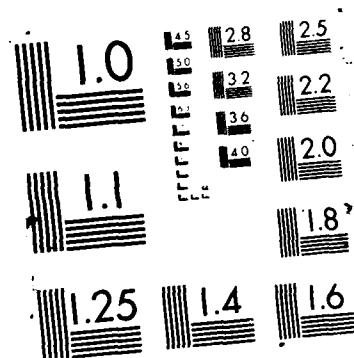FIELD EVALUATION OF INTERACTIVE SIMULATION FOR
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Field Evaluation of Interactive Simulation for Maintenance Training: SH-3 Helicopter Electro-Mechanical Bladefold System

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SH-3 Helicopter Electro-Mechanical Bladefold System

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This report describes an evaluation of the training effectiveness and suitability of an interactive simulation device and its instructional and simulation software used in connection with SH-3 helicopter electro-mechanical bladefold system training in the Naval Air Maintenance Training Group Detachment training environment. Although the study did not have sufficient subjects in all measurement categories for the application of statistical analysis methods, the results indicate that the training device is an effective supplement to both hydraulic and electrical systems training currently being performed on the SH-3 helicopter composite trainer. Trainees using the interactive training system required less time to complete troubleshooting exercises on the composite trainer, made fewer replacement errors, and obtained higher grades on written tests relating to the bladefold systems.

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FOREWORD

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SUMMARY

Problem and Background

The number of training systems available to support hands-on training of critical maintenance skills are often too few to allow individual trainees sufficient time on training tasks. While important for component task consolidation, the exclusive use of actual equipment or high fidelity simulation devices for teaching systems maintenance bears inherent cost and pedagogical limitations that can, and often do, affect the quality of available training. Recent advances in training systems technology make it possible to separately develop and exercise the cognitive skill involved in systems diagnosis and troubleshooting training. A generalized maintenance training system (GMTS) was developed to minimize the effects of limited training hardware availability and to increase training effectiveness in existing laboratory maintenance training. The Navy Personnel Research and Development Center was tasked by the Naval Air Systems Command (NAVAIR APC205-ON) to evaluate the new technology in connection with the SH-3 helicopter electro-mechanical bladefold system in the Naval Aviation Maintenance Training Group (NAMTRAGRU) detachment environment.

Objectives

The objectives of this effort were to (1) determine the effectiveness of the bladefold electro-mechanical training system (BEMTS) in developing organizational-level maintenance skills of aviation structural mechanic, hydraulic (AM(H)) and aviation electrician (AE) trainees assigned to the bladefold system portion of the NAMTRAGRU Detachment 1069 SH-3 helicopter hydraulic and electrical systems training courses, (2) to establish a performance baseline for future testing of intelligent tutoring system techniques in connection with BEMTS freeplay simulation capabilities, and (3) to evaluate the suitability of BEMTS to the NAMTRAGRU training environment.

Approach

Two identical BEMTS were installed at the NAMTRAGRU Detachment 1069, Naval Air Station, North Island, CA to supplement training in the SH-3 helicopter bladefold system portion of the airframe and hydraulic systems and the electrical systems organizational-level maintenance courses. For the evaluation, trainees attending the two courses were divided into balanced groups based on years of experience in aviation maintenance and relative class standing. Trainees in each experimental group used the BEMTS as a supplement to their training, while trainees in each control group spent equivalent time in independent study reviewing class notes, system schematics, and troubleshooting manuals. A total of 97 trainees, 71 AM(H)s and 27 AEs, participated in the evaluation.

Results

The evaluation results, though statistically inconclusive, indicate that both the experimental groups received higher final grades on written and performance test, took less time to troubleshoot malfunctions on the SH-3 composite trainer, and made fewer diagnostic and troubleshooting errors than did their control group counterparts. The results of user acceptance and suitability interviews and questionnaires indicate that the instructors and trainees generally liked the technology and considered it well suited for bladefold system maintenance training. Intermittent BEMTS hardware and software problems that occurred early in the evaluation effort caused initial concern about overall

training system availability. However, most hardware and software problems were resolved and did not adversely affect the on-going evaluation.

Conclusions

The use of BEMTS can be expected to (1) reduce mean troubleshooting time and mean errors to problem solution for both AM(H) and AE technician trainees performing exercises on the SH-3 helicopter composite trainer, and (2) increase mean test scores on written tests of bladefold systems knowledge for both AM(H) and AE technician trainees. Further, the data collected in this effort established an adequate performance base from which to measure and assess the effects of intelligent tutoring techniques.

Other conclusions addressing the continued use of BEMTS in NAMTRAGRU Detachments are: (1) the BEMTS simulation was not appropriately configured to provide the visual and auditory symptoms that AM(H) technicians use to diagnose and troubleshoot hydraulic system failures, (2) instructor requirements associated with BEMTS use remain to be determined, (3) developing new simulation and lesson materials and revising existing materials are not within the present or projected capabilities of NAMTRAGRU instructors, (4) and BEMTS configuration is not consistent with recent trends toward standardization on PC compatible hardware.

Recommendations

1. Given the positive direction of the results of using BEMTS as a supplement to the present hands-on equipment training approach in SH-3 bladefold system training, NAVAIR and NAMTRAGRU should continue to support a policy to refine and institutionalize the technology base established in the BEMTS.

2. The BEMTS hardware components that are not commercially available should be replaced with PC compatible devices. Future testing should include an investigation of BEMTS software transportability to other aviation maintenance training courses where similar low-cost training systems are being planned or used.

3. The BEMTS simulation and tutorial lesson data bases should be expanded to include other applicable portions of the SH-3 helicopter maintenance training courses and additional tests should be conducted to measure the actual impact of BEMTS on instructor workloads under full curriculum implementation conditions.

4. The display techniques incorporated in the BEMTS freeplay and tutorial paradigms should be expanded to implement the visual and auditory cues AM(H) technicians use to diagnose hydraulic systems failures and tests should be designed to measure the applicability and effectiveness of these simulation and training enhancements.

5. Responsibility for BEMTS simulation and lesson authoring should not be assigned to the user command unless such tasking includes appropriate training and corresponding augmentations in instructor staffing plans.

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INTRODUCTION

Problem

The number of training systems available to support hands-on training of critical maintenance skills are often too few to allow individual trainees sufficient time on training tasks. While important for component task consolidation, the exclusive use of actual equipment on high fidelity simulation devices for teaching systems maintenance bears inherent physical and pedagogical limitations. These include:

1. Fault insertion capabilities are often limited and cannot adequately support a comprehensive systems troubleshooting training program.

2. Training conditions may be unsafe for novice technicians.

3. Less training equipment than required to meet actual training needs is often available.

4. Training system upgrades and modifications are typically behind fleet installations.

5. Trainee performance is often difficult to evaluate objectively.

6. When more than one trainee is assigned the same performance task, individual performance deficiencies are not easily measured or corrected.

7. Training often focuses on repair tasks rather than on the functional relationships that lead to an in-depth understanding of the hardware system.

These limitations can significantly affect the quality of available training and the ability of the technical training commands to provide qualified first- and second-term technicians to the fleet.

Background

Recent advances in training systems technology make it possible to separately develop and exercise the cognitive skills involved in system diagnosis and troubleshooting. These skills involve such tasks as formulating hypotheses about a given system failure, selecting and performing appropriate system tests, and making inferences from the results of each test. The ability to exercise these skills as well as monitor and track student performance makes this technology even more attractive for future applications of intelligent tutoring systems.

The bladefold electro-mechanical training system (BEMTS) is a computer-based interactive simulation and training device. It was developed to eliminate some of the physical and pedagogical limitations inherent in the exclusive use of actual equipment trainers in maintenance oriented training programs. In its present configuration, BEMTS consists primarily of off-the-shelf commercial hardware incorporating a microcomputer, a videodisc player, and two CRT monitors (a high resolution video/graphics color monitor and a monochrome computer text monitor). Each monitor has touch-sensitive panels for user input and a portable keyboard for instructor input and lesson authoring. The underlying simulation and training concept involves the use of static photographic images (scenes) stored on a videodisc to present visual representations of the target system

(bladefold) and of the test equipment used for system diagnosis. Individual scenes include the system and component-level views needed to access and manipulate system controls and to acquire information about the present state of the system. BEMTS can display computer generated graphics and overwrite graphics on individual video images.

BEMTS software supports both structured learning and freeplay troubleshooting exercises. In the SH-3 helicopter training program, BEMTS provides instruction on electrical and hydraulic components of the bladefold system and also a troubleshooting practice environment that supplements the hands-on training performed on the bladefold system composite trainer. The structured training scenario employs a standard inter-active tutorial format focusing on component nomenclature, location, and related course declarative-knowledge objectives. The freeplay scenario has two training options. The first is a semistructured procedure-following paradigm in which the trainee performs serial tasks in accordance with predefined steps of procedure. The second is a freeplay troubleshooting paradigm in which the trainee is presented with indications of a system failure (gripe) and is required to isolate the failure to a faulty component and to restore the system to normal operations. For all lessons, the BEMTS retains a record of student performance that can be accessed and evaluated by course instructors.

The BEMTS is intended to develop organizational (O) level and intermediate (I) level maintenance skills by simulating equipment normally available only in the hardware laboratory. The simulation data base is constructed to replicate system conditions and modes of operations. During normal operation, the trainee can exercise the bladefold system from power-up through blade spread. The setting for all panel light configurations and other system cues is normal during each phase of the blade-spread cycle. System faults are inserted into the data base as predefined problems and in all instances, are represented by single component failures. During a training exercise, trainees are given a brief description of the fault symptoms by means of an operator's complaint; for example, "Rotor wing head positions, but the blades do not fold." With this information, the trainees use BEMTS to verify the fault and troubleshoot the system. Trainees use actual system technical documentation in isolating the fault. To replace a suspected faulty component, the trainees simply touch the replace function on the simulator control menu. They are allowed to replace as many components as necessary to restore the system to normal operations. However, each inappropriate replacement lowers the final perfor-mance score.

The Navy Personnel Research and Development Center (NAVPERSRANDCEN) was tasked by NAVAIR (Code APC205-ON) to evaluate the BEMTS in the training setting and to establish a performance baseline that could later be used to measure the gains that might be achieved through the use of intelligent systems techniques in O- and I-level maintenance training. Data collection for evaluating the baseline configuration began in November 1985 following completion of on-site acceptance testing of two BEMTS devices and of a one-week instructor training course covering BEMTS operations.

Objectives

The objectives of this effort were to (1) determine the effectiveness of the bladefold electro-mechanical training system (BEMTS) in developing organizational-level main-tenance skills of aviation structural mechanic, hydraulic (AM(H)) and aviation electrician (AE) trainees assigned to the bladefold system portion of the NAMTRAGRU Detachment 1069 SH-3 helicopter hydraulic and electrical systems training courses, (2) to establish a performance baseline for future testing of intelligent tutoring system techniques in

connection with BEMTS freeplay simulation capabilities, and (3) to evaluate the suitability of BEMTS to the NAMTRAGRU training environment.

APPROACH

BEMTS Acceptance Testing

BEMTS acceptance testing was conducted both at the contractor facility and at the NAMTRAGRU Detachment 1069 training site. Tests were conducted at the training site to determine compliance with installation specifications and to assist in evaluating the suitability issues related to device integration. All hardware, software, and lesson materials deficiencies were noted and tracked during the remainder of the test and evaluation period. Instructor comments were also noted and tracked.

Instructor Training

Following completion of acceptance testing, NAMTRAGRU Detachment instructors attended one-week training course conducted by the BEMTS research and development team. The training course covered BEMTS operations, instructor functions, and student use. Instructors had time to become familiar with both the tutorial and freeplay lessons in the lesson and simulation repertoire. Detachment instructors were interviewed at the end of the training course to obtain their perceptions of the adequacy of the training course.

Subjects

Subjects were 71 AM(H) trainees attending the SH-3 helicopter airframe and hydraulic systems organizational maintenance course and 27 AE trainees attending the SH-3 helicopter electrical systems organizational maintenance course conducted at NAMTRAGRU Detachment 1069, NAS North Island. Trainees in the courses differed in years of Navy service and experience in aviation maintenance training, but had no previous training in SH-3H helicopter maintenance.

The airframe and hydraulic class is shorter and scheduled more frequently during the training year than is the electrical class. An average of just over two AM(H) classes were conducted for each AE class during the BEMTS test and evaluation period. This normal sequencing of classes resulted in the substantial difference in the total number of trainees tested within each technical skills category.

Procedures

The SH-3 bladefold system represents approximately 20 percent of the curriculum in both the airframe and hydraulic systems and the electrical systems organizational maintenance training courses. Class size varies from six to eight trainees per class. Each class averages about 20 hours of training time in the laboratory troubleshooting bladefold system malfunctions on the SH-3 composite trainer. Troubleshooting practice on the composite trainer is performed as a team evaluation. Because it is considered impractical to have more than four trainees on the composite trainer at one time, classes are typically divided into two or more teams. The teams rotated to the composite trainer at intervals determined by the time required to complete one or more problem scenarios (about 2 hours). Teams not on the composite trainer are assigned to independent study reviewing class notes, troubleshooting manuals, and system schematics. Instructors are

available to answer any questions and to offer technical assistance as required during the independent study periods.

During the BEMTS test and evaluation, students in the hydraulic and electrical classes were divided into two technically equal groups of three or four trainees per group. Training course instructors estimated technical equality on the basis of time in the Navy, prior aviation maintenance experience, and relative class standing. Both groups received the normal classroom instruction on the bladefold system in their respective training courses. The SH-3 composite trainer only (control) group followed the normal training schedule rotating between the composite trainer and independent study. The BEMTS (experimental) group was rotated between the SH-3 composite trainer and the BEMTS device.

With two BEMTSs available, each BEMTS group was divided into teams of one or two trainees per device depending on group size. Each team was introduced briefly to the device and instructed in its operations. An instructor remained nearby to monitor team progress and to assist as needed. After the trainees completed the tutorial lessons on BEMTS, they moved to the freeplay troubleshooting exercises. Instructors selected the sequence of troubleshooting exercises for each team. Because BEMTS allows trainees to proceed at their own pace, the actual number of freeplay troubleshooting problems completed differed between teams and groups.

The following performance measures were used to determine BEMTS training effectiveness:

1. Individual measures.

    a. An instructor's rating of each trainee's performance for the laboratory portion of the course.

    b. The score (percent correct) on the written bladefold test in each course.

2. Team measures.

    a. Time for each team to complete troubleshooting a system malfunction on the composite trainer with instructor prompting.

    b. Time for each team to complete troubleshooting a system malfunction on the composite trainer without instructor prompting (final exam).

    c. Number of errors made by teams during troubleshooting exercises.

A checklist of typical troubleshooting errors (Appendix A) was developed to assist in recording group performance on the composite trainer during laboratory exercises. Because trainees solved problems as a group during laboratory sessions, each trainee in the group received the same solution time for observed system troubleshooting activity.

Operational Suitability and User Acceptance

The following items were monitored to assist in evaluating the suitability of the BEMTS in the existing NAMTRAGRU training environment:

1. Physical integration.
2. Availability
3. Appropriateness for bladefold system training.
4. User acceptance.

User acceptance was measured through interviews and questionnaires administered to participating instructors (p. B-1) and trainees in the BEMTS group (p. B-2). Questionnaires were also administered to instructors and trainees (both experimental and control groups) to elicit opinions concerning training simulators (p. B-3) and the SH-3 composite trainer (p. B-4) respectively.

Analysis

Given the small sample sizes in both the hydraulic and electrical groups, statistical methods were not used to examine group differences in the time-to-troubleshoot malfunctions on the composite trainer or the number of errors made during troubleshooting. For the same reason, statistical methods were not used to examine the trainee performance of the electrical groups on bladefold system written and final performance tests. Performance difference on bladefold system written and performance tests for the hydraulic groups were analyzed using t-ratios. User acceptance data were analyzed using the mean ratings of responses made on a 5-point scale to statements included in the User Acceptance Questionnaires (pp. B-1 and B-2).

RESULTS

BEMTS Acceptance Testing

Table 1 lists the problems encountered with BEMTS hardware, software, and lesson materials during acceptance testing and initial student use as well as their causes and how they were corrected.

Instructors participating in acceptance testing were interviewed to obtain their initial impressions of the BEMTS device. Their comments are summarized below:

1. The BEMTS provides a safe learning environment.

2. Tutorial lessons seem to match course lessons.

3. The BEMTS should allow trainees to learn procedures step by step.

4. The BEMTS should help to reduce some of the wear-and-tear on the composite trainer.

5. The BEMTS should provide immediate feedback when trainees give wrong answers.

6. BEMTS operations need to be simplified because instructor operations are "unfriendly." There are too many things to do that, if omitted, will lead to later

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Table 1

Problems Identified and Corrections Made During BEMTS Acceptance Testing

Problem	Cause and Correction
1. Software problems prevented operation of the procedures following routine in the freeplay format.	Users could lock the trainer program by performing certain steps out of sequence. The program was changed to prevent this occurrence.
2. Graphic materials did not always appear on the image display of one BEMTS trainer after bootup.	A hardware difference was found to exist between the two BEMTS trainers. The difference concerned the initial setting of an installed microchip. A software patch was written to properly initialize the microchips on bootup.
3. Some touch points were missing and touch panels were out of calibration.	Missing touch points were added and panels were recalibrated.
4. One trainer locked during bootup.	The hard disk system contained two competing files. This problem was solved by reloading trainer files on the hard disk system.
5. Several trainer exercises contained incorrect lesson information and trouble-shooting feedback.	Lesson data base was corrected in accordance with instructor-reviewer specifications.
6. Some prompts in the tutorial lessons did not state clearly which display to touch to continue the lesson.	Text messages were added to indicate the appropriate display screen with active touch points.
7. Support documentation was incomplete.	Upgrades were made by the development contractor.

problems. For example, student data are lost if the floppy diskette is removed from the drive at the wrong spot in the program.

7. The room selected for BEMTS is too hot and has no air conditioning.

8. An on-site computer expert might be needed in the event the system fails.

9. Collectively, instructors prefer actual equipment trainers over devices of the BEMTS type.

Instructor Training

Instructor comments regarding the BEMTS operations training course are summarized below:

1. Both the course and course length were minimally adequate.

2. The contractor-furnished instructor operations manual was poorly organized and difficult to understand.

3. Classroom presentations were well organized and cleared up ambiguities in the instructor operations manual.

4. The instructor operations manual should include simplified procedures to help the operator use and understand the various system diskettes that come with the BEMTS.

Physical Integration

A 9- by 18-foot office space contained the two BEMTSs separated by a printer they both shared, a standard size desk for instructor use, and adequate 115 volt 60 Hz electrical power, power outlets, and fluorescent lighting for the BEMTS installation. Air conditioning was not available in the training space and fans were sometimes used to lower temperatures that reached as high as 90°F during the summer months. Although not an ideal training environment, the high temperatures did not appear to affect student or equipment performance.

Training Effectiveness

Tables 2 and 3 summarize the performance data for the hydraulic classes. The experimental group obtained a significantly higher mean score on the bladefold system written test than did the control group. The difference in the mean scores received for laboratory troubleshooting performance was not statistically significant, although the

Table 2

Individual Training Effectiveness Measures: Hydraulic Classes

| | Mean Score (%) | | | | |
Item	Control Group n = 35	Experimental Group n = 36	Difference	df	t-Test
Bladefold written test	89.7	93.1	3.4	69	2.01*
Laboratory trouble-shooting	67.7	69.2	1.5	69	.60

*p < .05.

Table 3

Team Laboratory Performance Measures: Hydraulic Classes

	Mean Result		
Item	Control Group n = 10	Experimental Group n = 10	Difference
Time (min) to troubleshoot malfunctions (prompted)	30.7	27.4	3.3
Time (min) to troubleshoot malfunctions (Unprompted)	43.3	29.4	13.9
Number of troubleshooting errors to problem solution	.89	.74	.15

experimental group did obtain a slightly higher mean score. In team laboratory performance, the experimental group achieved a lower mean time to troubleshoot malfunctions on the composite trainer in both the instructor prompted and unprompted categories and in the mean number of errors to problem solution. Because of the small number of teams in the sample, these differences were not subjected to statistical tests of significance.

Tables 4 and 5 summarize the mean performance data for the electrical classes. Because of the limited number of classes and trainees available during the testing period, individual and group performance data were not subjected to statistical tests of significance. However, as with the hydraulic groups, the trends observed for the electrical experimental group were all in a positive direction regarding BEMTS effectiveness. The electrical experimental groups obtained slightly higher mean scores on written and final performance tests than did the control groups. They also achieved a lower mean time to troubleshoot malfunctions on the composite trainer and lower mean number of errors to problem solution in both the prompted and unprompted categories.

Table 4

Individual Training Effectiveness Measures: Electrical Classes

	Mean Score (%)		
Item	Control Group n = 13	Experimental Group n = 14	Difference
Bladefold written test	87.4	90.6	3.2
Laboratory troubleshooting	91.6	93.9	2.3

Table 5

Team Laboratory Performance Measures: Electrical Classes

| | Mean Result | | |
| | Control Group n = 4 | Experimental Group n = 4 | |
Item			Difference
Time (min) to troubleshoot malfunctions (prompted)	46.6	25.9	20.7
Time (min) to troubleshoot malfunctions (unprompted)	44.0	19.8	24.2
Number of troubleshooting errors to problem solution	1.6	.55	1.05

Performance data within each measurement category show a consistent positive trend for the experimental groups. The most notable difference between the experimental and control groups was in the time required to complete troubleshooting on the composite trainer without prompting. Mean differences of 13.9 and 24.2 minutes to problem solution were recorded for the hydraulic and electrical classes respectively. These differences represent an average reduction of 43 percent in the time required to complete a typical troubleshooting problem on the composite trainer for both experimental groups. The experimental group in the electrical classes recorded similar percentage gains in the other two laboratory performance categories.

Equipment Availability

Table 6 shows the downtime accumulated for both the SH-3 composite trainer and the BEMTS during the testing period. The composite trainer was down for 8 days awaiting

Table 6

Trainer Downtime for Preventive and Corrective Maintenance

| | Downtime | | | | | |
	Composite Trainer		BEMTS (2 devices)		Difference	
Preventive maintenance	4.5	hours	4.2	hours	.3	hours
Corrective maintenance	8	days[a]	1	day[a]	7	days
	2	hours	10.7	hours	8.7	hours

[a]Awaiting replacement part.

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delivery of a check valve that was not available locally. The 2 hours recorded for corrective maintenance involved the replacement of the one-way check valve and an auxiliary pressure switch.

BEMTS downtime consisted 1 day to replace a faulty high resolution display monitor and approximately 11 hours for corrective maintenance. BEMTS corrective maintenance involved the repair of several hardware and software problems that instructors initially identified during acceptance testing (Table 1) but in many instances took several weeks to repair. Because the test and evaluation effort actually began before all identified problems had been resolved, BEMTS use by one early hydraulic class had to be cancelled. Of the remaining problems, over 70 percent involved some form of instructor-operator error. Instructors often overlooked a procedural step in preparing student floppy diskettes correctly or in removing them from the computer. These oversights would cause the BEMTS programs to stop and often resulted in the loss of recorded student data. Corrective actions involved turning system power off and on or depressing the reset button to reboot the system. A system modification was installed in the third month of testing which eliminated the use of student floppy diskettes. This modification resolved many of the observed instructor difficulties in preparing BEMTS for student use and the computer program stops associated with floppy diskette operations.

Downtime for preventive maintenance was approximately equal for the BEMTS and composite trainers and did not interfere with on-going training.

User Acceptance

Tables 7 and 8 present the mean responses based on a scale of 1 to 5 to items included in student (p. B-2) and instructor (p. B-1) user acceptance questionnaries. In general, trainees in the experimental groups indicated that the BEMTS was easy to use, helped them to understand the course materials, helped them to learn how to troubleshoot the bladefold system, and measured their troubleshooting ability accurately. Instructors in both training courses indicated that BEMTS lessons were compatible and consistent with course objectives and that the training received on BEMTS was a useful supplement to that received on the composite trainer. According to the instructors, BEMTS student data collection features of the BEMTS were only marginally effective in monitoring student performance and BEMTS lesson authoring software did not offer an easy method for developing new lessons. Instructors overwhelmingly agreed that the use of BEMTS added to their workload.

Follow-up interviews with the instructors tended to validate the responses received on the user acceptance questionnaires. Instructors in both the hydraulic and electrical system courses considered the BEMTS appropriate for use in bladefold system training. They also stated that the knowledge and skills taught using the tutorial and troubleshooting lessons were relevant and consistent with stated course objectives and compatible with those taught on the composite trainer. According to most of the instructors, BEMTS incorporates useful training materials and approaches that could be expected to increase the quality of training in NAMTRAGRU Detachments. However, they consistently pointed out that they did not believe BEMTS could be used effectively alone. In their opinion, BEMTS should only be used to complement existing training. Instructors agreed that teaching safety precautions was the weakest area in BEMTS training. They commented that safety related feedback is either unrealistic or nonexistent.

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Table 7

Student Acceptance of BEMTS

| Item | | Student Mean Responses[a] | |
		Hydraulic Group	Electrical Group
1.	The tutorial lessons helped me to learn about the bladefold system.	3.67	4.53
2.	The tutorial lessons were too long.	2.14	1.94
3.	The tests at the end of the tutorial lessons were too difficult.	1.41	1.67
4.	The problems helped me learn to troubleshoot.	3.89	4.71
5.	The problems were too difficult to solve.	1.81	1.53
6.	The problems took too long to solve.	2.31	1.94
7.	A variety of troubleshooting problems was presented.	4.31	4.82
8.	The computer was easy to use.	4.03	4.76
9.	There was enough training time on the computer.	3.61	3.65
10.	More time should be spent doing troubleshooting problems on the computer.	3.14	3.47
11.	Training time on the computer was often wasted.	1.29	2.25
12.	Computer breakdowns interfered with training.	2.47	1.76
13.	The computer helped me to understand the actual equipment.	3.67	4.65
14.	My performance on the computer was an accurate measure of my troubleshooting ability.	3.08	3.94

[a]Responses based on a scale of 1 to 5 where 1 = strongly disagree and 5 = strongly agree.

Table 8

Instructor Acceptance of BEMTS

| Item | Instructor Mean Responses[a] | |
	Hydraulic Course	Electrical Course
1. The tutorial lessons are well designed for bladefold instruction.	3.90	4.50
2. The tutorial lessons meet course objectives.	3.80	4.50
3. The troubleshooting lessons are well designed for bladefold instruction.	3.20	4.50
4. The troubleshooting lessons meet course objectives	3.50	4.00
5. The computer trainer provides a useful supplement to the actual equipment.	3.60	4.50
6. The authoring software is easy to use.	2.70	4.25
7. The authoring software provides an effective method of developing new lessons.	2.50	2.50
8. The record keeping features of the computer trainer simplify the task of individual student management.	3.30	3.00
9. The addition of the computer trainer does add significantly to the instructional workload.	1.40	1.50
10. Student data produced by the computer trainer are helpful in student management.	2.80	2.75
11. Student data produced by the computer are useful in assessing student abilities.	2.80	3.25

[a]Responses based on a scale of 1 to 5 where 1 = strongly disagree and 5 = strongly agree.

A separate questionnaire was given to instructors to obtain their opinions concerning the general use of simulators in training (p. B-3). Table 9 presents the instructors' mean responses (on a scale of 1 to 5) to items comparing the use of simulators to actual equipment in training. Consistent with the ratings received on the BEMTS user acceptance questionnaire, instructors in both the hydraulic and electrical courses agreed that simulators were a good idea, monitored student performance better, helped in meeting course training objectives, and provided training in less time and at lower cost than did actual equipment. They were less inclined to agree that simulators were more reliable and easier to maintain or use than actual equipment. The two instructor groups differed in their answers to questions relating to training effectiveness and simulator fidelity. The electrical instructors did not believe that simulators could be as effective as the actual equipment or that high simulator fidelity was required to meet training needs.

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Table 9

Instructor Evaluation of Training Simulators

Based on my knowledge and experience, I think that training simulators:	Instructor Mean Responses[a]	
	Hydraulic Course	Electrical Course
1. are a good idea.	4.67	4.60
2. can be as effective as actual equipment.	3.44	2.20
3. must look like actual equipment.	4.67	2.80
4. can provide training at a lower cost than actual equipment.	3.33	3.40
5. can provide training in less time than actual equipment.	3.33	3.20
6. can present more complex training problems than actual equipment.	3.56	3.60
7. are more reliable than actual equipment.	2.56	2.60
8. can be maintained as easily as actual equipment.	2.89	2.00
9. teach safety better than actual equipment.	3.22	1.40
10. provide for better monitoring of student performance than actual equipment.	3.78	4.00
11. are as easy for instructors to use as actual equipment.	3.22	2.80
12. are as easy for students to use as actual equipment.	3.22	3.60
13. are something I would use as an integral part of the courses that I teach.	3.89	4.20

[a]Responses based on a scale of 1 to 5 where 1 = strongly disagree and 5 = strongly agree.

The hydraulic instructors indicated that simulators could be as effective as actual equipment but required high actual equipment fidelity. The two groups also disagreed on the ability of simulators to teach safety procedures.

A third questionnaire (p. B-4) was given to all students to obtain their opinions of training performed on the SH-3 composite trainer. Table 10 presents the students' mean responses (on a scale of 1 to 5) to items relating to the composite trainer effectiveness and ease of use. Both experimental and control groups agreed that training with the composite trainer was effective in helping to learn troubleshooting procedures, that training time was well spent, and that their performance on the composite trainer measured their system troubleshooting ability accurately.

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Table 10

Student Evaluation of SH-3 Helicopter Composite Trainer

| | Student Mean Responses[a] | | | |
| | Hydraulic Course | | Electrical Course | |
Item	Experimental Group	Control Group	Experimental Group	Control Group
1. I can follow the cockpit checklist without making mistakes.	4.64	4.63	4.47	4.85
2. I can use the schematics to trouble-shoot the bladefold system.	4.44	4.34	4.46	4.71
3. I know the names and locations of the bladefold components.	4.00	3.74	3.94	3.92
4. I understand how to troubleshoot the bladefold components.	4.39	4.37	4.59	4.77
5. I feel comfortable working on the bladefold system.	4.36	4.00	4.82	4.38
6. There was enough training time on the equipment.	3.94	4.20	4.23	3.88
7. Training time on the equipment was often wasted.	1.39	1.37	1.29	1.15
8. A variety of troubleshooting problems was provided.	4.75	4.86	4.82	4.85
9. The problems helped me learn to troubleshoot.	4.78	4.66	4.88	4.92
10. The problems were too difficult to solve.	1.81	1.40	1.59	1.38
11. The problems took too long to solve.	2.08	1.91	1.65	1.85
12. Equipment breakdowns interfered with training.	1.31	1.31	1.59	1.38
13. More time should be spent doing traoubleshooting problems on the actual equipment.	3.39	3.51	3.71	3.54
14. My performance on the actual equipent was an accurate measure of my troubleshooting ability.	3.86	3.97	4.15	4.29

[a]Responses based on a scale of 1 to 5 where 1 = strongly disagree and 5 = strongly agree.

DISCUSSION

Simply stated, the questions posed for this evaluation were (1) will technician trainees demonstrate better system troubleshooting performance on the SH-3 helicopter bladefold system composite trainer as a result of using BEMTS, and (2) is this technology suited to the existing training environment? The answer to the first question is a qualified yes. Only in the hydraulics classes did the samples contain enough trainees to perform a statistical analysis on written and laboratory performance test scores. Although the experimental group mean score was higher for both of these measures, only the difference in the written test scores was found to be statistically significant. Since the experimental and control groups in both the hydraulic and electrical classes scored well within a range to assume mastery of the course materials, the recorded superiority of the experimental groups on these measures (Tables 2 and 4) is not overwhelming.

The differences in mean scores for time to troubleshoot a malfunction on the composite trainer and the number of errors to problem solution (Tables 3 and 5) are much more impressive. In the hydraulics classes, the experimental group averaged 13.9 minutes less to troubleshoot malfunctions without prompting than did the control group. In the electrical classes, the experimental group averaged 24.2 minutes less on this measure. The electrical experimental group also averaged 20.7 minutes less to troubleshoot malfunctions with prompting and averaged one less error to problem solution where the control group averaged less than two errors. While the mean scores for the hydraulic experimental group did not equal the magnitude of difference recorded for the electrical experimental group in these latter measures, they were consistently higher than the control group scores. Given the small number of trainees in the test sample, the reliability of the positive trend may be questioned. However, BEMTS performance data appear to replicate the results of similar tests of the simulation and training approach (Cicchinelli, 1984; Rigney, 1980) and continue to be quite encouraging.

The simulation and training techniques employed in BEMTS were originally developed using electronic equipment for concept evaluation. The underlying principles involve techniques to separately develop and exercise the cognitive skills associated with system diagnosis and troubleshooting. For electronic systems, symptom diagnosis most often involves the use of test equipment. The SH-3 helicopter bladefold system is an electro-mechanical system that electrically requires many of the same circuit diagnosis and testing skills employed in troubleshooting electronic systems. On the hydraulic side, system diagnosis and testing are very different. Hydraulic system failures are often analyzed and isolated by observing the tensioning effects on hydraulic lines, the stability of the blade spread/fold cycle, or by the occurrence of auditory and visual anomalies in mechanical sequences. BEMTS did not include capabilities for developing and exercising auditory or visual skills. The omission of these capabilities from the simulation could very likely have contributed to the differences observed in laboratory troubleshooting performance between the hydraulic and electrical experimental groups.

The data collected in this test and evaluation provide no easy answer to the question of how well the technology is suited to the NAMTRAGRU training environment. The BEMTS was designed as a system prototype to test the simulation and system trouble-shooting practice concept in SH-3 helicopter maintenance training and for future testing of intelligent tutoring system applications in the NAMTRAGRU training environment. Acceptance testing of the BEMTS prior to installation in the NAMTRAGRU facilities uncovered several minor equipment and training material problems that were easily solved. However, acceptance testing did not subject the BEMTS to the same level of scrutiny that accompanied implementation and student use. As with any new technology,

instructors need time to become familiar with both BEMTS operations and the content and format of the various instructional paradigms employed. Many of the problems noted occurred within the first three months of testing. Many of these problems were attributed to poor touch panel calibration, a general disagreement by instructors concerning the syntax or terminology used to explicate system and component functions, or operator error. Other problems involved intermittent spurious operation of the computer system and/or the controlling software. Since the BEMTS research and development team could not replicate many of the difficulties, not all of these intermittent problems were isolated or resolved.

One of the most frequently cited BEMTS problems and the one which contributed most to negative responses by instructors was associated with the use of floppy diskettes. When delivered by the development contractor, BEMTS required that the instructors initialize a separate floppy diskette for each student and/or pair of students assigned to a BEMTS device. The initialization process required instructors to create a student diskette with a student number, name, and the trainer exercises in which the student would participate (tutorial and/or freeplay). Instructors received no feedback to verify that the diskette was properly initialized. The procedures also required that floppy diskettes be inserted and removed only at specific points during the boot-up and sign-off process. If a diskette was not properly initialized, the computer system would lock or perform random and unpredictable operations. If the diskette was removed before the training program menu was displayed, student performance data would be lost and the computer would lose synchronization. Both problems required that the instructor reboot the system and start at the beginning of the lesson selection process. After the first four classes had completed testing, the BEMTS research team installed a software modification that included a menu driven selection routine to replace the procedures used with the original instructor utility program. The menu selection routine eliminated most of the keyboard entries, prompted all required instructor actions, and allowed instructors to create student files directly onto the computer hard disk system, thereby eliminating the use of student floppy diskettes in the training mode. This modification resolved many of the instructor difficulties associated with using BEMTS and also many of the instructor complaints relating to the computer system.

The bladefold system represents about 20 percent of the SH-3 helicopter training course and the BEMTS was actually used in less than 20 percent of available bladefold system training time. The BEMTS test and evaluation increased the instructors normal workload by approximately the number of hours the instructors spent monitoring trainees using BEMTS. It is not clear if these additional hours were imposed because of BEMTS requirements or NAMTRAGRU policy to have at least one instructor in all spaces where electronic equipment is being operated. Available data do not reveal whether BEMTS would actually impose significant staffing changes if its use was expanded to include other applicable portions of the SH-3 helicopter course and it was installed in a space normally manned by staff instructors.

Although the contractor training course briefly discussed simulation and lesson authoring, NAMTRAGRU instructors were not required to author or modify any lessons during the evaluation. Until the new instructor utility menu system was modified, most instructors found the tasks associated with preparing the BEMTS for student use difficult to master. Simulation authoring, lesson development and modification are much more complicated. Currently they require an in-depth understanding of the computer operating system, the use of computer text and graphics editors, computer filing systems, how the simulation data base is structured, instructional design methodologies as well as operational systems knowledge. This combination of skills and knowledge is not commonly

available in most training commands and is not easily passed down to replacement instructors. These tasks for those commands that are not currently using various forms of the technology are additive and will definitely impose on existing instructor workloads. They will also require a minimum of 40 hours of training to allow instructors to become familiar with both the simulation and tutorial lesson data file formats and associated authoring procedures.

CONCLUSIONS

Although the results of this test and evaluation are inconclusive because of the limited number of students in the test sample, they suggest that BEMTS is an effective supplement to SH-3 helicopter bladefold system hydraulic and electrical training currently conducted on the SH-3 helicopter composite trainer at NAMTRAGRU Detachment 1069. Specifically, the findings indicate that:

1. The use of BEMTS reduces mean troubleshooting time and mean errors to problem solution for both AM(H) and AE technician trainees performing exercises on the SH-3 helicopter composite trainer.

2. The use of BEMTS increases mean test scores on written tests of bladefold systems knowledge for both AM(H) and AE technician trainees.

3. The data collected in this effort establish an adequate performance base from which to measure and assess the effects of on-line intelligent tutoring techniques used in conjunction with BEMTS freeplay troubleshooting exercises.

The following conclusions address the continued use of BEMTS in NAMTRAGRU maintenance training courses and future testing for intelligent tutoring system applications:

1. The BEMTS did not adequately simulate or provide the kind of visual and auditory fault symptoms that AM(H)s use to diagnose and troubleshoot the bladefold system. While these features are within the capabilities of existing hardware and software configuration, modifications to the existing simulation data base and videodisc are required to determine the cost and performance impact resulting from these simulation enhancements.

2. Because it was not possible to accurately determine whether the additional hours spent by instructors in monitoring BEMTS student progress were device or regulation driven, changes to existing NAMTRAGRU detachment staffing requirements as a result of using BEMTS could not be determined.

3. BEMTS simulation and lesson authoring and materials upgrade tasks are not within the present or projected capabilities of NAMTRAGRU instructors. Therefore, all changes and modifications to existing lesson materials and the development of new materials will require outside support or additional training for instructors.

4. The BEMTS prototype is not consistent with recent trends toward standardization on PC compatible hardware.

RECOMMENDATIONS

1.   Given the positive direction of the results of using BEMTS as a supplement to the present hands-on equipment training approach in SH-3 bladefold system training, NAVAIR and NAMTRAGRU should continue to support a policy to refine and institutionalize the technology base established in the BEMTS.

2.   The BEMTS hardware components that are not commercially available should be replaced with PC compatible devices.   Future testing should include an investigation of BEMTS software transportability to other aviation maintenance training courses where similar low-cost training systems are being planned or used.

3.   The BEMTS simulation and tutorial lesson data bases should be expanded to include other applicable portions of the SH-3 helicopter maintenance training courses and additional tests should be conducted to measure the actual impact of BEMTS on instructor workloads under full curriculum implementation conditions.

4.   The display techniques incorporated in the BEMTS freeplay and tutorial paradigms should be expanded to implement the visual and auditory cues AM(H) technicians use to diagnose hydraulic systems failures and tests should be designed to measure the applicability and effectiveness of these simulation and training enhancements.

5.   Responsibility for BEMTS simulation and lesson authoring should not be assigned to the user command unless such tasking includes appropriate training and corresponding augmentations in instructor staffing plans.

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APPENDIX A

TROUBLESHOOTING CHECKLIST

CHECKLIST OF TROUBLESHOOTING ERRORS

ERRORS	1	2	3	4	5	6	7	8	9	10	11	12
1. Violates safety rules.												
2. Performs operational checklist incorrectly.												
3. Does not notice checklist discrepancy												
4. Unable to trace discrepancy on schematic.												
5. Uses wrong schematic.												
6. Overlooks cues (visual or auditory).												
7. Does not perform visual inspection.												
8. Unable to systematically isolate possible malfunctioning components.												
9. Unable to locate components on Trainer.												
10. Measures test readings incorrectly.												
11. Unable to explain basis of malfunction.												
12. Does not work as a team member.												
13. Unable to describe function of components.												
14. Unable to describe sequence of operation.												
15. Unable to name components.												

PROBLEMS

APPENDIX B

USER ACCEPTANCE QUESTIONNAIRES

The following statements describe the BEMTS. Circle the number that best expresses how much you agree or disagree with each statement.

	Disagree Strongly			Agree Strongly	
1. The tutorial lessons are well designed for bladefold instruction.	1	2	3	4	5
2. The tutorial lessons meet course objectives.	1	2	3	4	5
3. The troubleshooting lessons are well designed for bladefold instruction.	1	2	3	4	5
4. The troubleshooting lessons meet course objectives.	1	2	3	4	5
5. The computer trainer provides a useful supplement to the actual equipment.	1	2	3	4	5
6. The authoring software is easy to use.	1	2	3	4	5
7. The authoring software provides an effective method of developing new lessons.	1	2	3	4	5
8. The record keeping features of the computer trainer simplify the task of individual student management.	1	2	3	4	5
9. The addition of the computer trainer does not add significantly to the instructional workload.	1	2	3	4	5
10. Student data produced by the computer trainer are helpful in student management.	1	2	3	4	5
11. Student data produced by the computer are useful in assessing student abilities.	1	2	3	4	5

USER ACCEPTANCE QUESTIONNAIRE
STUDENT EVALUATION OF BEMTS

The following statements describe experiences with the BEMTS trainer.
Circle the number that best expresses how much you agree with each
statement. Circle 1 if you do not agree at all with the statement;
circle 5 if you agree very much with the statement.

	Do Not Agree At All				Agree Very Much
1. The tutorial lessons helped me to learn about the bladefold system.	1	2	3	4	5
2. The tutorial lessons were too long.	1	2	3	4	5
3. The tests at the end of the tutorial lessons were too difficult.	1	2	3	4	5
4. The problems helped me learn to troubleshoot.	1	2	3	4	5
5. The problems were too difficult to solve.	1	2	3	4	5
6. The problems took too long to solve.	1	2	3	4	5
7. A variety of troubleshooting problems was presented.	1	2	3	4	5
8. The computer was easy to use.	1	2	3	4	5
9. There was enough training time on the computer.	1	2	3	4	5
10. More time should be spent doing troubleshooting problems on the computer.	1	2	3	4	5
11. Training time on the computer was often wasted.	1	2	3	4	5
12. Computer breakdowns interfered with training.	1	2	3	4	5
13. The computer helped me to understand the actual equipment.	1	2	3	4	5
14. My performance on the computer was an accurate measure of my troubleshooting ability.	1	2	3	4	5

USER ACCEPTANCE QUESTIONNAIRE
INSTRUCTOR EVALUATION OF TRAINING SIMULATORS

The following statements describe opinions about training simulators.
Circle the number that best expresses how much you agree or disagree
with each statement.

	Disagree Strongly			Agree Strongly	

Based on my knowledge and experience,
I think that training simulators:

1.	are a good idea.	1	2	3	4	5
2.	can be as effective as actual equipment.	1	2	3	4	5
3.	must look like actual equipment.	1	2	3	4	5
4.	can provide training at a lower cost than actual equipment.	1	2	3	4	5
5.	can provide training in less time than actual equipment.	1	2	3	4	5
6.	can present more complex training problems than actual equipment.	1	2	3	4	5
7.	are more reliable than actual equipment.	1	2	3	4	5
8.	can be maintained as easily as actual equipment.	1	2	3	4	5
9.	teach safety better than actual equipment.	1	2	3	4	5
10.	provide for better monitoring of student performance than actual equipment.	1	2	3	4	5
11.	are as easy for instructors to use as actual equipment.	1	2	3	4	5
12.	are as easy for students to use as actual equipment.	1	2	3	4	5
13.	are something I would use as an integral part of the courses that I teach.	1	2	3	4	5

USER ACCEPTANCE QUESTIONNAIRE

STUDENT EVALUATION OF ACTUAL EQUIPMENT TRAINER

The following statements describe overall experiences in actual equipment trainer. Circle the number that best expresses how much you agree with each statement. Circle 1 if you do not agree at all with the statement; circle 5 if you agree very much with the statement.

		Do Not Agree At All			Agree Very Much	
1.	There was enough training time on the equipment.	1	2	3	4	5
2.	Training time on the equipment was often wasted.	1	2	3	4	5
3.	A variety of troubleshooting problems was provided.	1	2	3	4	5
4.	The problems helped me learn to troubleshoot.	1	2	3	4	5
5.	The problems were too difficult to solve.	1	2	3	4	5
6.	The problems took too long to solve.	1	2	3	4	5
7.	Equipment breakdowns interfered with training.	1	2	3	4	5
8.	More time should be spent doing trouble-shooting problems on the actual equipment.	1	2	3	4	5
9.	My performance on the actual equipment was an accurate measure of my troubleshooting ability.	1	2	3	4	5

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