learning trends, to prescribe further training and remedial training, and to assign a grade or score describing the quality of student performance. Evaluation not only defines requirements for future training, but it also establishes a basis for the comparison of students with each other. As a result, the evaluation process must be as objective as possible to preclude erroneous allocation of training sessions and to minimize errors in the assignment of grades.

f) Critiquing. Efficient learning requires that the student's errors be identified, and that means be developed to correct or avoid them in subsequent practice. Post-lesson critiques and debriefings are used to summarize performance and performance trends observed during practice, and to review approaches to improving performance in subsequent sessions. Instructor notes, standardized instructor checklists and the instructor's general impressions are used in post-flight debriefing. Frequently, print-outs of relevant parameters and, occasionally, dynamic recordings of performance are available in flight simulators to facilitate

the debriefing process.

The simulator instructor has three additional responsibilities requiring attention in the development of efficient and effective interface systems, which are relatively unique to the simulator.

g) Simulator Setup. Prior to training, the simulator must be configured to the requirements of the training situation. Environmental conditions, fuel status, gross weight and center of gravity, stores loads, radio facilities, geographic position, and the simulator operating mode must be established to provide the practice conditions required. In addition, simulated malfunctions are programmed to provide practice in emergency procedure and degraded-mode operation.

h) Program Modification. During training, the instructor must continually estimate the value of the prevailing training conditions for promoting efficient learning. Where student performance is inadequate, the instructor may choose to modify the training situation to meet the needs of the individual student. This can be done in flight, but is more within the capability of the simulator.

i) Communications. The simulator instructor may act as the operator of the ground radio facilities with which the student must communicate. Many ground facilities can be simulated without voice inputs. In some simulators, voice inputs are simulated with taped messages and in others, phonemes or words are stored in random access memory and a program synthesizes messages by stringing these stored elements together for output. In most cases, however, the instructor must provide voice messages for GCA, air traffic control and tactical problems.

### 3. EARLY INSTRUCTOR STATIONS

These tasks have been accomplished in simulators, over the years, in a variety of ways. Early flight simulators were used to teach contact flight skills. The responsibilities of and the information provided to the instructor were minimal. Later trainers were used to teach instrument flying and radio navigation; the instructor progressed from adjusting rough air and regulating the relative volume of radio range signals to monitoring RPM, airspeed, altitude and heading, and finally, inserting a limited

variety of malfunctions. In the C-8 trainer, produced in 1945, the instructor had fewer than two dozen indicators and controls to work with. In addition, the trainer had a mechanical "crab" which left an ink trace on a chart of the navigational area. The "crab" provided an important instructional capability: the instructor could now monitor flight path control to a degree never possible in flight, and a series of prescribed flight patterns was developed to facilitate evaluations of heading, turn rate, attitude and ground speed control.

Over the years, simulators were improved, but most improvements were based upon engineering technology. Developments in computation, hydraulics, servo-mechanisms, optics, and other technologies provided better and better representation of more and more of the flight environment. Improvements in computation brought with them increases in the kinds of information available for use by the instructor, and increases in the ways in which the training situation could be manipulated for improved learning transfer to the flight environment. As control and information capabilities increased, the interfaces between the instructor and the simulator, and between the instructor and the student, became more meaningful.

Increased emphasis on simulation during the Korean War and during the development of the first commercial jet transports, together with rapid advances in simulation-related technologies, resulted in rapid increases in simulator capability and instructor responsibility. Trainers developed early in this period were used to train instrument flying and radio instrument navigation skills but, very shortly, procedures training capabilities were incorporated so that training could be given in specific aircraft types. In 1950, the C-11 trainer, designed to represent aircraft of the F-80 class, had some 29 displays and indicators and 41 controls at the instructor's station. By 1952, the B-47B trainer had an approach deviation recorder, a ground track recorder, and well over 200 indicators and controls, used in training a pilot and a copilot. Later devices, used in training pilots and radar operators, made even more demands on the instructor's attention. Some simulators included positions for two instructors at the same console, one to train the pilot, the other to train the radar or tactics operator, with "instructional" and

"simulator operating" tasks divided between them.

By the late 1960's, it was apparent that the size and complexity of the instructor's station was taxing the capacity of the simulator instructor; each instructional task required searching among a large number of switches and knobs for those relevant to that task, then searching again among the cockpit repeater displays and the simulator and problem status indicators for the information needed to monitor, evaluate, and guide the student's performance.

Although instructor station design philosophy has always dictated grouping components by instructional function and by similarity with the cockpit, the complexities of pilot and flight crew tasks, and of the instructional process, made these principles difficult to implement. In general, instructor consoles were organized to group the controls and displays relevant to the various simulator and aircraft systems by function and by system. Environmental controls and displays were in one group, components related to engines in another, fuel in another, and malfunctions grouped by system in another console area. Flight instrument repeaters were frequently grouped exactly as in the aircraft.

In monitoring a procedure, then, the instructor was required to remember the prescribed sequence of control actions, the instrument indications associated with each, and the location of all of this information on his console. If he wanted to insert a malfunction, he had to locate the appropriate insert switch, and recall the new set of display locations associated with the malfunction procedure. Monitoring inflight procedures was somewhat more complex, in that it was usually necessary for the instructor to analyze aircraft handling skills along with the procedural performance, requiring further division of attention and display interpretation.

Various attempts have been made to consolidate control and display functions and to time-share console areas and components to reduce the complexity and the size of the instructor station. Of the earliest attempts at simplifying the instructor's station is represented in a system developed by the Naval Training Equipment Center (then the Naval Training Device Center). This system is used

to monitor student procedures.<sup>(12)</sup> The steps associated with a selected procedure are projected on the rear of a screen, so that each step is adjacent to an indicator light. Trainee execution of the step results in lighting of the corresponding indicator. This display provides immediate indication of in-sequence and out-of-sequence procedures.

Systems have also been developed to simplify the insertion and deletion of malfunctions, and to reduce the hardware and the console space devoted to malfunctions. In one system,<sup>(4)</sup> malfunction titles are arranged by system in matrices of indicator lights. Malfunctions are inserted by pressing a button representing the system code, another button representing the number of the malfunction in that system group, and an insert button. The malfunction indicator light remains illuminated until the malfunction is corrected, or deleted. Another system<sup>(2)</sup> not only reduces panel space requirements, but provides additional data for the interpretation of malfunction procedures. The instructor inserts a malfunction by first selecting a system. A schematic diagram of the system is projected on a screen at the instructor's console. Each component of the system which can be failed is linked by a line drawn to a switchlight on the panel adjacent to the screen. Pressing the switch inserts the malfunction to which it is linked.

#### 4. CRT INSTRUCTOR STATIONS

Today, CRT displays are becoming more and more common in flight simulator instructor stations. They have enabled significant reductions in instructor station size, and consequent reductions in demands on the simulator instructor's visual scanning capacity.

CRT'S have the following primary characteristics:

- a) Flexibility in displaying many different types of information.
- b) Little or no delay in shifting from one type of information to another.
- c) Display of only the information required at a given time for a given training function.

d) Immediate access to information as required.

e) Flexibility in formatting instructional information.

f) Graphic display of discrete data whose interrelationships are more meaningful than their individual, absolute values.

g) Display of both alphanumeric and graphic data as required.

h) Display of graphic information in three dimensions, or in perspective.

i) Color CRTS when color coding or color representation of data provides added information and/or flexibility.

j) Ported CRTS to permit rear-projected information to be combined with electronically generated data on the same display area.

CRT data can be accessed, programmed, and modified in a number of ways. Currently, CRT displays are programmed and accessed by alphanumeric keyboards and discrete function switches. Capabilities also exist for accessing and modifying data displayed on a CRT by light pen;<sup>(1)</sup> the display system is programmed to act on data at which the light pen is aimed. Another system<sup>(13)</sup> senses the location of a finger, a pencil, or similar object touching the display screen; data in the display can be programmed to be acted on by the system computer when its location is touched.

A number of simulators currently in the field, or under development use CRT'S at the instructor's station. Operational experience with CRT-oriented simulator stations is limited, but nine current designs using the unique capabilities of CRT display systems are discussed here, in terms of their contribution to simulator instructional technology. One of these, the Air Force's Advanced Simulation In Undergraduate Pilot Training (ASUPT)<sup>(5)</sup> system is designed specifically to support research in training device design, including the design and utilization of various instructor station configurations. These systems are summarized in Table 1. Descriptions of the functional characteristics of the instructor stations are contained in Reference 10. The functions performed by CRT'S include:

Table 1. . . CRT INSTRUCTIONAL FUNCTIONS

SIMU- LATION	A/C	CRT	FUNCTION					
			PROGRAM CONTROL	PROGRAM MODIFICATION	AUTOMATED TRAINING	REAL-TIME MONITORING	COMMUNI- CATIONS	DEBRIEFING & EVALUATION
2B24	UH-1H	(2 TYPES) SANDERS ADDS/900	αGC	αGC EDIT AREA	αGM ADAPTIVE TRAINING	αGC*	αGC*	αGM
2B31	CH-47C	SANDERS ADDS/500	αGM	αGM EDIT AREA	αGM MISSION PREPRO- GRAM	αGM	αGC	αGM
2B33	AH-1Q	ADDS/500	αGM	αGM EDIT AREA	αGM MISSION PREPRO- GRAM	αGM	αGC	αGM
2F87	P-3C	ADDS/500	αGM	αGM EDIT AREA	αGM MISSION PREPRO- GRAM	αGM	VOICE GENERA- TION SYSTEM (GCA)	αGM
2F101	T-2C	ADDS/500	αGM	αGM EDIT AREA	αGM MISSION PREPRO- GRAM	αGM	αGM	αGM
2F107	KC-130F	ADDS/500	αGM	αGM EDIT AREA	αGM MISSION PREPRO- GRAM	αGM	αGM	αGM
ASUPT	T-37B	VECTOR GENERAL 3D2		αGM EDIT AREA	αGM ADAPTIVE (RE- SEARCH)	αGM	αGM	αGM
		MONITOR SYSTEM 5205	α/S RC					
SAAC	F-4E	ADAGE AGT-150	αGM	TTY	αGM TARGET PREPRO- GRAM	αGM	αGM	αGM
AFTS (GCA)	(GENERAL AVIATION)	TEKTRONIX 4010	αGM	TTY/ TAPE	αGM ADAPTIVE TRAINING	αGM	VOICE GENERA- TION SYSTEM (GCA)	αGM

\*COLOR ON PROTOTYPE 2B24 ONLY

α= ALPHANUMERIC      R = RASTER DISPLAY  
S= SYMBOLS            G = GRAPHIC  
C= COLOR                TTY = TELETYPEWRITER  
M= MONOCHROME

a. Program Control. CRT'S are used to display data required in the control of the simulator training program. They display sets of initial problem conditions defining the position and configuration of the aircraft being simulated and the environment in which training is to be conducted. They also display information on the sequence of events, maneuvers and tasks to be practiced, the locations and characteristics of the ground facilities to be used and the malfunctions available or preprogrammed for insertion. The performance parameters to be achieved in practice and the tolerances defining acceptable performance are also displayed.

In Device 2B24<sup>(3)</sup>, two alphanumeric displays having five separate display areas each are used to set up and control the training problem. One of these CRT'S is used for training program control. The other automatically displays air traffic control messages to be relayed to the student over the simulated radio system by the instructor. Each of the four areas of each display is dedicated to a specific cockpit. The fifth area is reserved for editing and modifying the data displayed in the four cockpit-related areas. With this arrangement, two instructors can share responsibility for the four cockpits. When all four cockpits are being used for GCA practice, four instructors can be employed, using two remote GCA consoles, with the instructor monitoring four graphic flight path displays located at the main console.

The other devices being considered are designed to be used by one instructor, instructing one student, or one crew, although Devices 2F87(F)<sup>(7)</sup> and 2F107<sup>(9)</sup> (the P3C and KC-130F QFT's, respectively) include a position at the instructor station for a flight engineer instructor. In effect, one of the two instructors operates the console while the other monitors the console displays and the trainee station, depending on the nature of the problem being practiced at a given time.

Device 2B33<sup>(11)</sup>, because of the tactical training requirements associated with AH-1Q, has one instructor station mounted on each of two motion bases, one for the pilot trainee and one for the gunner. The two separate motion platforms, visual systems and instructor stations permit simultaneous training for the two crewmembers, but the two systems can be linked for integrated crew training. During integrated training, the pilot instruc-

tor is given control of the problem, but the gunner instructor can still select any of the display formats provided at his station, to facilitate performance monitoring.

b. Program Modification. Program data to be modified, and undergoing modification, are displayed on CRT'S at the instructor station. In most cases, an edit area is reserved on the CRT, so that data can be modified and the change verified before it is actually entered in the computer program. In Device 2B24, the edit area of the Auxiliary Information Display is shared among the four cockpits. Function switches associated with a given cockpit are used to display program data and to move selected data to the edit area. A keyboard is used to modify the program as required, with modifications displayed in the edit area for verification prior to insertion in the program. In Devices 2F101<sup>(16)</sup> and 2F107 using three CRT'S and Devices 2F87(F), 2B31<sup>(8)</sup> and 2B33, two CRT'S, an edit area in one of the display formats together with a keyboard and a set of function switches, permits program modification much as it is accomplished in Device 2B24. The ASUPT system, designed for research, uses CRT/keyboard systems for program modification, and a variety of more conventional switch matrixes, so that experiments can be conducted to identify the advantages and disadvantages of each method for various types of training.

c. Automated Training. Some simulators permit automatic training missions to be programmed from the instructor station, by using keyboards and function switches to call up and organize training program data displayed on the CRT. The instructor preprograms missions by calling up the pages of initial conditions, maneuvers, malfunctions and segments available to him, selecting the mission elements required and storing them in the computer for later utilization as part of the programmed mission. In Devices 2F101, 2F87(F), 2F107, 2B31 and 2B33 data relevant to three mission legs are displayed at one time. These data provide information about the preceding, the current and the next scheduled leg to be flown. This permits the instructor to maintain perspective on the history of the session, so that he can make meaningful evaluations and program modifications.

Both Device 2B24 and ASUPT have significant capability for conducting automated

adaptive training, but little experience exists to date to indicate how much or how little instructor intervention is required in such programs.

d. Real-Time Monitoring. The IOS CRT is used to display information needed to monitor, evaluate and guide student practice. A major, unique contribution of the CRT is in permitting data to be organized and interrelated for optimum instructor interpretation and performance diagnosis. Each of the simulators reviewed presents real-time data in alphanumeric and graphic form. Airspeed, heading and other relevant values are provided on the CRT for precise monitoring. In Device 2B24, these presentations are supplemented by two sets of instruments, to be time-shared with the four cockpits, which repeat the forms of the instruments used by the trainee in the cockpit.

In Devices 2F101 and 2F107, simplified representations of the cockpit displays are provided in one of the CRT display formats. These displays provide frequency and rate information which is not readily available in the alphanumeric format. In addition, each device provides a graphic display of the navigational area and of the ground track of the simulated aircraft. Additional symbolic data are associated with the graphic displays along the aircraft trace to alert the instructor to performances and events having special instructional importance.

ASUPT and SAAC have unique capabilities for displaying not only ground track, but flight path and aircraft altitude in analog form. The instructor (or experimenter) can select displays with two aircraft in perspective, and a record of their flight paths. In ASUPT, this display can be used to monitor aircraft relationships in formation flying, or to monitor the flight path generated in an aerobatic maneuver. In SAAC, the flight path display is used to monitor the spatial relationships between two aircraft engaged in simulated air combat.

In Devices 2B31 and 2B33, 2F87(F) and 2F107, the instructor's position permits direct monitoring of the student's visual scene. In ASUPT and in SAAC, CRT displays are provided at the remote instructor station, to permit monitoring of the visual scene. In SAAC, a set of indicators is used to supplement the visual scene repeater, to show the

experimenter or a person representing the back-seat Radar Intercept Officer, the data he would see in the cockpit, which he must relay to the pilot or use in monitoring pilot performance. This is necessary because of the problems inherent in repeating the pilot's 360° field of view at the IOS. Experiments in ASUPT will eventually define ways of presenting relevant out-of-the window visual information at the IOS. It is likely that most of these will involve use of CRT'S, but adequate formats are not yet well defined.

Device 2F107 is unique with respect to real-time monitoring. Cockpit display representations are available on the IOS CRT'S, but, because the IOS is in the cockpit, the instructor can also view the student's displays directly. The display formats used for CRT presentation, provide data required by the instructor, whose tasks, and presumably information requirements, are different than the pilot's. As a result, it is anticipated that the CRT representation of cockpit displays will be more useful than the instructor's direct view of the student's displays. Also, the CRT permits other relevant information to be provided adjacent to the instrument representations, making monitoring simpler and more meaningful.

e. Communications. CRT'S are used to display messages needed by the instructor in providing communication inputs during training. Air Traffic Control and GCA messages are synthesized by the computer, and displayed for the instructor, so that he can relay them to the student as appropriate. In some trainers, including AFTS, Device 2F87(F) and ASUPT, ATC and GCA messages are composed from stored words and word sounds based on student pilot performance so that minimal instructor involvement is required. In other systems, messages are displayed on a CRT at the appropriate time for the instructor to relay to the student over the simulated radio communication system. In each case, the CRT facilitates instructor performance. In the first case, it provides data for monitoring performance and, in the other, it not only provides appropriate data for monitoring, but it also reduces instructional variability and instructor workload.

f. Debriefing and Evaluation. Reference to the CRT information, by viewing the tube directly or a hard copy of the displayed data, aids the instructor in debriefing

the student and evaluating his performance. Storing this information permits comparison of early trials with later ones and also comparison of performance among students. Performance recording and replay capability can be used to provide CRT displays for student debriefing, but in most cases, hard copy printouts are provided to support debriefing, freeing the simulator for more appropriate use. In devices in which the CRT is in the trainee station, as in the 2B24, 2F107, 2F87(F) and ASUPT, the CRT can be used for critiquing and debriefing within a training exercise. The instructor records performance, freezes the trainer, and replays the performance for the trainee. Some thought has been given to placing debriefing CRT'S in debriefing rooms, but none of the devices discussed here has this capability.

## 5. IOS CONFIGURATIONS \*

CRT-equipped instructor stations can be configured in various ways, depending on the complexity of the instructor station, its location, and its mode of utilization. It also depends to some extent on the configuration of the aircraft itself. Where an instructor's seat is available in the aircraft itself, it tends to be used in the simulator. ASUPT, the Air Force's research simulator, will conduct formal experiments on the use of in-cockpit instructor's stations. Experience with earlier ME-1 and F-4 trainers, indicates that, for elementary skill training, the in-cockpit station is valuable for initial training, with less and less direct instructor contact required as student skill levels increase. Also, it appears important for the student, at some stage in training, to be isolated from the instructor, so that he can learn to rely on his own judgment.

It was recognized many years ago that the simulator instructor station had the potential to provide the instructor with more, better, and more meaningful information on student and aircraft performance than is possible in the aircraft. In theory, a remote instructor station would remove the instructor from the distractions impinging on him in the cockpit, it would provide only the information relevant to specific training functions at a specific time, and it would provide all of this in a location outside the student's environment. Device 2B24

\* IOS - Instructor/Operator Station

is the first major implementation of this philosophy. Most instruction is given from a remote station, using CRT displays to provide the instructor with the information required to monitor, guide, and evaluate student performance as it is needed. It is noteworthy that in the 2B24, an in-cockpit station is provided also, but this has a dual function: the instructor can use it to guide early learning and the development of initial skills and knowledges, and the student can use it in the absence of the instructor to call up briefings, demonstrations and measurement programs, and to review his own performance on a graphic CRT behind his seat.

Most commercial simulators and simulators for crew training use in-cockpit instructor stations to provide direct contact among students and instructors, and to facilitate the monitoring and evaluation of crew interaction skills as well as individual performance. Where visual simulation is employed, the in-cockpit station has the advantage of providing the instructor with a view similar to the pilot's, on the assumption that instructor viewing of the visual scene can facilitate the evaluation and guidance of visual skills. It is possible, however, that the visual scene with which the pilot deals does not provide adequate information to support the instructor's job. The instructor, after all, is not concerned with flying the simulator, but in evaluating and guiding the student's attempts to learn to fly it. As a result, the instructor's task is markedly different from the student's, and it is reasonable to assume that his information requirements are also different. The Air Force's Simulator for Air-to-Air Combat (SAAC) provides displays at the operator's station which give the simulator operator, who may act as a rear-seat instructor or Radar Intercept Officer, information equivalent to that ordinarily acquired visually in the rear seat. He can report to the student the azimuth, elevation, range, aspect and flight path of a target which he cannot actually see.

In some simulators, multiple instructor stations are used to provide differential training for two or more crew members, as well as integrated crew training. The F-4 and F-111 simulators provide training for pilots and RIOs or copilots, and many commercial simulators provide for pilot and flight engineer training. Since they also provide integrated crew training, the dual instructor station is

frequently managed by one instructor. Conventional instructor station configurations make this difficult, because individual displays for nearly all of the information required by the instructor are always present on the console. This means that the instructor must scan a mass of irrelevant display components to find the data needed for each training function. In some simulators, he must scan an area 8 or 10 feet long. So far, CRT'S have not been used extensively on dual instructor stations, except to repeat information displayed on a CRT at the trainee's station, and to set up situations for tactical training. It is possible that the development of automated training techniques has made the dual instructor station less necessary.

## 6. FORMAL EVALUATIONS

The Naval Training Equipment Center's Human Factors Laboratory (Code N-215) is engaged in a series of training effectiveness evaluation of several major training systems. Three of these systems involve complex training devices which incorporate CRT'S at the instructor station. Instructors and students who have used the devices have been observed and interviewed. Although these evaluations are still in the early stages, some observations on the use and acceptance of CRT'S at the instructor station are reported.

a. Automated Flight Training System (AFTS) GCA Module.<sup>(14)</sup> This module, developed by Logicon, Inc., is designed to provide an automated adaptive training program for an operational flight trainer. Automated ground controlled approach procedures were integrated with the TA-4J Aircraft Operational Flight Trainer (Device 2F90) and the system is being tested at the Naval Air Station, Chase Field, Beeville, Texas, with student Naval aviators.

The GCA module provides full support to student and instructor by performing all routine functions including syllabus and trainer configuration control automatically, until overridden by instructor input.

The GCA module contains a voice generation system which automatically provides appropriate GCA messages, and a graphic display of GCA performance for instructor monitoring.

The Cubic Corp. "DIGITALK" speech generation system assembles a fixed vocabulary into phrases and sentences under computer control. This equipment provides the GCA voice command input requirement. The voice system generates words and phrases and assembles them into the standard GCA phraseology for approach control. This system also provides the voice command input for feedback and diagnostic messages concerning student performance.

A graphic CRT (Tektronix Display Terminal Model 4010) and a line printer (Tally Corp. Model 2000) with keyboard are located near one of the instructor stations of Device 2F90. The results of each approach are output to this display subsystem. The CRT provides a time plot of each approach in the format of a GCA Precision Approach Radar (PAR) display; i. e., a vertical profile of aircraft position with respect to the glide slope, and a horizontal profile of aircraft position with respect to course (see Figure 1). The printer provides a hard copy summary of conditions and performance for each approach.

b. The Trainer Experiment. One experimental and one control group are being used: the experimental group is trained using the Automated GCA concept; the control group is trained in the conventional manner (i. e., with instructor and present syllabus). In each case, training is to proficiency, and the automatic performance measurement capabilities of the GCA module are used in addition to instructor scoring.

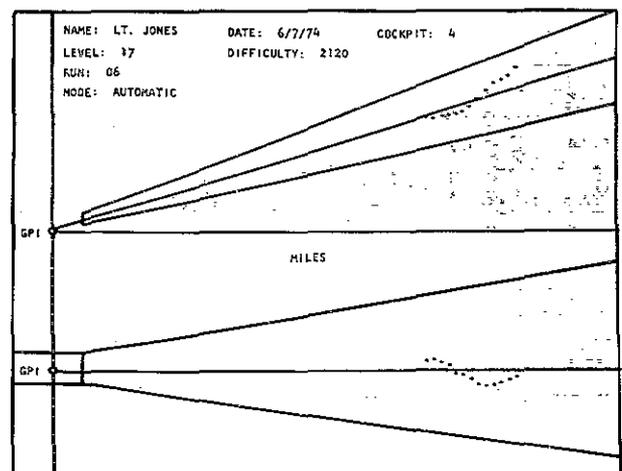


Figure 1 GCA DISPLAY GEOMETRY

Two operation modes are available: a manual mode and an automatic mode. Both modes are similar in that they provide GCA training. However, the automatic mode provides for fully automated training with adaptive syllabus control and simulated GCA controller.

The manual mode requires that the instructor enter the conditions for each GCA approach and act as the GCA controller. In both modes, performance measurement is provided.

Conventional training on Device 2F90 requires the instructor to monitor the repeater flight and engine instruments on the instructor console. The information derived in this matter is then interpreted and commands relayed to the student via intercom. Since better (or more easily interpretable) information is provided by the vertical and horizontal profiles shown on the CRT, the instructor can anticipate errors and, thereby, lead the student to perform within a much tighter envelope. In order to prevent this and not bias the comparison between automated system performance and that provided by conventional instruction, the instructor is not permitted to view the CRT during the evaluation.

Although it was not the intent of the evaluation to show the superiority of the CRT display over conventional instructor station instruments, it has resulted in a demonstration of its potential for GCA training. The CRT is a more realistic tool for the instructor to use, since the GCA controller at the field is watching a similar tube display.

c. Device 2F101 Evaluation. Device 2F101 evaluation is just beginning. An initial visit was made to the trainer installation at NAS, Chase Field, by NAVTRAEQUIPCEN engineering psychologists to obtain preliminary information on which to base an evaluation work plan. So far, instructors feel that they need actual flight and engine instruments at the instructor's console similar to the ones the student has in the cockpit. This initial reaction is not unusual since change in familiar procedures is not accepted easily. As in the case of the automated ground controlled approach module, acceptance may come with experience. A relatively short period of familiarization, such as will be experienced during the two-week operator training course,

may be all that is necessary to convince training personnel of the advantages of this concept. For example, two instructors who attended a training course on this device said that their objections to CRT'S diminished after familiarization. The big advantage, they thought, was from a maintenance standpoint where the failures of individual panel instruments were eliminated.

More definitive data will be available concerning the use of CRT'S at the instructor station after completion of this evaluation. A consensus will be obtained by analyzing student and instructor test data and information gleaned by means of interviews and questionnaires. Comparison of performance data of basic students (T2C Aircraft) trained on Device 2F90, which does not use CRT'S in its basic configuration, with that of basic students trained on the 2F101 should provide a revealing analysis. Although, it may prove difficult to attribute any differences in performance to the use of CRT'S, subjective data from instructor experience with the two types of instructor station design should be enlightening. From a performance evaluation standpoint, it is probably safe to predict that meaningful evaluation data will be more easily extracted by means of hard copy printouts of tube display data from Device 2F101.

## 7. FUTURE POSSIBILITIES

The evolution of flight simulators has brought about increases in simulator fidelity and in the definition and automation of instructional functions. Further advances will occur in both areas, both as a result of formal research programs and because of the economic and safety implications of increased training efficiency and training effectiveness. Improved simulator instructional support is closely linked to increased and improved use of cathode-ray-tube-like displays to mediate simulator instructional information.

The essence of CRT display utilization is in the planning of simulator training applications; conventional switch/dial/knob instructor stations made all simulator capabilities immediately available, tending to place the burden of instructional planning, sequencing, and control on the individual instructor at the time of instruction. Reducing instructor station size and complexity through the display of training data on CRT'S, and the control of

training through the use of keyboards, made less information and fewer functions available on the instructor's console at a given time. This in turn forced simulator designers to allocate information to displays by defining each training function individually, and by grouping training functions for maximum commonality to the range of training to be accomplished.

While instructor stations were being reduced in size, the planning required to permit time-sharing of display and control components, together with improved understanding of computer capability, resulted in a gradual reallocation of instructional functions among the instructor, the computer, and the hardware available for flight simulator development. For many years, the model for analyzing and defining simulator instructional concepts was the flight instructor in the aircraft. This resulted in the development of better ways of handling flight instruction in the ground environment, but it has also resulted in some neglect of the simulator's unique ability to provide training, and training transfer, which is impossible, uneconomical, or impractical in in-flight training. Further developments in flight simulator instructional efficiency must be oriented toward the objectives associated with operational flying, and to exploiting the potential of the simulator for supporting efficient and effective learning.

The further development of flight simulators depends on further understanding of the dynamics of learning as it relates to operational flying, and as it occurs in flight skill training, whether it is accomplished on the ground or in the air. Experience in the development of CRT display systems and automated training programs indicates that the learning process can be further enhanced by further integration of CRT displays to provide better information both to the instructor and to the trainee. Two activities are foreseen in making optimum use of flight simulator instructor stations: first, CRT'S will be employed in more new simulators and retrofitted in existing devices; second, greater use will be made of CRT capabilities for providing information at the right time, in the right form, and at the right place in enhancing simulator training and transfer. Both developments will involve greater understanding of both specific training problems and of the simulator and

in-flight learning processes themselves.

## 8. EXTENDED USE OF CRT'S

Many simulators currently being developed rely heavily on CRT'S in the instructor area. Future simulators will continue to use CRT'S, but it appears that there will be a greater tendency to use CRT'S to increase the ratio of students to instructors. Device 2B24 permits some training of four students to be conducted by one instructor. Further definition of instructional functions and development of automated training approaches will permit more simultaneous instruction by one instructor. Device 2B24 was designed to permit greater instructor involvement in periods when instructor participation was heavy, particularly in two or more simultaneous GCA lessons when the instructor acts as the GCA operator. Recent incorporation of automatic voice synthesis systems will permit reduced instructor involvement in this area of training. Similarly, the development of computer performance-diagnosis concepts will further reduce the need for continuous instructor monitoring with automatic trainee cueing and guidance even further reducing routine demands on the instructor. Throughout these developments, the CRT will provide better data to support instructor management of training as well as supporting more effective instructor participation where his direct involvement is still required.

The CRT used as a training management tool also has great potential in the integration of the various components of complete training systems. Training efficiency, in the final analysis, is best expressed as the ratio of the value of the missions made possible by training to the training cost in money, time, personnel, and facilities. Training in complex skills requires many approaches and many training media, not as discrete events but operating as an integrated system. The CRT has the ability to display the information required to effect system integration and to assess and control the involvement of each system component. In the future, the flow of students through a training system and the improvement of the system through the application of data from evaluations of system products in operational missions will be monitored and controlled from CRT training system management stations.

## 9. FURTHER ENHANCING SIMULATION VALUE WITH STATE-OF-THE-ART SYSTEMS

Current CRT data formatting capabilities are somewhat ahead of demands for instructional data and data formats. Three-dimensional and pseudo-3-D display systems are a case in point. Flight data information can be displayed much more effectively in these systems than has ever been possible before, but little information exists as to how this type of display can be used to enhance instructional efficiency. This is due partly to the tendency to consider simulator instruction as analogous to flight instruction. The simulator instructor, using a 3-D display in teaching aerobatic procedures, has information not available to the flight instructor, but making effective use of it demands more insights into the learning of aerobatic procedures than is currently available to simulator display designers. Traditionally, the instructor monitors student performance so that he can anticipate and sense student errors, diagnose the possible reason for these errors, and generate a guidance scheme designed to preclude, correct, or eliminate them. A 3-D flight path display may be able to facilitate this process, if the information is properly displayed and if it can be integrated with other relevant information such as airspeed, angle of attack, stick position, and so on. Making effective use of this unique display capability will require extensive analysis of the instructional function, as it appears feasible in the flight simulator. It will result in capabilities for more efficient and effective learning by providing for more accurate diagnosis and guidance than is currently possible.

Recent emphasis on the use of out-of-the-window visual systems has greatly expanded the utility of the flight simulator. At the same time, it has introduced some instructor monitoring problems, which appear within the capability of the CRT. ASUPT will eventually develop concepts for displaying visual information at the instructor station, but in the meantime, the problem may have to be solved in a production simulator. Again, emphasis must be on support of the instructor's task rather than on making the instructor's display look like the student's visual scene. The CRT has the inherent capability to provide almost any display adequate to the task. The problem is in

defining the task, and what is an adequate display.

Further enhancement of simulator training value will involve more extensive and more sophisticated employment of CRT'S, provided the instructional functions in which CRT'S might be employed are adequately defined.

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#### ABOUT THE AUTHORS

*DR. EDWARD A. STARK received his Ph.D. in Psychology from the Ohio State University in 1955. He has performed a number of analyses of simulation requirements for training tank, helicopter, fighter, and ASW crews. He was Singer's Principal Investigator on a Naval Training Equipment Center study of the Navy's Undergraduate Pilot Training System, and was responsible for human factors support in the development of the Air Force's Advanced Simulator for Undergraduate Pilot Training research. He was also Principal Investigator on a NAVTRAEQUIPCEN study to define an Experimental Training Simulation System. Most recently, Dr. Stark participated in the design, conduct, and analysis of pilot evaluations of various systems in the Simulator for Air-to-Air Combat.*

*MR. JOSEPH A. PUIG received his B.A. and M.S. degrees from New York University and an M.A. degree in Experimental Psychology from St. John's University. He is currently engaged in the evaluation of training systems and studies in the application of human factors technology to simulation. He is a member of the Institute of Electrical and Electronic Engineers.*