# LESSONS LEARNED FROM CURRENTLY FIELDED NAVY EMBEDDED TRAINING SYSTEMS

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## ABSTRACT

A number of embedded training systems are currently in use or under development by the U.S. Navy. Consequently, there is a need to consolidate the experiences and findings of these embedded training development efforts, to evaluate the effectiveness of various high-level features of in-place embedded training systems and to assess the applicability of those features to future embedded training systems and sub-systems. This paper documents the lessons learned from the development and use of 15 operational training systems in the Navy. The choice of systems to be studied was based upon accessibility of the systems, their capabilities, general applicability, and technological and instructional complexity. The instructional features of the systems selected were identified and described and a taxonomy was created. Effectiveness evaluation criteria were developed and on site collection of data was accomplished by interviewing users of in-place embedded training systems and administering a standardized assessment instrument. The analysis and evaluation of these training systems found few systems which could be considered true embedded training systems. Many systems made use of test target generators or data input devices which provide only rudimentary tools for training. Recommendations for the design of future embedded training systems are presented. These guidelines address the following areas of ET design: configuration, training characteristics, support, and policy.

## INTRODUCTION

Embedded training (ET) is defined by the Navy as "training that is provided by capabilities built into or added onto operational systems, subsystems or equipment to enhance and maintain the skill proficiency of fleet personnel". Many systems in the Navy currently have embedded training capabilities to some extent and have had for some time. Yet, very little is known about the effectiveness of these current in-place systems. With respect to proposed training systems, there is a benefit to be gained from review of existing designs and the accompanying training results associated with the use of these designs.

### Purpose.

The purpose of this project was to examine in-place embedded training systems and to consolidate lessons learned with respect to the various system capabilities and designs and their effectiveness for training. This effort resulted in a description of technology-based issues to be considered when selecting embedded training as a training methodology.

### Background.

Due to the complex nature of tactical, sensor, and weapon systems many operator and team interaction skills are highly perishable. Maintaining skill proficiency requires that shipboard personnel receive frequent and effective training, opportunities to practice, and performance feedback. The ability to provide the appropriate training for all personnel is often precluded by mission requirements, unavailability of qualified instructors, equipment, or necessary team members, and a lack of flexibility to provide "individualized" instruction. Training opportunities are also limited by collateral shipboard duties, safety considerations, and a host of other situational factors. Embedded training can improved these conditions by introducing the capability for training directly into the operational environment and by addressing specific training needs and problems.

Embedded training may take many forms depending on the application, but typically includes the following characteristics in varying degrees:

A. Uses the operational equipment (consoles, displays, indicators) as the primary training media.

- o Generates simulated operational data, signals or targets.
- o Simulates real world faults, malfunctions, and interferences.
- o Requires trainee interaction with the operational equipment.

B. Uses limited instructional support features to manage the training process.

- o Allows flexibility for automated or instructor control of training scenarios/lessons.
- o Provides performance measurement/feedback.
- o Performs records management or exercise 'storage' functions.

There is a general consensus that ET design should include the above characteristics, yet the degree to which they should be implemented and at what point these implementations fail to be cost effective is still undefined.

## APPROACH

This effort was designed to provide for the systematic examination and consolidation of the experiences and lessons learned from the use of Navy embedded training systems. The guidelines developed as a result of this analysis, provide alternative configurations for future embedded training designs. Thus, the guidelines had to address the full range of potential ET characteristics, variations in their implementation, and trade-offs associated with these variations. This required that the analysis select and examine systems which represent a variety of ET characteristics and capabilities applied in varying degrees.

Given the above requirements, it was determined that the analysis of systems should encompass a wide spectrum of ET complexity. Since the concept of ET is to provide training on the operational equipment and to provide some form of instruction and performance measurement, these capabilities were identified as requiring examination in the study. The intent was to identify both positive and negative training features as well as identify desirable features which were absent from current designs. The methodology applied for this project involved the following steps:

- o Select ET systems for analysis
- o Identify instructional characteristics to be examined
- o Develop effectiveness evaluation criteria
- o Collect data on in-place systems
- o Compile and analyze findings

_ET System Selection_.

Due to the large number of current Navy systems which have some degree of ET capability, only a subset of these systems could be selected for evaluation within the available time and resource constraints. The selection of systems was based on a combination of criteria which included accessibility for analysis, operational system capabilities, and technological and instructional complexity. Available documentation relative to these requirements was reviewed to establish an initial baseline of system descriptions. Outside agencies, system users, and system developers were consulted as needed for additional information. This information was then examined by an in-house panel of instructional designers and Navy subject matter experts for the delineation of the most appropriate subset of systems. The systems selected and examined in this study include:

- o Aegis Combat Training System (ACTS)
- o Lesson Translator (L-Tran)
- o Combat Simulation Test System (CSTS)
- o Radar Environmental Signal Simulator (RESS)
- o Guided Missile Training Round (GMTR)
- o Operational Training Software (OTS) for SLQ-32
- o Sonar Target Signal Simulator (STSS)
- o Operational Readiness Assessment and Training System (ORATS)
- o Onboard Trainer (OBT) for the AN/SQR-17A
- o AN/BQR-T4 Sonar Signal Simulator.
- o Video Signal Simulator (VSS)
- o Performance Measurement and Evaluation (PME) System
- o Unit 34 Sonar Target Generator
- o Automatic Detection Tracking System Simulator (ADSIM)
- o AN/SQS-56 Target Simulator

_Instructional/System Characterization Identification_.

A consistent and structured approach to system evaluations required the development of a detailed data collection instrument and survey guide. The first step in this process was the identification of specific embedded training elements that required examination. Existing documentation on the selected systems, recent embedded training literature, and applicable principles related to trainer device and simulation systems were reviewed to identify and develop a set of specific characteristics which are or could be included in embedded training design.

The features that were identified fell into two general categories; training and support features. Training features include such things as targets, equipment characteristics, scenario design, communications requirements and trainee/machine interactions. Support features include such things as performance measurement, target control capability, supporting documentation, freeze control and replay/playback.

_Effectiveness Evaluation Criteria_.

The second step in the design of the data collection questionnaire was the development/ specification of criteria by which effectiveness could be judged and measured. The instructional feature capabilities provided the basis for the development of evaluation criteria. Fleet objectives, recent research on evaluation techniques, and results obtained from previous embedded training efforts were also used for this process. The effectiveness criteria addressed two issues:

- o Human and system performance. The ability of the system to present realistic training, control the training, evaluate the students' performance, and train the trainee in a manner replicating the actual environment.

- o Payoffs. Payoffs include reducing training related costs by providing such things as reduction of shore-based schooling time; reducing time to train by utilization of the maximum capability of the system's technology through use of efficient training concepts; and improving performance by application of training techniques which directly transfer skills/knowledge acquired during training to the operational environment.

Specific criteria for measuring effectiveness relative to these issues included:

- o Capability for performance measurement and feedback
- o Reliability of equipment performance
- o Usability of ET system
- o Updateability of ET courseware
- o Time required and cost of ET system use
- o Manpower requirement
- o Student Proficiency improvement
- o Impact of ET system on operational environment
- o Ability to merge training and actual environment cues/targets.

Questions surrounding these criteria were incorporated into the data collection instrument/survey guide as the final input.

Data Collection Process.

The process of data collection entailed numerous field visits to the sites where systems were installed and used. This included both surface combatants and submarines located in various Eastern U.S. Naval Bases. The data collection instrument served as the guide for interviews with fleet Subject Matter Experts (SMEs) and ET system users. Information collected during system demonstrations also served as input to the evaluation process. Various crew members were interviewed from six ships and two submarines. Additional inputs were obtained from Fleet School Instructors and SMEs at the Squadron level. Results obtained from the analyses are described in the Findings Section.

Data Compilation and Analysis.

Data obtained from various users on specific systems were compiled to produce comprehensive assessments of system capabilities and associated training effectiveness. Lessons learned with respect to these capabilities across systems identified the issues for which ET design guidelines were developed.

## GUIDELINES

Recommendations based on the results of this study are presented in the form of guidelines for designing future embedded training systems. The guidelines are grouped and discussed in terms of the following areas of consideration for ET design:

- o Configuration
- o Training Characteristics
- o Support
- o Policy

Configuration.

Configuration refers to both the physical and functional make-up of the training system with respect to the operational system. The specific issues discussed include:

- o Impact on operational system
- o Interaction with operational system
- o Simulation vs. stimulation
- o Mix of training with real world presentations

Impact on Operational System. If use of ET causes realignment or readjustment of the operational system or increases the maintenance requirements, its use as a training tool is likewise reduced. The requirement for a realignment and adjustment of the operational system for training is usually associated with the use of strap-on training simulators which do not adequately interface with the system. Alignment must be conducted so that the system will accept the parameters of the simulated data, signal or video.

Guidelines.

1. If an ET System uses the operational systems components, it should be integrated as a peripheral capability and not dominate or impair the system's operational capabilities.

2. ET design should minimize the wear and tear and power requirements of the operational system components.

3. If a system has a small number of operational consoles, ET should be designed to allow training data to mix with real world data.

4. Simulation of data inputs must have the same parameters as the operational data at the injection point so that the system will accept and present the information as it would real data.

Interaction with Operational Systems. Interaction refers to the way an ET System interfaces with components of an operational system or with several different operational systems, (i.e., sonar, radar, fire control). This interaction determines the level of training possible for a system (individual, sub-team, team or multiple team.)

Guidelines.

1. ET should be configured to provide for both individual and team training.

2. Data injection should be handled in a similar fashion whether a system is operating in it's training or operational mode.

3. Multiple Team training can be supported if several ET systems are coordinated to interact and exchange information.

Stimulation vs. Simulation. The simulation/stimulation issue refers to the way in which the training data is injected into the system during ET. Stimulation is signal injection at or near the sensor elements, i.e., radar antenna, such that the entire operational system is used for signal processing. Simulation refers to the generation of data or signals that act like real world signals injected at the operator station and affect only the indicator, e.g., radar console.

Guidelines.

1. With respect to training effectiveness, simulation and stimulation are basically of equal value, if the simulation can provide high realism in data, target, or signal presentation. Issues such as redundancy, cost, implementation, updateability, reliability, and target controllability should be considered when selecting the method of data injection.

Mix of Real World and Simulated Environments. Key issues to address when considering the mix of real and simulated vs. only simulated data are the complexity of the real world environment, the capability of the operational system to support a fully simulated training system, and the loss of operational capacity during training.

Guidelines.

1. If simulation alone is to be used, the simulation must replicate the real world environment to a degree necessary for effective training.

2. If a system is limited in redundancy, a mix of real world and training signals should be considered as a possible ET design.

3. Mixing real world and simulated data could possibly create safety hazards by masking real world information.

Training Characteristics.

Characteristics of a training system include training methodology features (TMF) and instructional support features (ISF). TMF include targets, equipment characteristics, scenario design, communications requirements and trainee/machine interactions. ISF include performance measurement, target control capability, supporting documentation, freeze control and replay/playback. Together with the support features discussed earlier, these training characteristics make an ET system a training system as opposed to one which merely provides practice.

Training Methodology. Training Methodology is defined by type of training, training control features, use of documentation, and presentation of training material.

Type of Training. Individual training for ET applications tends to be in the form of self-directed, self-paced training while team training tends to be controlled and provided by the training supervisor at the commands discretion. The level of training (individual or team) will help to deter-mine the type and complexity of automated features required for training.

Guidelines.

1. Capabilities for both individual and team training must be defined and designed into system ET.

2. When designing ET for individuals, there must be features included to represent input communication or data from missing team members.

3. When designing ET for individuals, support features must be provided for performance measurement.

Training Control Features. Training control features include scenario control software or methods, ET system initiation and control equipment, and processes for controlling targets.

Guidelines.

1. If ET is part of the operational system, scenario control equipment must be designed into the system or reside in peripheral equipment which interfaces with the system.

2. Capabilities must be provided for play of canned ET scenarios and development of custom ET scenarios.

3. Scenario control software must be designed to include all parameters of the operational environment.

4. Control and initiation of ET must consider the type of training to be performed, method of scenario control to be used, and the control station must be in a location easy for the trainee and the supervisor to use.

5. Minimal switch actions and time should be required for initiating training and purging the scenario from the system.

6. If the scenario requires control of targets the capabilities must be provided to maneuver targets throughout the entire scenario.

7. If adversary targets are to be maneuvered during the scenario, the system must be designed to provide evasive actions based on "friendly" target maneuvers or actions.

Presentation of Training Information. The presentation of training data must be such that it replicates the real world to a level that is effective for training in a particular application.

Guidelines.

1. Analyses are required to identify training objectives, and based on these objectives, a set of guidelines will be developed that determine the level of fidelity of data inputs.

2. Training situations requiring highly interpretive skills, require an extremely high degree of realism and target/environment fidelity to ensure effective training.

3. Applications requiring a high degree of realism must determine the most economical and/or feasible methodology (simulation alone or mix of real and simulated) for presenting information.

Instructional Support Features. Instructional support features provide an automated monitoring, controlling and recording capability for ET.

Guidelines.

1. Freeze action appears to be the most applicable and desirable control feature for shipboard ET. This function should allow instructors to stop all scenario action for redirecting training activities and providing feedback and should allow the scenario to be restarted at the point where it was stopped.

2. Replay/playback involves either a recording mechanism or a hard copy, visual presentation of scenario events. This feature seems to be the most applicable performance measurement tool for scenario/team experience.

3. Specific measures of track accuracy are more desirable and should be included for performance measurement of individual operator training as in sonar and radar operations but are less desirable for team exercises.

4. Knowledge based embedded training systems may require some individual testing capabilities.

Support.

Evidence provided by users of ET during the analysis process indicated that maintenance, documentation and users guidance were the biggest support problems. In some cases, maintenance was nearly impossible due to lack of documentation. Users guides were often inadequate or non-existent. In some cases, the ET system was several revisions behind updates on oper-ational systems.

Guidelines.

1. Documentation for ET systems should include both operation and maintenance procedures to a level specific enough to allow for full use of training capabilities and shipboard maintenance.

2. Upgrade of operational capabilities must include procedures for upgrade of the ET system.

3. Design work for the ET system must consider update, maintenance and reliability factors along with those for the operational system.

Policy.

U.S. Navy and individual ship policy has a great impact on the use and effectiveness of ET. Policy directs how and when ET is to be used, and who will be trained. "Policy" is stated in many ways; Local and Navy wide directives and instructions, desires and emphasis of the ships captain, and those of the supervisors who conduct the training.

Command Support. Evidence shows that the most effective ET takes place when the commanding officer supports its use as a training tool.

Guidelines.

1. When designing ET for a new system, review applicable directives and instructions to determine the requirements for implementation of ET in that type of system.

2. If no instructions exist or limited guidance is available, consider development of recommended Navy instructions to ensure proper use of the designed ET.

Inclusion in Scheduled Maintenance or Qualification Processes. Information from the survey suggests that if ET is made part of the personnel qualification process, it will be used on a regular basis for proficiency training. This is however, a two edged sword. If the ET is not well defined or designed, it's value as a qualification tool is eliminated. Likewise, if ET is part of a newly designed system, the ET equipment must be included in the maintenance schedule for the operational system.

Guidelines.

1. Scheduled maintenance for the operational system must provide for the maintenance of the ET system as well.

2. The personnel qualification requirements for an operational system should include a qualification procedure for the ET system as well.

Training Management. Basically there are two methods of conducting ET, unannounced and scheduled. Unannounced ET takes place at the discretion of supervisors and is unknown to the trainee. The advantage of this method is that the operator doesn't know the target is simulated and is reacting to that information as if it were real, thus allowing for an accurate assessment of skills/knowledge. The main disadvantage is that intended actions by other members of the ships team may cause severe safety infractions through ship maneuvers or other overt activities. If unannounced training sessions frequently occur, the operators attention may be reduced because they expect targets to be simulated without notice. Scheduled training, on the other hand, is safer and, because of better planning, may be more effective.

Guidelines.

1. Consider whether unannounced ET is a requirement for the system. If it is, some method of simulation and stimulation is required which will provide target realism high enough so the operator being trained cannot discern it as a training input.

## CONCLUSIONS

The analysis and evaluation of existing on-board training systems found few systems which could be considered totally embedded training systems. With the exception of the ACTS and L-TRAN most made use of equipment such as target generators or signal generators, adapting their parameters to provide training targets. Little, if any, of the hardware was originally designed to support training activity. Most of the training using these systems used paper based scenarios which provided an event list keyed to time for a sequence of activity. These systems require labor intensive, manual control of training exercises and rarely contain any automated features to conduct training. In most applications, these systems were basically used to provide practice opportunities for tracking targets.

Instructional features were rarely found in ET systems in the fleet. Performance measurement, was in most cases, subjective or used charts and DRT traces for reconstructing the exercise as an evaluation tool. Feedback, instructional guidance, replay/playback, and other automated training support features were generally non-existent.

Basically, ET used in the fleet today provides the rudimentary tools for training. Its use varies from ship to ship based on the interest and training skill of the ship's crew, and the command interest and interpretation of basic Navy Policy. There are few specific directives addressing ET, although OPNAV Instruction 1543.XX is now in preparation. While this directive will serve to guide the acquisition and to some extent, the design of embedded training, detailed policies are needed to guide the use of ET once it is implemented in the fleet. Currently, only a few ships are actually monitoring and mandating the use of ET Systems as part of the shipboard training process. In one instance, the use of ET was made a requirement for personnel qualifying on an operational system which provided incentive for its use on a regular basis. Unless such requirements are built into shipboard or Navy training policy, embedded training may not be used to its full potential and will not recognize the full training benefits or effectiveness possible, even with the best designed ET systems. Such policies will need to accompany the implementation of future ET systems.

The greatest concern in the embedded training arena today is how to design systems which can effectively and efficiently support fleet training requirements within the operational system capabilities and shipboard environment. As with policy, there are currently no substantive directives or guidelines to be used in ET design and development. The results obtained from this study provide an assessment of the effectiveness of current designs and a set of guidelines based on these assessments for the design of future systems.