USING AN EXPERT SYSTEM FOR INTERACTIVE AND REMEDIAL TRAINING

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Summary

In mid-1984, the first advanced SHORAD (Short-Range Air Defense) Institutional Trainer became operational. This trainer included for the first time, some of the most advanced concepts ever offered in a training device. One of these concepts is an instructor expert system, devised to reduce the instructor's workload which is normally high in a trainer of this complexity. The SHORAD Trainer consists of six two-man crew training positions controlled from a dual-position instructor station. Target aircraft are flown against the crews being trained who are in turn evaluated on their performance. The targets are realistic; they take evasive measures based on actions taken by the crew being trained such as radar lock-on, missile firing, and employment of various electronic counter-measures. The instructor expert system automatically controls each training situation, adapting in real time the target behavior in response to every student action at each student station.

This instructor expert system also includes evaluation and automatic remedial training, accomplished by a real-time evaluation process that determines when the crew needs help. Help is provided through voice synthesized prompts, textual messages, or through assignment of remedial training, such as slowing targets down when tracking accuracy appears to be a problem. All of these are accomplished automatically, based on the crews' performance, requiring no instructor activity. Records of all activities are retained to analyze what tasks were difficult for a given student as well as what tasks require additional training for all personnel. Immediate benefits of this instructor expert system are a consistently challenging training program tailored to each student's achievement, and a comprehensive monitoring of the overall training program that frees the instructor for one-on-one contact when a student needs personalized help.

Status

This device has been operational for over one year. The students trained have performed extremely high on all service qualifications and have consistantly out performed personnel trained utilizing other methods.

The utilization of this instructor expert system or ultra advanced CAI, has proven to be extremely effective and has allowed the instructor staff more time to provide individual attention to selected students.

Introduction

The SHORAD Institutional Trainer, which is commonly referred to as a Conduct of Fire Trainer, became operational in mid-1984. The design of this trainer included advanced trainer features never before combined in a single trainer. For this reason, considerable attention during design and development was focused on the workload of the instructors. This was accomplished through the use of an instructor expert system. The key capabilities included in the instructor expert system are 1) computer assested simulation of missing crew member; 2) interactive computer controlled targets; and 3) instructional record keeping. With these advanced training capabilities included, the student-instructor ratio easily dropped from 2:1 to 12:1.

The system as delivered is shown in Figure 1. It is composed of six 2-man crew stations, an instructor station with dual-instructor positions, a computer image generation subsystem, an executive processor, and a power distribution subsystem. Each crew station contains a simulation processor, a graphics subsystem, an input/output subsystem, a voice synthesizer/voice recorder, student key pads for each crew member, and a communications subsystem.

Computer Assisted Simulation of the Missing Student

The system will train either the gunner or squad leader independently, or both as a team. For single-team member training, conventional design would require someone to take the part of the missing crew member for both physical actions and voice commands. This would normally be done by a member of the instructor staff, thus increasing the instructor workload. It was determined that this was not appropriate, and that the trainer must meet the requirement without instructor involvement.

The SHORAD Trainer's "Data Directed Design" uses multi-level exercises which make it easy to simulate the missing crew member's actions. Figure 2 shows the gunner being trained while the computer takes all of the appropriate squad leader's actions. The delivered configuration has a physical separation between the two operators; therefore, the only indications a trainee-operator has of his team member's actions are verbal acknowledgements and the visual result presented to the crew member being trained. The multi-level exercise structure is composed of a master exercise for system simulation and a training exercise addition for specific training functions as shown in Figure 3.

The multi-level exercise structure makes it easy to accommodate exercise changes when the operation of the tactical equipment changes. The master exercise portion of the exercise contains the system emulation functions, system reactions, system responses, system sequences, and all other characteristics which duplicate

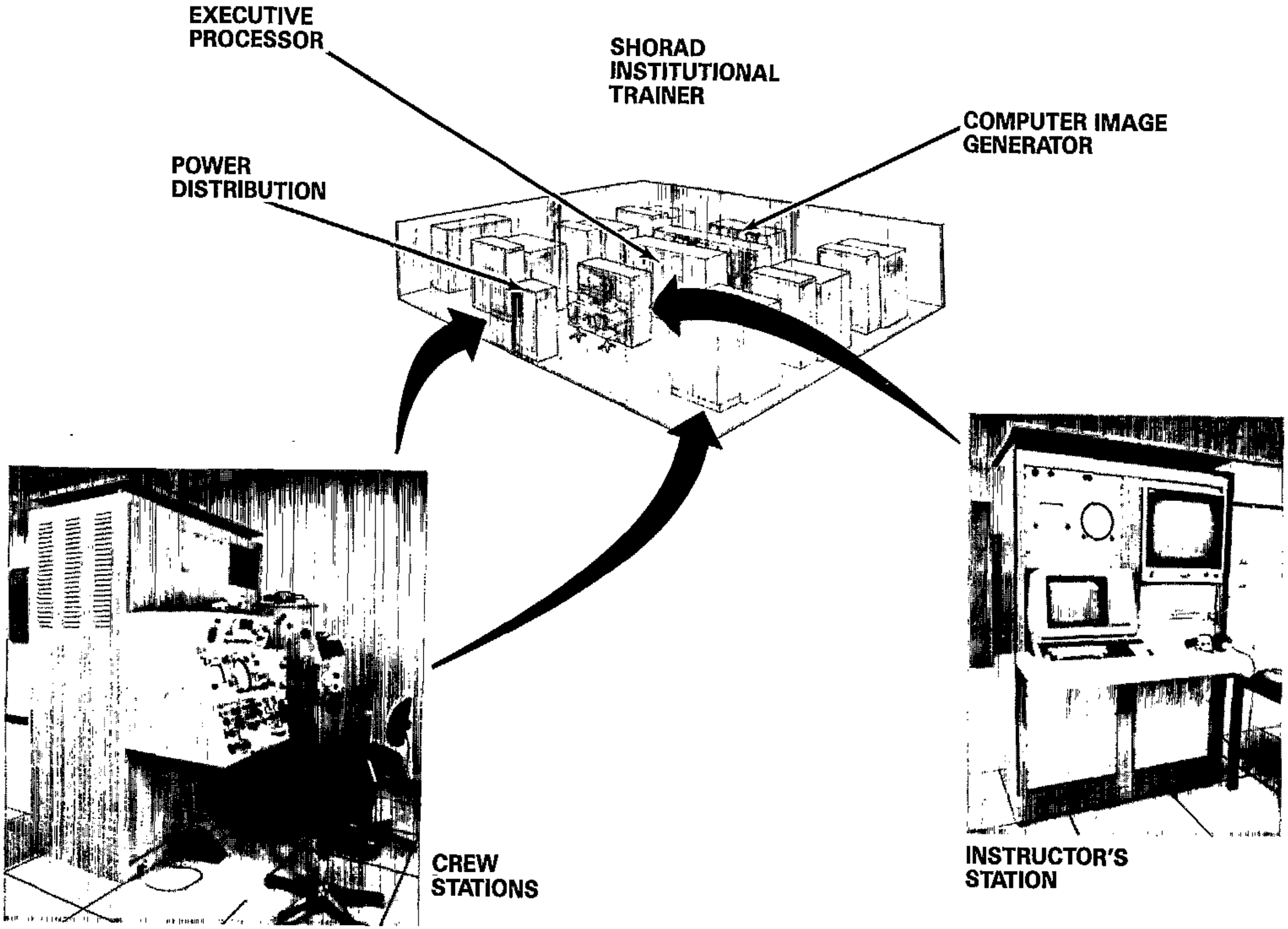

Figure 1. Shorad Institutional Trainer. Representation of delivered six-crew station and 2-position instructor station.

Figure 2. SHOROAD Crew Station. The gunner is being trained while the missing squad leader's functions are being performed under computer control.

Content of
Master Exercise

- Emulation of Prime System
- Exact prime system reaction including timing of all displays and indicators to all actions
- Proper sequence of all events to emulate proper operation
- Realistic high fidelity instructional replication of all displays
- Proper response to all actions including accurate timing

Content of
Training Exercises

- Merges with master exercise and overrides as appropriate
- Provides all computer-aided prompts
  - Voice
  - Textual
- Exact symptoms to simulated faults including all displays, indicators and responses.
- Provide computer assisted simulation emulating all actions and voice messages of a missing crew member
- Establishes all evaluation monitoring and grading parameters
- Establishes parameter restrictions for procedural training thru free play training in defining which functions are activated.

Figure 3. Exercise Structure

system operations. Therefore, when a system operation change is required, only the master exercise needs to be changed. This change is then in effect when any training exercise is conducted. The other portion of an exercise contains the training aspects which are unique to each exercise. This portion of the exercise is defined based on the instructional strategy and training tasks being trained. The type of functions contained in the training portion of an exercise are exercise or task specific such as CAI prompts, simulation of missing crew members, voice commands, remedial training grading, equipment faults and training sequences. The training portion of an exercise is small and changes can be made easily. Blending the master exercise with the training exercise results in a training program that is flexible to change and controls all emulation and training aspects. Changes to both portions of an exercise can be made utilizing the user friendly English oriented authoring language provided.

When the crew member being trained takes an action, the normal response for that action is taken by the computer, ensuring the stimuli presented to the student crew member is appropriate. Time delays and simulated operator errors can also be placed in the training exercise to provide appropriate realism. In addition, voice commands are often required to direct a crew member to take an action. Adding voice commands to the exercise via voice synthesizer, gives the student appropriate verbal stimuli based on the actions taken by him as well as those simulated by the computer for the missing crew member. This technique makes it possible to train single crew members or crews using lock-step instruction, free play instruction, or any combination of conditions. This method of directing the computer to respond as if the instructor had been taking all the correct actions and providing the verbal commands is fully under exercise control and does not require software modifications when system operational changes occur. The instructional prompts are all based on the student's actions, or the lack of actions, and can be either general or specific in nature. Instructional CAI prompts (either verbal or textual) can be provided to include complete step-by-step actions including a detailed explanation of why the action is to be taken.

Interactive Computer Controlled Targets

Training devices requiring moving targets have traditionally been designed using either Fixed Flight Paths or Pilot Controlled Flight Paths as shown in Figure 4. The first type, Fixed Flight Paths or raid tapes are shown in the upper portion of the figure. These targets are not interactive to the students actions. The figure shows a target entering from the upper right and exiting the lower left. The flight path including all maneuvers is fixed and will not vary. Under these conditions, the student observes the target and take the appropriate action, however, the target is not realistic in that evasive actions will not be taken as would be the real life situation. Although this is unrealistic, it is a method of providing targets under a controlled scenario at a relatively low cost. The lower portion of

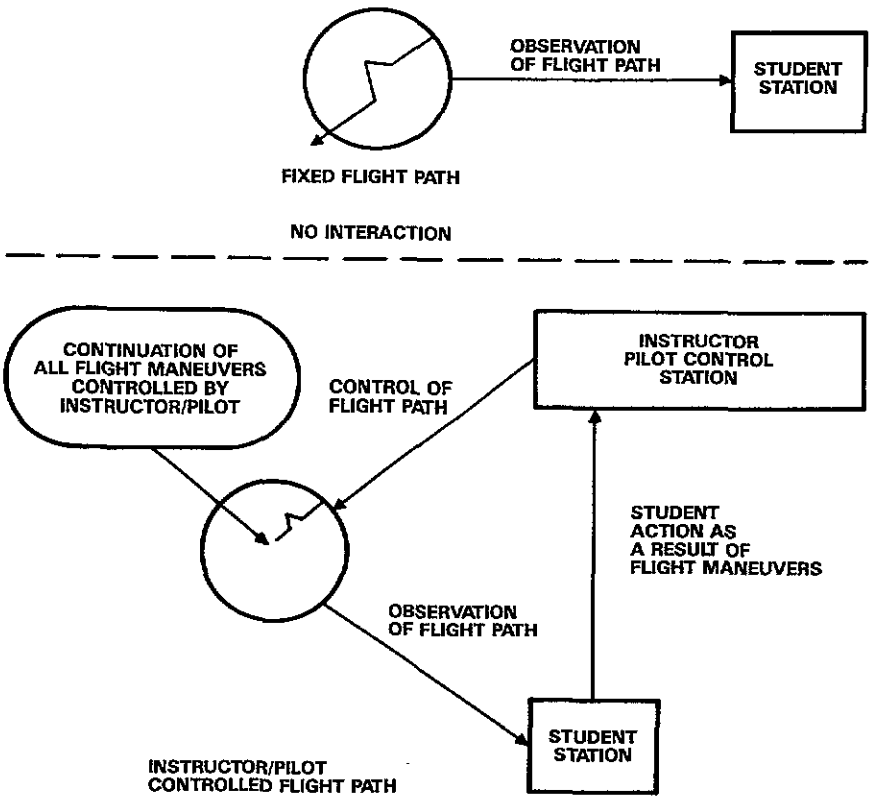

Figure 4. Comparison of Fixed Flight Paths Versus Instructor Controlled Flight Paths

figure 4 depicts a closed loop process utilizing instructor staff members or pilots flying simulated targets. In this example, the target enters the target area from any location, the student observes the target and takes an action. If this action would result in a live aircraft taking an evasive action, the instructor pilot will take this action and the result will be presented to the student. The student would continue to take the necessary action and the loop would continue. This method provides target realism in that the aircraft maneuvers are based on the student's actions. This is an important requirement in some situations - for example, when a student operating a tracking radar locks onto a target, it is reasonable to expect that the target will take an evasive action in anticipation of being fired upon. Using human controlled target simulation provides several advantages; however, it requires a large instructor staff, thus a higher operational cost. Moreover, the exercise's difficulty and consistency are dependent on the pilot/instructor providing the same flight profile and evasive actions for each student.

The features from each method were combined on this SHORAD Trainer. In this improved method, fixed flight paths were developed consistent with the tasks being trained. Then branch points were established where alternate flight paths could be taken, depending on the actions taken by the student. These branch points included evasive actions, changes in primary mission to attack a secondary asset, or to retreat. Each flight profile was designed with the following in mind: tactical mission, the logical points where branching would occur, and the tactically correct branching to support the training tasks. With this method, all of the normal branching provided by an instructor in flying against a student operator is achieved without the instructor, while ensuring that the exercises are consistent for all students. This provides uniformity in instructional content and evaluation for all students. An example of a typical flight path with three branch points is shown in Figure 5.

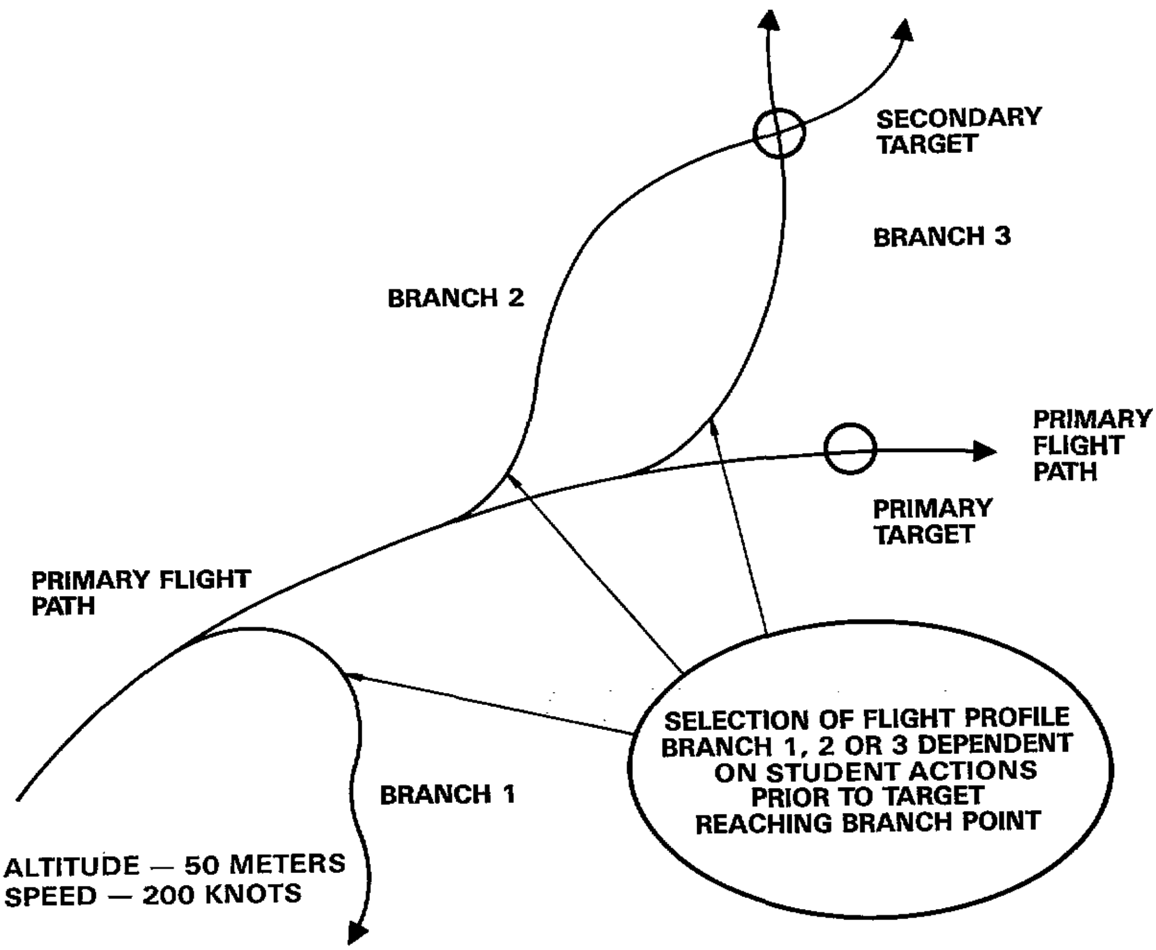

Figure 5. Interactive Computer Controlled Flight Paths

Flight paths vary depending on actions taken by the student and the objective of the exercise.

Automatic Evaluation and Assignment of Remedial Training

Devices used for training purposes almost always provide some method of exercise evaluation. When this is done on an action-by-action basis, instructional decisions can be made on what exercise the student should perform next. This action-by-action evaluation can be automatically grouped into categories such as sub-tasks, tasks, mission success or exercise completion. By utilizing tasks and sub-tasks as appropriate categories and keeping records of the student progress for each task and subtask, the computer can automatically determine which exercise should be assigned next, as shown in Figure 6. This could be an advance exercise or an earlier exercise on which the student needs refresher training. The progression of each student is established based on the performance level of each student on a given task, and sub-task. In addition, remedial training may be required for a portion (or all) of any exercise. If during the evaluation process, it is determined that a student is having difficulty with a given sub-task (falls below an established threshold) the exercise will branch to remedial training for that sub-task without instructor intervention. The exact remedial training is determined by which sub-task was failed.

In the example, a student failing Sub-task 1.3 would automatically be assigned remedial training for Sub-task 1.3. The student would remain in remedial training on this sub-task a length of time based on his progress and the training strategy before an instructor is notified that this student needs additional help. Remedial training could be totally tutorial by moving into a lock-step training process with voice prompts via the voice synthesizer. In this manner, the voice prompts which are part of the computer aided instruction portion of an exercise could be either activated immediately and progress as the student proceeds through the remedial exercise, or they could be time delayed giving the student a few seconds to take an action before the voice prompt helps him. The voice prompt can be repeated if the student does not take the specified action in the time allocated.

Sometimes, it is also appropriate to give prompts in text form. This is provided via a readout device. Both voice prompts and the readout messages can be given to the student crew member independently or together as a team.

A second type of automatic remedial training occurs when a student is having trouble tracking targets. In this method, a variety of automatic exercise actions can take place. For example, the targets can be slowed down so they will be easier to track. If this is not appropriate, then the tracking accuracy window can be relaxed to allow the student to gain confidence and experience. In all cases, once the student is able to pass the remedial exercise, the exercise is gradually advanced until the student reaches the criteria level required for the task or sub-task.

Once the student fails a sub-task and is placed in remedial training, he is automatically prevented from jumping out of that task and must complete all sub-tasks before progressing to the next task.

In the example, if the student completes Sub-task 1.3 and his performance is average, in the expected range, he would progress to Sub-task 1.4. The student who performed exceptionally high on Sub-task 1.3, knows how to perform not only this task but also Sub-task 1.4 because of the way the exercise was structured; he is automatically advanced to Task 2.0. At the completion of Sub-task 2.2, the student with either high or average performance level, would automatically be advanced to the next exercise.

In the example, a student who completes Task 4.0 at the high level would be advanced to the next exercise based on instructional strategy, the content of the exercise, and evaluation parameters. In this example, Task 4.0 would be structured to contain key parameters that would verify the student could adequately perform both Tasks 4 and 5 without more detailed instruction contained in the sub-tasks.

During a review exercise which is normally a free play exercise, the student is also evaluated on a task level. Normally, at the end of the review exercise, any student failing a task, would be returned to the appropriate exercise to receive refresher training on the task failed. After completing this refresher task, he would be returned to the review exercise and again evaluated. Because the exercise is a free play exercise, variables are automatically changed so he cannot memorize the review exercise.

There are times when it is best to stop the exercise because of a critical error or persistent problem, and require the instructor to deal with the student personally. Through exercise controlled freezes, training will be halted automatically. The instructor will be notified so he can provide the assistance required when it is convenient. Through this use of computer aided instruction, the instruction will stop at selected key points without requiring the instructor to continually monitor the detialed progress of all students.

Instructional Record Keeping

One tedious time-consuming task for any instructor is checking his records and assigning exercises to each student. Need for this has all been eliminated by allowing each student to sign on at any station. The computer checks his records, and assigns the appropriate exercise. The exercise assigned could be a remedial exercise, a previous exercise for refresher training, the next scheduled exercise, or an advanced one depending on the particular student's previous progress.

EXERCISE SUBJECT TASKS	1 TRAINING 1, 2			2 TRAINING 3, 4, 5				3 TRAINING 6, 7, 10				6 REVIEW 1 - 12			
	PROGRESSION				PROGRESSION				PROGRESSION				PROGRESSION		
TASK/ SUBTASK	H	A	F	TASK/ SUBTASK	H	A	F	TASK/ SUBTASK	H	A	F	TASK/ SUBTASK	H	A	F
1.0	2.0	1.1	1.1	3.0	4.0	3.1	3.1	6.0	6.1	6.1	6.1	1.0	FREE PLAY MUST COMPLETE ALL		E1-1
1.1	1.2	1.2	R	3.1	3.2	3.2	R	6.1	6.2	6.2	R	2.0			E1-2
1.2	1.3	1.3	R	3.2	4.0	4.0	R	6.2	6.3	6.3	R	3.0			E2-1
1.3	2.0	1.4	R	4.0	E3	5.0	4.1	6.3	7.0	7.0	R	4.0			E2-2
1.4	2.0	2.0	R	4.1	4.2	4.2	R	7.0	10.0	7.1	7.1	5.0			E2-3
2.0	2.1	2.1	2.1	4.2	5.0	4.3	R	7.1	7.2	7.2	R	6.0			E3-1
2.1	2.2	2.2	R	4.3	5.0	5.0	R	7.2	10.0	10.0	R	7.0			E3-2
2.2	E2	E2	R	5.0	E3	5.1	5.1	10.0	E4	E4	10.1	8.0			E4-1
				5.1	5.2	5.2	R	10.1	10.2	10.2	R	9.0			E4-2
				5.2	5.3	5.3	R	10.2	E5	E4	R	10.0			E3-3
				5.3	5.4	5.4	R					11.0			E5-1
				5.4	E4	E3	R					12.0			E5-2

H = HIGH LEVEL
A = AVERAGE LEVEL
F = FAIL
R = REMEDIAL

PREFIX E = EXERCISE
NONE = TASK OR SUBTASK
TASKS ARE ALL X.0
SUBTASKS ARE X.1 THROUGH X.n

Figure 6. Exercise Student Progression. The progression of each student is based on curriculum, instructional strategy, and exercise content depending on student performance.

Conclusions

By incorporating these features, the computer will perform the actions normally taken with the same thought and logic that an expert instructor would use while at the same time reducing the workload normally encountered. It is critical, however, that the decision algorithms, logical branch points, remediation content, and instructional strategies be developed by personnel who fully understand instructional theories and who are knowledgeable of the background, experience, and knowledge of the students being trained.

Training devices offering these beneficial features are possible only when extensive and detailed exercise evaluation processes are employed as part of the basic system design. As these systems become more common, the role of the instructor will shift from one of being overloaded with routine tasks to one of developing instructional strategy and of assisting students on the more complex, difficult-to-assimilate tasks.

Biography

Mr. David J. Harbour is Manager of Simulators and Training Devices at the Ground Systems Group of Hughes Aircraft Company. He received his BS degree in Electrical Engineering from Oklahoma State University. Dave manages the Program Office responsible for on-going simulator and training device programs including Advanced Program Development. He was previously Program Manager for the Roland Institutional Training Devices and prior to that, Technical Director for the Firefinder Radar Training Devices. Prior to these assignments, Dave was responsible for the development of training material, instructional strategy, and course conduct for many defense systems.