LOW COST AIRCREW TRAINING SYSTEMS

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ABSTRACT

Two prototype low-cost systems have been developed for air crew training. These systems provide instruction in cockpit procedures and various flight tasks at approximately one quarter the cost of conventional training approaches. Savings are estimated to be $1.5 million for one of the low-cost systems, a cockpit procedures trainer for the SH-3H aircraft; $3.2 million savings are estimated for the other low-cost system, a part task trainer for the EA-3B aircraft. This report discusses the cost-saving approaches and the acceptability and cost effectiveness associated with these two developments. Efforts to translate the low-cost approaches to several "follow-on" production systems are discussed. Research and development plans for further improving low-cost training technologies also are described.

INTRODUCTION

The military requires training systems that cost less than current systems and still perform at least as well. Costs to be saved include not just dollars, but also personnel, energy resources and time - time for system development, maintenance efforts and operator/instructor personnel.

Unnecessarily high training costs in any of these resource areas always have been undesirable. Nevertheless, for the most part, the training community received the resources they requested and used the resources to provide useful but excessively expensive training systems. High training costs are no longer just undesirable; they are intolerable. No longer are ample resources available for training. If military training is not as efficient as it can be, there will not be enough resources to go around, and the result will be reduced Navy effectiveness. Research and development (R&D) offers a possible solution to this problem by showing how to build more cost effective training systems. Such R&D should allow wider distribution of effective training systems in the Fleet, with consequent benefits to Naval operations.

In pursuit of this R&D solution, the ultimate goal of the R&D program discussed in this report is to improve the process for acquiring "low-cost" training systems, i.e., systems that are lower in cost (in all critical resource areas) than conventional systems, but no less effective. To achieve this goal, low-cost training systems are conceived, designed and developed, and then implemented and evaluated in operational settings. Efforts are made not only to describe the cost saving features of the R&D developments, but also to formulate general procedures and rationale for the design of additional and better low-cost systems.

Distinguishing features of this R&D are:

- Comprehensiveness - To assure that resources saved at one point are not paid back at another, this R&D is concerned with all phases in the life cycle of a training system, from conception through obsolescence.
- Operational Implementation - Heavy emphasis is given to urgent operational requirements for use of the products from these projects.
- Eclectic Approaches - A variety of diverse areas and methods (e.g., performance measurement, visual displays, instructional strategies, etc.) are employed in efforts to reduce training costs.
- Cost Reduction - The emphasis is on reducing the costs of training certain skills to a specified minimum level, as opposed to enhancing student performance (which, nevertheless, is expected as a side benefit) with associated increases in initial training costs.

In line with the project objective, beginning in 1978, two prototype low-cost aircrew training systems have been conceived, designed, and fabricated. Costs were $335,000 for a low-cost cockpit procedures trainer (LCCPT) for the SH-3H aircraft, and $800,000 for a low-cost part task trainer (LCPTT) for the EA-3B aircraft. These costs are approximately one-fourth that of comparable conventional training systems.* Table 1 shows, for each aircraft, the costs and designations of the low-cost and conventional trainers.

* The 75 percent savings attributed to the low-cost systems is a conservative estimate to allow for errors in estimating costs for the conventional trainers. The estimates were based on original system costs corrected for inflation and costs of similar, more recently developed trainers.

TABLE 1. COSTS FOR LOW COST AND CONVENTIONAL TRAINERS

Aircraft	Device	Cost
SH-3H	2C44 (Conventional CPT)**	$1,800,000
	2C62 (LCCPT)	$ 335,000
EA-3B	2F29 (Conventional OFT)***	$4,000,000
	2C63 (LCPTT)	$ 800,000

**CPT = Cockpit Procedures Trainer
***OFT = Operational Flight Trainer

The dollar amounts specified for the two low-cost systems do not include costs for Government furnished equipment (GFE). Although some GFE was used, GFE equipment, as opposed to simulated parts, was not considered necessary for training effectiveness. (In support of this, many of the components supplied by GFE in Device 2C63 were simulated in Device 2C62, with no apparent loss in training effectiveness.) The GFE that was used was included in the low-cost devices because it was available and desired by the Fleet Project Team.

GFE in Device 2C62 consisted only of the throttle quadrant, which was used instead of modifying a simulated throttle quadrant, which was originally provided with the trainer. All else was simulated. GFE for Device 2C63 included all panels and inactive switches, some active switches, throttle and throttle quadrant, yoke and rudder pedals. Simulated equipment consisted of some active switches, all instruments, all wiring and the shell. Additional costs for simulating the components which were provided for by the GFE are estimated at approximately $200,000 for Device 2C63 and $10,000 for Device 2C62. These costs were not included in the prices for the two low-cost devices because the prices given for the conventional trainers also do not reflect GFE costs. These unaccounted costs would be expected to be as great or greater for conventional systems than for the low-cost systems, because an effort was made to discourage use of GFE parts for the low-cost systems for purposes of the R&D project. The seventy-five percent savings claimed for the low-cost systems is valid, however, even if these additional GFE costs are added to the low-cost systems costs and not to those of the conventional trainers.

Development times for the low-cost systems range between one to two years versus two to four years required for conventional programs. Although not fully demonstrated yet, the modular and simpler low-cost design is expected to produce fewer maintenance problems, with reduced repair time and costs.

Additional life-cycle savings will be realized from less expensive facility requirements for low-cost systems. Also, instructor involvement with the training process has been reduced 34 percent in a preliminary effort, and further reductions in instructor time (along with improved trainee performance) are expected with improvements in device utilization procedures. This reduction saves personnel costs; but, more importantly, it allows greater utilization of the limited number of available instructors for other important tasks.

DESIGN CHARACTERISTICS AND CONCEPTS

Design Characteristics

The low-cost systems consist of: (1) Device 2C62 (see Figure 1), an LCCPT designed to provide training for all normal and emergency cockpit procedures as performed in the SH-3H helicopter; and (2) Device 2C63 (see Figure 2), an LCPTT constructed to train all normal and emergency procedures and many flight and navigation tasks required for the EA-3B aircraft.

Figure 1. Device 2C62 (LCCPT)

Figure 2. Device 2C63 (LCPTT)

Detailed descriptions of the two low-cost systems may be found in a generic specification.[1] The description that follows is intended to identify the general nature of the systems, their principal training features, and differences between them and conventionally designed, higher cost counterpart training systems.

General Nature. Each low-cost system has three major components: (1) the cockpit, with controls and displays representing those of the real aircraft; (2) the instructor/student station, providing a means for problem initiation, performance monitoring, data retrieval and computer programming; and (3) the computer system, which activates and coordinates all other systems of the trainer.

The simulated cockpits contain functional components which are similar to the aircraft in relative position, size, appearance, tactile and proprioceptive feel, and operating characteristics. Cockpit displays significant to training react to student actions in all important respects just as does the actual aircraft. Flight control feel is simulated only in Device 2C63 (yoke and rudder). Appropriate sound cues of the aircraft also are simulated. Nonfunctional mockups were used where functional components are not cost-effective. These mockups duplicate the corresponding components of the aircraft in appearance and location only. As described earlier, some Government furnished equipment was used.

Principal Training Features. The instructor/student station contains keyboard controls and CRT displays, and is located for convenient operation by an instructor. The controls and displays can be rotated into position for operation by a student instructor or for self-instruction. (For some training sessions, the instructors' normal interactions with trainees were replaced by allowing the trainee to practice procedures in the devices on his own or with the assistance of another trainee.) To set up a problem, one presses a key on the keyboard, which automatically creates displays which are appropriate for the procedure to be performed. The CRT lists cockpit controls that need to be repositioned manually before the procedure begins. When these controls are in proper positions for the procedure, the student attempts to perform the procedure in the usual manner through operations in the simulated cockpit. Approximately fifty normal and emergency NATOPS (Naval Air Training and Operating Procedures Standardization) procedures can be practiced in this way and over 100 individual aircraft malfunctions can be presented to the student in a similar fashion with each of the two low-cost systems.

To complete a Prestart Checklist Procedure, for example, the trainee performs the following steps: (1) complete "Preflight" operations; (2) check "Upper Fuel Caps/Sextant Cover/Spoilers Flaired"; (3) assure that "Cabin Circuit Breakers" are in; (4) assure that "LH or RH Fuel Boost Circuit Breakers" are in; and so on to the end of the procedure. Procedures vary in length from seven steps (e.g., a hydraulic failure) to thirty-two steps (for a start procedure) with many actions required for most steps.

Errors made during the execution of the procedures are indicated by displaying on the CRT or hard copy printout, the numbers and names of the procedural steps performed correctly, incorrectly or omitted by the trainee, in the order of their performance. The time for completing the procedure is indicated on the hard copy printout and the CRT.

To indicate a student's progress, a record of the performance of each student instructed on the system is shown for each procedure. These records include, e.g., the number of errors on the last four trials, total trials, etc. Cumulative totals are provided across a class to indicate group progress and to allow an individual to compare his performance with his classmates. Examples of these totals are: the number of trainees who *attempted* each procedure, the number of trainees who achieve criterion performance on each procedure, etc.

The LCPTT, in addition to all NATOPS cockpit procedures, allows training for normal and emergency flight tasks* as indicated in Table 2.

TABLE 2. FLIGHT TASKS TRAINED WITH THE LCPTT

- takeoffs	- takeoff/landing emergencies
- climbs	- flight control boost system failures
- turns	- run away trim
- cruise	- fuel management procedures
- descents	- TACAN and radio navigation
- approaches	- radio/communications procedures for crew coordination
- landings	- instructor simulated ground communication

* After completion of the training effectiveness evaluation, the LCCPT (Device 2C62) was modified in accordance with the instructors' requests to include limited flight capabilities. Altitude, speed and pitch simulation could be controlled with collective inputs. This provided a task for time-sharing practice with cockpit procedures, allowing trainees to learn to perform the procedures and control the aircraft, simultaneously.

Low-cost visual displays (developed in part under a different R&D project at this Human Factors Laboratory) complement instrument displays with schematic, computer generated imagery of carrier and field landings in the practice of flight tasks. A low-cost, torque-motor control loading system (adapted from a similar system developed by the Naval Air Test Center at Patuxent River) will soon be implemented in efforts to increase the fidelity of the "feel" of yoke and rudder control movements.

Differences with Conventional Systems. There are four major differences between the low-cost systems and their conventional counterparts: (1) the low-cost systems are lower fidelity devices with respect to some of their components and response characteristics (see next section for examples); that is, the physical similarity of the low-cost systems to the actual aircraft is less than is that of the conventional systems; (2) the low-cost systems include simulation of engine and other sounds associated with performance of the training tasks, whereas conventional CPT and part task trainer (PTT) systems include no sound simulation; (3) the design of the low-cost systems permits a limited self- and peer-instructional capability including computer aided problem set-up, and automatic scoring of student performance[2]; and (4) commercial standards were used for system parts and documentation.

Design Concepts

The design characteristics described in the foregoing, which are responsible for the noted cost savings, are the result of conscientious applications of rather pedestrian design concepts. Generally, the design concepts indicate that training systems should include: (a) only features essential for achieving the training objectives; and (b) instructional aids that facilitate the learning. Significant contributions to achievement of the low-cost goals are found in day-to-day implementations of the low-cost design concepts in the face of a variety of problems associated with computer automation and field settings.

Guidance for the application of the low-cost design concepts may be found in the previously referenced generic specification. More general and extended guidance is being developed in the forms of guidelines for performing the analyses that dictate the low-cost features.[3,4] Further guidance also is being initiated, with the support of the Office of Naval Research, in the forms of systematic approaches to help assure that particular characteristics of training systems, management procedures, procurement policies and organizational variables are maximally conducive to the design, acceptance and use of the training system. The importance of such guidance is especially important for innovative technology, as with low-cost systems, where the goal is cost effective training, rather than replication of some operational environment. Without such guidance, training programs are built in accordance with far less than the best of available technology, and desirable features of systems are not well utilized (see, e.g., Caro, Shellnut and Spears).[5]

Analyses were performed to include in the training system only the minimal features required to satisfy the training objectives. To accomplish this, discussions were held among Human Factors personnel, engineers and subject matter experts in which efforts were made to determine whether certain cost-saving features, as listed in Table 3, could be implemented for each training task, with no loss in training effectiveness. These analyses resulted in simulation fidelity levels that are lower than those of conventional systems.

TABLE 3. COST SAVING FIDELITY FEATURES

- Elimination of redundant capabilities
- Approximate (vice exact) cockpit dimensions
- Chairs vice aircraft-type seats
- Photographs vice panels
- Compressed instrument faces
- Restricted needle movements
- Discrete vice smooth needle movements
- Silk screen instrument faces
- Malfunctions that give onset cues but not progressive degradation
- Limited flight dynamics

In reference to Table 3, a malfunction needs to be simulated only with one engine if required operator responses to the same malfunction in the other engine are the same. Simulation of the various engine malfunctions would be distributed among all engines, however. This also applies to hydraulics, fuel tanks, generators, etc. The approximate cockpit dimensions of the low-cost systems were not noticeably different from more exact (and costly) constructions. Tasks could be learned as well using chairs instead of more expensive seats. In many cases, photographs of a panel were as useful as more realistic panels. Graduations on instrument faces could be compressed imperceptably and the full range of needle movement could be reduced for some tasks to help restrict needle movements to 270 degrees (allowing the use of a D'Arsonval meter movement rather than more expensive servo mechanisms). Discrete needle movements could be used instead of smooth movements, where the dynamics of the movement were not important cues for action. (Trainer cockpit indicators do not have to move as far or track in the identical manner as the aircraft indicators if these characteristics are not essential cues, as determined in discussions with subject matter experts, for the tasks to be learned.) Silk screening methods were less expensive than using real instrument faces. The simulation of a malfunction was terminated at a point where important cues for action are provided; all the effects of inappropriate actions are not provided. (For example, cues for an engine fire are simulated without including progressive degradation of the system that results from failure to correct the emergency.) Flight dynamics limited to 60 degrees for bank and 45 degrees for pitch saves money and still were sufficient to provide significant flight training. In these cases, higher fidelity would not contribute to greater training effectiveness; or at least, the contribution was not considered sufficient to justify the higher costs.

As with any training system, learning not achieved in the low-cost systems is accomplished with other media (e.g., classrooms, operational-flight trainers, aircraft, etc.) where the learning is more cost-effective. A trainee, for example, adjusts rapidly to the real panels of the aircraft when trained with pictures of panels that are not directly involved in the procedures to-be-learned; especially where, e.g., operational flight trainer (OFT) sessions with more realistic panels are involved. It is more cost effective to achieve the small amounts of learning associated with realistic panels in the OFT or aircraft, because the realistic or real panels are required in the systems for other critical functions. The learning, therefore, is accomplished with no additional development costs; and because the learning is rapid, increases in utilization costs (of the OFT or aircraft) are small.

Decisions regarding the design of "training aids" (e.g., automated performance monitoring, student performance records, assisted problem set-up, etc.) were based largely on their expected contributions to the: (a) operation of the training system; (b) cueing of appropriate trainee responses; and (c) provision of useful performance feedback to trainees and instructors.

This, generally, is the rationale for designing the training fidelity, defining the task components to-be-trained with various media and providing instructional and operating aids for the two prototype systems. The approach appears to be valid (see evaluation results in the following section) in the current applications. Details of the current approach need to be better documented and its cost effectiveness needs continually to be increased.

Approximately 50 percent of the noted savings in development costs is attributable to these "fidelity" analyses. The remaining 50 percent savings is due to the use of equipment and documentation that satisfy but do not exceed the requirements for administering the training and supporting the system. Commercial (vice military) parts and standards were employed to obtain approximately equal savings for less costly materials and less complex documentation.

ACCEPTABILITY AND COST-EFFECTIVENESS

Device 2C62 Evaluation

The acceptability and training effectiveness of the LCCPT under normal and modified conditions of use have been documented.[2] Information was obtained from two separate evaluations at two different operational sites (HS-1 and HS-10). Results from the first evaluation indicated that the LCCPT does what it was designed to do. The LCCPT allowed training of the same content, to the same level of proficiency, and with equal efficiency as the more expensive, conventionally designed counterpart device. The second evaluation demonstrated that, with proper utilization procedures, the role of the flight instructor when training with the device could be reduced.

The first evaluation consisted of a transfer-of-training experiment. Performances of trainees who were instructed on the low-cost device were compared with performances of trainees taught on the conventional device. The comparisons were made both in the trainers and in the aircraft.

A savings of $1.5 million was realized with the LCCPT on development costs alone ($335,000 cost for Device 2C62 versus $1.8 million cost for Device 2C44), and trainee performance in the trainers and aircraft was equivalent for the two systems. Table 4 shows the time required by trainees to achieve satisfactory performance in the aircraft and devices for the low-cost and conventionally trained groups. The hours-to-proficiency in the trainers and aircraft are in favor of (i.e., lower for) the low-cost device, but these differences do not approach statistical significance.

TABLE 4. TRAINING TIMES IN HOURS

	FLIGHT	
	Aircraft Training	Device Training
2C62 (LCCPT) Group		
Mean	15.58	14.33
S.D.	0.81	1.11
N	6	6
2C44 (Conventional CPT) Group		
Mean	16.68	15.81
S.D.	2.70	2.38
N	16	16
Mean Diff	1.10	1.48
t	0.97	1.45

The LCCPT required modifications to increase its simulation fidelity for a few of its components in order to be acceptable to instructors involved in the first evaluation. As described previously and indicated in Table 4, the lower fidelity levels appear not to have degraded critical task performance. In order to adapt to the lower fidelity of the new device, the instructors did modify their normal instructional methods. The instructors emphasized to the trainees operational cues that were missing in the device in order to achieve the high standards reflected in the evaluation results. This could account for the high student performance in spite of the lower device fidelity. This research demonstrates, at least for the procedures monitored, that instructors can use lower fidelity devices to achieve training results that are equal to those of higher fidelity devices. The LCCPT was modified to include significant changes recommended by the instructors prior to the second evaluation.

The instructors expressed confidence in the basic ability of the LCCPT. Additional validation of this opinion was a contribution of the second evaluation. The training conditions of the second evaluation were sufficiently different from those of the first evaluation to test the "robustness" of the LCCPT, i.e., its ability to continue to train as well under a variety of operational conditions.

Experimental data on a conventional training system were not obtainable for comparison with the LCCPT in the second evaluation. Therefore, a detailed comparison of performance of low-cost versus conventional devices, as was done in the prior evaluation, was not repeated. However, in the second evaluation, the LCCPT satisfied operational standards for trainee performance as a replacement for an Operational Flight Trainer (Device 2F64B) in syllabus sections that called for cockpit procedures training. All four trainees received satisfactory ratings in the LCCPT. Only one of the four trainees failed a procedure in the aircraft, a normal occurrence according to the instructors. This finding extends the finding from the first evaluation - that the LCCPT provides training for cockpit procedures that is the equal of a conventionally designed system - to another situation and another system. The similarity of results across the two situations helps to establish that the conclusion derived from the first evaluation concerning the high training effectiveness of the LCCPT does have general validity.

The second evaluation was conducted to determine whether the training effectiveness of the LCCPT as observed in the first evaluation could be extended to a situation wherein peer- and self-instruction are used to streamline the instructors' interactions with trainees. This evaluation showed that some of the relatively costly and much demanded instructor time could be redirected to other activities, with no apparent training detriment. A 34 percent reduction (10 hours for traditional approach versus 6.6 hours for low-cost approach) in the time instructors normally spend with trainees, was obtained. This reduction, however, was accompanied by a 166 percent increase (10 hours versus 26.6 hours) over previous syllabus schedules in the amount of time the device was used by trainees (student voluntary access to the device was unrestricted). The extent to which this tradeoff between decreases in instructor time and increases in device usage time is necessary with the current or any other approach is not known. Further, the extent to which this tradeoff may have undesirable effects (e.g., where device time is more scarce than instructor time) also is not known.

The LCCPT provided instruction for six additional trainees from two classes which immediately preceded the class from which the present data were obtained. The performances of trainees from these prior classes were not included in the foregoing analyses because the peer- and self-instruction conditions were not yet sufficiently implemented with these classes to test their efficacy. (The instructors needed to become more familiar with and confident about the new device and syllabus before integrating the peer- and self-instructional procedures into their training routines.) Thus, the data from these earlier classes do not reflect on the major experimental issue of evaluation two. These "pilot" data, however, do provide additional support for the basic effectiveness of the LCCPT. All trainees from these two earlier classes passed all tests in the trainer and in the aircraft; in fact, their ratings were quite similar to those of the third class--the class of major concern for the second evaluation. Mean performance ratings for trainees in these two prior classes were 3.05 and 3.06 in the LCCPT and 3.05 and 3.02 in the aircraft for the first and second classes, respectively. These ratings are comparable to ratings for the third, "experimental" class, i.e., 3.08 in the LCCPT and 3.02 in the aircraft. Thus, these "pilot" data are consistent with the conclusions derived from the other data presented in this report from both evaluations of Device 2C62.

Device 2C63 Evaluation

A $3.2 million savings ($4 million cost for a modern version of Device 2F29 versus $800,000 for Device 2C63) is estimated for development of the LCPTT relative to the costs for developing a conventional system to train the same skills. Although data on trainee performance still are not yet ready for analysis, the LCPTT has been providing training in the Fleet (at VAQ-33, Key West) since early in 1981 to the apparent satisfaction of trainees and instructors. In addition to evaluation of overall effectiveness, special efforts will be made to evaluate the contributions of the low-cost visual and control loader by comparing the training effectiveness of the LCPTT with and without a visual and with the control loading system versus a spring-loaded control system.

TRANSLATION OF BENEFITS

The products from these projects already have changed some long- and strongly-held beliefs and attitudes regarding training system design and use. Actions also are changing. First, the low-cost training systems developed under this R&D program have been adopted to provide "valuable priority training..." (HS-10 message of 19 Jan 82) in Fleet applications, in accordance with the experimental demonstrations. Second, the savings demonstrated for the two low-cost, R&D systems are being translated into similar savings for several production training systems; the costs of these production models represent significant breakthroughts in training system design. Of even greater significance, however, is the role these projects can play in opening the door for exploration of the much greater potential that the training technology field appears to offer.

The prime targets for current products are CPTs and PTTs developed by the Navy. Several "follow-on" trainers,* which are largely based on or significantly influenced by the current products, have been tasked for development by the NAVTRAEQUIPCEN, in addition to the two original prototype trainers. In addition to air crew trainers, one of the follow-on trainers will teach driving skills for an assault amphibious vehicle. The contribution these products can make to still other type trainers has not yet been determined. It appears, however, that significant contributions from current products can be made to a wide variety of trainers.

In addition, low-cost CPTs are being developed for commercial use by Appli-Mation, Inc., and American Air Lines for a variety of different aircraft, e.g., DC-8 (1 unit for Trans American Airlines); S-76 (1 unit for American Air Lines); 737 (3 units; for CPAIR, Gatwick Training Center and Southwest Airlines); 727 (2 units; for Mexicana Air Lines & Federal Express). These commercial training systems are based on the designs of the two prototype systems developed under the current projects and show similar cost savings. Similar to the two prototype systems, the costs of the commercial and the NAVTRAEQUIPCEN production low-cost developments are approximately 75 percent less than conventional counterparts with, in some cases, a decrease in required instructor time. Thus, the current project is responsible for an approach to training system design that in its ramifications apparently is markedly changing development practices, both in and out of the Navy.

* Production trainers under development at the NAVTRAEQUIPCEN that are based on and/or heavily influenced by the products of this project include Devices 17A67, 2C63A, 2C64, 2C61, 2C67, and a CPT for the EA-6B aircraft (device designation not yet known).

FUTURE PLANS

The current training systems are considered to be products of relatively conservative applications of low-cost approaches. (For example, video disc, computer generated imagery and computer assisted instruction technology might replace actual three-dimensional cockpit simulations.) Exploitation of this potential should involve definition and demonstrations of the most cost-effective combinations of fidelity designs and utilization procedures. Preliminary guidelines need to be completed for facilitating the application of low-cost approaches as well as the acceptance of the approaches and the products by the user community. Then, these guidelines need to be tested and improved. The desirability of incorporating the guidelines into an automated system developed at this laboratory for aiding in the process of instructional system design[6,7,8] needs to be investigated; and if desirable, the guidelines need to be incorporated.

The current training effectiveness evaluation for the LCPTT needs to be completed, and life-cycle data are needed on low-cost systems to assess cost-effectiveness over the life of the systems.

These and other efforts are needed to help assure that the advances made in the current program are not lost. Worse yet, the advances may become human factors and general training setbacks through misunderstandings and misuses of the new approaches. These dangers are quite real in that the "follow-on" production systems currently being developed are based in large part on the partially defined and sketchily documented low-cost approach. Training system development, in all forms, is a highly complex and creative process. The complexity and demands for creativity of relatively new approaches, such as the low-cost developments, are highly amplified, and will continue to be until more of the questions concerning low-cost approaches can be answered and more of the process becomes routine.

Enough justification for low-cost approaches has been provided by the current, and other, related investigations to encourage significant investments of R&D resources toward demonstrating and improving the technology and to recommend careful implementation of low-cost approaches in operational training programs.

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