GUIDELINES FOR EMBEDDED TRAINING DECISIONS

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ABSTRACT

While Army policy requires training developers to consider embedded training (ET) first and foremost among training options, effective implementation of this policy has been hampered by the lack of specific procedures for determining what to embed early in prime system development. This paper describes specific procedures that assist a user in making those early ET decisions. Although task information has traditionally been the primary criterion used in selecting media for training, it is thought to be less important in deciding when to use ET than are the following factors: policy; system availability for training; the technical feasibility of ET implementation; the effects of ET on system reliability, availability, and maintainability; the impact of ET on system manpower and personnel requirements; the need for training-specific interface hardware; safety; and cost-effectiveness. These factors are incorporated in three sets of flowcharts, designed to be used in different stages of the acquisition process.

INTRODUCTION

Embedded Training (ET) is a training capability that is built into an operational system and requires access to and use of that system to conduct training. An Embedded Training System (ETS) is that part of the training system that includes the embedded training capability. While the concept of ET has been in existence for some time, instances of its successful implementation in Army systems are relatively rare. The emphasis on ET is increasing, however, as a result of several changes in Army policy, practice, and weapons systems. First, realistic unit training is being emphasized as a means to better prepare our forces for combat. Second, overall cost reduction has become mandatory while many of the costs associated with the operational use of the weapons system for training, such as increasingly powerful and sophisticated ammunition and the ranges on which it can safely be fired, are increasing. Third, more systems have embedded computer capability, which can support training if designed appropriately.

Aware of these factors, the Vice Chief of Staff, Army, and the Under Secretary of the Army stated as policy in March 1987, "An embedded training capability will be thoroughly evaluated and considered as the preferred alternative among other approaches to the incorporation of training sub-systems in the development and follow on Product Improvement Programs of all Army materiel systems."[2]

However, effective implementation of this policy has been hampered by the lack of specific procedures for making early decisions about what training to embed and what to provide by other means. This paper describes the development of a guide to help users to determine, early in the acquisition process, what training to embed into the prime system. Prime system refers to the operational system for which the training, embedded or otherwise, is required.

PROBLEM

Historically, training media selection decisions have been based on prime system design characteristics and the nature of the tasks to be trained. However ET poses unique problems for decision makers in that ET requirements must be determined early enough to be included in the prime system design. A Stand-Alone Device (SAD) can be based on prime system characteristics because the concept formulation process for the SAD training system typically lags the concept formulation for the prime system. ET, in contrast, is a part of the design of the prime system itself and its concept formulation and design must proceed concurrently. Furthermore, the task level information historically used to make training decisions is usually not available in time to be of much use in making ET decisions.

A BRIEF HISTORY OF PREVIOUS WORK

ET has been used in limited applications for at least three decades[6], but did not receive widespread attention until the 1980's. The 1980's were characterized by flurry of ET research activity. ARI, PM TRADE, and their contractors were highly productive, producing a ten-volume set of guidelines and procedures designed to support the effective consideration, definition, development and integration of ET capabilities. In addition to these documents, several ET surveys and literature reviews were completed, and development and evaluation studies were conducted for several systems including the Fiber Optic Guided Missile and the Howitzer Improvement Program.[4] While these guidelines provided detailed procedures for making ET decisions late in the acquisition process, they provided only general information for making decisions early in the acquisition process.

Researchers at the Naval Training Systems Center were also busy during this time, but their primary focus was on identifying design guidelines for effective ET for shipboard and other Navy systems.[1,7] Meanwhile, work was also proceeding in identifying requirements for aircrew ET applications.[8] More recently, Eagle Technology, Inc. and Vector Research, Inc., under contract to ARI, initiated the development of an Embedded Training Candidates Model for determining, very early in the weapon system development process, the feasibility and value of including ET capabilities in the weapon system.[3] Although this work was technically sound, it was terminated while in a preliminary stage and was never formally published. A later effort by the same organizations[5] resulted in a design architecture for a decision support system for making early training strategy decisions, including ET. Again, while the work was technically sound, the next step, that of developing the functional specifications for the system, was never undertaken.

EMBEDDED TRAINING SYSTEM CHARACTERISTICS

To maximize training effectiveness, an Embedded Training System (ETS) must be a well integrated component of the total training system. All of the training needs for a given system, individual or unit are not likely to best be satisfied by ET. The ETS should therefore train only those tasks, functions and missions to which its characteristics are best suited. Other training media should be used where they can train more effectively than ET or train equally well at a lower cost. ETS effectiveness also depends on the incorporation of the following training features: a means of assessing student performance; a means of providing feedback to the student to reinforce and improve correct performance; and a means of record keeping, to allow the management of individual and collective training and identify deficiencies requiring additional training.[10]

The typical ETS is a computer-based system, either integral to or adjunct to the prime system, which, when activated, interrupts or overlays the system's normal operational mode to enter a training and assessment mode. The ETS also includes the facilities, expendable supplies and materials, and personnel required to provide embedded training. Although embedded training system designs can assume many different forms, they share the common characteristic that the student is trained using the actual controls and displays of the actual equipment. They differ along a continuum in the extent to which the ETS is fully contained within the prime system. These guidelines consider three types of ETS, defined below, that represent discrete points along an ET continuum that includes a potentially unlimited number of ET architectural types.

Fully Embedded

All training features, except for perhaps easily installed training software or courseware, are fully contained in the prime system itself. They go to war with the system. They meet the prime system Reliability, Availability, and Maintainability (RAM) requirements. A fully embedded ETS, on a vehicle, could train while the vehicle is moving, as in tactical engagement simulation. Fully embedded training is usually distributed with the prime system on a "one for one" basis.

Appended ("Strap-On")

Components of an appended ETS can be installed on or attached to the prime system when needed, and removed when they are not. An appended ETS will nevertheless require permanent, designed-in, components (such as sensors, mounting brackets, and connectors). An appended ETS could be used in assembly areas or in close proximity to combat. It could go to war with the system if it were so designed, although that is not a necessary characteristic of an appended ETS. It could train "on the move." Ruggedization may be required. One appended ETS could serve multiple prime systems, but could serve only one at any given time.

Umbilical

The umbilical ETS is similar to the appended system, but involves, in addition, physical connection(s) to external components, such as a computer, communications system, or Instructor/Operator console. As with an appended ETS, it requires some built-in features to interface with the external components of the system. An umbilical ETS may interconnect many systems, as in simulated networking for force-on-force training. The umbilical ETS is not a go-to-war training system. It cannot train "on the move." Ruggedization is unlikely to be required. One umbilical ETS can serve multiple prime systems.

Since these types differ along a continuum, it is possible to conceive of an ETS which is not easily classified, such as an ETS with an on-board ET component which communicates with an external component via radio or infrared transmission, rather than through a physical connection.

PROCEDURE

The guide for early ET decisions has been developed in accordance with the following principles. First, the decision process must be phased and linked to information availability. Tentative decisions must be made initially, and then revised as more information becomes available. Second, early decisions should be biased in favor of the use of ET, because it is easier to delete a requirement for ET than to add one after prime system design has begun. Early decisions should favor ET also because that is directed by Army policy. Finally, the specific tasks that the student must perform and specific prime system characteristics are only two of the factors which should affect the media selection decision.

The first step in the development of the guide was to identify the factors to consider when deciding what training to embed. The second was to identify the information needed and formulate the specific questions that must be answered to assess those factors. The third was to structure those questions in a way that would lead the user to a set of logical conclusions, taking into account the changing availability of information during the acquisition process.

To accomplish this, we first reviewed the previous research literature. Eagle Technology, Inc. defined three categories of factors that should affect decisions about what training to embed: Requirements, Opportunities, and Costs.[3] We modified their definitions slightly to produce the following concepts. Requirements-based factors are "high level mission, conceptual, and mission-based factors, and are relatively independent of the prime system" (p. 4-7). Consequently, decisions based on many of these factors can be made relatively early in the acquisition process. Requirements-based factors can influence the prime system design. Opportunity-based factors are derived from the prime system characteristics, the man-machine interface, and the training resources available in the training environment. Cost-based factors include the life-cycle costs of both the prime system and the training system.

Strasel and his associates identified eight major factors related to the probable effectiveness of ET.[10] Those factors are defined in Table 1. We initially added one new factor: policy, which was discussed by Strasel and his associates[10] as a question to be answered ("Are there policy decisions that dictate the use of ET for knowledge and skill acquisition training in the system?" (p. 9)). We established an initial list of sub-factors to consider by combining these two organizational schemes into a 3x9 matrix. For example, the policy factor now had requirements, opportunities, and cost sub-factors.

Following identification and definition of the factors and sub-factors, we reviewed a number of research reports to identify specific questions that others have used in deciding what to embed. Our purpose was twofold. First, the questions suggested changes to our list of factors, either by indicating new factors which needed to be considered, definitions which needed to be revised, factors which were so similar that they could safely be combined, or factors which were not logically sound. Second, the questions suggested how each factor should be considered.

The previously mentioned report by Eagle Technology, Inc.[3] provided our primary source of questions. We also found questions in reports by Strasel[10], Hinton, Braby, Feuge, Stults, Evans, Gibson, and Zaldo[5] and suggestions for questions (not in question form, but readily converted) in Strasel, Dyer, Aldrich and Burroughs.[11] Together, these sources provided a list of 43 questions. We sorted the questions according to the sub-factors we had defined.

TABLE 1. MAJOR FACTORS RELATED TO PROBABLE EFFECTIVENESS OF EMBEDDED TRAINING. (From Strasel, Dyer, Roth, Alderman, and Finley[10])

Factor 1: The Nature of the Tasks and Skills Demanded by the System Concept - What are the Requirements for Sustainment Training.

Factor 2: The Feasibility of Implementation of ET.

Factor 3: Avoidance of ET Interference with Operations.

Factor 4: Need for Training-Specific Hardware Interface Requirements.

Factor 5: System Availability for Training.

Factor 6: Effects on System Reliability, Availability, and Maintainability.

Factor 7: Impacts on System Manpower and Personnel Requirements.

Factor 8: Cost-Effectiveness of ET (compared with alternative sustainment training capable of achieving the same training goals).

We then generated additional questions to fill the gaps. For example, our sources provided no questions about: policy issues; the availability of the prime system for training; Manpower, Personnel, & Training (MPT) requirements and costs; and safety requirements and costs. Our sources also did not distinguish among the various types of ET (fully embedded, appended, and umbilical). We prepared lists of the advantages and disadvantages of each type, and used them as a basis for additional questions.

As we were identifying, generating, and organizing questions, we found it necessary to revise our list of sub-factors. Safety was added. The "Nature of the Tasks and Skills Demanded" was divided into two factors: "Training Content" and "Characteristics of the Training Environment". The definition of the "Need for Training-Specific Hardware Interface Requirements" factor was expanded to include all training-specific interface requirements, not just hardware. Finally, the factor "Avoidance of ET Interference with Operations" was subsumed under the factor "System Availability for Training."

When the question generation process was completed, we had approximately 100 questions. Sample sub-factors, sub-factor definitions, and typical questions are shown in Table 2.

TABLE 2. SAMPLE SUB-FACTORS, DEFINITIONS, AND QUESTIONS

Sub-factor: Policy-requirements

Definition: Conceptual-level statements about the requirements for embedded training. These may range from very general to detailed statements of what is to be accomplished with embedded training.

Sample questions:

Do policy statements or documents indicate an overall preference for, preference against, or neutrality toward embedded training, all other factors being equal?

Are there policy constraints which limit or preclude the use of alternatives to embedded training, such as maneuver areas, live fire ranges, or the use of simulators or devices in the unit?

Sub-factor: System Availability for Training - Opportunity

Definition: The percentage of time during which the prime system can be made available for use as a trainer and still fulfill its prime (combat) mission.

Sample questions:

What percentage of the time can the prime system be made totally available for ET?

Can independent training be provided simultaneously at different duty positions?

Sub-factor: Training Content - Cost

Definition: The life cycle cost of developing, modifying, and maintaining the courseware and other required training materials.

Sample questions:

How complex is the management of the training expected to be? Include management of individual and crew progress, assignment of training sequences, scheduling of training, and scheduling and ordering of all support personnel and materials.

Is extensive networking required in order to provide the ET?

The next step in the process was to review the entire set of questions and sort them into phases on the basis of the expected availability of the information needed to answer each question. The phases were defined as follows:

Phase I: Phase I activities should be conducted about Milestone 0, Concept Studies Approval, for the prime system. The information expected to be available is: general policy and guidance documents regarding both the prime system and its supporting training system; a copy of the Blueprint of the Battlefield; the Mission Need Statement for the prime system; and the expected acquisition schedule for the prime system.

Phase II: Phase II activities are conducted during the Concept Exploration and Definition Phase. The information assumed to be available is (in addition to that available for Phase I): data on the training environment, including the structure of the units expected to receive the prime system, their locations, and the training facilities and resources available to them; and results from the Early Comparability Analysis (ECA).[12]

Phase III: The Phase III analysis should be conducted about Milestone I, Concept Demonstration Approval, of the prime system. The information assumed to be available is (in addition to that obtained for Phases I and II): the prime system Operational Requirements Document; a description of the prime system concept produced by the concept formulation process; detailed information about the predecessor system, if there is one; the results and supporting data of the conduct of HARDMAN Comparability Analysis[9]; and a description of the soldiers who will operate and maintain the prime system.

Phase IV: The Phase IV analysis should be conducted during the Concept Demonstration and Validation Phase of the prime system acquisition cycle. The information assumed to be available is (in addition to that obtained for Phases I, II, and III) data and information from simulations, mock-ups, testbeds, and tests and evaluations.

Next we independently identified the phases at which we expected sufficient information to be available to answer each question. We then compared our results, resolved differences, and assigned each question to one or more phases.

For each Phase, the questions were organized into a logical sequence leading to training alternative recommendations. Many complex questions were divided into a series of simpler questions. Flow diagrams were developed. Finally, textual explanations of each flowchart segment or block, and worksheets to present the results, were developed.

Questions about the costs of training alternatives were grouped separately into a Training Alternatives Cost Summary (TACS). The TACS could be completed at any time, but usually following the Phase III or Phase IV analysis. Cost questions were organized into a TACS Worksheet, rather than a series of flowcharts.

RESULTS: A GUIDE FOR EARLY EMBEDDED TRAINING DECISIONS

These procedures produced A Guide For Early Embedded Training Decisions,[13] which consists of nine sections and an appendix. Sections 1, 2, and 3 provide introductory material and "how to use" information. Sections 4, 5, and 6 consist of flowcharts for phases I, II, and III/IV, respectively. Within each phase, flowcharts are separated into blocks of related questions. Each block includes questions to be answered by the evaluator and is accompanied by help text that explains the decision process represented in that block. ET decisions are made on the basis of how the evaluator answers the flowcharted questions. Section 7, the Training Alternative Cost Summary, requires the completion of a cost estimating worksheet, rather than working through flowcharts, as required in the other phases. Appendix A provides information regarding the ten factors listed in Table 2 of this paper.

USER FEATURES

The ET guidelines were developed to provide specific early guidance to the user in making decisions about embedded training. To this end every effort has been made to keep the procedures performed by the user as simple as possible. Basically, the user is required to step through a series of flowcharts. Each flowchart question constitutes a decision point, where a "YES" or "NO" answer leads to another question, and so on, until a decision is reached. Figures 1 and 2 are examples of Phase II flowcharts for Blocks 2 and 3, respectively. Help text is provided with each flowchart block to explain the purpose of that block of questions and to provide the logic and rationale behind the selection and sequencing of the flowchart questions.

For keeping records of the decisions made, the Guidelines include a Training Alternative Summary Matrix Worksheet. Figure 3 is a completed sample matrix showing the results of a Phase II analysis of four prime system functions: navigation, vehicle maneuvering, target acquisition, and weapons function management. Training alternatives are identified as Preferred, Recommended, Alternative, or Excluded depending on whether they best satisfy, fully satisfy, minimally satisfy, or fail to satisfy training requirements.

The guidelines also provide worksheets to help the user estimate the costs of ET and other training system alternatives. The Training Alternative Cost Summary may be used to compare alternative training systems on four cost categories: Design and Development, Procurement, Maintenance, and Operations. The cost worksheets supplement the decision flowcharts by providing additional criteria for making ET decisions. A sample worksheet used in estimating Design and Development costs is included as Figure 4.

Phase II, Block 2. Can the prime system support ET, given MPT and RAM requirements?

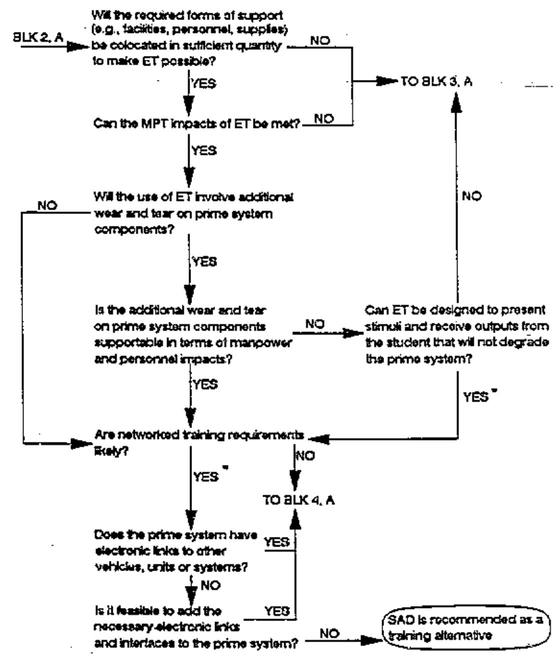

Figure 1. Block 2 Flowchart for Phase II Training Decisions.

Phase II, Block 3. Are other training alternatives supportable in terms of MPT and training facility requirements?

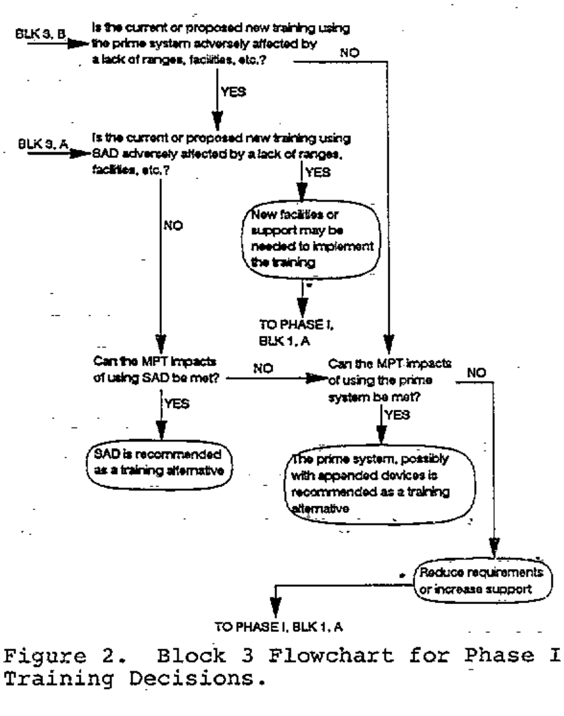

Figure 2. Block 3 Flowchart for Phase II Training Decisions.

TRAINING ALTERNATIVE SUMMARY MATRIX

MISSION, FUNCTION, TASK OR SUBTASK	AET	ET			APPENDED DEVICE	SAD	CBI	CLASSROOM
		FULLY	APPENDED	UMBILICAL				
TARGET ACQUISITION		R	R					
NAVIGATION							P	P
VEHICLE MANEUVERING						R		
WEAPONS FUNCTION MANAGEMENT		R	R	R				

LEGEND
P = PREFERRED
R = RECOMMENDED
A = ALTERNATIVE
E = EXCLUDED

Figure 3. Sample Training Alternative Summary Matrix

STATUS AND PLANNED ACTIVITIES

The ET guidelines have been refined and improved based on comments provided by experts in the embedded training area, but the guidelines have not yet been applied to a system acquisition. We plan to apply the guidelines to improve the quality of ET decisions for the Armored System Modernization (ASM) Program. The application will occur in conjunction with the development of the integrated training system for the ASM tank variant. We expect that some changes to the guidelines will occur as the direct result of this practical application.

Currently the user of the ET Guidelines must work through the flowcharts and associated worksheets manually, recording decisions and recommendations on training alternative and cost summary worksheets. However,the flowcharts and help sections were designed with a computer-based implementation in mind. One advantage of computer-based ET Guidelines is the increased speed with which the user could render decisions about the advisability of using ET for the various missions, functions or tasks. Another advantage is that the computer could keep track of the decisions made as the user progresses through the flowcharts, alleviating the user from the tedious task keeping detailed records of the decision process and maintaining a permanent audit trail of the decision process. Such an audit trail could greatly facilitate subsequent review and revision as the prime system and the training system evolve. The computer could also keep track of media decisions and maintain a file of decisions and recommendations that affect the cost of the training alternatives. A computer implementation of the ET guidelines is planned following their application to the ASM program, if funds are available for that implementation.

	AET	APPENDED	EMBEDDED TRAINING			SAD
			FULLY	APPENDED	UMBILICAL	
Design & Development. What is the cost of designing and developing the training subsystem for each training alternative? Consider the following:	$____	$____	$____	$____	$____	$____
What is the cost of designing new (or upgraded) ranges and facilities?	$____	$____	$____	$____	$____	$____
What is the development cost of the training management system? Consider how complex the management of the training is expected to be. Include management of individual and crew progress, assignment of training sequences, scheduling of training, and scheduling and ordering of all support personnel and materials.	$____	$____	$____	$____	$____	$____
What are the costs of developing supporting documentation (e.g., Instructor/Operator manual, maintenance manuals, etc.)?	$____	$____	$____	$____	$____	$____
What are the courseware development costs?	$____	$____	$____	$____	$____	$____
Does the training alternative require the development of complex simulations? If so, do these simulations require a direct view of the outside world?						
Is the courseware development required within the "state of the art"?						
Does the training require that the simulations function in an interconnected network?						
Must the hardware and software interact with system components that provide simulated motion (e.g., a motion platform)?						
What are the hardware and software development costs?	$____	$____	$____	$____	$____	$____
Does the training require that the simulations function in an interconnected network?						
Must the hardware and software interact with system components that provide simulated motion (e.g., a motion platform)?						
Is training system component ruggedization required?						
Is training system component miniaturization required?						

Figure 4. Training Alternative Cost Summary

SUMMARY

Problems in implementing embedded training have prevented it from realizing its full potential. These problems are the result of the requirement to specify embedded training requirements well before the information traditionally used in making training media decisions (e.g., task characteristics) is available. Previous ET work has not been successful in providing specific procedures for making early ET decisions, but some researchers[3,5,10,11] in the area have provided the raw materials (i.e., the concepts and questions) for making these decisions. Starting with known characteristics of effective embedded training systems, a bias for ET derived from its recognized advantages and the assumption that the decision process must be phased and linked to information availability, a set of guidelines were developed for making early embedded training decisions. The development process entailed identifying approximately 100 questions and organizing these by categories for inclusion in media decision flowcharts and cost summary worksheets. The guideline procedures, require the analyst to manually work through a series of detailed decision flowcharts and training alternative cost summary worksheets to produce early embedded training recommendations. A computer-based version of the ET guidelines is planned as is their application to the Armored System Modernization training system acquisition.

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