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ABSTRACT

An individual trainer for giving students in the radar intercept observer (RIO) schools concentrated practice in procedures for air-to-air intercepts was designed around a programmable graphics terminal with two integral minicomputers and 8k of core memory. The trainer automatically administers practice in computing values of variables in the intercept triangle, and in making the turns required to put the fighter into position for a sidewinder attack. In an initial field trial at the RIO school, Glynco, Georgia, each of 29 students received 10 hours of practice on this trainer. Data for the values of 33 variables were automatically recorded and were analyzed. It was concluded that this form of computer assisted instruction does produce worthwhile gains in fluency of performance and understanding of the intercept problems. (Author)

Technical Report: NAVTRAEQUIPCEN 71-C-0219-1

DESCRIPTION AND INITIAL EVALUATION OF A COMPUTER-BASED INDIVIDUAL TRAINER FOR THE RADAR INTERCEPT OBSERVER

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An individual trainer for giving students in RIO schools concentrated practice in basic procedures for air-to-air intercepts was designed around a programmable graphics terminal with two integral minicomputers and 8K of core memory. The trainer automatically administers practice in computing values of variables in the intercept triangle, and in making the turns required to put the fighter into position for a sidewinder attack.

In an initial field trial at the RIO school, Glynco, Georgia, each of 29 students received 10 hours of practice on this trainer. Data for the values of 33 variables were automatically recorded and were analyzed.

These data show that between first and last blocks of trials, mean values of all of the ten response-latency variables decreased by an average factor of 2.5, mean number of turns-per-intercept decreased from 4.7 to 3.4, and mean hit-probabilities increased from .807 to .879.

Manually collected data included scores on an experimental in-flight checklist, and answers to an opinion questionnaire. These were the basis for cross-comparisons between experimental and control groups, and for acceptability information. These comparisons and this information were generally favorable to the experimental trainer.

It was concluded that this form of CAI does produce worthwhile gains in fluency of performance and understanding of the intercept problem.

FOREWORD

Some years ago, a new concept in instructional procedure - generally referred to as computer-aided instruction (CAI) - appeared on the training scene. Much enthusiasm developed over some apparent capabilities contained in CAI which promised to renovate current teaching practices. Ventures to discover, demonstrate, and exploit the capabilities of CAI were made in increasing numbers. Now, after a decade or so of work, the prevailing attitude toward CAI still is highly optimistic. A couple of obstacles to progress, however, have been revealed.

One such obstacle is that CAI places a great burden on the designer of instruction in that he must specify in minute detail all aspects of the training program. (This is in contrast with the more traditional approaches to training wherein many aspects and details of instruction typically are left to the discretion of human instructors.) Contributing to this difficulty is that the process of specifying CAI features must be done anew for each new tasks area for which CAI is desired. That is, there is no generally available method to use to decide questions such as: which of all the CAI components developed to teach, e.g., maintenance skills can be utilized in CAI required to train Radar Intercept Observers (RIOs), Air Traffic Controllers, or Electronic Counter Measures Operators?

A second major obstacle to progress in the field of CAI is that there is no good way to determine the extent to which various instructional components of CAI contribute to training effectiveness. This means that the designer of a training program may decide to implement too few CAI features or perhaps the wrong ones for maximal training effectiveness. On the other hand, he may try to utilize all aspects of CAI that occur to him at the time. In this case he may develop an elaborate instructional program only to find that much of it is superfluous or detrimental to his training goals.

The present project was motivated by a desire to ease both of these sources of difficulty for CAI program development. The plan of approach toward this end, generally, is to compare the utility of various instructional features of CAI with one another. This will be done both within tasks and also across different tasks. Empirical studies will provide specifications of CAI components for the tasks involved and provide a basis for theoretical analyses. Theory, in turn, will suggest CAI features which will benefit training on skills across various tasks. Futher empirical research will test and suggest modifications to theoretical notions, and, in the process, also contribute to the store of detailed specifications of CAI features which, then, are available for future applications. Both the empirical and theoretical activities will be oriented toward providing information about the relative appropriateness of CAI features singly and in combination for the training of a variety of skills.

As a preliminary step in this program of research and development, CAI for teaching RIO skills has been developed and evaluated. According to plan, information derived from this effort is being used in an ongoing endeavor to construct a general model for the type of CAI needed to teach individual skills for operational jobs including and related to the RIO's job.

Considering all the evidence developed in this project collectively, it appears that the CAI program discussed in this report would contribute considerably to training effectiveness if it were implemented as is into operational training situations for RIOs or, with suitable modifications, for jobs similar to the RIO's job. However, the progress and evaluation of that progress reported herein is considered to be only a beginning when measured against the foreseen capabilities of CAI and ideal evaluation. Such goals and ideals will continue to be pursued in the ways of empirical research on CAI for military jobs and also theoretical model development activities.

Arthur S Blaiwes

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Scientific Officer

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INTRODUCTION

Training human operators to meet the challenges of modern warfare occupies the efforts of great numbers of people and demands massive expenditures of money and time. Results are often disappointing. Students fail to perform at the desired level, or produce only marginal performance. Although there can be many different reasons for this - training is conducted in many different environments and under many different circumstances - achieving control over training processes is a pervasive problem. Training requires a combination of resources, methods and procedures that is sensitive to individual differences among students and that contains adaptive control mechanisms based on objective measures of the individual student's rate of progress. This has been very difficult if not impossible to achieve without the assistance of the special technologies now becoming available.

Training is itself a technology in search of firm theoretical foundations. Only recently have learning theorists addressed themselves to the complexity and richness of human learning outside of the austere abstractions of the academic laboratory. The result has been a gratifying amount of exciting research on cognitive processes (for an outstanding example, see Anderson and Bower, 1973) and some outstanding results in the classroom (Atkinson, 1969; Suppes, Jerman, and Brian, 1968; and Suppes and Morningstar, 1972).

The purpose of the research reported here was to develop and test an individual skills trainer which would combine advanced features in computer graphics and computer programming with an approach to training based on current information about cognitive information-processing (Rigney, et.al. 1972). The major features of this approach are briefly described below.

THE ORGANIZATION OF HUMAN PERFORMANCE

Properly controlled practice results in increased proficiency. This may be the fundamental law of training. Its power is demonstrated everyday in literally thousands of different settings. Great fluency in performance is produced by large amounts of properly controlled practice. This may be the second law of training. Of course, the key phrase in these statements is "properly controlled." Repetition only provides the context in which mediating processes can occur. These should be directed by the manipulation of conditions external to the learner, e.g., by instructional operators. Instructional operators are ways of presenting stimulus material, and operations that can be required of the student that will facilitate learning and improve retention.

Despite the universality of these laws, it is not always easy or even feasible in some training environments to provide opportunity for properly controlled practice to each student in amounts sufficient to bring him up to a desirable level of fluency. Performance-Structure-Oriented Computer-Aided Instruction (CAI) was developed to provide individualized, properly controlled practice as automatically as possible. That is, it should bring the individual student up to some desired level of proficiency without requiring the intervention of an instructor during the practice period.

The view of performance as a highly organized serial mixture of subgoals and associated action clusters, sustained by groups of mediating processes, has been fully described elsewhere (e.g., Rigney, in Degreene, 1970). This is essentially an information-processing conception derived from the literature of information-processing (Reitman, 1965) cognitive (Neisser, 1967), and cybernetic (Pask, 1973) psychology in general, and from recent literature on mediating processes in learning and memory (e.g., Tulving and Donaldson, 1972; Carroll and Freedle, 1972; Sheehan, 1972; and Bower, 1972). Some of the major kinds of mediating processes that are required to sustain performance at its highest level are at least suggested in figure 1.

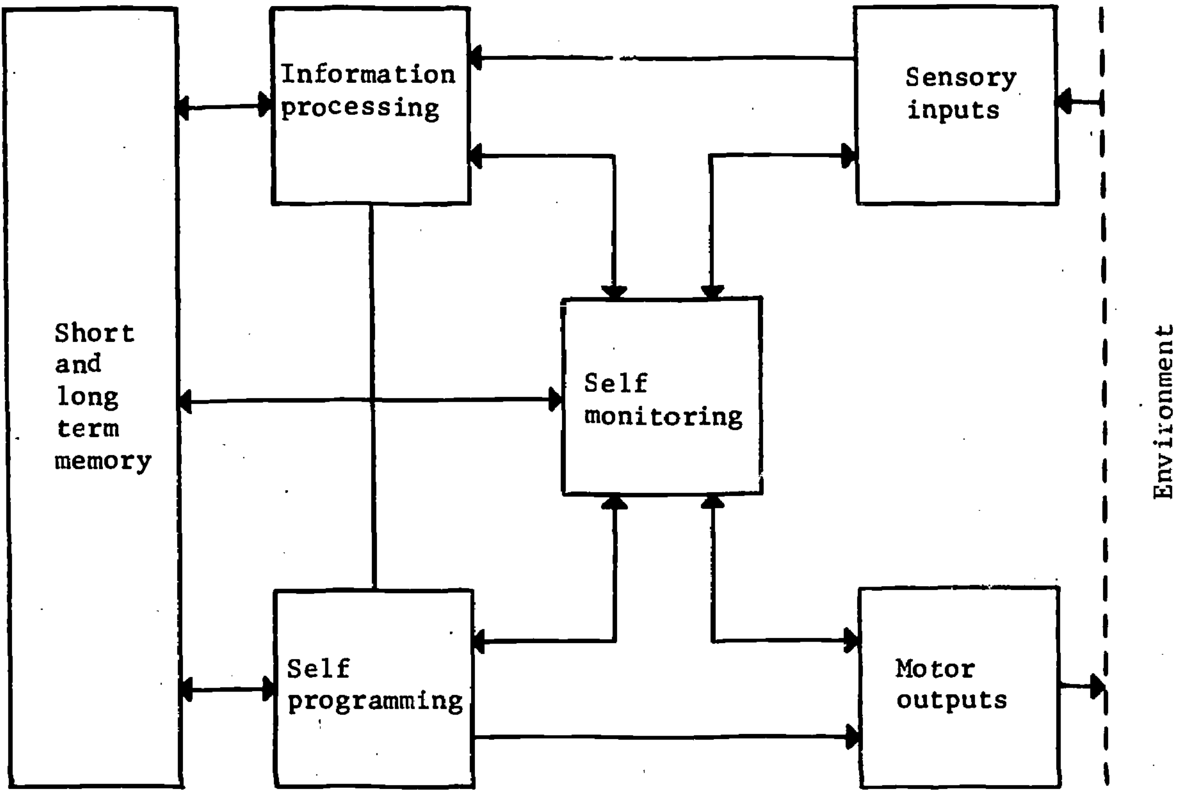


Figure 1. The Organization of Serial-Action Performance

We suggest that many mediating processes in each box in the illustration are learned, and that this learning consists essentially of elaboration of complex processes from some sort of primitive substrate of biologically determined processes, perhaps common to all humans. According to this view of the organization of performance, it can occur at several levels of serial integration.

At the highest level, the performer generates the series of activities involved by a self-program that is flexible enough to meet the contingencies of the immediate situation. Perhaps this self-program is a skeleton routine that is filled out with one of several available subroutines at each point in the performance, somewhat in advance of the activities to be generated by that subroutine. The requirement for this extemporaneous self-programming would depend upon the unpredictable variability in the performance requirements. When he can stay at this highest level, the performer is essentially through with training. He can perform autonomously and meet criteria for proficiency.

Before this time, the performer is dependent on external instruction. He may be able to sustain his performance at the top level only some of the time. In between, he must concern himself with learning some needed subskill he did not know, or with learning some needed information he did not have, or with learning to string subskills together into the correct serial mixture, and to monitor his performance for errors and for correct timing. As both Bruner (1966) and Pask (1970) have pointed out, in the early stages of learning the student is not in a position to instruct himself. He has entered into a kind of contract with the instructor, human or machine, which includes the idea that this instructor will be responsible for providing effective, high quality instruction, until the student has learned enough to become more self-directed.

If the above views of the nature of performance are correct, any method for teaching students how to perform by giving them properly controlled practice must be sensitive to structures; to the serial patterns of performance, to the levels of integration of performance, to task structures, and to, where these are involved, device structures.

One way to do this is to simulate essential characteristics of the performance situation, providing (a) a series of graded practice problems, (b) procedures for moving across levels of performance organization, (c) adaptive control sensitive to individual differences, (d) instructional operators matched to the different learning requirements, and (e) sufficiently detailed response analysis to guide adaptive control and to provide a description of how well the system is working.

The major features of our particular approach are:

a. The performance is the criterion test. Students are continually practicing "taking the test."

b. Students can iterate between the top level and lower levels of performance, receiving extra drill on subskills in which they are weak and returning to the top level to try again to perform at that level.

c. No time is wasted in presenting material the student already knows. If he can do it, he is automatically transitioned by the program logic to more difficult material.

d. The student learns self-monitoring and self-programming processes needed in the context of the actual performance, as well as the information-processing skills that usually are the major concern of instruction.

SECTION II

ANALYSIS OF THE RIO'S TASKS IN AIR INTERCEPTS

RIO'S ROLE IN AIR INTERCEPTS

The Radar Intercept Observer (RIO) is a critical element in a complex man-machine relationship in the aircraft as a weapons system. The complexity of the basic delivery device, the aircraft, and the high speeds at which it usually operates create operational situations which tax the maximum performance capabilities of a single individual or pilot. Extended-range weapons, such as missiles, and high aircraft speeds render visual methods of target acquisition virtually useless, and have led to the development of sophisticated electronic devices for this purpose.

The pilot is the first element in this weapons control system, maintaining the precise operation of the aircraft. The RIO is the second integral element of control, analyzing data concerning target activity, and transmitting to the pilot action control commands based on these data.

Experience has aided the development of procedures that attempt to minimize the complexities of the intercept process for the student RIO. Incorporation of these procedures into a performance repertoire requires extensive practice on the part of the student. Practice in the flight environment, however, is very costly, therefore only a minimum of the total practice hours that would be desirable are available in terms of funds, instructors, and aircraft.

The RIO's basic problem is to place two moving objects (his own and an enemy aircraft) into an optimal juxtaposition demanded by the operational parameters of his air-to-air weapon. This must be accomplished as rapidly as possible to minimize detection by the enemy, and without exposing his own aircraft to enemy weapons if possible. The high relative speeds of aircraft operations leaves the RIO little time for reflection, uncertainty, or the correction of errors.

The basic element of interception is the solution of a problem in relative motion, in itself a difficult problem to conceptualize and solve. The RIO gathers the data for the solution of this problem from (a) his own aircraft's instruments which display flight parameters, and (b) a radar display from which the relative position and movement of the opposing aircraft (bogey) may be derived by visual observation and interpretation. From this observed data, the RIO will derive estimates of the opposing aircraft's flight parameters. He may receive initial estimates of these from a ground or shipboard radar site where circumstances so permit. Ground radar data is usually provided during the early phase of training, until the RIO has developed a reasonably effective intercept capability.

ELEMENTS OF THE RIO'S INTERCEPT TASKS

The activities of the RIO during an intercept may be divided into four major task components.

RADAR OPERATION. The first is the operation of the radar system to monitor (or track) the bogey's movements. The radar system must be operated in a manner that will maximize its capabilities for target acquisition. The operational capabilities of the radar system will vary widely with changes in the external environment, particularly weather. Since the electronic emission characteristics of the radars are fixed, the RIO must vary the display of gain and contrast to maximize his own target detection and tracking potential. Additionally, he must manually manipulate the antenna elevation position during search until such time as the opposing aircraft is within the automatic tracking envelope of the radar system. Display control, antenna control, and mode control must be performed with the other elements of the intercept process.

INFORMATION GATHERING VIA DISPLAY INTERPRETATION. The second major task component is the derivation of target data from observation of the relatively complex display format of the radar system. Radar displays vary with the type aircraft in which the RIO performs his mission. Display attributes analyzed here are those of the radar training system (AN/APQ 94-T1) utilized in RIO basic training at Naval Air Station, Glynco, Georgia.

The particulars of the AN/APQ 94 are published in NavWeps 01-60GBA-2-6.1 (declassified 5 January, 1972) and will not be discussed in detail. There are some aspects of the display, however, which appear pertinent to the RIO's scope-interpretation problem.

The size of the display is four inches high by two inches wide. The vertical of the display corresponds to range and may represent a maximum of 20, 40, or 60 miles as selected by the RIO. The width of the display represents antenna azimuth and represents a 90° sector of space 45° left and right of the aircraft heading. The position of the target return on the display determines its range from the fighter and its azimuth, termed "Angle Off." The large scale factor limits the RIO's discrimination of both range and azimuth. Bearing discrimination is probably degraded by the lack of reference marks along the azimuth dimension.

Added to the discrimination problem is the presence of supplementary display elements which the RIO must control manually and observe visually. These include the acquisition symbol, artificial horizon bar, antenna tilt symbol, and five function lights that ring the display. In the track mode, the ROC circle, missile climb capability symbol, and missile maximum range symbol are added to the display.

Information Analysis, Integration, and Decision Making. Initially, with the entry into an active intercept, the RIO must perform a series of specific arithmetic computations and transformations vital to the establishment of his spatial relationship to the opposing aircraft. Through these mathematical steps, values are established for the elements of the intercept triangle. The intercept triangle is a hypothetical figure which one might draw as representative of the spatial relationships that presently exist, and will exist over some time period, between the interceptor and opposing aircraft. The intercept triangle provides the mathematical and conceptual basis for the intercept as a process. It is the geometric figure formed by the fighter's path of flight, the bogey's path of flight, and a hypothetical line connecting the fighter and bogey at any instant of time. The angular and linear (distance) relationships thus established form a basis for the management of relative motion, and for predicting the future relative positions of the two aircraft. An example of the intercept triangle is depicted in figure 2. Any change in the flight parameters of either aircraft will change their spatial relationship, and thus the quantities which determine the triangle's form.

The size and form of the triangle change with the passage of time. The values of Target Aspect (TA) and Angle Off (AO) will increase or decrease unless the Fighter Heading also is a collision course. In that case, the values of TA and AO remain constant and equal.

Two values within the intercept triangle, the angular size of TA, and the linear value of range (RG i.e., the distance between the fighter and opposing aircraft) literally "control" the actions of the RIO up to a certain point in the intercept. This point varies with the type weapon being utilized by the fighter. In reality, there is some degree of variability in this limiting relative position, determined by certain aircraft characteristics such as turn radius and turn rate. There is, therefore, a certain volume of space located relative to the enemy aircraft, through which the fighter should pass to perform a successful intercept. If he fails to pass through this intercept aperture, it may still be possible to complete an intercept, but at the cost of excessive maneuvering, high "g" turns, and greater fuel usage, to name only some of the requirements. Under these latter conditions the probability of a successful intercept is materially reduced.

Mathematical Computations. Under the best of conditions, the RIO will commence an intercept with knowledge of the enemy aircraft's base course and speed, as well as his range and compass bearing, from the fighter. With these elements known, and his own course and speed, the RIO may "solve" or compute the values of the intercept triangle needed to close on the enemy.

A series of computational algorithms are utilized in the resolution of this problem. These algorithms must be learned and recalled as necessary. A list of the required algorithms is shown in table 1. The computations require little mathematics beyond simple arithmetic. However, certain angular values are labeled either left or right with reference to either the fighter or enemy aircraft's compass heading. The determination of Left-Right labels for Target Aspect, Angle Off, and Make up Angle may be accomplished by a simple rule. Unfortunately, this rule does not hold true for all conditions, due to the discontinuity of compass values at a heading of North (360°). Under this condition the problem of reference labeling (RIGHT or LEFT) of values quickly becomes non-trivial for the neophyte RIO.

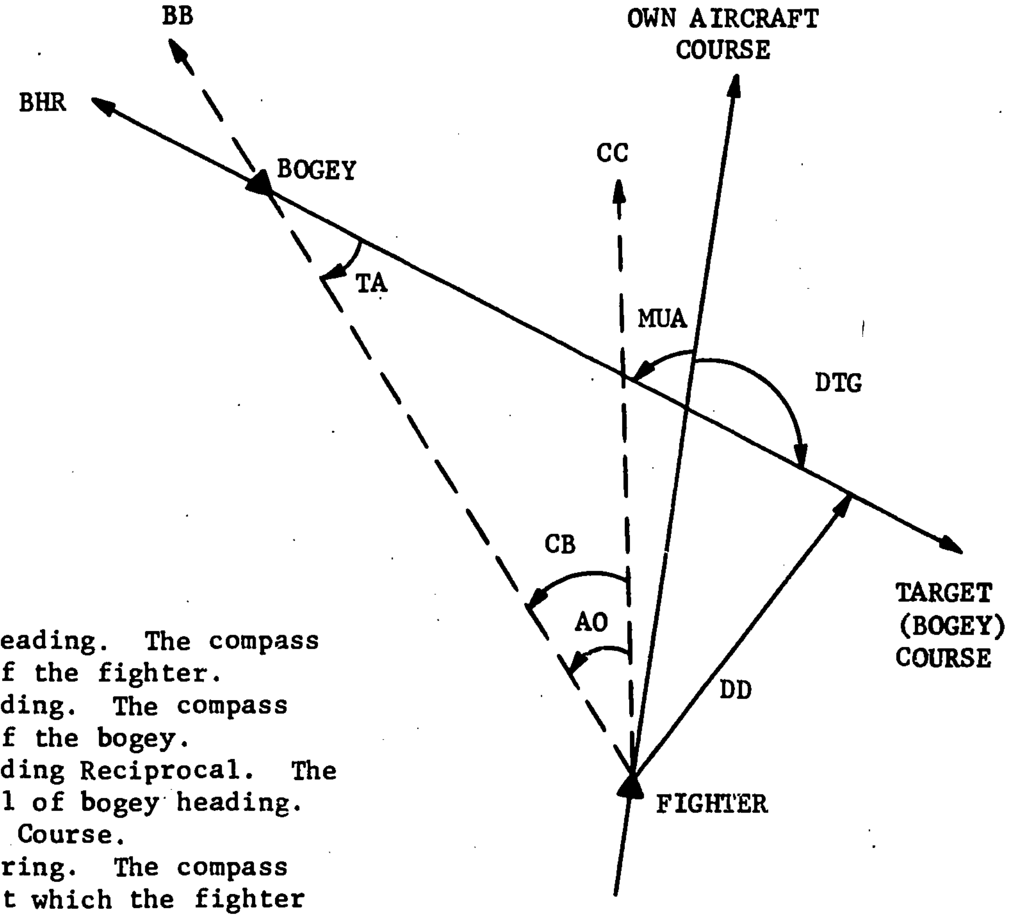


Figure 2. Air Intercept Geometry

FH - Fighter Heading. The compass heading of the fighter.

BH - Bogey Heading. The compass heading of the bogey.

BHR - Bogey Heading Reciprocal. The reciprocal of bogey heading.

CC - Collision Course.

BB - Bogey Bearing. The compass bearing at which the fighter would visually observe the bogey.

CB - Collision Bearing. The constant compass bearing at which the bogey will be seen when on Collision Course.

AO - Angle Off. The angle relative left or right of fighter's longitudinal axis where the bogey would be visually seen.

TA - Target Aspect. The angle relative left or right of target's longitudinal axis where the bogey would visually observe the fighter.

MUA - Make Up Angle. The angle formed by BHR and FH.

DTG - Degrees (of heading change) to go to target course.

DD - Displacement Distance. The perpendicular distance from the fighter to the bogey track.

TABLE 1. COMPUTATIONAL ALGORITHMS FOR TOTEBOARD VALUES

	Value Name	Abbreviation	Formula
Data initially provided or available from flight instruments	Fighter Heading	FH	
	Bogey Bearing	BB	
	Bogey Heading	BH	
To be determined by RIO and entered into Toteboard	Bogey Heading Reciprocal	BHR	BH+180°(if BH $<$ 180°) BH-180°(if BH $>$ 180°)
	Target Aspect	TA	$\lvert BHR-BB \rvert$ TA is labeled Left(L) or Right(R) if BB is Left or Right of BHR.
	Collision Course	CC	BB+TA (if TA is Right) BB-TA (if TA is Left)
	Make UP Angle	MUA	$\lvert FH-BHR \rvert$ MUA is labeled Left(L) or Right(R) if BHR is Left or Right of FH.
	Degrees To Go	DTG	180°-MUA regardless of label.
	Angle Off	AO	$\lvert FH-BB \rvert$ labeled Left(L) if BB $<$ FH Right(R) if BB $>$ FH
Useful to RIO but not required to be entered into Toteboard	Displacement Distance	DD	Range X SinTA Must be approximated in flight. Approximation algorithm $\text{Range}/_{12}$ x $\text{TA}/_{5}$ = DD (approx.)

The determination of intercept values upon which maneuvering decisions will be based occupies a finite time, and cannot be eliminated. Additionally, the computational and labeling procedures must be performed in a particular order. That order is shown in table 1.

High aircraft speeds bring the two aircraft into close proximity within a maximum of 2 to 3 minutes, and usually less. The RIO must learn to calculate rapidly, and with little error. An error, once made, seldom can be fully corrected within the time remaining to intercept. Rapid closure, numerous calculations, and the need to continually manipulate the radar, essentially prohibit recording calculated values. The RIO must hold the results in his memory as he progresses through the list of operations. The outcome is a high information-processing rate for the RIO's mental processes.

INTEGRATION AND DECISION MAKING. The calculation and labeling provide only the data upon which the RIO must formulate maneuvering decisions. The changes, and change rates, of the positional relationships represented by existent angular and linear values determine the progress of the intercept. Decision making forms the third element of the intercept process.

It must be presumed that the RIO compares his observations with some internalized model of the intercept process. This internalized model generates expectancy data based upon initial orientation and past maneuvers. The internal process model predicts such values as drift and drift rate of radar returns, range and changes in range, and the change in bearing or bearing limits in time. When a specific change of a flight parameter does not produce the predicted relative movement, the RIO must initiate a corrective change in flight parameters. Determination of intercept progress is derived from the "B" scope presentation once the bogey has been acquired on radar. Changes in flight parameters to produce a specific relative motion are subject to errors in display interpretation and in computation. The necessity to shift attention to radar manipulation may produce time-related errors. The RIO may fail to calculate correct flight parameters because his attention is focused on the radar.

CONTROL COMMANDS TO THE PILOT. The fourth element in the RIO's flight task is the verbalization of his decisions in the form of commands to the pilot to modify the aircraft flight parameters. Verbalization of decisions concerning the intercept demands a greater amount of RIO attention than would appear necessary, particularly for the RIO student. The verbalization of commands acts as an intrusion into other processes demanded by other task elements.

SECTION III

THE INSTRUCTIONAL STRATEGY

The opportunity to develop individual job skills through intensive practice in a permissive environment can be provided by computer-controlled trainers. These devices can be designed so that instructor monitoring is not continuously required. They can be sufficiently responsive to individual differences to eliminate time wasted by traditional "lock-step" training methods.

As has been outlined above, the RIO's role involves a number of different kinds of tasks. The RIO often has a high information-processing load to deal with in a real-time, essentially hostile, and therefore stressful, environment. It is essential that he develops fluency in performing these tasks, so that he can successfully process information at the rates demanded by real-time tactical operations. It is well known that intensive practice can enable the performance of tasks without constant attention, freeing the focus of attention for higher-order considerations. Intensive practice under proper conditions also results in a performer with more confidence in himself and more resistance to perturbation by stress (Kay, 1970). The following are major features of the instructional strategy:

a. Enough features of the job-environment are simulated to provide a realistic context.

b. Basic information-processing tasks, computing values in the intercept triangle, are assigned a special, "static mode" in which bogey and fighter speeds are 0, so that the student can build up fluency to the point that he can keep up with real-time demands later, when bogey and fighter are travelling at speeds up to 500 knots.

c. Immediate knowledge of results is provided for all intercept-triangle values and for the outcome of the intercept problem. Latencies (in seconds) are provided for the mental computations.

d. Displays of the intercept geometry are provided; both as computer-controlled (automatically shown after the student makes an error), and as student-controlled (depress function key) features. In the static mode, a static intercept triangle is displayed. In the dynamic mode (bogey and fighter moving), the true motion of the two is displayed by a triangle that changes shape as the intercept develops. The student can compare the true motion seen in this display with the relative motion seen on the simulated B-scan that also is displayed. The intercept geometry at the time of firing also is displayed, showing jet heat-cone and missile acquisition-cone, and a probability-of-hit figure.

e. An updated display of all the intercept triangle values is available during the dynamic mode, if the student depresses a function key.

f. The student can temporarily stop the real-time problem by hitting a function key if he feels he is getting behind the problem.

g. Four problem categories, each with 16 intercept problems, representing different initial positions, headings, ranges, and values of Angle Off are presented in four sectors (quadrants) and at eight different bogey and fighter speeds. Speeds increase by 40 knot increments, from lowest to highest. These combinations provide 512 practice problems. Heading and bearing values are changed as the student progresses from static to low to high speed levels.

h. Trials-to-criterion logic automatically moves each student to the next speed level as soon as he solves four problems in succession with no errors, no use of on-demand functions, and all probabilities of hit at or above .80.

i. If a student achieves less than a P-hit of .80, the computer automatically puts him into a "free-fly" mode and that same problem is repeated in this mode. In the free-fly mode, the displays of the intercept triangle, of the B-scan, and of the updated triangle values in the toteboard, are continuously on the CRT. The student "flies" the fighter by issuing turn commands via the keyboard. In this way, students can experiment to find the best interception path to fly, and can relate numerical values of variables to the true motion of the intercept triangle and to the relative motion on the B-scan.

SECTION IV

THE CAI SYSTEM

The hardware part of the trainer is a programmable graphics terminal, or "smart" terminal generally used in conjunction with a larger computer, either as a remote terminal in a time-sharing system or hard-wired into other types of systems. However, this terminal includes features that make it well suited for use as part of a small, stand-alone CAI system in military training environments where geographic and size-of-school constraints make large, centralized CAI systems impossible or uneconomical. The terminal is compact, occupying less space than a small desk. The graphics CRT, two minicomputers, 8K of core, and a variety of special processing, graphics, and IO accessories are contained in this space. The terminal contains two programmable minicomputers, one general-purpose, and one for display processing. The cycle time of 2 usecs is fast enough to permit generation of relatively complex, animated graphics displays within the normal 40 cps refresh rate. The hardware is organized for microprogramming, which provides for an extensive instruction repertoire for standard data-processing. The graphics instructions include three different ways of producing images; moving a dot by changing X, Y coordinates, drawing by moving a short vector (approximately 1/126 inch) a unit at a time, or drawing longer straight lines with three instructions per line. Software for standard alphanumeric symbols is provided by the manufacturer. The terminal keyboard is completely programmable. The keys are treated essentially as peripheral input devices. Depressing a key sets a programmed flag and enters the octal code identifying that key in a register. What happens after that is entirely up to the programmer.

Programs and data can be loaded into core memory relatively rapidly from audio-tape casettes. Since the programs define the "course" that is to be implemented by the trainer, the hardware described above can be used for as many different "courses" as can be programmed. Together, these features are an attractive potential for an individual-skills trainer for tasks that must be performed in real-time and that involve graphics displays in the operating environment or that could be learned more quickly through the mediation of special graphics displays.

SECTION V

THE COMPUTER PROGRAM

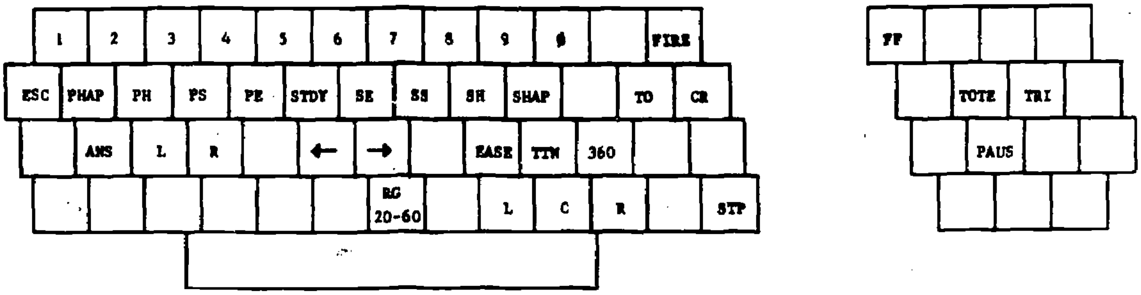
In this type of trainer, the computer program creates the instructional environment, implements the instructional strategy, and records and analyzes the data. In a very real sense, the software is the trainer. In this case, the program consists of approximately 7500 instructions and intercept problem specifications written in assembly code. Some appreciation for the size and complexity of this program can be gained from considering the following major operations implemented in the program.

a. It accepts and responds to the student's entries via the keyboard. A diagram of the function keys is given in figure 3; the accompanying legend briefly describes each function, which is implemented by a subroutine in the program. In a sense, depressing a key is equivalent to a subroutine call.

b. It provides three instructional modes: static, dynamic, and free-fly. In the static mode, students practice performing the mental arithmetic necessary to compute values of intercept triangle variables, given initial positions and headings of fighter and bogey. This mode is called static because the fighter and bogey do not move from their initial positions. They fly at zero speed. A drawing of the intercept triangle, with the variables labeled, is given in figure 2. The algorithms for computing values of these variables are described in table 1. A "toteboard" display is continuously present in the static mode. This display lists initial headings of fighter and bogey, bogey range and bearing, and the intercept triangle variable names in following rows (see figure 4). When the student computes a value for a variable, it appears in the toteboard opposite the name. If the student's value is incorrect, after 3 seconds, it disappears. If the value is correct, it remains in the space adjacent to the variable name (see figure 5), and an arrow at the right end of the row moves down to the next row. The student can try to compute the correct answer as often as he wishes, but latency to correct response is recorded, and he knows an objective of the practice is to reduce latency. As a last resort, the student can depress the answer key, which causes the correct answer to be displayed adjacent to the variable name.

On the first error the student makes, the intercept triangle for that particular problem is automatically displayed on the screen above the toteboard, so that the student can see the geometry of the situation. The display for this condition is shown in figure 6.

The basic display for the dynamic mode is shown in figure 7. In the dynamic mode, the fighter and bogey are flying at any of eight speeds. The student must compute values for the intercept triangle as he did in the static mode, but now, while he is doing this the problem is progressing; the longer the total latency, the further he gets behind the current situa-



0-9 ... Use to Enter Numerical Values (up to three digits)

FIRE .. Fires Sidewinder and Presents a Display of Relative Aircraft Locations and Hit Probability

ESC ... Erase Erroneous Input

PHAP .. Hard as Possible Turn to Port

PH .... Hard Port Turn

PS .... Standard Port Turn

PE .... Easy Port Turn

STDY .. Steady (this stops the turn)

SE .... Easy Starboard Turn

SS .... Standard Starboard Turn

SH .... Hard Starboard Turn

SHAP .. Hard as Possible Turn to Starboard

TO .... Turn To (New Heading)

CR .... Executes Turn Commands and Toteboard Entries (Static Phase)

ANS ... Displays Correct Answer for Intercept Triangle Variable

L ..... Left (for AO, TA, MUA)

R ..... Right (for AO, TA, MUA)

← .... Moves B-Scan Cursor to Left

→ .... Moves B-Scan Cursor to Right

EASE .. Reduces Turn One Step (Steady if already easy turn)

TTN ... Increases Turn One Step (no affect if hardest possible turn)

360 ... Executes a Turn of 360° to Left or Right When Depressed Following Any Port or Starboard Turn Command

RG 20-60 .. Change B-Scan Range Scale to Different Scale (20 and 60 Miles)

L ..... Left Sector Radar Scan (45L - 8R)

C ..... Center Sector Radar Scan (20L - 20R)

R ..... Right Sector Radar Scan (8L - 45R)

STP ... Halts Program when Asking for Problem Number

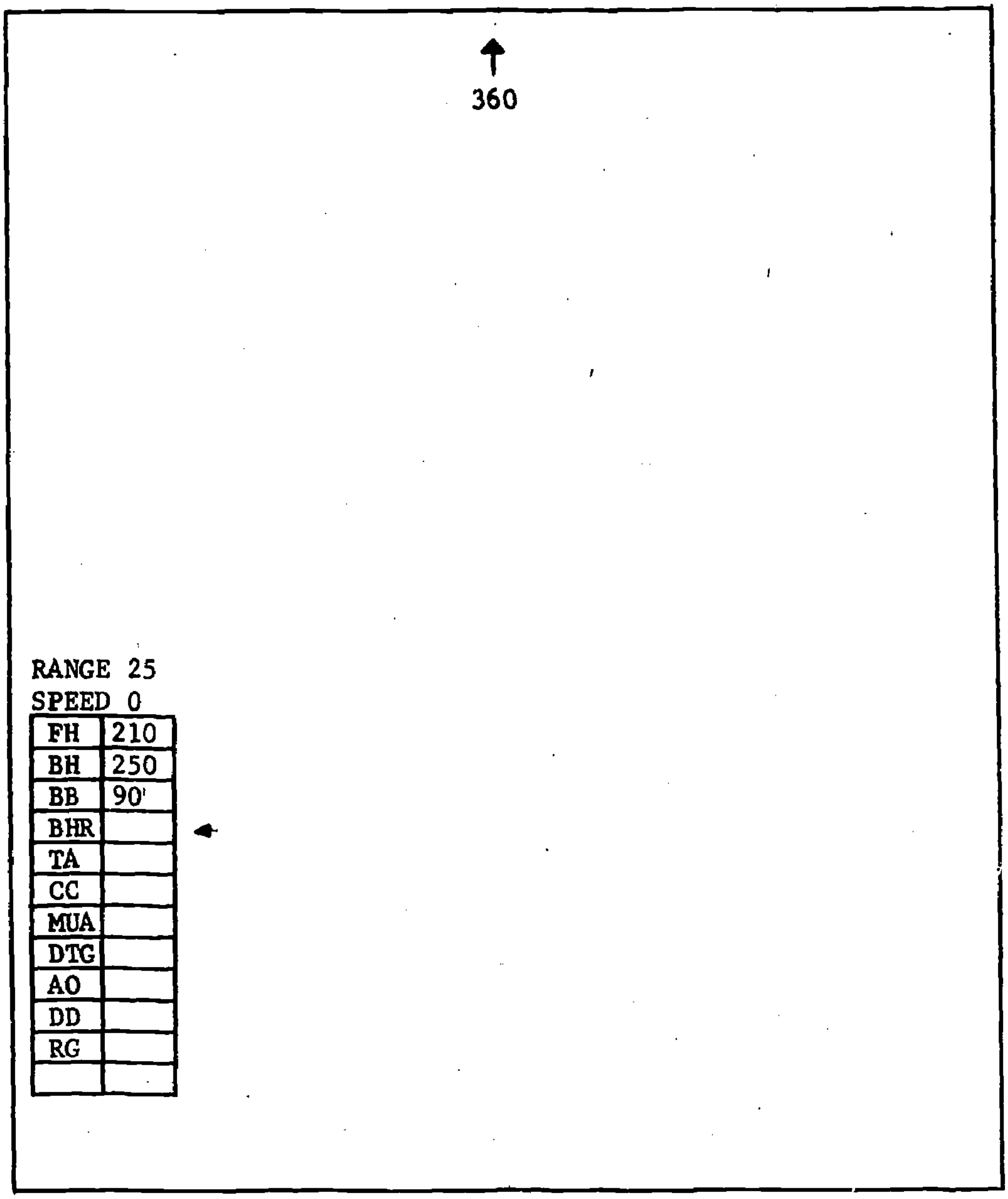
FF .... Depress after Depressing <u>FIRE</u> to Enter Free-Fly Mode

TOTE .. Displays Toteboard in Dynamic Mode

TRI ... Displays Intercept Triangle in Dynamic Mode

PAUS .. Sets Fighter and Bogey Speeds to Zero in Dynamic Mode until Depressed Again

Figure 3. Intercept Trainer Function Keys

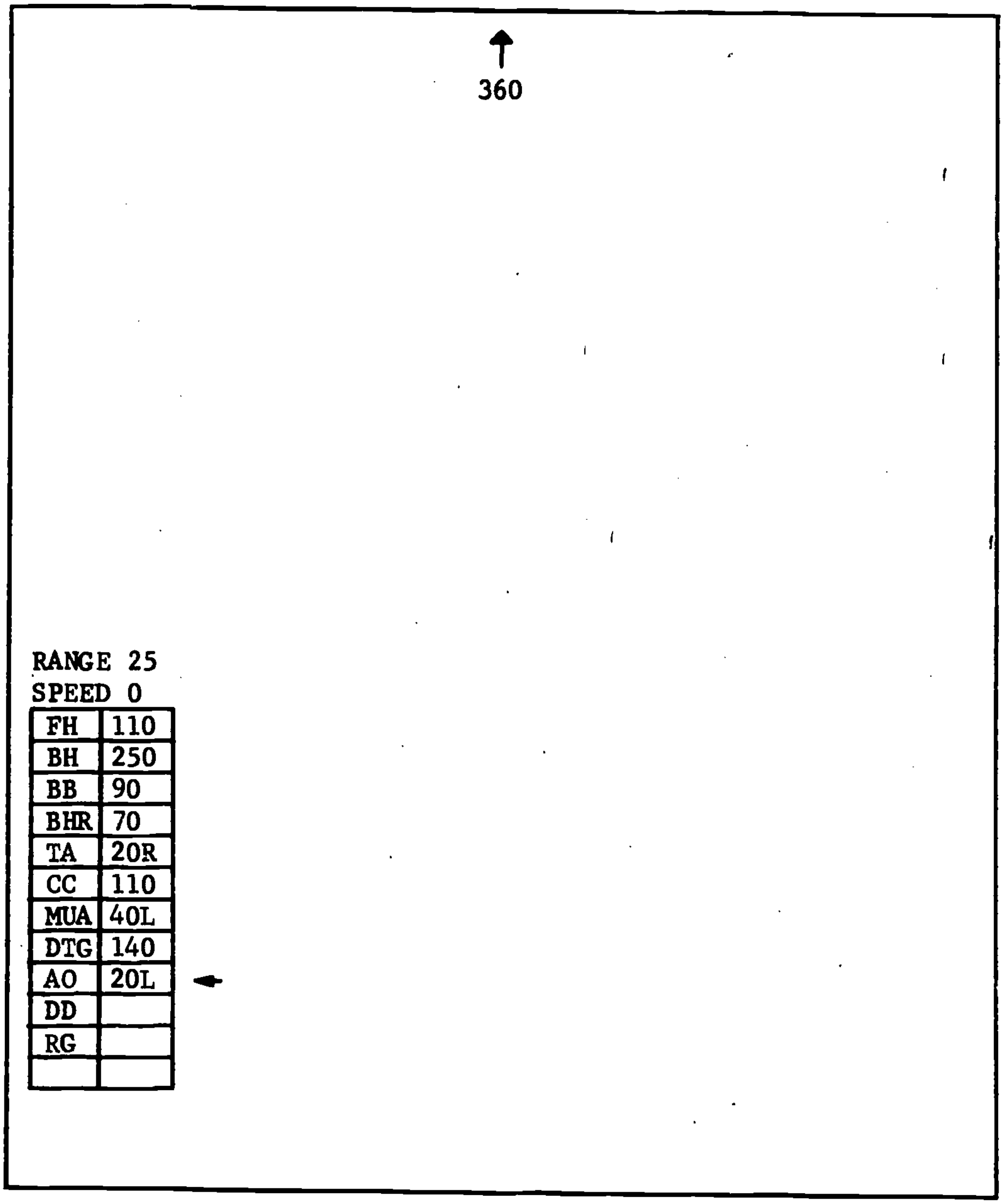


RANGE 25
SPEED 0

FH	210
BH	250
BB	90
BHR	
TA	
CC	
MUA	
DTG	
AO	
DD	
RG	

Figure 4. Static Mode Display

"Toteboard" with data provided at earliest stage of training. Response arrow designates intercept triangle element to be determined and entered into the display via the keyboard. When the designated value is correctly entered and evaluated, the arrow will move to the next value designated in the computational sequence.

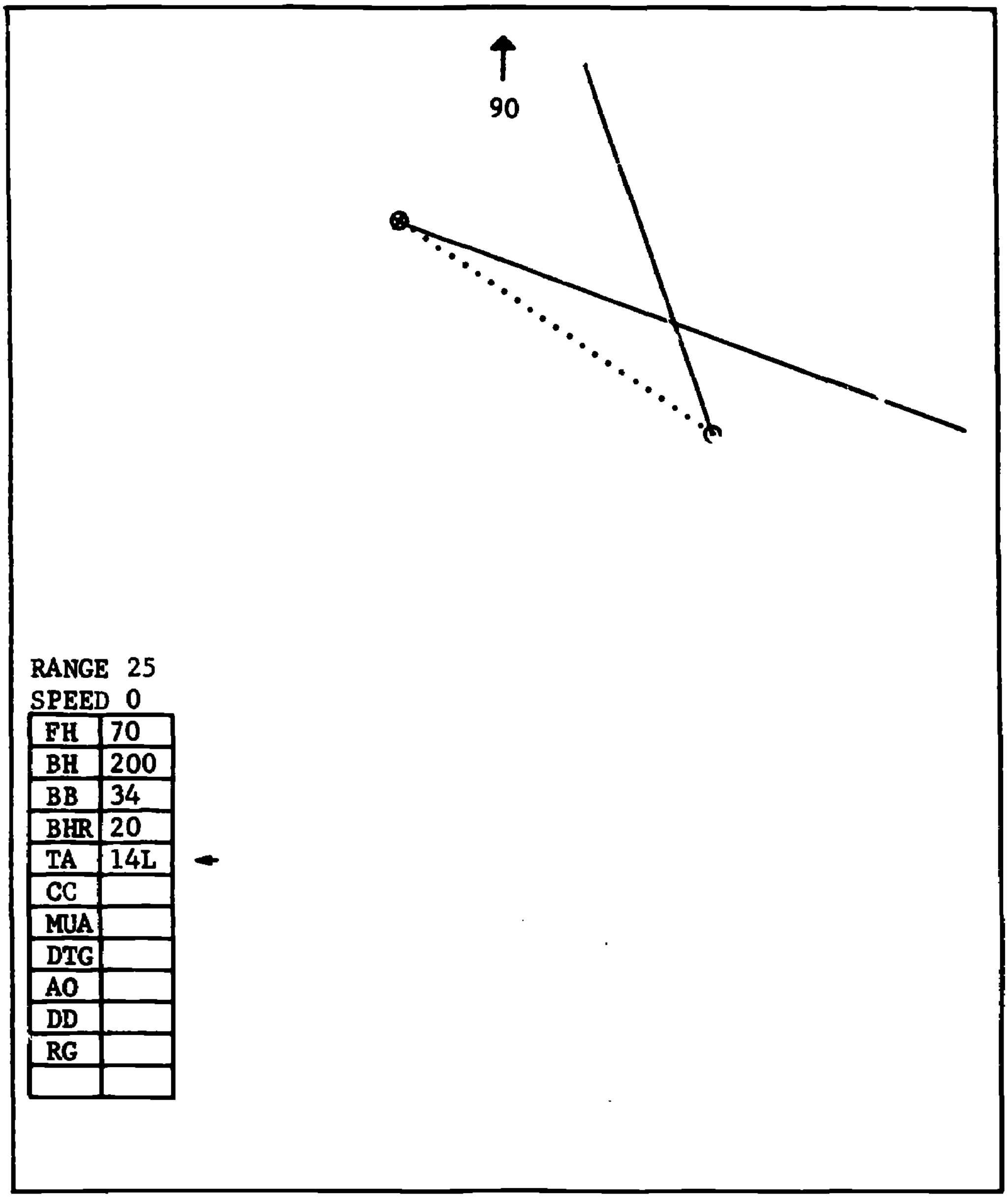


RANGE 25
SPEED 0

FH	110
BH	250
BB	90
BHR	70
TA	20R
CC	110
MUA	40L
DTG	140
AO	20L
DD	
RG	

Figure 5. Static Mode Display

"Toteboard" with values of intercept triangle elements correctly entered. The final value of the required set (AO) has been entered but not evaluated by the computer. Upon evaluation as correct, the computer will request selection of a new problem.



RANGE 25
SPEED 0

FH	70	
BH	200	
BB	34	
BHR	20	
TA	14L	◄
CC		
MUA		
DTG		
AO		
DD		
RG		

Figure 6. Static Mode Display

"Toteboard" with incorrect value entered in TA (correct response is 14R). The situational display appears as a result of an erroneous entry and remains displayed throughout the problem. The value entered as TA (14L) will disappear in 3 seconds indicating an error. The arrow will remain in position until the correct entry is made and accepted.

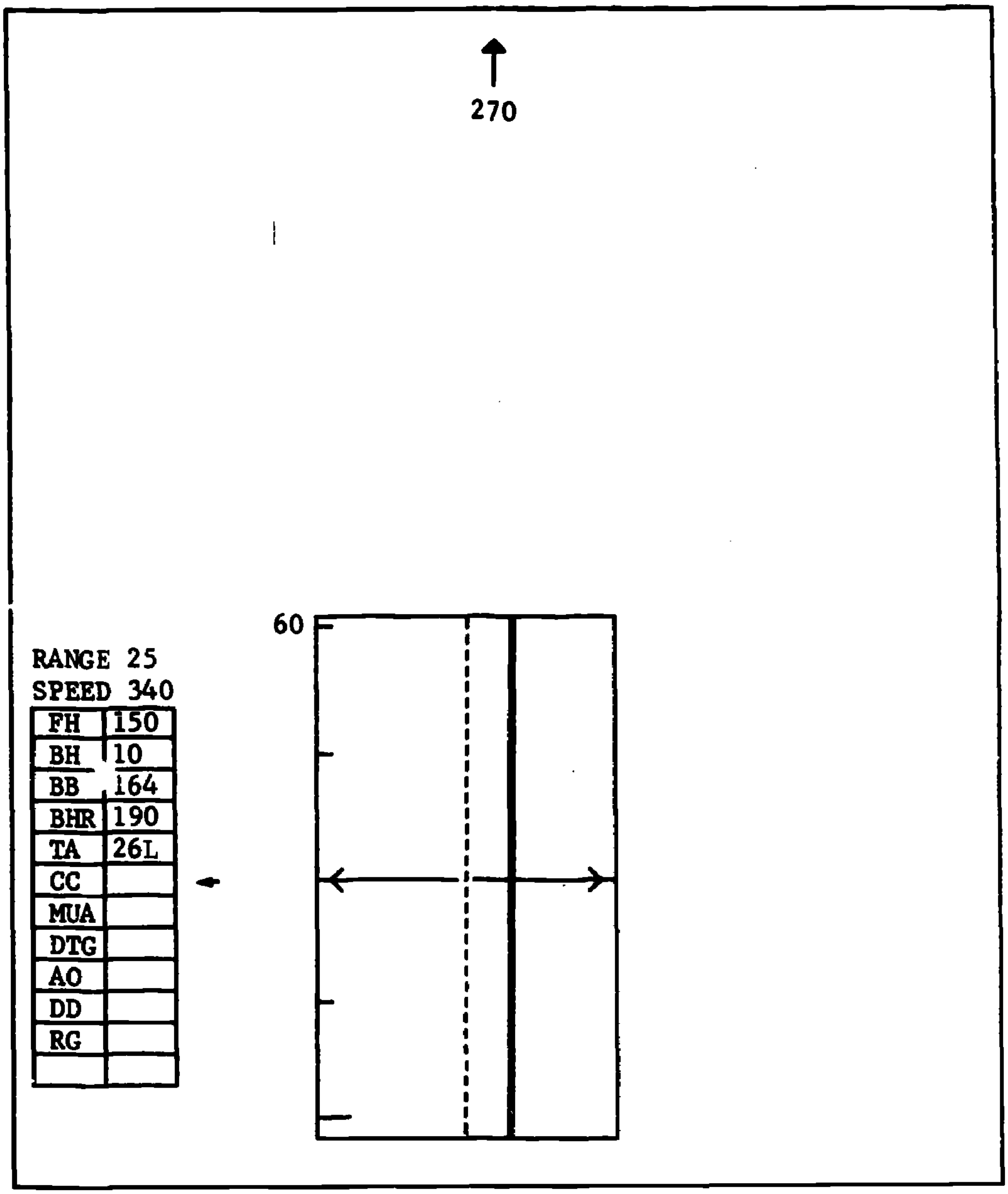


Figure 7. Dynamic Mode Display

"Toteboard" with basic data and B-scope simulation. B-scope is set at 60-mile range, and own aircraft is in level flight as indicated by the Horizon Line. "Toteboard" values must be correctly completed before computer will accept maneuvering commands. Designation arrow indicates next value to be determined and entered.

tion. However, values in the toteboard are based on initial conditions until the student enters the correct collision course. At that point, the fighter turns to collision course and toteboard values are recomputed on the basis of the new heading. The toteboard values disappear after the student enters a value for Angle Off. The result is the display of figure 8. Updated values from then on are available to the student if he depresses a function key (see figure 9). Similarly, the intercept triangle is also available by depression of a function key, resulting in the display shown in figure 10. The primary display in the dynamic mode is the simulated B-scan, including target acquisition, turn indicator, rate-of-closure circle, and full and sector scan illustrated in figure 11. The student's task, after he solves for intercept triangle values, is to learn to use the B-scan to fly the fighter through a sidewinder intercept. Three major turns are usually involved; to collision course, for displacement distance, and firing turn. Minor turns to correct for drift on the B-scope also may be necessary. The intercept is ended by the student depressing the "FIRE" key. This causes the geometry at the moment of firing, including a hit probability, to be displayed as in figure 12.

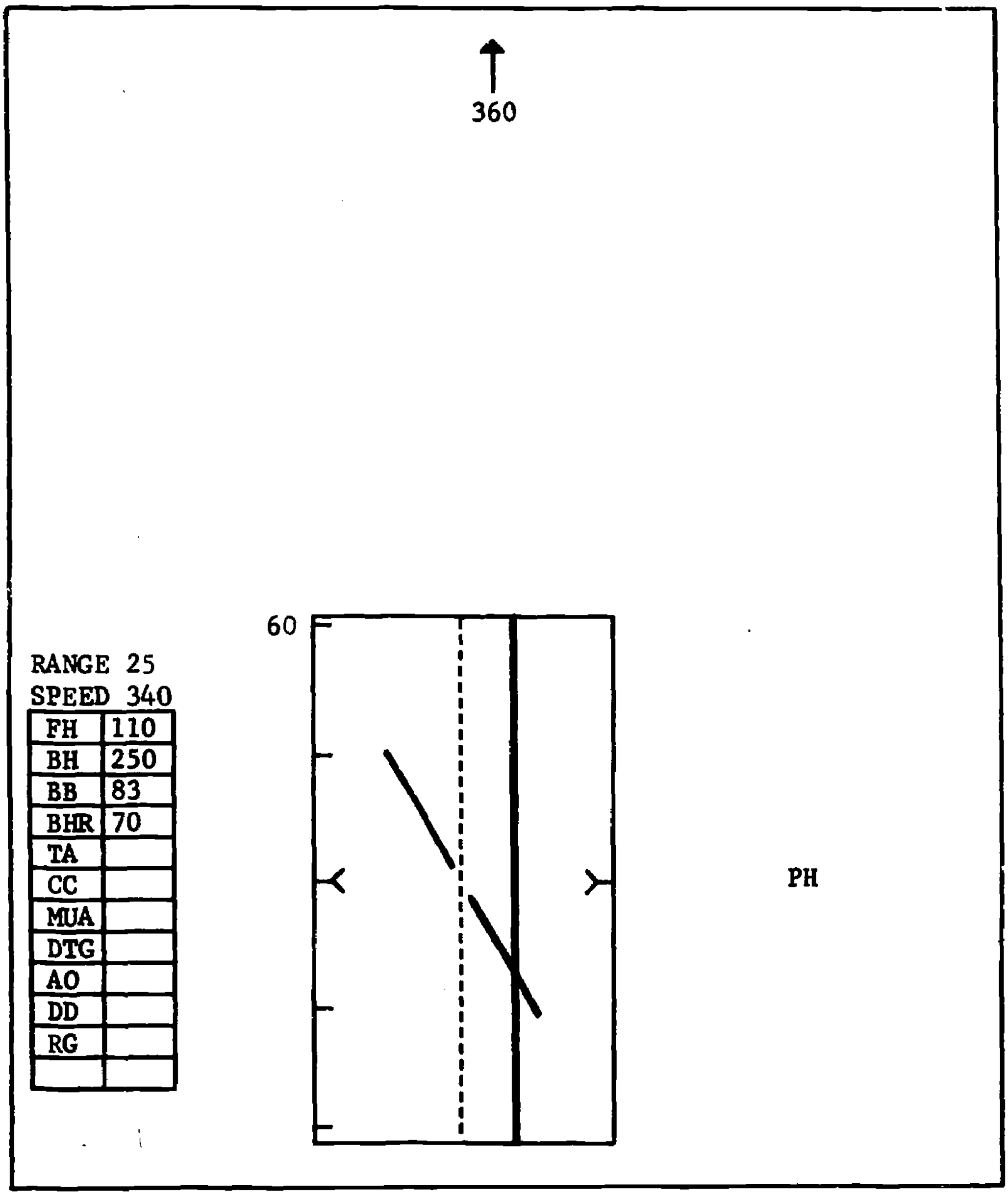
If the student makes an error while computing values for the intercept triangle, a moving version of the triangle geometry is displayed on the screen above the B-scan, so that the student can watch the problem develop in "true" motion and can compare this to the relative motion seen on the B-scan. This display format is illustrated in figure 13.

The "free-fly" mode is entered from the dynamic mode. If the P-hit for a problem is less than .80, the student is automatically shifted into the free-fly mode, where he repeats the problem. In this mode, all the updated displays are continuously available; the toteboard, the B-scan, and the dynamic triangle. The student can use information from these numerical and geometrical displays, while flying the fighter through the intercept. He can repeat a problem as often as he wishes until he feels he has mastered it. The graphic display for the free-fly mode is illustrated in figure 13.

c. The program simulates interceptions by computing the positions and headings of fighter and bogey every 1/10 second and every time the student changes fighter heading. The computational subroutines compute the values of all intercept triangle variables, using trigonometric functions, and a vertical reference (on the screen) that takes on any of four values in degrees, 360 (or 000), 90, 180, 270, representing the four quadrants in which an intercept problem is displayed. The problems are driven by the speeds at which the aircraft move. The turns of the fighter are driven by turn rates for a trainer aircraft using any one of four "doctrine" turns. The outputs of the computational subroutines are used in a variety of other subroutines: to correct students' answers, to display correct values in the toteboard, to update the B-scan and intercept triangle displays, and to provide the basis for computing hit probabilities.

It must be appreciated that all computations are done in binary arithmetic; student inputs, and outputs to displays are in decimal; and all integer representations internally are in octal.

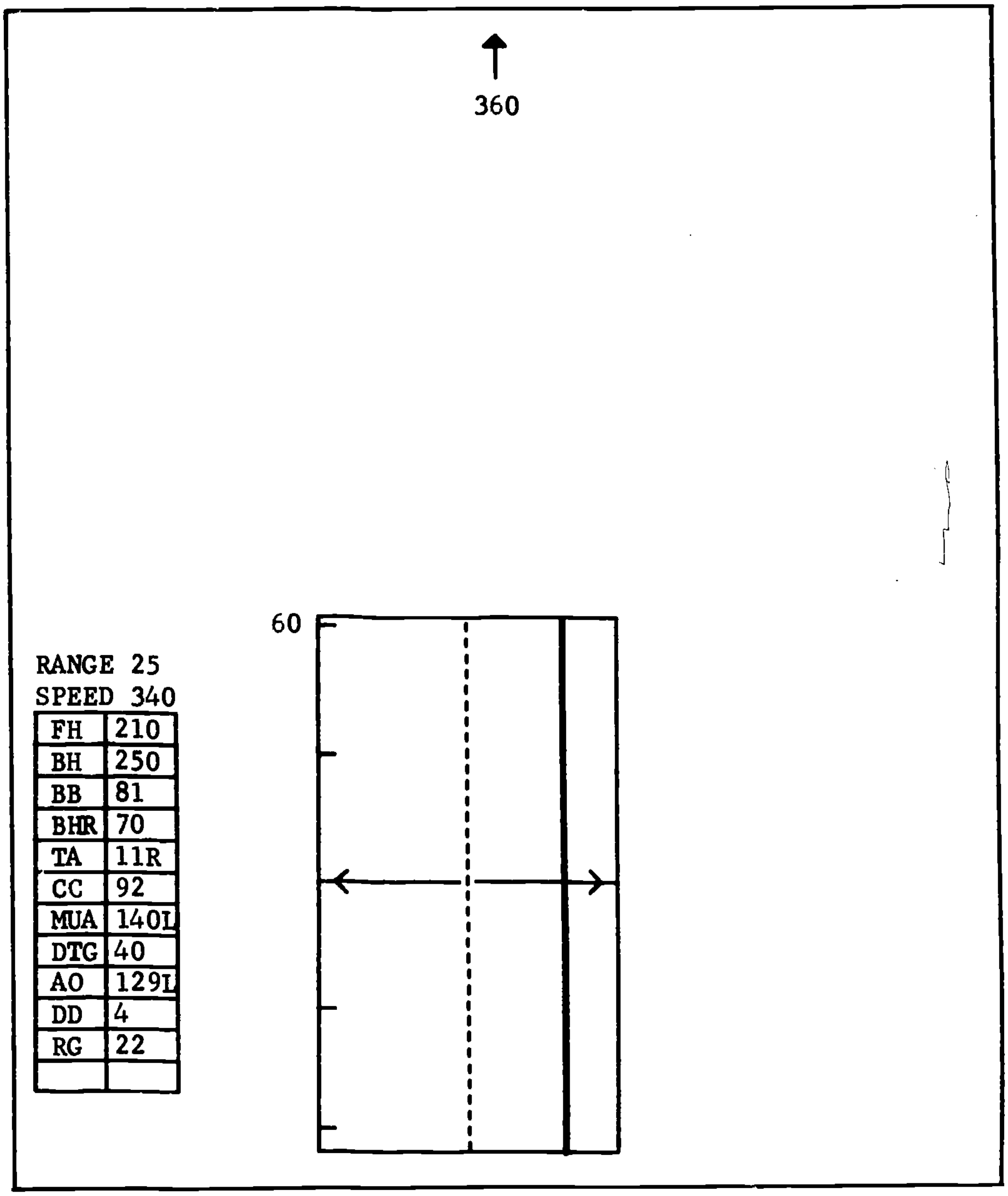
d. The program generates all the displays described above: the alphanumeric toteboard, the static and dynamic triangles, the B-scan, and the fire



FH	110
BH	250
BB	83
BHR	70
TA	
CC	
MUA	
DTG	
AO	
DD	
RG	

Figure 8. Dynamic Mode Display

All "Toteboard" values entered correctly. "Toteboard" clears all entries below BRH and designation arrow disappears. Maneuvering commands may be entered and will be displayed to the right of the B-scope. Fighter is in hard turn to port. Horizon Line reflects bank angle (60° left).



RANGE 25
SPEED 340

FH	210
BH	250
BB	81
BHR	70
TA	11R
CC	92
MUA	140L
DTG	40
AO	129L
DD	4
RG	22

Figure 9. Dynamic Mode Display

B-scan active. Student depressing "Toteboard" key; all values in "Toteboard" displayed as long as the key is depressed. Values are constantly updated to reflect changes in relative motion.

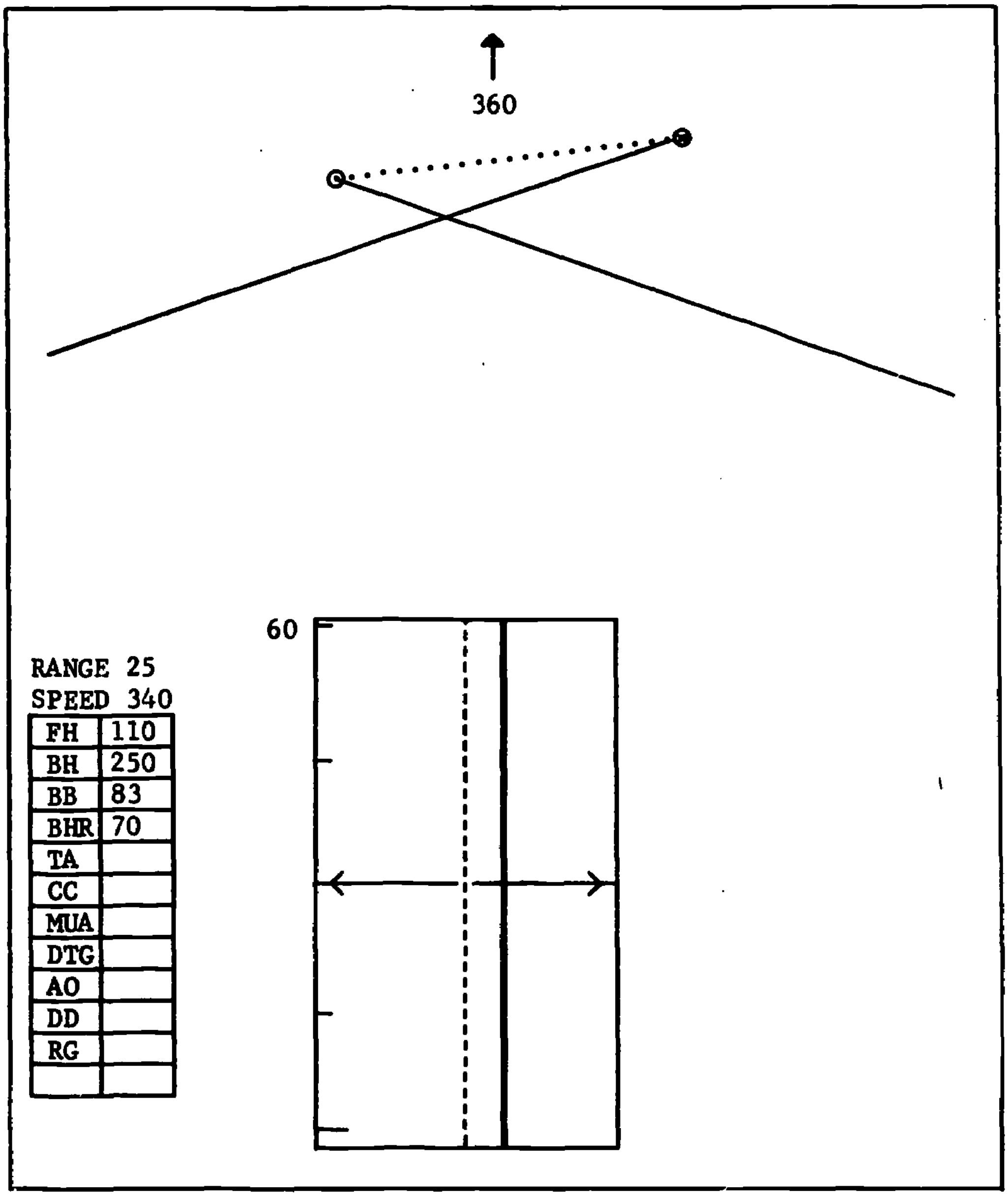
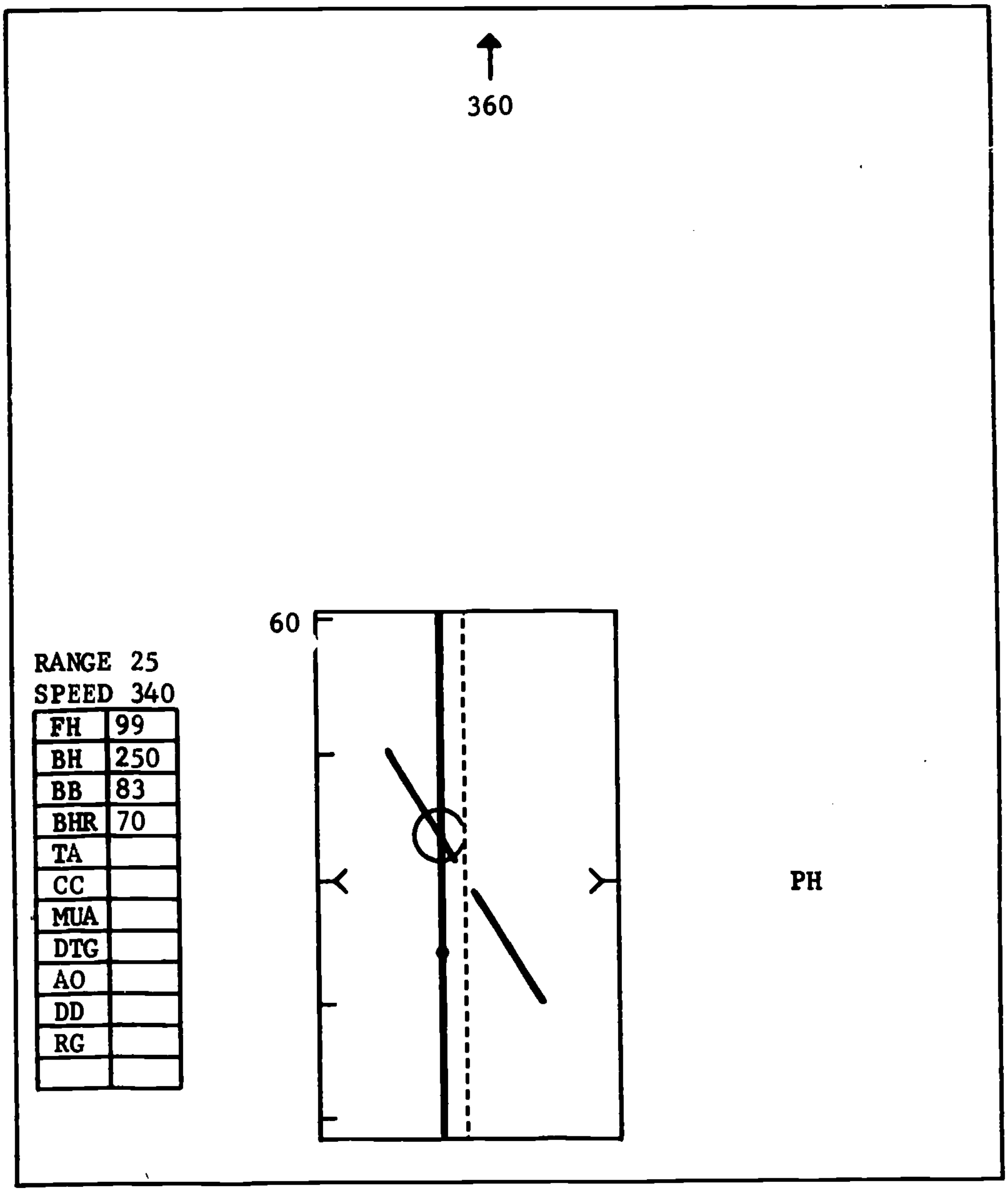


Figure 10. Dynamic Mode Display

B-scan active. Depressing "triangle" key causes intercept triangle to be displayed as long as key is depressed. Triangle elements constantly changing to reflect relative motion.

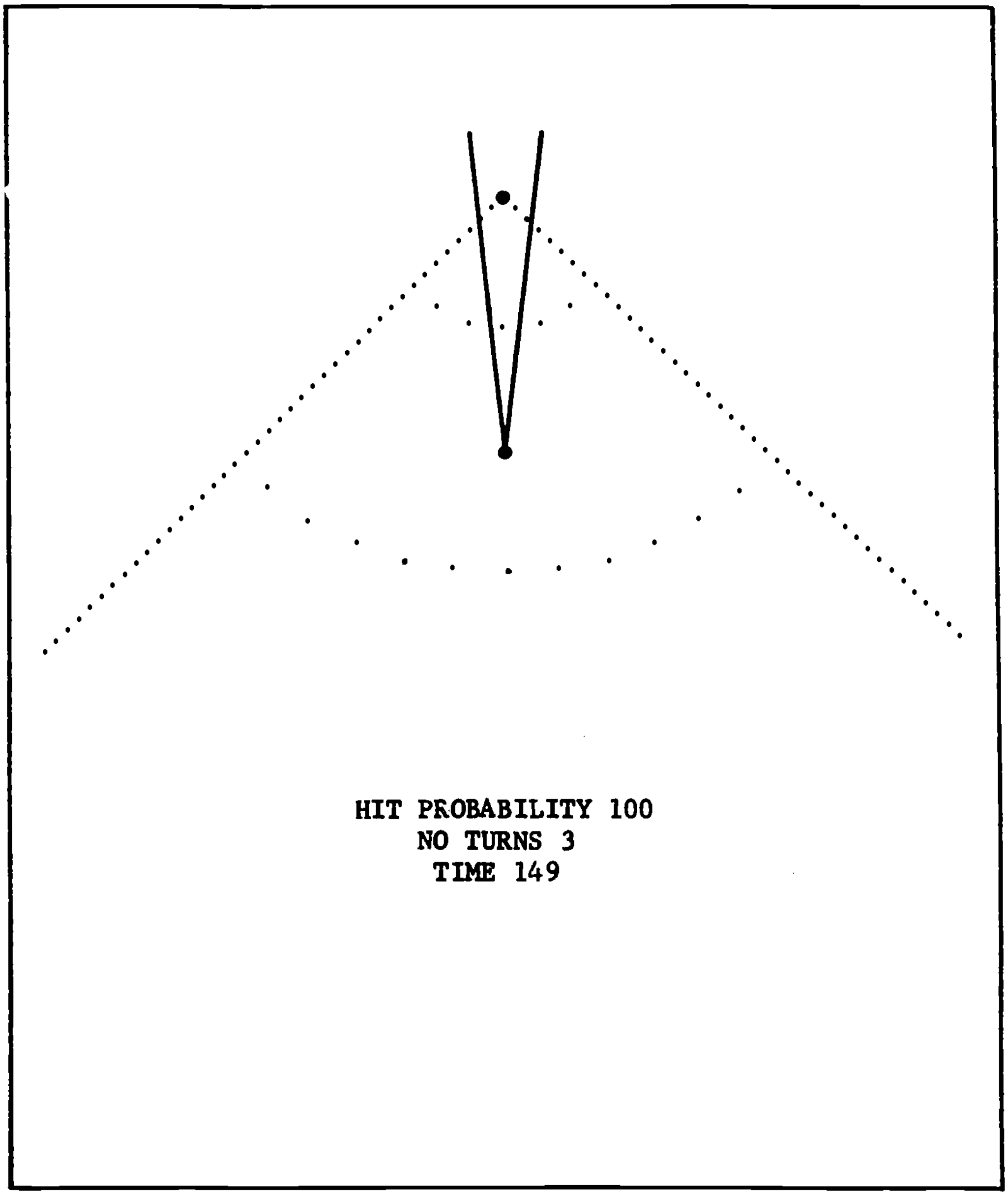


RANGE 25
SPEED 340

FH	99
BH	250
BB	83
BHR	70
TA	
CC	
MUA	
DTG	
AO	
DD	
RG	

Figure 11. Dynamic Mode Display

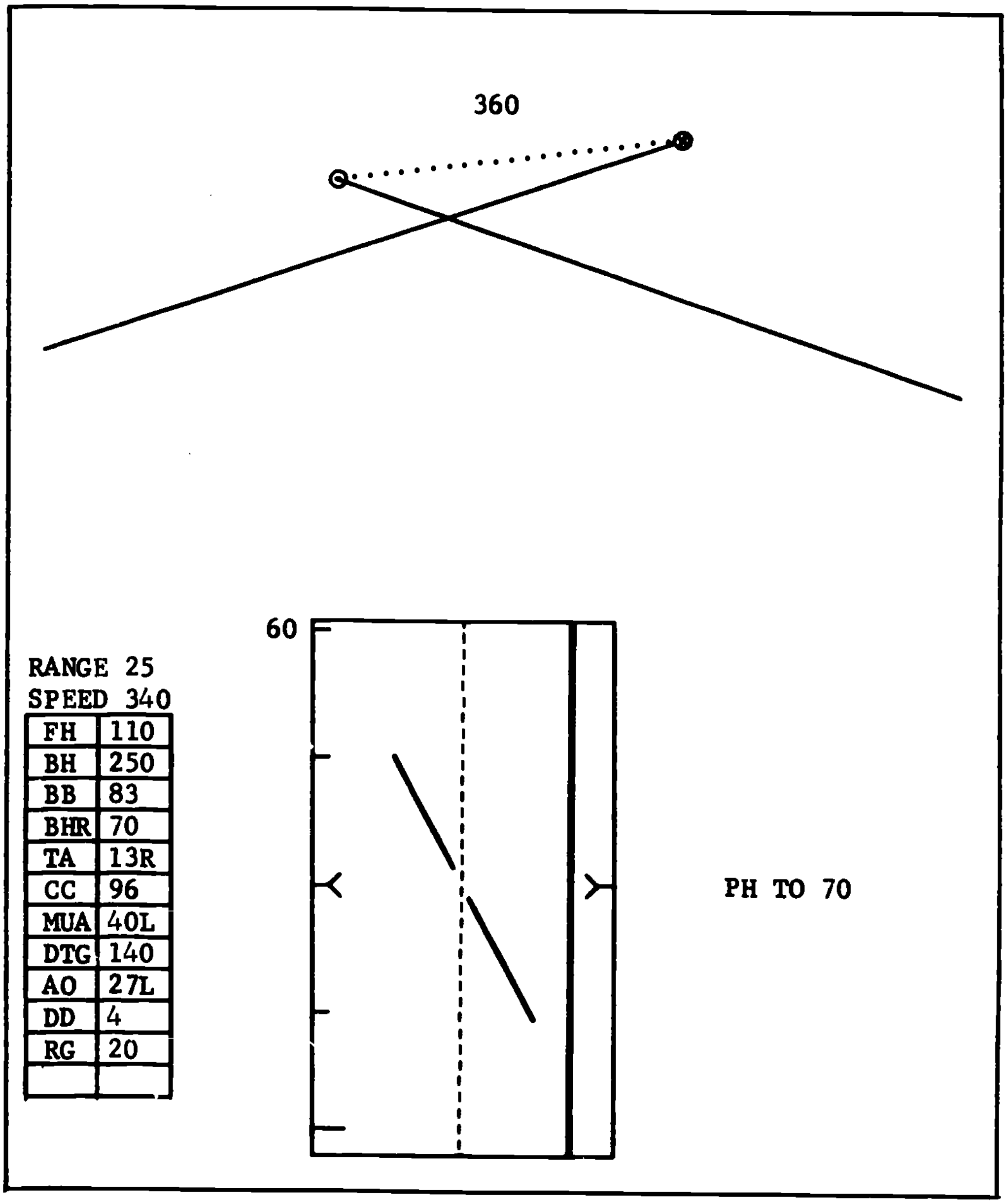
Radar in "Track" mode, aircraft in hard turn to port at 60^{o} of bank angle. ROC circle displayed while in "Track" mode.



HIT PROBABILITY 100
NO TURNS 3
TIME 149

Figure 12. Hit Probability Display

Presented in either dynamic or free-fly modes upon depression of FIRE key. Displays relative position of bogey at time of firing, position of fighter inside bogey heat cone, and bogey relative to missile tracking cone. Alphanumerics provide p-hit score, total number of turns utilized to intercept and total elapsed time of intercept.



RANGE 25
SPEED 340

FH	110
BH	250
BB	83
BHR	70
TA	13R
CC	96
MUA	40L
DTG	140
AO	27L
DD	4
RG	20

Figure 13. Free-Fly Mode Display

Intercept triangle and "Toteboard" values continually displayed and updated to reflect relative motion. B-scan reflects relative positions of Fighter and Bogey. Aircraft in hard turn to port.

geometry. The subroutines to do this are written in display instructions and are implemented by the display processor minicomputer. The general-purpose minicomputer can be said to be the dominant of the two computers, since it not only watches the clock and turns the display processor on, it also makes up the "display list," consisting of a series of jump (to display subroutines) commands and stores this list in core. The display processor then executes this list, one jump (one subroutine) at a time by reading each instruction from core. (The display processor cannot write on core). The display processor steals one fetch cycle from the general-purpose mini each time it accesses core. When it has finished the entire display list, it turns itself off and waits for the other mini to turn it on again at the start of the next 1/40th of a second.

One of the most difficult display programming problems is to coordinate display updating in real-time with random keyboard inputs requiring changes in displays.

e. The program records student response histories, implements trials-to-criterion logic, provides knowledge of results to the student, and transforms response histories into permanent records. The trials-to-criterion logic provides for moving the student from the static phase to the dynamic phase, and to successively higher speed levels in the dynamic phase each time the student achieves a criterion of four successive problems with no errors and within acceptable time limits. Knowledge of results are provided as described above in discussing the modes. Recording the response histories on permanent records could be done in any of a number of ways. Because the initial data were collected on a military base - geographically remote from the nearest time-sharing access point and telephone lines out of the base could not be tied up - and the terminal had only 8K memory, student data were punched on paper tape, using a teletype tape-punch on-line with the terminal. Student responses, scores, and a time and range, in miles between aircraft, were written on a short buffer memory. This buffer was read out and the contents were punched on tape in real-time, i.e., as the data were generated by the student. The buffer served to protect against data loss due to the slow punch speed of 110 bits per second (110 baud). Student responding might otherwise get ahead of tape punching. This procedure proved to be a satisfactory expedient for that environment, since a silencing case could be fitted over the teletype.

However, the RIO trainer generates a phenomenal amount of data. Consider that each student practices with the trainer for 10 hours. In that time he may work through several hundred problems. Each problem yields 33 different units of data, and many of these units may occur several times during the course of a problem. The result is roughly 5,000 to 10,000 data items per student. Clearly, these data must be analyzed by a computer, using the most efficient possible processing techniques available for writing tapes to disk files, and for computing summary statistics. All of this processing is done using a Fortran program written for the purpose. The steps in tape processing are:

(1) Punch master tape from individual student tapes.

(2) Write master tape on sequential ASCII disk files using 300 baud tape reader.

(3) Edit anomalies and rewrite these data strings.

(4) Run the statistical analysis Fortran program on the files.

(5) Print results in formats as close as possible to table formats for the technical report.

SECTION VI

THE DESIGN FOR THE FIELD TRIAL

The intercept trainer was installed in the RIO school at Glynco, Georgia for preliminary evaluation of its validity, reliability, and acceptability in that training environment. Two types of validity were of immediate interest; instructional strategy validity for improving student performance in the flight phase of air-to-air intercept training, and content validity in relation to the curriculum and training methods in use at the school. After inspecting the trainer, the school staff suggested several minor changes in the displays and procedures. These were made as running changes over approximately the first month the trainer was in operation at Glynco. The data for the group (four students) from the first class that used the trainer were therefore not included in the data analysis. Although the intercept trainer was designed to teach basic procedures, using generalized displays and aircraft parameters (e.g., turn rates), it inevitably was compared with the 15C4 radar trainer at the school. A number of suggestions for changes resulted from the understandable interest of the school staff in having more radar training procedures incorporated in the Behavioral Technology Laboratories trainer. These suggestions could not be implemented for two reasons; lack of time to write the necessary programs, and shortage of core in the 8K device. However, there is no reason that many additional features of this nature could not be incorporated in a device with 16K of core. Indeed, one of the great advantages of this type of individual trainer is that changes and additions in training functions usually can be made by programming rather than by redesign of the hardware.

Establishing that the individual trainer does or does not improve student performance in the subsequent flight phase of the RIO course is a matter requiring a series of studies and relatively rigorous control over situational variables. For the preliminary evaluation, a two-random groups post-test only design was planned, using groups randomly constituted from each RIO class in turn, and using an in-flight instructor checklist as the measure of dependent variables. It would have been more desirable to have recorded student data in-flight essentially identical to that recorded automatically on the ground by the BTL trainer. However, facilities for doing this would have required resources beyond the scope of the project. The checklist is reproduced in figure 14a and b. The columns numbered 1 through 5 are for use during or after check flights, which are the school's performance tests. Acceptability will be assessed from student comment sheets and from interviews with the school staff.

NAME ____________________ DATE ____________________
CLASS ____________________
INSTRUCTOR ____________________ FLT CODE ____________________

	1		2		3		4		5	
	y	n	y	n	y	n	y	n	y	n
CC: Initial Hdg. within approx. limits										
Overshoot Hdg										
Undershoots Hdg										
Turn wrong direction										
BOGEY DRIFT: Aware of drift rate										
direction										
CC CORRECTIONS: Corr. by proper amt										
direction										
Are further corrections necessary										
Corr. by proper amt										
direction										
LATERAL DISP: Disp. turn, position										
Final displacement: DD = 4-5 mi										
DD > 4-5 mi										
DD < 4-5 mi										
COUNTERTURN: Good start position										
Angle off error										
Range error										
Controls Bogey drift										
Cold side										
Hot side										
Counterturn corrections										
Overcorrects										
Undercorrects										
FINAL POSITION: Angle off OK										
Range OK										
Weaves fighter										
AREO REPORTS: Reports correct AO										
Rg										
-------- AO										
Rg										
-------- AO										
Rg										
-------- AO										
Rg										

Figure 14a. In-Flight Performance Checklist

INTERCEPT NUMBER	1		2		3		4		5	
	y	n	y	n	y	n	y	n	y	n
DOES THE STUDENT:										
1. Determine and turn to CC in an acceptable time span?										
2. Recognize and correct drift in an acceptable time span?										
3. Anticipate arrival at pt. of turn for DD and give turn directions on time?										
4. Anticipate arrival at counterturn pt. and give turn directions on time?										
5. Remain "in step" with the problem so that he is not rushed?										
6. Appear to have confidence in his decisions/problem evaluation?										
7. Interpret B-scope indications correctly for Range and Angle Off?										
8. Provide sufficient amplifying commentary?										
9. Recognize and correct errors in an acceptable time span?										
10. Avoid confusion and keep control of the problem if errors occur?										

Do you have any amplifying comments that have not been covered?

Figure 14b. In-Flight Performance Checklist

SECTION VII

DATA ANALYSES

Data from the manually administered checklist, from automatically-recorded student response histories, and from student records at the school were used in the analyses. By far the largest volume of data was automatically recorded, by procedures described earlier. This is a significant new capability computers bring to the training environment. Response-by-response histories can be recorded, providing a "micro-view" of student progress.

ANALYSIS OF AUTOMATICALLY-RECORDED STUDENT RESPONSE HISTORIES

The summary data for the values of most of the thirty-three variables that were recorded are arranged in seven groups of tables:

a. Initial target aspects of problems.

b. Average number of problems attempted.

c. Probability of hit scores.

d. Response latencies for different segments of the intercept.

e. Response errors in solving the intercept triangle.

f. Number of turns, type of turn, and amount turned during an intercept.

g. Use of on-demand support keys.

A few of the variables, for example, the frequency of usage of the sector-scan, lock-on, and break lock keys were not included in this analysis since they were of minor importance.

The tables in each group are discussed in the accompanying text. These summaries consist of means and standard deviations listed for the static mode (speed of bogey and fighter = 0) and for the eight speed levels in the dynamic mode. Since the students progressed from the static mode through the dynamic mode speed levels (220 knots to 500 knots), the trends across columns in the tables reporting student-response data reveal changes attributable to practice, as driven by higher and higher speeds. For example, means and standard deviations for latencies decreased. The last column and last row in each of these tables contain the table row and column means and standard deviations, respectively, with one or two exceptions.

More detailed data, individual student summaries, and trial-by-trial trends per student, are available as computer listings.

INITIAL TARGET ASPECTS. Variables that defined differences among intercept problems were: quadrant of the compass in which they occurred, initial positions and headings of bogey and fighter, initial range, and speed. Initial positions also defined target aspect, the angle off the bogey's nose formed by the intersection of the fighter heading with the bogey heading. Target aspect influences intercept tactics. For example, at low target aspects, the fighter may have to turn out to achieve adequate displacement distance, before turning in for a sidewinder attack. Therefore, four categories of target aspects: 0-7 degrees, 8-14 degrees, 15-24 degrees, and over 24 degrees, were used. These categories were equally represented in the problem sequencing and in the trials-to-criterion logic. These data, given below in table 2, indicate target aspect means and standard deviations of problems within each category. Data are summarized in terms of each of these four target aspect categories in all of the following tables.

PROBLEMS ATTEMPTED IN STATIC, DYNAMIC, AND FREE-FLY MODES. Both trials-to-criterion and fixed-learning-time logic were used in this study. Students could progress to the next speed level by solving four successive problems with no errors and a probability-of-hit (in the dynamic mode) ≥ .80. However, the school assigned a block of ten hours for each student to practice on the BTL trainer. Thus, if a student transitioned to the highest speed level, 500 knots, before he used his ten hours, he remained at that level until he finished ten hours of practice. Under these conditions, the number of problems solved within levels varied as a consequence of individual differences among students.

The detailed analyses were performed on numbers of problems attempted (tables 3 and 4), since fine-grained information, e.g., latencies for triangle values and turns (number, degrees, type) was contained in these problems even though the student may have made a poor score or may have committed some errors.

In the static mode, a problem was classified as attempted if the student finished all six triangle variables, even though he made one or more errors or took more than 120 seconds. In the dynamic mode, a problem was classified as attempted if the student completed at least one turn after collision course, but did not complete the intercept, or if he completed the intercept, but his P-hit score was less than .80. Table 5 presents the means and standard deviations for numbers of problems done in free-fly, which was designed to allow the student to experiment with turning the fighter, while toteboard with continuously updated values, true geometry, and B-scan were simultaneously displayed. This mode was automatically entered and the problem was repeated if the student did not achieve a P-hit ≥ .80. It also could be voluntarily entered. The relatively large number of problems in the first and last speed levels (220 knots and 500 knots) shown in table 5 are probably due to initial difficulties of the students coming into the first level at which they had to fly a complete intercept, and to the effects of the 500 knot speed, at the opposite end of the practice sessions, on problem difficulty. The data in table 5 are not a subset of any of the above tables, and were not included in the following analyses.

TABLE 2. INITIAL TARGET ASPECTS OF INTERCEPT PROBLEMS IN FOUR CATEGORIES: 0-7, 8-14, 15-24, AND 25-40

	STATIC			DYNAMIC LEVELS: SPEED						
	PHASE	220	260	300	340	380	420	460	500	ROWS
MEAN	0.	2.7	2.8	2.9	3.1	3.1	3.4	3.1	3.1	3.0
STD DEV	0.	2.0	1.8	1.9	2.0	2.0	2.2	2.3	2.2	2.1
MEAN	0.	10.1	10.2	10.3	10.0	10.1	10.4	9.9	10.1	10.1
STD DEV	0.	1.8	1.8	1.8	1.7	1.7	1.8	1.7	1.7	1.7
MEAN	0.	17.6	17.6	17.6	17.6	17.5	18.3	17.7	17.9	17.8
STD DEV	0.	3.3	3.1	3.1	2.9	3.2	3.3	3.1	3.1	3.1
MEAN	0.	31.8	32.2	31.3	32.1	32.5	30.7	33.0	31.5	31.7
STD DEV	0.	6.9	6.1	5.7	5.9	6.4	4.7	7.0	5.9	6.2
COLS	0.	15.8	15.8	16.4	15.7	16.7	15.6	15.3	15.6	15.8
	0.	11.4	11.2	11.2	11.1	11.5	10.7	11.5	10.9	11.1

TABLE 3. MEAN NUMBER OF ATTEMPTS TO COMPLETE THE TOTEBOARD BY THE STUDENT SAMPLE (N = 29)

	STATIC			DYNAMIC LEVELS: SPEED						ROW
	PHASE	220	260	300	340	380	420	460	500	TOTALS
MEAN	3.7	6.8	2.7	3.0	2.6	1.6	2.4	2.3	11.4	36.6
STD DEV	3.9	4.3	2.5	3.4	3.1	1.6	2.5	1.9	9.6	8.3
MEAN	4.0	7.0	2.8	2.3	1.8	1.8	1.8	1.7	9.4	32.5
STD DEV	4.1	4.3	2.2	2.8	2.0	1.7	2.2	2.2	8.1	8.8
MEAN	6.7	7.7	3.3	3.6	3.1	2.0	2.5	2.5	13.5	44.9
STD DEV	5.4	5.7	2.5	3.7	3.1	2.0	3.2	2.2	12.1	12.1
MEAN	8.2	7.4	2.8	3.4	2.2	2.0	2.2	1.7	10.3	40.1
STD DEV	6.1	4.2	2.7	4.0	2.2	1.7	2.4	1.7	9.4	11.1
COL TOTALS	22.5	28.9	11.5	12.2	9.7	7.5	9.0	8.2	44.7	154.1
	17.5	16.1	8.1	12.9	9.6	5.2	9.1	6.5	37.4	36.8

TABLE 4. MEAN NUMBER OF DYNAMIC ATTEMPTS BY THE STUDENT SAMPLE (N = 29)

	STATIC			DYNAMIC LEVELS:		SPEED				ROW
	PHASE	220	260	300	340	380	420	460	500	TOTALS
MEAN	0.	6.7	2.7	3.0	2.5	1.6	2.4	2.2	11.5	32.4
STD DEV	0.	4.1	2.5	3.4	3.0	1.6	2.4	1.8	9.6	7.7
MEAN	0.	6.8	2.7	2.3	1.8	1.8	1.8	1.6	9.4	28.2
STD DEV	0.	4.3	2.2	2.8	2.0	1.7	2.2	2.1	8.2	7.5
MEAN	0.	7.6	3.3	3.5	3.1	2.0	2.5	2.4	13.4	37.8
STD DEV	0.	5.6	2.5	3.6	3.1	2.0	3.2	2.1	12.0	10.9
MEAN	0.	7.1	2.7	3.3	2.2	2.0	2.1	1.7	10.2	31.3
STD DEV	0.	4.1	2.7	4.0	2.2	1.7	2.3	1.7	9.3	9.1
COL TOTALS	0.	28.2	11.4	12.0	9.5	7.4	8.9	8.0	44.4	129.8
	0.	15.7	8.1	12.7	9.4	5.2	8.9	6.2	37.2	31.8

TABLE 5. MEAN FREQUENCY OF VOLUNTARY USAGE OF FREE FLY (N = 29)

	STATIC			DYNAMIC LEVELS:		SPEED				ROW
	PHASE	220	260	300	340	380	420	460	500	TOTALS
MEAN	0.	2.4	0.8	0.4	0.2	0.1	0.2	0.1	1.6	5.8
STD DEV	0.	2.5	1.5	1.1	0.6	0.4	0.5	0.4	1.7	3.3
MEAN	0.	2.1	0.6	0.4	0.1	0.0	0.3	0.3	2.5	6.4
STD DEV	0.	2.7	1.9	1.1	0.4	0.2	0.8	0.8	3.1	4.7
MEAN	0.	1.4	0.2	0.2	0.1	0.1	0.3	0.2	2.3	5.0
STD DEV	0.	1.1	0.6	0.6	0.4	0.3	1.0	0.7	2.7	3.3
MEAN	0.	2.4	0.3	0.1	0.2	0.2	0.1	0.1	1.8	5.2
STD DEV	0.	2.3	0.6	0.4	0.5	0.4	0.3	0.4	2.8	3.9
COL TOTALS	0.	8.4	2.0	1.2	0.6	0.4	0.9	0.8	8.1	22.4
	0.	5.6	3.5	2.6	1.1	0.9	1.7	1.6	8.3	9.8

In some of the following tables, some values are so close to zero that rounding operations produced minor discrepancies between values of means and standard deviations; e.g., a mean of 0.0 and a standard deviation of 0.1 or 0.2.

PROBABILITY OF HIT SCORES. The probability of hit score at the end of an intercept problem indicated to the student how well he had placed the fighter for firing. This score is a terminal index, and as such probably is a better measure of the student's skill in turning to attack than of his skill in earlier maneuvers. Nevertheless, he would necessarily have to be successful in placing the fighter in a "window" located off the near side of the bogey which defines the spatial limits for starting a successful final turn. The criteria for transitioning to a higher speed level included the requirement that P-hit ≥ .80.

These "final scores" for the problems flown in the dynamic mode are summarized (P-hit x 100) in table 6. The students evidently were able to increase the P-hit score up to the 340 knot speed level. Thereafter, the mean P-hit across all problem categories (bottom row) declined slightly. The 500 knot speed, at the initial ranges used, evidently gave the students considerable difficulty in the 8° - 14° target aspect problem category (second row of table).

TABLE 6. HIT PROBABILITY (x 100) FOR SIDEWINDER ATTACK
STUDENT SAMPLE SIZE = 29

	STATIC	DYNAMIC LEVELS: SPEED								
	PHASE	220	260	300	340	380	420	460	500	ROWS
MEAN	0.	77.6	78.6	88.5	91.5	93.8	89.7	93.0	90.8	87.1
STD DEV	0.	39.3	39.3	30.6	25.6	21.0	30.1	24.1	27.4	31.7
MEAN	0.	78.7	91.9	87.8	97.5	98.3	90.2	83.6	81.5	85.1
STD DEV	0.	38.4	24.9	31.0	14.0	5.3	27.0	35.7	37.6	33.7
MEAN	0.	84.7	95.4	95.0	96.0	94.4	89.3	89.8	88.8	90.1
STD DEV	0.	33.6	18.5	19.8	18.3	22.1	27.8	28.4	29.5	27.7
MEAN	0.	80.0	86.3	90.1	92.7	89.3	96.3	89.2	89.5	87.8
STD DEV	0.	35.6	31.9	27.7	24.5	28.6	14.0	30.2	27.6	29.6
COLS	0.	80.4	88.4	90.7	94.3	93.8	91.3	89.3	87.9	87.7
	0.	36.8	29.8	27.1	21.3	21.5	25.7	29.3	30.6	30.6

RESPONSE LATENCIES. The next ten tables (7-17) summarize response latency data. These data were recorded for each of the intercept triangle variables, and for major segments of an intercept problem. Inasmuch as the RIO students must learn to perform in real-time in a rapidly developing situation, it is essential that they develop fluency in performing the mental arithmetic required to solve the different triangle values, to minimize the extent to which they get behind the current status of the problem.

The latency data summarized here demonstrated that, overall, students did improve in fluency. This is shown in table 7, in which latency values for the first (either static phase or first dynamic speed level (220 knots)) and last (500 knots) blocks of trials are listed. These means and standard deviations are taken from the following tables. Mean latencies on the last trials were two to three times smaller than on the initial block of trials. There are no negative differences between pairs of these means. The table also illustrates the marked reduction in variability of responses that resulted from the training. Standard deviations were reduced by factors which ranged from 3.3 to 9.8. This is of great practical significance for tasks which must be performed in real-time.

ERRORS IN COMPUTING VALUES OF TRIANGLE VARIABLES. Students made relatively few errors per problem in performing these computations. The overall summary, table 18, shows an average of 0.9 errors per problem on the initial block of trials (static phase). On the last block of trials (500 knots), this rate had fallen to 0.3 errors per problem. It is likely that the arithmetic and the algorithms for computing the values were either already known or easily learned by the students. Tables 19 through 24, which summarize errors in computing values of specific triangle variables, tell the same story.

Comparison of these data with the latency data illustrates the value of the drill and practice type of CAI in this context, where it is not sufficient just to know the algorithms. The student must be able to apply the algorithms to compute the necessary values as rapidly as possible.

DATA ON TURNS DURING THE INTERCEPTION. In the dynamic mode, once the student entered the correct collision course, the fighter turned to this heading. The student then had to maneuver the fighter into position for a sidewinder attack by turning to establish the correct displacement distance, and then turning approximately 180° to come to the bogey heading in a position astern at the proper range for firing a sidewinder. At very low target aspects, instead of turning in to collision course, the student should turn out from the bogey track to establish the correct displacement distance.

There is an optimum flight path for making an interception from a given set of initial conditions. Algorithms for evaluating turn data, based on the concept of an optimum path, were incorporated in the computer program used to summarize the data. These are described below. We emphasize that these criteria are relatively crude.

TABLE 7. LATENCIES (IN SECONDS) FROM FIRST AND LAST BLOCKS OF TRIALS
STUDENT SAMPLE SIZE = 29

LATENCY VARIABLE		FIRST BLOCK	LAST BLOCK	FIRST/LAST
TIME TO:				
Collision Course (CC) Input	M	35.7	13.3	2.7
	SD	55.9	5.7	9.8
CC To Fire	M	238.1	101.7	2.3
	SD	83.5	25.0	3.3
	FIRST/LAST RATIOS OVERALL :		M	2.5
			SD	6.5
TIME TO COMPUTE:				
Bogey Heading Reciprocal	M	8.3	3.8	2.2
	SD	8.0	2.2	3.6
Target Aspect	M	12.6	4.1	3.1
	SD	16.5	2.5	6.6
Collision Course	M	14.8	5.4	2.7
	SD	19.4	3.4	5.7
Make Up Angle	M	13.9	4.8	2.9
	SD	15.7	3.3	4.8
Degrees-To-Go	M	6.9	3.1	2.2
	SD	8.2	2.3	3.6
Angle Off	M	11.4	4.6	2.4
	SD	12.7	3.2	3.9
	FIRST/LAST RATIOS OVERALL :		M	2.6
			SD	4.7

TABLE 8. LATENCY: TOTALS FOR COMPLETING THE INTERCEPT TRIANGLE
N = 29

	STATIC	DYNAMIC LEVELS: SPEED								
	PHASE	220	260	300	340	380	420	460	500	ROWS
MEAN	51.0	47.1	37.2	29.2	31.3	25.6	25.3	25.2	21.2	32.3
STD DEV	42.0	31.7	13.9	9.9	18.4	9.6	8.6	9.3	6.6	23.7
MEAN	71.0	52.4	40.6	34.8	32.8	31.6	30.0	24.4	25.5	39.7
STD DEV	50.4	30.6	14.8	12.2	11.4	14.5	11.2	6.8	8.9	28.7
MEAN	73.9	49.3	43.3	34.3	35.7	32.2	30.9	29.9	27.9	41.1
STD DEV	51.7	25.0	19.4	14.1	15.0	10.3	15.1	14.7	11.6	29.7
MEAN	68.9	58.7	47.9	38.2	39.2	37.6	33.9	32.7	28.5	46.0
STD DEV	39.7	31.0	21.5	16.3	18.0	14.5	12.5	11.8	10.0	29.3
COLS	67.9	51.9	42.3	34.2	34.8	32.1	30.0	28.0	25.8	40.0
	46.4	29.8	18.1	13.9	16.3	13.1	12.5	11.7	10.0	28.5

TABLE 9. LATENCY: TIMES TO CC INPUT
N = 29

	STATIC	DYNAMIC LEVELS: SPEED								
	PHASE	220	260	300	340	380	420	460	500	ROWS
MEAN	28.7	23.1	17.4	14.5	15.1	12.8	13.6	13.0	11.4	16.6
STD DEV	56.6	16.3	5.4	5.3	6.5	4.6	5.1	4.8	3.9	20.4
MEAN	41.0	25.3	21.4	17.7	16.8	16.3	15.9	13.3	12.9	20.7
STD DEV	68.5	16.2	10.7	7.9	7.4	8.7	8.3	4.9	5.4	27.2
MEAN	37.6	25.7	22.7	17.9	18.1	16.7	16.1	15.0	13.9	21.0
STD DEV	56.5	16.1	13.6	9.0	8.3	6.1	9.0	7.1	6.3	25.1
MEAN	34.6	30.5	26.3	20.0	22.2	18.9	17.8	17.4	14.9	23.9
STD DEV	47.7	19.7	16.3	9.0	15.9	6.6	6.7	7.4	6.2	25.4
COLS	35.7	26.2	22.0	17.6	18.0	16.4	15.8	14.6	13.3	20.6
	55.9	17.3	12.6	8.3	10.3	7.0	7.5	6.4	5.7	24.8

TABLE 10. LATENCIES FROM CC TO FIRE (END OF PROBLEM)
N = 29

	STATIC	DYNAMIC LEVELS: SPEED								
	PHASE	220	260	300	340	380	420	460	500	ROWS
MEAN	0.	247.8	206.9	174.7	148.1	130.8	125.9	114.6	104.8	155.9
STD DEV	0.	82.4	55.5	46.8	25.7	24.3	23.0	22.1	24.2	73.0
MEAN	0.	235.3	213.4	155.3	145.1	131.5	120.1	113.4	100.8	155.3
STD DEV	0.	85.3	97.1	26.6	36.8	29.5	31.1	41.0	24.0	79.2
MEAN	0.	227.8	187.3	163.2	144.7	130.1	119.2	110.6	98.9	145.9
STD DEV	0.	70.6	58.9	36.5	30.6	18.9	27.0	17.8	25.1	65.2
MEAN	0.	242.6	197.0	159.2	145.0	134.9	119.5	111.5	102.8	155.2
STD DEV	0.	94.2	38.9	22.0	21.9	25.9	24.2	16.7	26.5	74.5
COLS	0.	238.1	200.4	163.5	145.7	131.9	121.3	112.5	101.7	152.7
	0.	83.5	66.2	35.1	28.8	24.7	26.2	25.1	25.0	72.7

TABLE 11. MEAN LATENCIES FOR ALL TYPES TOTEBOARD ENTRIES
N = 29

	STATIC	DYNAMIC LEVELS: SPEED								
	PHASE	220	260	300	340	380	420	460	500	ROWS
MEAN	8.5	7.8	6.2	4.9	5.2	4.3	4.2	4.2	3.5	5.4
STD DEV	14.1	11.0	5.0	3.3	5.9	2.8	2.9	3.0	2.0	7.3
MEAN	11.8	8.7	6.8	5.8	5.5	5.3	5.0	4.1	4.2	6.6
STD DEV	16.1	9.3	5.0	3.8	3.6	4.0	3.9	2.1	2.5	8.0
MEAN	12.3	8.2	7.2	5.7	6.0	5.4	5.2	5.0	4.6	6.8
STD DEV	15.4	8.2	6.2	4.1	4.9	3.4	4.0	4.2	3.5	8.1
MEAN	11.5	9.8	8.0	6.4	6.5	6.3	5.6	5.4	4.8	7.7
STD DEV	12.4	10.1	7.0	4.9	6.6	4.8	3.9	3.9	3.2	8.4
COLS	11.3	8.6	7.1	5.7	5.8	5.3	5.0	4.7	4.3	6.7
	14.4	9.7	5.9	4.1	5.4	3.9	3.7	3.5	2.9	8.0

TABLE 12. LATENCIES TO COMPUTE BOGEY HEADING RECIPROCAL
N = 29

	STATIC	DYNAMIC LEVELS: SPEED								
	PHASE	220	260	300	340	380	420	460	500	ROWS
MEAN	6.7	6.9	5.2	4.7	5.7	4.1	4.4	4.2	3.7	5.0
STD DEV	4.8	5.9	2.2	2.7	5.1	2.0	2.6	2.1	1.7	3.9
MEAN	9.3	7.7	5.4	4.6	5.1	5.2	4.7	4.5	4.0	5.8
STD DEV	9.6	8.0	3.0	2.1	3.1	5.6	3.6	1.9	2.4	5.9
MEAN	9.6	6.9	6.5	4.7	5.4	5.1	4.4	4.3	3.7	5.7
STD DEV	9.8	6.3	5.8	2.5	4.3	3.3	3.5	2.6	2.3	5.7
MEAN	7.4	6.6	6.3	4.9	5.0	4.0	4.8	3.7	3.7	5.4
STD DEV	6.2	4.8	5.2	2.6	3.4	1.5	3.2	1.5	2.2	4.4
COLS	8.3	7.0	5.9	4.7	5.3	4.6	4.6	4.2	3.8	5.5
	8.0	6.4	4.4	2.5	4.1	3.5	3.2	2.1	2.2	5.0

TABLE 13. LATENCIES TO COMPUTE TARGET ASPECT
N = 29

	STATIC	DYNAMIC LEVELS: SPEED								
	PHASE	220	260	300	340	380	420	460	500	ROWS
MEAN	9.5	6.8	5.3	4.7	3.9	3.9	3.7	3.6	3.3	4.9
STD DEV	20.6	5.5	2.4	2.9	1.7	1.8	1.5	1.9	1.9	7.4
MEAN	15.8	7.5	6.2	6.1	4.3	4.4	4.2	3.8	3.7	6.5
STD DEV	22.6	5.6	4.4	4.9	2.5	2.8	2.6	1.7	2.1	9.4
MEAN	13.6	7.6	6.4	5.9	5.3	4.7	5.7	4.8	4.3	6.7
STD DEV	16.6	7.0	4.6	5.2	3.2	1.9	4.6	3.2	2.6	8.2
MEAN	11.5	10.7	8.5	6.8	8.7	6.6	6.1	6.1	5.0	8.1
STD DEV	8.7	12.0	6.5	4.9	13.6	2.9	3.6	3.8	2.8	8.2
COLS	12.6	8.2	6.6	5.9	5.5	4.9	5.0	4.5	4.1	6.6
	16.5	8.2	4.8	4.6	7.1	2.6	3.5	2.9	2.5	8.4

TABLE 14. LATENCIES TO COMPUTE COLLISION COURSE
N = 29

	STATIC PHASE	DYNAMIC LEVELS: SPEED 220	260	300	340	380	420	460	500	ROWS
MEAN	12.6	9.3	6.9	5.1	5.5	4.9	5.4	5.3	4.4	6.6
STD DEV	22.7	10.9	5.8	2.2	2.8	2.6	3.4	3.3	2.4	9.3
MEAN	15.9	10.1	9.9	7.0	7.4	6.7	7.0	5.0	5.2	8.4
STD DEV	23.8	8.3	8.2	4.2	4.7	4.2	5.4	3.4	2.8	10.4
MEAN	14.4	11.2	9.8	7.3	7.3	7.0	6.1	5.8	5.8	8.6
STD DEV	16.1	11.1	9.3	4.9	3.5	3.9	3.4	3.1	3.8	9.2
MEAN	15.7	13.3	11.5	8.3	8.4	8.4	6.9	7.7	6.2	10.3
STD DEV	18.0	11.6	11.4	5.9	4.9	5.0	3.1	5.6	4.1	11.1
COLS	14.8	11.0	9.5	7.0	7.1	6.8	6.3	5.9	5.4	8.5
	19.4	10.6	8.8	4.7	4.1	4.2	3.9	4.0	3.4	10.1

TABLE 15. LATENCIES TO COMPUTE MAKE UP ANGLE
N = 29

	STATIC PHASE	DYNAMIC LEVELS: SPEED 220	260	300	340	380	420	460	500	ROWS
MEAN	9.9	9.4	6.7	6.2	5.2	5.2	4.7	4.6	3.6	6.1
STD DEV	9.9	9.9	4.3	5.7	2.6	5.0	4.7	3.5	2.0	6.6
MEAN	12.9	12.3	7.4	6.9	6.1	5.1	5.0	4.0	4.6	7.7
STD DEV	14.8	12.7	4.1	4.0	2.9	2.2	3.7	1.6	2.2	8.9
MEAN	15.7	10.4	8.6	6.4	7.1	5.6	6.3	6.6	5.5	8.4
STD DEV	20.2	10.1	6.9	4.1	4.7	2.5	5.6	8.2	4.5	10.4
MEAN	14.7	13.4	9.4	7.4	7.3	8.3	6.8	6.9	5.5	9.6
STD DEV	13.5	12.0	6.6	3.9	4.1	6.9	5.5	4.7	2.9	9.5
COLS	13.9	11.4	8.1	6.7	6.4	6.1	5.7	5.6	4.8	8.0
	15.7	11.3	5.7	4.5	3.8	4.8	5.0	5.5	3.3	9.1

TABLE 16. LATENCIES TO COMPUTE DEGREES-TO-GO
N = 29

	STATIC	DYNAMIC LEVELS: SPEED								
	PHASE	220	260	300	340	380	420	460	500	ROWS
MEAN	4.6	5.1	4.3	3.9	3.4	3.4	3.2	3.0	2.9	3.7
STD DEV	2.1	4.2	2.9	2.1	1.7	1.7	1.5	1.7	1.7	2.7
MEAN	7.2	5.3	4.5	4.1	4.0	4.3	3.6	3.1	3.4	4.5
STD DEV	6.9	3.6	3.0	2.6	3.4	3.3	3.6	1.3	2.4	3.9
MEAN	8.3	5.1	4.2	4.0	4.1	3.9	3.4	3.1	3.3	4.5
STD DEV	12.1	5.0	2.4	2.6	5.5	4.1	2.3	1.7	2.9	6.0
MEAN	6.6	5.1	4.3	3.8	3.5	4.2	3.3	3.1	2.9	4.3
STD DEV	6.1	3.5	2.3	2.9	1.8	5.6	2.1	1.4	1.6	3.9
COLS	6.9	5.1	4.3	3.9	3.8	4.0	3.3	3.1	3.1	4.3
	8.2	4.1	2.6	2.6	3.7	4.0	2.4	1.5	2.3	4.4

TABLE 17. LATENCIES TO COMPUTE ANGLE-OFF
N = 29

	STATIC	DYNAMIC LEVELS: SPEED								
	PHASE	220	260	300	340	380	420	460	500	ROWS
MEAN	7.8	9.5	8.7	4.6	7.6	4.3	3.9	4.5	3.4	5.9
STD DEV	9.6	20.4	9.2	2.5	12.5	2.0	1.8	4.0	1.9	10.6
MEAN	9.9	9.2	7.2	6.1	5.9	5.9	5.5	3.9	4.6	6.7
STD DEV	8.1	12.5	4.0	3.4	3.4	4.6	3.1	1.7	2.5	7.2
MEAN	12.4	8.1	7.8	6.1	6.5	6.0	5.1	5.2	5.2	7.1
STD DEV	14.0	6.6	4.5	3.9	6.5	3.7	2.7	2.2	3.7	7.3
MEAN	13.0	9.7	7.9	7.0	6.2	6.1	6.1	5.3	5.2	8.1
STD DEV	14.2	9.9	3.9	6.2	2.7	2.6	3.7	2.2	3.7	8.8
COLS	11.4	9.1	7.9	6.0	6.6	5.6	5.1	4.8	4.6	7.0
	12.7	13.1	5.8	4.4	7.7	3.4	3.0	2.8	3.2	8.6

TABLE 18. TOTAL ERRORS IN SOLVING INTERCEPT TRIANGLE
N = 29

	STATIC PHASE	DYNAMIC LEVELS: SPEED 220	260	300	340	380	420	460	500	ROWS
MEAN	0.6	0.8	0.4	0.6	0.6	0.5	0.2	0.3	0.1	0.4
STD DEV	1.1	1.6	1.0	1.2	1.6	1.1	0.5	0.7	0.4	1.1
MEAN	1.1	0.6	0.3	0.5	0.4	0.5	0.2	0.2	0.2	0.5
STD DEV	1.7	1.1	0.6	1.1	0.9	1.0	0.7	0.5	0.6	1.0
MEAN	1.0	0.5	0.4	0.3	0.4	0.3	0.4	0.2	0.3	0.4
STD DEV	1.4	0.9	0.9	0.6	0.9	0.6	0.9	0.5	0.8	0.9
MEAN	0.6	0.7	0.5	0.4	0.4	0.3	0.5	0.4	0.3	0.5
STD DEV	1.2	1.2	1.0	1.0	0.8	0.7	0.9	0.7	0.8	1.0
COLS	0.9	0.7	0.4	0.4	0.5	0.4	0.3	0.3	0.3	0.5
	1.4	1.2	0.9	1.0	1.1	0.9	0.8	0.6	0.7	1.0

TABLE 19. ERRORS IN COMPUTING BOGEY HEADING RECIPROCAL
N = 29

	STATIC PHASE	DYNAMIC LEVELS: SPEED 220	260	300	340	380	420	460	500	ROWS
MEAN	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
STD DEV	0.2	0.3	0.1	0.2	0.1	0.1	0.3	0.4	0.1	0.2
MEAN	0.1	0.1	0.0	0.0	0.0	0.1	0.	0.1	0.0	0.0
STD DEV	0.4	0.3	0.1	0.1	0.2	0.2	0.	0.2	0.2	0.2
MEAN	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
STD DEV	0.7	0.1	0.2	0.2	0.4	0.2	0.3	0.1	0.2	0.3
MEAN	0.0	0.0	0.1	0.1	0.0	0.	0.1	0.0	0.0	0.0
STD DEV	0.2	0.1	0.3	0.2	0.2	0.	0.4	0.1	0.2	0.2
COLS	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.4	0.2	0.2	0.2	0.2	0.2	0.3	0.2	0.2	0.3

TABLE 20. ERRORS IN COMPUTING TARGET ASPECT
N = 29

	STATIC PHASE	DYNAMIC LEVELS: SPEED 220	260	300	340	380	420	460	500	ROWS
MEAN	0.1	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0
STD DEV	0.5	0.3	0.2	0.5	0.3	0.2	0.1	0.2	0.1	0.3
MEAN	0.3	0.1	0.	0.1	0.0	0.1	0.1	0.0	0.0	0.1
STD DEV	0.7	0.4	0.	0.5	0.2	0.3	0.3	0.1	0.2	0.4
MEAN	0.2	0.1	0.1	0.0	0.0	0.0	0.1	0.0	0.1	0.1
STD DEV	0.5	0.4	0.2	0.2	0.3	0.2	0.4	0.3	0.2	0.3
MEAN	0.1	0.2	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
STD DEV	0.4	0.6	0.3	0.6	0.5	0.3	0.3	0.3	0.3	0.4
COLS	0.2	0.1	0.0	0.1	0.1	0.0	0.1	0.0	0.0	0.1
	0.5	0.4	0.2	0.5	0.3	0.3	0.3	0.2	0.2	0.4

TABLE 21. ERRORS IN COMPUTING COLLISION COURSE
N = 29

	STATIC PHASE	DYNAMIC LEVELS: SPEED 220	260	300	340	380	420	460	500	ROWS
MEAN	0.1	0.1	0.0	0.	0.0	0.0	0.0	0.0	0.0	0.0
STD DEV	0.5	0.2	0.1	0.	0.3	0.2	0.2	0.2	0.3	0.3
MEAN	0.2	0.1	0.1	0.0	0.1	0.0	0.1	0.0	0.0	0.1
STD DEV	0.7	0.3	0.4	0.2	0.2	0.2	0.4	0.2	0.2	0.4
MEAN	0.1	0.1	0.1	0.0	0.0	0.1	0.0	0.0	0.1	0.1
STD DEV	0.4	0.4	0.3	0.3	0.2	0.3	0.2	0.1	0.3	0.3
MEAN	0.2	0.2	0.2	0.1	0.0	0.1	0.0	0.1	0.1	0.1
STD DEV	0.6	0.5	0.7	0.3	0.2	0.3	0.2	0.3	0.4	0.5
COLS	0.2	0.1	0.1	0.0	0.0	0.1	0.0	0.0	0.1	0.1
	0.5	0.4	0.4	0.2	0.2	0.3	0.2	0.2	0.3	0.4

TABLE 22. ERRORS IN COMPUTING MAKE UP ANGLE
N = 29

	STATIC	DYNAMIC LEVELS: SPEED								
	PHASE	220	260	300	340	380	420	460	500	ROWS
MEAN	0.2	0.3	0.1	0.3	0.2	0.3	0.1	0.1	0.0	0.1
STD DEV	0.5	0.9	0.4	0.6	0.5	0.6	0.2	0.4	0.1	0.5
MEAN	0.2	0.2	0.0	0.3	0.1	0.1	0.0	0.1	0.1	0.1
STD DEV	0.5	0.5	0.3	0.7	0.4	0.3	0.2	0.2	0.3	0.4
MEAN	0.3	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1
STD DEV	0.8	0.4	0.4	0.3	0.4	0.3	0.5	0.3	0.4	0.5
MEAN	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
STD DEV	0.7	0.6	0.4	0.3	0.3	0.4	0.3	0.5	0.3	0.5
COLS	0.2	0.2	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1
	0.7	0.6	0.4	0.5	0.4	0.4	0.4	0.3	0.3	0.5

TABLE 23. ERRORS IN COMPUTING DEGREES-TO-GO
N = 29

	STATIC	DYNAMIC LEVELS: SPEED								
	PHASE	220	260	300	340	380	420	460	500	ROWS
MEAN	0.0	0.0	0.0	0.0	0.0	0.0	0.	0.0	0.0	0.0
STD DEV	0.1	0.3	0.2	0.1	0.2	0.1	0.	0.1	0.2	0.2
MEAN	0.1	0.1	0.0	0.	0.0	0.1	0.0	0.	0.0	0.0
STD DEV	0.4	0.3	0.2	0.	0.2	0.3	0.1	0.	0.2	0.3
MEAN	0.1	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0
STD DEV	0.2	0.3	0.4	0.2	0.4	0.1	0.1	0.1	0.2	0.3
MEAN	0.1	0.1	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0
STD DEV	0.3	0.3	0.2	0.2	0.2	0.3	0.3	0.2	0.2	0.3
COLS	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.1	0.2	0.2

TABLE 24. ERRORS IN COMPUTING ANGLE OFF
N = 29

	STATIC PHASE	220	260	300	340	380	420	460	500	ROWS
MEAN	0.1	0.3	0.2	0.2	0.3	0.1	0.0	0.1	0.0	0.1
STD DEV	0.5	1.0	0.6	0.5	0.9	0.4	0.2	0.3	0.2	0.6
MEAN	0.2	0.2	0.0	0.1	0.2	0.2	0.0	0.0	0.0	0.1
STD DEV	0.8	0.6	0.3	0.3	0.6	0.5	0.1	0.2	0.2	0.5
MEAN	0.1	0.1	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.1
STD DEV	0.5	0.4	0.2	0.2	0.3	0.1	0.2	0.2	0.2	0.3
MEAN	0.2	0.1	0.1	0.0	0.1	0.0	0.1	0.0	0.0	0.1
STD DEV	0.5	0.5	0.3	0.2	0.3	0.1	0.4	0.2	0.2	0.3
COLS	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.1
	0.6	0.6	0.4	0.3	0.6	0.3	0.3	0.2	0.2	0.4

The measures for the optimal number of degrees turned are based upon the initial target aspect of the problem. They assume that the aircraft begins turning at collision course input, during the intercept triangle-solution phase of the problem. Three ranges of target aspect are considered, as follows:

a. Low (0-10 degrees). The aircraft must turn to increase target aspect sufficiently to turn 180^o to achieve the sidewinder attack position.
Optimum Degrees = 200 + ((10 - TA) * 4)

b. Medium (11-25). The aircraft must turn from collision course to bogey heading reciprocal before making the 180^o attack turn.
Optimum Degrees = 180 + (2 * TA)

c. High (26+). The aircraft is at a sufficiently high target aspect so that he cannot turn to bogey heading reciprocal and after a partial turn must reverse his turn direction in order to turn to attack.
Optimum Degrees = 130 - ((45 - TA) * 5)

Table 25 presents the mean total number of degrees turned per problem. It is apparent that students did turn more degrees in the low target aspect problems than in the higher target aspect problems. The somewhat different tactics that are required at low target aspects would account for this difference. There was an overall decrease in degrees turned per problem of 24.3, indicating the students became more effective with practice.

Tables 26 and 27 present absolute deviations, in degrees, of observed from estimated optimal, and ratio (x 100) between observed and estimated optimal total number of degrees turned per problem. These are crude indicators of how efficient the students were in relation to the model. Zero degrees deviation and a ratio score of 100 would indicate a perfect match.

Table 28 presents a summary of the mean number of turns per problem. These data show an overall reduction from 4.7 turns in the first block (220 knots) to 3.4 turns in the last block (500 knots). This suggests that students had to make fewer corrections to turns in later stages of practice.

Finally, tables 29-32 present summaries of total number of degrees turned per type of turn; easy, standard, hard, and hard-as-possible. (These turn rates were programmed and could be selected by the student, as described in a preceding section.)

The most striking feature of these data is found in table 32, for the hard-as-possible turn. There is a striking increase (from 43.3 to 113.8) in the number of degrees turned at this highest rate at the higher speed levels. It is likely that students did get behind the problem at these higher speeds. Drift rates on the B-scan, particularly in the latter stages of the intercept, can be quite alarming, leading the student to enter a hard-as-possible turn to bring the radar blip back into the center of the scope for firing position. This is not as efficient a procedure as using lower turn rates, because of the "G" loads it imposes on aircraft and crew.

TABLE 25. MEAN NUMBER OF DEGREES TURNED PER PROBLEM
N = 29

	STATIC	DYNAMIC LEVELS: SPEED								
	PHASE	220	260	300	340	380	420	460	500	ROWS
MEAN	0.	321.8	320.0	303.2	279.7	300.6	295.8	297.7	275.6	295.9
STD DEV	0.	131.1	98.9	79.5	45.4	166.4	71.7	71.2	58.4	92.9
MEAN	0.	293.7	281.0	275.3	284.2	258.7	278.0	273.7	268.3	277.6
STD DEV	0.	112.8	74.4	70.9	85.6	50.7	85.7	85.2	83.5	89.0
MEAN	0.	270.9	258.5	266.8	262.9	267.2	273.4	257.2	253.6	261.8
STD DEV	0.	103.5	57.6	61.7	60.8	70.8	136.0	48.5	70.3	80.7
MEAN	0.	244.6	223.4	216.5	224.4	216.7	229.0	212.3	232.8	230.0
STD DEV	0.	155.6	87.6	48.4	61.9	66.2	64.2	89.2	103.3	105.8
COLS	0.	281.9	269.9	263.7	262.5	258.5	269.7	262.2	257.6	266.0
	0.	129.9	86.8	72.4	66.6	98.7	98.2	78.7	80.8	95.1

TABLE 26. DEVIATION FROM ESTIMATED OPTIMAL NUMBER OF DEGREES
N = 29

	STATIC	DYNAMIC LEVELS: SPEED								
	PHASE	220	260	300	340	380	420	460	500	ROWS
MEAN	0.	98.0	91.4	75.1	56.4	74.7	73.2	74.0	54.2	72.2
STD DEV	0.	128.4	98.4	79.2	41.1	164.5	66.9	65.3	52.2	89.5
MEAN	0.	97.9	77.3	71.8	79.7	59.9	86.0	73.4	70.2	78.9
STD DEV	0.	105.2	73.2	69.1	85.9	43.9	72.6	81.3	78.4	83.8
MEAN	0.	66.4	46.5	54.7	52.6	61.7	66.6	48.2	55.0	57.0
STD DEV	0.	98.3	56.7	60.5	58.3	65.4	132.4	43.9	59.5	74.9
MEAN	0.	74.8	43.4	33.9	41.3	41.8	46.0	47.2	55.3	53.6
STD DEV	0.	144.5	75.6	36.1	48.2	50.6	59.7	64.1	95.0	96.1
COLS	0.	83.6	63.6	57.3	56.1	58.6	67.4	60.4	58.1	64.7
	0.	120.8	78.8	64.1	59.8	89.6	90.7	64.2	71.9	86.6

TABLE 27. RATIO DEGREES TURNED/ESTIMATED OPTIMAL x 100
N = 29

	STATIC	DYNAMIC LEVELS: SPEED								
	PHASE	220	260	300	340	380	420	460	500	ROWS
MEAN	0.	140.8	139.8	132.9	123.1	131.8	130.6	130.6	121.2	129.9
STD DEV	0.	59.7	43.1	34.8	20.8	70.2	31.5	29.8	25.7	41.0
MEAN	0.	143.5	137.1	134.3	139.1	126.5	135.9	133.7	131.2	135.7
STD DEV	0.	55.3	36.4	34.1	42.4	24.9	41.8	41.4	41.0	43.6
MEAN	0.	126.3	120.3	124.3	122.4	124.7	126.5	119.7	117.8	121.8
STD DEV	0.	49.4	28.3	29.9	29.4	34.6	63.6	23.3	33.4	38.5
MEAN	0.	127.1	115.5	110.1	115.8	113.3	115.6	110.4	119.7	118.5
STD DEV	0.	92.4	53.6	24.8	29.3	36.1	41.6	39.7	59.2	61.2
COLS	0.	134.1	127.7	124.4	124.2	123.5	126.9	123.6	122.0	126.0
	0.	66.6	42.0	32.1	31.2	43.4	47.1	34.1	41.1	47.0

TABLE 28. MEAN NUMBER OF TURNS PER PROBLEM
N = 29

	STATIC	DYNAMIC LEVELS: SPEED								
	PHASE	220	260	300	340	380	420	460	500	ROWS
MEAN	0.	5.3	4.5	4.7	3.9	3.7	3.9	4.0	3.7	4.3
STD DEV	0.	2.7	2.0	2.2	1.3	1.4	1.4	1.4	1.3	1.9
MEAN	0.	4.7	4.2	3.5	3.9	3.7	3.8	3.6	3.4	3.9
STD DEV	0.	2.6	1.9	1.1	1.7	1.7	1.1	1.3	1.2	1.8
MEAN	0.	4.1	3.5	3.7	3.7	3.6	3.4	3.3	3.1	3.5
STD DEV	0.	1.8	1.4	1.9	1.6	1.1	1.2	1.1	1.1	1.5
MEAN	0.	4.7	3.7	3.6	3.4	3.6	3.3	3.2	3.3	3.7
STD DEV	0.	2.5	1.5	1.4	1.0	1.3	1.1	1.1	1.3	1.7
COLS	0.	4.7	4.0	3.9	3.7	3.6	3.6	3.5	3.4	3.8
	0.	2.4	1.7	1.8	1.4	1.4	1.2	1.2	1.2	1.8

TABLE 29. NUMBER DEGREES TURNED IN EASY TURN
N = 29

	STATIC	DYNAMIC LEVELS: SPEED								
	PHASE	220	260	300	340	380	420	460	500	ROWS
MEAN	0.	56.1	51.0	26.5	19.0	29.9	14.2	12.1	9.4	26.3
STD DEV	0.	83.2	62.9	13.7	11.8	103.1	11.3	8.3	7.9	51.7
MEAN	0.	48.6	41.2	34.5	18.8	14.7	13.2	13.5	8.6	25.1
STD DEV	0.	43.6	17.6	54.5	11.0	9.6	11.4	30.2	9.5	33.3
MEAN	0.	60.3	38.4	30.4	20.5	16.8	10.9	11.9	8.9	25.5
STD DEV	0.	70.2	16.1	37.5	15.6	11.2	8.6	9.5	19.3	41.2
MEAN	0.	46.8	35.2	21.6	17.1	17.1	12.4	11.2	10.7	23.2
STD DEV	0.	26.6	15.9	13.3	15.2	13.6	8.7	9.0	24.0	25.2
COLS	0.	53.1	41.3	27.8	19.0	19.1	12.6	12.1	9.4	25.0
	0.	60.2	34.1	32.8	13.8	48.3	10.0	15.7	16.7	39.5

TABLE 30. NUMBER DEGREES TURNED IN STANDARD TURN
N = 29

	STATIC	DYNAMIC LEVELS: SPEED								
	PHASE	220	260	300	340	380	420	460	500	ROWS
MEAN	0.	77.8	74.2	65.5	52.9	58.5	48.9	42.7	40.1	55.7
STD DEV	0.	57.8	37.2	34.0	22.6	61.6	26.9	26.7	21.5	40.3
MEAN	0.	80.1	88.7	69.3	59.5	52.9	57.5	42.1	39.4	59.8
STD DEV	0.	45.4	50.4	31.3	27.1	23.4	34.1	28.6	23.4	39.3
MEAN	0.	79.7	83.3	78.6	68.8	53.4	51.6	44.7	40.8	59.7
STD DEV	0.	35.1	29.6	31.5	36.2	24.4	27.1	24.6	22.4	33.6
MEAN	0.	77.0	86.8	80.6	67.2	61.6	57.9	47.4	53.3	65.9
STD DEV	0.	59.9	36.5	30.4	33.4	31.6	27.4	26.1	26.1	40.4
COLS	0.	78.7	83.3	74.2	62.5	56.6	53.6	44.2	43.2	60.2
	0.	50.2	38.9	32.3	31.3	36.9	28.7	26.3	23.9	38.4

TABLE 31. NUMBER DEGREES TURNED IN HARD TURN
N = 29

	STATIC	DYNAMIC LEVELS: SPEED								
	PHASE	220	260	300	340	380	420	460	500	ROWS
MEAN	0.	116.2	110.0	127.7	122.8	100.5	105.5	94.5	87.6	104.1
STD DEV	0.	55.5	33.9	52.9	43.6	46.5	38.3	38.5	37.2	46.2
MEAN	0.	114.7	109.9	118.0	112.9	109.5	108.5	103.1	92.2	105.5
STD DEV	0.	64.7	34.6	40.5	30.7	38.1	60.0	40.1	38.6	48.1
MEAN	0.	104.3	108.1	112.8	116.4	107.7	104.3	101.2	93.2	102.4
STD DEV	0.	62.9	47.4	30.9	51.2	33.1	51.3	37.7	52.2	51.3
MEAN	0.	93.0	89.9	91.1	103.0	92.8	101.3	93.6	91.8	93.4
STD DEV	0.	104.2	67.4	37.6	36.0	40.7	31.6	41.4	56.5	66.2
COLS	0.	106.8	104.6	111.5	114.3	102.6	104.7	98.1	91.2	101.3
	0.	74.9	48.3	42.8	43.0	39.8	45.8	39.2	47.2	53.7

TABLE 32. NUMBER DEGREES TURNED IN HARD AS POSSIBLE TURN
N = 29

	STATIC	DYNAMIC LEVELS: SPEED								
	PHASE	220	260	300	340	380	420	460	500	ROWS
MEAN	0.	71.8	84.7	83.6	85.0	111.6	125.8	144.6	138.4	109.3
STD DEV	0.	76.6	67.7	60.6	42.5	60.0	70.4	78.1	62.3	72.3
MEAN	0.	50.4	40.8	53.5	92.9	81.7	98.8	115.0	128.1	87.1
STD DEV	0.	86.7	56.3	49.3	93.3	58.8	63.8	85.1	89.0	87.2
MEAN	0.	26.6	28.8	45.1	57.2	89.2	106.5	99.4	110.8	74.2
STD DEV	0.	51.0	47.9	61.7	40.7	77.7	153.7	49.5	64.8	77.8
MEAN	0.	27.7	11.5	23.2	37.1	45.2	57.5	60.1	77.0	47.4
STD DEV	0.	83.7	40.3	28.7	63.4	54.4	69.8	69.8	87.0	76.7
COLS	0.	43.3	40.7	50.2	66.6	80.2	98.4	106.8	113.8	79.3
	0.	77.4	59.7	56.2	62.9	67.6	102.8	76.3	78.6	81.4

USAGE OF ON-DEMAND SUPPORT KEYS. Tables 33-36 summarize these data. It is evident that (a) these students did not voluntarily use any of these keys very frequently, and (b) they did use the triangle-display key an average of 0.9 per problem in the first block of trials (220 knots). This dropped to an average of 0.1 times per problem in the last block (500 knots). The triangle key, when depressed, caused a geographic (true motion) dynamic display of bogey and fighter with corresponding heading vectors and connected bearing line (dotted).

As table 36 suggests, the answer key was available only during the computations for values of the intercept triangle.

These data are for voluntary use of these keys. It will be recalled that either static or dynamic triangle and continuously updated toteboard are automatically displayed after certain types of errors. These occurrences are not included in the following tables.

We believe the students should have used these keys more often, and that they did not do so because they were trying to make as good a showing as possible. Any problem in which they used an on-demand key did not count towards satisfying the trials-to-criterion logic for transitioning to the next level. However, the continuously-updated toteboard and the true-motion reference triangle also were automatically displayed when a student made an error or did not achieve a probability of hit score exceeding .80. It will be recalled that, in the latter case, the student had to repeat the problem in free-fly mode.

We do think these data suggest that program control over these instructional features, as well as over the entire instructional sequence, is preferable to student control in this situation.

ANALYSIS OF MANUALLY-RECORDED DATA

An in-flight performance checklist and a student questionnaire were used to collect data relating to transfer of training and to student acceptance of the trainer. The performance checklist was developed through consultation with members of the school staff at Glynco. The instructors were shown how to use it in a briefing session with them. Nevertheless, results were disappointing. We attribute this to two possibilities: (a) the checklist was made small in size for use in the air, resulting in a difficult format; and (b) some instructors did not take time to fill it out item-by-item while in the air.

The student opinion questionnaire was more successful in eliciting useful data.

Background information about students; aptitude test scores, school grades, etc., were not completely available for this report, and therefore, none are included.

TABLE 33. KEY USAGE: TRIANGLE KEY
N = 29

	STATIC	DYNAMIC LEVELS: SPEED								
	PHASE	220	260	300	340	380	420	460	500	ROWS
MEAN	0.0	1.0	0.6	0.0	0.0	0.0	0.2	0.0	0.1	0.3
STD DEV	0.2	2.7	2.4	0.2	0.2	0.3	0.7	0.3	0.7	1.4
MEAN	0.0	0.9	0.4	0.0	0.	0.0	0.1	0.2	0.2	0.3
STD DEV	0.1	0.9	1.1	0.1	0.	0.1	0.4	1.3	0.8	1.1
MEAN	0.0	0.7	0.3	0.1	0.1	0.0	0.1	0.1	0.1	0.2
STD DEV	0.1	1.8	1.8	0.5	0.5	0.1	0.9	0.3	0.3	1.0
MEAN	0.	1.2	0.5	0.1	0.3	0.	0.0	0.0	0.1	0.3
STD DEV	0.	2.9	1.5	0.3	1.4	0.	0.2	0.1	1.5	1.6
COLS	0.0	0.9	0.5	0.1	0.1	0.0	0.1	0.1	0.1	0.3
	0.1	2.4	1.7	0.3	0.7	0.2	0.7	0.6	0.9	1.3

TABLE 34. KEY USAGE: TOTEBOARD KEY
N = 29

	STATIC	DYNAMIC LEVELS: SPEED								
	PHASE	220	260	300	340	380	420	460	500	ROWS
MEAN	0.	0.6	0.1	0.	0.	0.	0.	0.0	0.1	0.1
STD DEV	0.	1.6	0.5	0.	0.	0.	0.	0.1	0.5	0.8
MEAN	0.	0.6	0.2	0.0	0.	0.	0.0	0.	0.1	0.2
STD DEV	0.	1.8	0.8	0.1	0.	0.	0.1	0.	0.9	1.1
MEAN	0.	0.5	0.2	0.	0.0	0.	0.0	0.	0.1	0.1
STD DEV	0.	1.4	1.0	0.	0.1	0.	0.2	0.	0.5	0.8
MEAN	0.	0.7	0.3	0.0	0.	0.	0.	0.	0.0	0.2
STD DEV	0.	1.8	1.3	0.2	0.	0.	0.	0.	0.3	1.0
COLS	0.	0.6	0.2	0.0	0.0	0.	0.0	0.0	0.1	0.2
	0.	1.6	0.9	0.1	0.1	0.	0.1	0.1	0.6	0.9

TABLE 35 KEY USAGE: PAUSE KEY
N = 29

	STATIC	DYNAMIC LEVELS: SPEED								
	PHASE	220	260	300	340	380	420	460	500	ROWS
MEAN	0.	0.7	0.4	0.1	0.	0.	0.0	0.0	0.1	0.2
STD DEV	0.	1.3	0.8	0.4	0.	0.	0.2	0.1	0.4	0.7
MEAN	0.	0.5	0.4	0.0	0.	0.	0.0	0.0	0.1	0.2
STD DEV	0.	1.0	0.9	0.1	0.	0.	0.1	0.1	0.5	0.7
MEAN	0.	0.4	0.1	0.0	0.0	0.	0.1	0.	0.1	0.1
STD DEV	0.	0.9	0.5	0.4	0.1	0.	0.4	0.	0.4	0.5
MEAN	0.	0.5	0.3	0.0	0.	0.	0.0	0.0	0.0	0.2
STD DEV	0.	1.0	0.7	0.4	0.	0.	0.2	0.1	0.1	0.6
COLS	0.	0.5	0.3	0.1	0.0	0.	0.0	0.0	0.1	0.2
	0.	1.1	0.7	0.4	0.1	0.	0.2	0.1	0.4	0.6

TABLE 36. KEY USAGE: ANSWER KEY

N = 29

	STATIC	DYNAMIC LEVELS: SPEED								
	PHASE	220	260	300	340	380	420	460	500	ROWS
MEAN	0.1	0.	0.	0.	0.	0.	0.	0.	0.	0.0
STD DEV	0.2	0.	0.	0.	0.	0.	0.	0.	0.	0.1
MEAN	0.1	0.	0.	0.	0.	0.	0.	0.	0.	0.0
STD DEV	0.4	0.	0.	0.	0.	0.	0.	0.	0.	0.1
MEAN	0.1	0.	0.	0.	0.	0.	0.	0.	0.	0.0
STD DEV	0.3	0.	0.	0.	0.	0.	0.	0.	0.	0.1
MEAN	0.1	0.	0.	0.	0.	0.	0.	0.	0.	0.0
STD DEV	0.2	0.	0.	0.	0.	0.	0.	0.	0.	0.1
COLS	0.1	0.	0.	0.	0.	0.	0.	0.	0.	0.0
	0.3	0.	0.	0.	0.	0.	0.	0.	0.	0.1

ANALYSIS OF MANUALLY-RECORDED IN-FLIGHT PERFORMANCE SCORES. Student performance during the first "check" flight (RT-8) was recorded by instructors utilizing the in-flight performance checklist (figure 14a and b). The checklist is divided into two sections. The first section records achievement of specific intercept elements. The second section concerns the more global aspects of overall performance (behavioral elements) as they are judged by the airborne instructors. All the checklist data are summarized in table 37. The Mann-Whitney U Test performed on these data indicated a slight difference ($z = 1.07$, one-tailed $p = .14$) in favor of the experimental group. This checklist is a very crude measure used only because more powerful measures were not feasible in this environment. Also, the individual skills trainer was not designed to teach all the subskills (e.g., radar operation) required of the RIO for satisfactory in-flight performance.

TABLE 37. MANUALLY RECORDED IN-FLIGHT CHECKLIST (SPECIFIC INTERCEPT ELEMENTS)

Student Ranks Out of a Total of $N_2 + N_1$ Students For Mann-Whitney U-Test

Number	Experimental Group $N_2=23$	Control Group $N_1=18$
1	37.5	29.5
2	20.5	33.5
3	23.5	26.5
4	20.5	13.0
5	38.0	16.5
6	37.5	18.5
7	33.5	23.5
8	29.5	22.0
9	33.5	38.0
10	8.0	6.0
11	13.0	33.5
12	38.0	4.0
13	4.0	2.0
14	33.5	13.0
15	16.5	33.5
16	26.5	13.0
17	8.0	18.5
18	13.0	10.0
19	4.0	
20	26.5	
21	26.5	
22	1.0	
23	8.0	
	$R_2=500.6$	$R_1=354.5$

$z = 1.07$ (corrected for ties)
$p = .1423$ (one-tailed test)

ANALYSIS OF QUESTIONNAIRE DATA

Each student was asked to complete a questionnaire designed to sample his opinions about the intercept trainer. These data are summarized in table 38. It is clear that a significant majority of the students found that the trainer was worthwhile. In table 39, the frequencies are listed after the alternatives in each question, to give more detailed information.

A content analysis of student comments in response to questions 15 through 19 was performed. The most frequent comment is described under each question. These comments indicate that students believed the trainer materially aided them in their flight performance, and that the static and free-fly modes were the most useful during learning. The major improvements desired by the students were altitude differential between bogey and fighter, with (antenna) tracking capability, and speed control over the fighter.

TABLE 38. ANALYSIS OF STUDENT ATTITUDES TOWARD THE TRAINER
N = 26

ITEM NUMBER		1	2	4	5	6	7	8	9	10	12	13	MEANS
VERY FAVORABLE	1	1	3	0	6	0	0	18	24	14	23	0	8.09
FAVORABLE	2	24	23	13	20	6	17	8	2	12	3	15	13.0
NEUTRAL	3	1	0	5	0	18	3	0	0	0	0	10	3.36
UNFAVORABLE	4	0	0	8	0	2	6	0	0	0	0	1	1.54
VERY UNFAVORABLE	5	0	0	0	0	0	0	0	0	0	0	0	0
KOLMOGOROV-SMIRNOV TEST OF MEAN FREQUENCIES: D = .412, P < .01													

TABLE 39. SUMMARY QUESTIONNAIRE DATA
N = 26

1. In comparison with other similar learning experiences, the recent experience with the intercept trainer was:

   a. Very enjoyable (1)
   b. Enjoyable (24)
   c. Neutral (1)
   d. Boring
   e. Extremely boring

2. As a method for teaching operating procedures, the intercept training system was:

   a. Very effective (3)
   b. Effective (23)
   c. Average
   d. Ineffective
   e. Very ineffective

3. While using the intercept training system to learn operating procedures, I would have liked to have had the system answer for me:

   a. Very many questions
   b. Many more questions
   c. A few more questions (7)
   d. No more questions (19)
   e. No questions

4. With the presence of an instructor and fully operating equipment I feel that intercept procedures would have been learned:

   a. In a much longer period of training
   b. In a longer period of training (13)
   c. In about the same time (5)
   d. In a shorter period of training (8)
   e. In a much shorter period of training

5. The intercept trainer is:

   a. Very easy to use (6)
   b. Easy to use (20)
   c. Neither easy or difficult to use
   d. Difficult to use
   e. Very difficult to use

TABLE 39. SUMMARY QUESTIONNAIRE DATA (CONT)

6. The initial instruction given on how to use the intercept trainer was:

   a. Much more than adequate to my needs
   b. More than adequate to my needs (6)
   c. Adequate to my needs (18)
   d. Less than adequate to my needs (2)
   e. Much less than adequate to my needs

7. About how long did it take you to learn to utilize the intercept trainer?

   a. About ½ of the first hour
   b. About 1 hour (17)
   c. About 1½ hours (3)
   d. About 2 hours (6)
   e. More than 2 hours

8. The immediate knowledge of errors provided by the intercept trainer:

   a. Greatly aided learning RIO operating procedures (18)
   b. Aided learning (8)
   c. Made no difference in learning
   d. Hindered learning
   e. Greatly hindered learning

9. Static mode requires that you perform necessary arithmetic computations without error in a specified time frame before continuing with intercepts. Did you find this:

   a. Very helpful in learning (24)
   b. Helpful in learning (2)
   c. Neutral
   d. Of very little help
   e. Of no help

10. The intercept trainer repeats an intercept in free-fly display format where you did not achieve criterion firing position in the initial attempt. This allows you to review the intercept and perceive your errors. Did you:

    a. Strongly like this capability (14)
    b. Like this capability (12)
    c. Have no like or dislike for this capability
    d. Dislike this capability
    e. Strongly dislike this capability

TABLE 39. SUMMARY QUESTIONNAIRE DATA (CONT)

11. In free-fly you could observe the relationships between intercept geometry and radar presentation during an intercept. Did you use this feature?

    a. Yes (26)
    b. No

12. If you used free-fly in the above way, do you believe it was:

    a. Very helpful in learning (23)
    b. Helpful in learning (3)
    c. Neutral
    d. Of very little help
    e. Of no help

13. The radar simulation provided by the intercept trainer was:

    a. Much more than adequate for learning basic intercept procedures
    b. More than adequate for learning basic intercept procedures (15)
    c. Adequate for learning basic intercept procedures (10)
    d. Less than adequate for learning basic intercept procedures (1)
    e. Much less than adequate for learning basic intercept procedures

14. Were there any particular intercept problems that were confusing? (0)

15. What particular system characteristics gave you the most trouble in using the intercept trainer?

    Learning to use keyboard--hitting wrong keys.

16. Do you believe that the time spent in practice on the intercept trainer will materially aid you in your flight performance? Why?

    Yes. The improvement in the ability to "see" what was going on in the problem (due to a greatly improved ability to visualize intercept geometry.)

17. What mode (static, dynamic, free-fly) of operation of the intercept trainer do you feel provided the greatest amount of learning of intercept procedures. Why?

    Static and Free Fly.

    a. Static: Because it greatly improved the ability to solve the variables of intercept geometry.

    b. Free-Fly: Could quickly recognize their errors.

TABLE 39. SUMMARY QUESTIONNAIRE DATA (CONT)

18. What specific aspects of the intercept training system did you like most? Least?

Most: The large number of intercepts that could be performed.

Least: The lack of speed control for fighter and the absence of altitude differential and the resulting lack of practice in tracking.

19. Do you have any particular suggestions concerning any aspect of trainer operation or the data within the program that you feel would have aided you in learning intercept procedures more thoroughly? (Please detail your suggestions and advise why you feel as you do.)

Most frequent comment: Add the third dimension to the problem to allow the student to practice the tracking (in elevation) that he must perform in flight.

SECTION VIII

SUMMARY AND CONCLUSIONS

An individual skills trainer for complex cognitive tasks that must be performed in real-time was developed by implementing concepts from cognitive and information-processing psychology with advanced computer graphics and minicomputer technology. The trainer automatically administers drill and practice in performing procedures required of the Radar Intercept Officer during air intercepts, and automatically adapts to individual differences in entering skills and learning rates among students. It records response data at the microstructure level of performance. These data were used to describe individual variations and individual progress in terms of latencies, errors, and final probability-of-hit scores.

This trainer was field-tested in the RIO school, Glynco, Georgia, using 29 students from classes while undergoing training in the school. Part of the time ordinarily spent watching other students being trained in the 15C4 radar trainer was allotted to the experimental trainer.

The results clearly reveal marked improvements in performance of the simulated air intercept procedures; mean latencies in solving for values of the intercept triangle by performing mental arithmetic and in completing the intercept were reduced by factors ranging from 2.2 to 3.1. Reliability of speed in responding, indicated by the reduction in variability in latencies, was similarly improved. Improvements also were observed in reductions in the number of turns required to complete an intercept, and in increases in the probability-of-hit scores.

Students were polled for information about their attitudes toward the trainer as a device for assisting them to learn air intercept procedures. Their attitudes were preponderantly favorable. The following conclusions seem to be warranted:

a. The small, portable, stand-alone graphics terminal, which is one type of so-called smart terminal, has tremendous potential as an individual skills trainer in remote environments where, for a variety of reasons, larger systems are infeasible. The particular smart terminal used in this research, although a product of reasonably advanced technology, could be markedly reduced in size, and could be given greatly increased computing power and storage through the application of LSI (Large Scale Integration) techniques. A device of the approximate size and weight of a portable TV set, with nanosecond-range computing speeds and megabyte-range storage could be distributed aboard ships and in other, similarly remote environments and would be a means for automatically accomplishing effective training under precise control.

b. The individual skills trainer described here is a significant step in the direction of automatic control over the microstructure of training processes, and training outcomes. Nevertheless, the adaptive control logic used was relatively crude, and the data-recording and analysis techniques could be (and are being) stream-lined considerably. Automatic control over training processes has far-reaching implications for increasing the effectiveness of military training by reducing the variability in the implementation of training that is an unavoidable consequence of the variability among the instructors and in the other resources that can be assembled by any local command.

c. The Performance-Structure-Oriented CAI approach to performance training functioned very well here. It was interesting for the students and it produced results. Nevertheless, we regard this particular implementation as a relatively crude beginning. As basic research now underway by many investigators develops more knowledge about cognitive structures and human information processing, and more powerful computer programming techniques for manipulating these structures and processes in the context of CAI, we can expect to see exciting advances in the effectiveness of training procedures.

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13. ABSTRACT

An individual trainer for giving students in RIO schools concentrated practice in basic procedures for air-to-air intercepts was designed around a programmable graphics terminal with two integral minicomputers and 8K of core memory. The trainer automatically administers practice in computing values of variables in the intercept triangle, and in making the turns required to put the fighter into position for a sidewinder attack.

In an initial field at the RIO school, Glynco, Georgia, each of 29 students received 10 hours of practice on this trainer. Data for the values of 33 variables were automatically recorded and were analyzed.

It was concluded that this form of CAI does produce worthwhile gains in fluency of performance and understanding of the intercept problems.

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