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Early Training Strategy Development for Individual and Collective Training

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U.S. Army Research Institute

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**Early Training Strategy Development
for Individual and Collective Training**

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FOREWORD

The Army's need for a top-down approach for developing training to support new weapons systems was reported by the Army Science Board in 1985. In response to this need, the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) is conducting research to develop and evaluate training design rules and guidelines that are applicable early in the weapons system design process. These guidelines will facilitate development of an integrated set of requirements for training devices, simulators, and simulations, including embedded training, for both weapons systems and units.

This report documents the results of the initial work in that process. The first goal was to create a preliminary model of the process by which the training strategies for new weapons systems are developed. The second goal was to estimate the benefits of implementing the model. The final goal was to identify the research required before the model could be implemented.

The work described in this report is part of research task 3105, Techniques for Early Estimation of Training System Requirements, conducted for the Army Project Manager, Training Devices (PM TRADE), by the ARI PM TRADE field unit under a Memorandum of Understanding, "Expanded MOU Between PM TRADE and ARI," dated 14 July 1986. The model described in this report provides the basis for development of a more detailed systems engineering analysis of the training development process.


EDGAR M. JOHNSON
Technical Director

EARLY TRAINING STRATEGY DEVELOPMENT FOR INDIVIDUAL AND COLLECTIVE TRAINING

EXECUTIVE SUMMARY

Requirement:

The training strategy for a new weapon system identifies the training devices required, the tasks each device will be used to train, and the circumstances under which each device will be employed. The Department of the Army requirement to consider embedded training (i.e., use of operational equipment and training software to provide training) as the first option for new weapon systems forces early development of training strategies.

Training development tools are being developed that can support parts of the process of developing a training strategy. The Automated Systems Approach to Training (ASAT) is designed to support preparation of the Army Training and Evaluation Program (ARTEP) documents that guide the training of units on collective and individual tasks (Science Applications International Corporation, 1988). The Optimization of Simulation-Based Training Systems (OSBATS) is a collection of prototype tools that assist in the design of training devices (Sticha, 1988; Sticha, Blacksten, Buede, Singer, Gilligan, Mumaw, and Morrison, 1988). What is missing is an overall model that shows how these and other tools could be integrated to support training strategy development. A need exists to create a preliminary model of the process by which the training strategies for new weapons systems are developed, estimate the benefits of implementing the model, and identify the research required before the model could be implemented.

Procedure:

This report describes an early training estimation model in terms of four functions: ARTEP development, front-end analysis, training strategy development, and training strategy comparison. The first two functions address identifying tasks to be trained and analyzing training-relevant features of these tasks. The third function addresses generating feasible training strategy options. The fourth function is concerned with comparing the cost effectiveness of training strategy options. Each function was defined in terms of goals, subfunctions, inputs, outputs, benefits, and developmental risks.

Findings:

Major benefits that accrue from this model are listed below.

- It focuses the training device design process on preparing units to perform their missions, the bottom line of Army training.
- It allows for comparing the cost effectiveness of embedded training with other options very early in weapon system development.
- It integrates individual skills training across duty positions, individual skills training with collective training; collective task training across unit missions; and collective task training across echelons.
- It identifies individual tasks with a high payoff in terms of progressive training value.
- It defines collective training targets of opportunity with a high payoff in terms of progressive training value.
- It ensures minimal duplication among training devices and products in terms of training objectives addressed.
- It provides the level of detail regarding fidelity and instructional support feature requirements needed to compare the cost effectiveness of device alternatives.
- It ensures that embedded training is used when it is the most cost effective option for individual or collective training.

Implementation of the concept required to gain the benefits listed above will require the development and integration of new tools to address collective training, unit training, and newer training device options like networked simulation.

Utilization of Findings:

These findings will be used by the Project Manager for Training Devices (PM TRADE), the U.S. Army Training Doctrine Command (TRADOC), and the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) to define future development of training design tools in a way that ensures they will support the development of integrated training strategies.

EARLY TRAINING STRATEGY DEVELOPMENT FOR INDIVIDUAL AND COLLECTIVE TRAINING

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EARLY TRAINING STRATEGY DEVELOPMENT FOR INDIVIDUAL AND COLLECTIVE TRAINING

Introduction

The goal of training Army units to perform their missions is becoming more difficult to attain as both the cost of training on operational equipment and the need to reduce expenditures increase (Armstrong and Deaver, 1990). The careful application of training devices and simulators to new weapon systems is one way to address this problem. Devices and simulators can make it possible to provide soldiers with hands-on practice without the expenditures for ammunition, fuel and equipment maintenance typically associated with training on operational equipment.

Today a wide range of media are available that can be used to supplement classroom lectures and training on operational equipment to meet training needs. These media range in complexity from the networking of full-mission simulators that simulate all or most of the subsystems of an item of equipment to forms of computer-based instruction which are knowledge-based and involve no simulation. The plan or strategy for applying training devices to support training on new weapon systems is developed through the process of concept formulation to ensure that training is conducted in a cost-effective manner (U.S. Army Materiel Command and U.S. Army Training and Doctrine Command, 1988).

The training device strategy for a new weapon system identifies the training devices required, the tasks each will be used to train, and the circumstances under which each device will be employed (U.S. Army Training Support Center, 1988). This strategy must of course be part of a total training strategy that includes training methods in addition to those that are device-based. The training strategy should describe "the integration of the training subsystem and the development of the total [weapon] system and the integration of the developing system into ongoing training systems" (U.S. Army Training and Doctrine Command, 1982).

In addition to meeting the requirements noted above, the training strategy for a new weapon system must be developed early in the development of the weapon system. According to TRADOC Regulation 351-9 (1982), the training strategy or Outline Individual and Collective Training Plan (OICTP) should "identify the constraints which training requirements and resources may impose on the design of the materiel system". The option of embedded training (ET), "training that is provided by capabilities designed into or added to operational systems" (Department of the Army, 1987), increases the importance of an early integration of training strategies and weapon system development (Strasel, Dyer, Roth, Alderman, and Finley, 1988.)

The 1985 Army Science Board Summer Study on Training and Training Technology reached certain conclusions relevant to the problem of strategies for training devices (Peden, Barth, Bonder, Caro, Fried, Jones, LaBerge, Morrison, O'Neal, Pauly, Pettigrew, Rathjen, Simmons, Welch, Williges, and Zarafonetis, 1985). First, the study concluded that "a top-down systems engineering approach to the definition and development of training systems for units is not being accomplished" and "a total systems technique will yield the most efficient mix of devices, ranges, simulators and simulations in an effective manner." Second, the study concluded that "current training guidance focuses mostly on individual devices, simulators, and simulations" and there is a need for top-down training strategies which incorporate and integrate all appropriate training devices.

The Army would benefit from a systematic means of developing and assessing training strategies early in concept formulation for new weapon systems. This would ensure timely and accurate consideration of embedded training and enhance the overall cost-effectiveness of the training system. This systematic method should include individual training, collective training, institutional training and unit training.

Background

The functions performed by the training design community in developing and refining strategies are summarized in Figure 1. The functions of identifying the tasks to be trained, analyzing tasks and developing training strategy options are the responsibility of Army school training developers (U.S. Army Training Support Center, 1989). The training strategy options which emerge from this portion of the process should reflect lessons learned when analyzing the training-relevant characteristics of the task including the conduct of a media analysis. The job of developing information to be used in comparing strategy options is a cooperative effort of Army Schools and the U.S. Army Project Manager for Training Devices (PM TRADE) referred to as the Trade-Off-Determination (Department of the Army, 1989). The TRADE-Off-Determination includes such considerations as the technical feasibility of various options and the cost of implementing these options. Comparison of training strategy options to select the best option is a joint effort of Army schools and PM TRADE and the analyses which combine to prove the best mix of training devices are referred to as the Trade-Off Analysis and the Cost and Training Effectiveness Analysis (U.S. Army Materiel Command and U.S. Army Training and Doctrine Command, 1988).

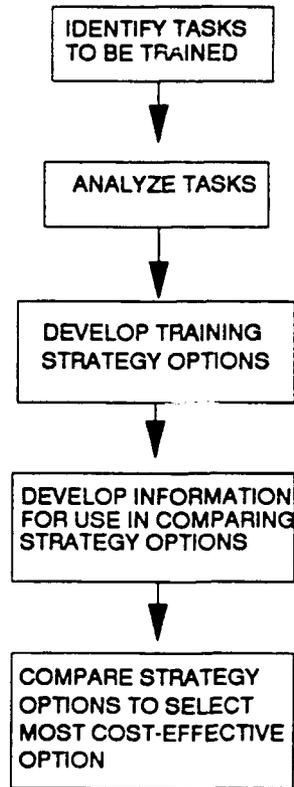


Figure 1. Overview of the ideal process for developing training strategies for a new weapon system.

Problems in developing and comparing training device strategies have been described by various researchers. First, training devices are often selected before the tasks to be trained are identified and analyzed (Heeringa, Baum, Holman, and Peio, 1982; Dynamics Research Corporation, 1984, Meliza and Lampton, in preparation). This problem is due, in part, to the fact that training device design and acquisition is often driven by technology rather than training strategies, and the training requirements addressed by the device are often determined by the capabilities of a specific training technology rather than the requirements of the task or tasks to be trained (Hofer, Ozkaptan and Kincaid, 1987). That is, Army schools often adopt a particular training device option without first finding out whether the option is truly cost-effective. Second, training strategies are often vague and fail to link the tasks to be trained with specific training devices (Meliza and Lampton, in preparation).

The Army recognized the need to develop procedures for producing quick, early estimates of the training resource requirements necessary to provide training on new weapon systems at least a decade ago (Roth, Warm, Peters, O'Brien, Hawley, Pence, Robinson, Masterson, and Criswell, 1989). In 1984, Dynamics Research Corporation noted that "Early front-end analysis techniques which could help produce more objective estimates of training requirements early in the acquisition process, are not employed in OICTP [Outline Individual and Collective Training Plan] preparation". A subsequent Army Science Board Ad Hoc Subgroup on Army Analysis concluded that front end analyses are not being performed consistently (Christie, 1987).

MANPRINT Product Four (Roth, Warm, Peters, Masterson and Criswell, 1987; Ditzian, Roth and Johnston, 1987) is the most recent in the HARDMAN series of tools for producing manpower, personnel and training resource estimates (Mannle, Guptill, and Risser, 1985). It is concerned with improving the quality of early estimates of training resource requirements for new weapon systems by identifying weapon systems and subsystems already in existence which might be expected to have training requirements similar to those of a new weapon system. MANPRINT Product Four gives training developers access to data on the current training strategy for these comparable systems. MANPRINT Product Four by itself is not a complete solution to the problem of early training estimation because it specifically addresses only individual task training within Army schools. Collective training and individual training in units are not addressed by MANPRINT Product Four.

The primary focus of MANPRINT Product Four is to develop estimates of the resources required to conduct training on a new weapon system based on resource requirements for conducting training for comparable systems. This approach is of limited utility as the Army attempts to develop training strategies encompassing individual and collective training in institutions and units. The proliferation of training device options (such as ET and simulation networking) combined with the increased emphasis on applying devices to individual, collective and combined arms training in units has created a large gap between early training estimation techniques that are available versus those that are needed.

Training Development Tools. In an attempt to incorporate collective training, unit training and new device options (such as ET) into early training estimation, ARI and the U. S. Army Project Manager for Training Devices (PM TRADE) sponsored the development of an architectural model for an Integrated Training System Decision Support System, referred to as TRASER. The TRASER model (Hinton, Feuge, Braby, Stultz, Evans, Gibson, and Zaldo, in preparation) describes the training development process for a new weapon system throughout the four phases of the Life

Cycle Systems Management Model (LCSMM). In addition to incorporating collective and unit training into the area of early training estimation, TRASER attempts to integrate various training development tools. These tools include MANPRINT Product Four, and three other systems under development within ARI; the Automated Systems Approach to Training (ASAT), the Optimization of Simulation Based Training Systems (OSBATS) and Embedded Training.

ASAT is designed to aid schools in preparing the Army Training and Evaluation Program (ARTEP) documents which guide the training of units on collective and individual tasks (Science Applications International Corporation, 1988). ASAT (Bloedorn, Crooks, Merrill, Saal, Meliza and Kahn, 1985) was intended to reduce the work required to revise the ARTEP documents required to field new weapon systems and produce ARTEP Mission Training Plan (AMTP) and Drill documents. These documents provide such information as how to integrate the training of specific individual and collective tasks.

OSBATS is a decision support system which uses information about specific individual tasks, device options, instructional support features, and student throughput to compare the cost-effectiveness of training device design options for individual training in institutions (Sticha, Blacksten, Buede, Singer, Gilligan, Mumaw and Morrison, 1988). OSBATS employs five modules (Simulation Configuration, Instructional Feature Selection, Fidelity Optimization, Training Device Selection, and Resource Allocation) which can be used in an iterative fashion to refine design options.

Current ET guidance is in the form of a ten-volume set of instructions intended to aid training designers in identifying candidate systems or tasks for embedded training and subsequent implementation of embedded training (Finley, Alderman, Peckham, and Strassel, 1988). Volume 2 of the ET guidance (Strasel, Dyer, Roth, Alderman and Finley, 1988) addresses the early selection of ET candidates by asking the four broad questions listed below.

- Are there general and/or weapon-specific policy decisions which dictate the use of embedded training?
- Do the tasks involved in maintaining and operating the equipment require sustainment training?
- Is it feasible to develop an embedded training component for the weapon system?
- Is it likely that embedded training will be a cost-effective alternative to other training options?

Training development tools exist which can support parts of the process of developing a training strategy. What is missing is an overall model which shows how these and other tools could be integrated to support training strategy development, especially early in the concept formulation process for training devices. While the TRASER model makes many valuable contributions to the design of an early training estimation and refinement system, details about how the various training development tools would support the development of training strategies are lacking. Further, the TRASER model integrates the above training development tools within the phases of the LCSMM for which they were originally designed. MANPRINT Product Four and ET are largely in the first phase of the LCSMM, while ASAT and OSBATS are in the second phase of the LCSMM. The quality of early training estimation should be enhanced by using ASAT and OSBATS as tools within the first phase of LCSMM.

The authors assume that the reader is familiar with the tools described above. The reader is referred to Hinton et al (in preparation) for information on TRASER, Bloedorn et al (1985) for information on ASAT, Ditzian et al (1987) for information on MANPRINT Product 4, and Sticha et al (1988) for information on OSBATS.

Objectives

One objective of this report is to present a preliminary high level model for early development and comparison of training strategies which incorporates ASAT and OSBATS by using data from comparable weapon systems. A second objective is to estimate the benefits of implementing the model. The third objective is to identify the research required before the model could be implemented. The discussion of the model and the benefits begins on page 7 of the report. The description of the work required begins on page 31.

The model presented in this report places little emphasis on the development of strategies for classroom individual training in institutions, because other tools appear to address that area adequately. The model includes training using operational equipment or training devices within institutions, and it includes individual and collective training in units.

Early Training Strategy Model

Overview and Benefits of the Model

The early training estimation model is described in terms of four functions; ARTEP Development, Front End Analysis, Training Strategy Generation, and Training Strategy Comparison (see Figure 2). The first two functions address the activities of identifying tasks to be trained and analyzing training-relevant features of those tasks. These functions should be performed by training developers within the Directorate of Training Development at an Army school, prior to and during the early phases of concept formulation for the weapons system. The third function addresses the activity of generating training strategy options. It should be performed by PM TRADE engineers (in the case of embedded training, training devices, and simulators) or training developers (in the case of other training approaches). The fourth function is concerned with comparing the cost-effectiveness of training strategy options. It should be performed by training developers. The third and fourth functions should be completed in time for the results to be incorporated into the Required Operational Capability (ROC) documentation (U.S. Army Materiel Command and U.S. Army Training and Doctrine Command, 1988).

The system is described this way for three reasons. First, it follows the sequence of steps in the ideal training device development process shown in Figure 1. Second, it is comparable to the concept formulation process employed by the Army Materiel Command and PM TRADE in that it requires the generation and comparison of alternative solutions. Third, many of the ARI training development tools tend to apply to more than one step in the ideal process, making it difficult to organize the model by training development tools.

Each function is described in terms of its overall goal, its sub-functions and outputs, inputs required, benefits, and developmental risks.

The benefits of the model, relative to the current device design process, are listed below.

- It focuses the training device design process on preparing units to perform their missions, the bottom line of Army training.
- It allows for comparing the cost-effectiveness of embedded training with other options very early in weapon system development.

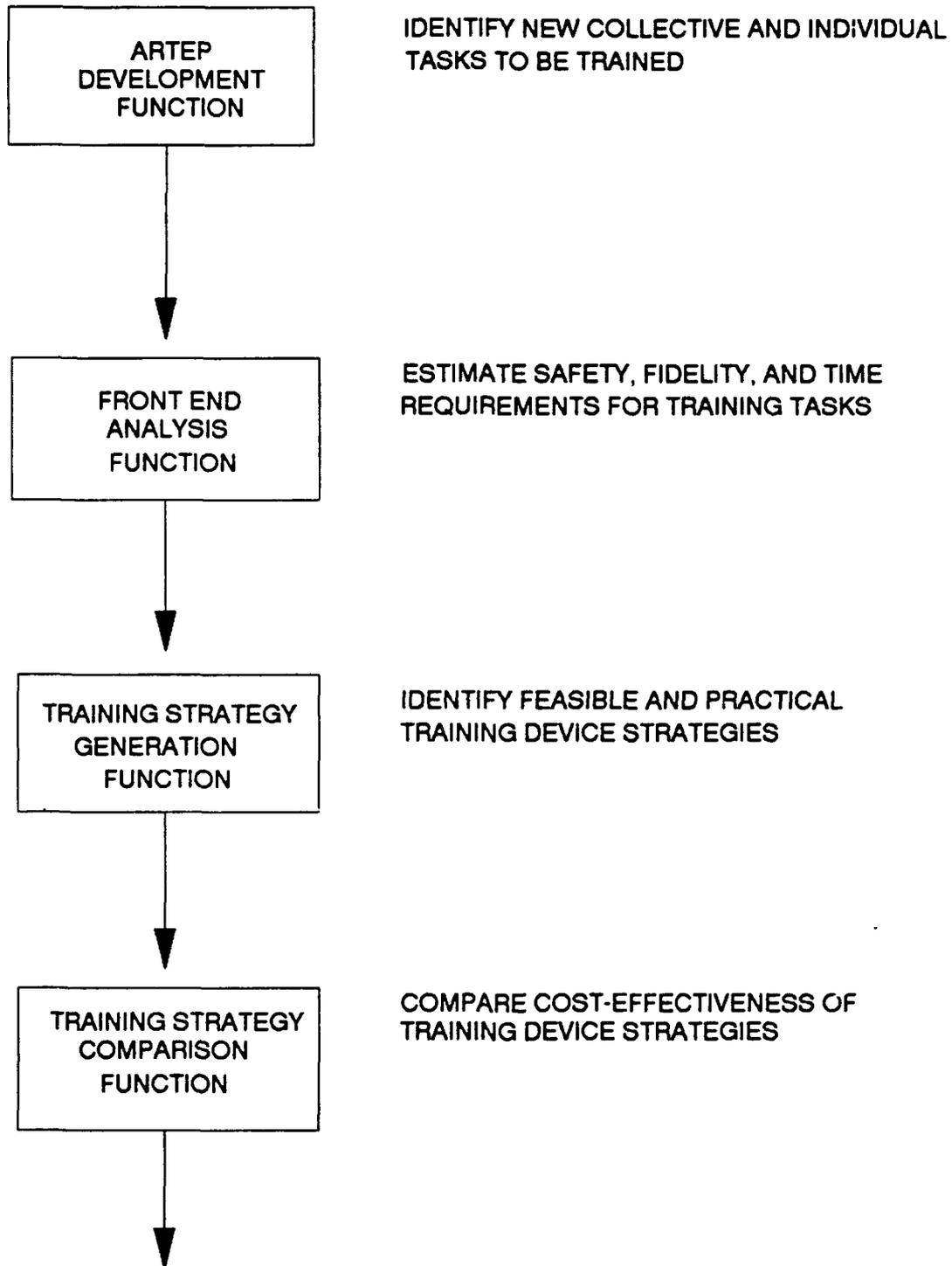


Figure 2. Early Training Strategy Development Model Overview.

- It integrates:
 - individual skills training across duty positions
 - individual skills training with collective training
 - collective task training across unit missions
 - collective task training across echelons.
- It identifies individual tasks with a high pay-off in terms of progressive training value.
- It defines collective training targets of opportunity with a high pay-off in terms of progressive training value.
- It insures minimal duplication among training devices and products in terms of training objectives addressed.
- It provides the level of detail regarding fidelity and instructional support feature requirements needed to compare the cost-effectiveness of device alternatives.
- It insures that embedded training is used when it is the most cost-effective option for either individual or collective training.

ARTEP Development Function

Goal. Figure 3 illustrates the information flow associated with the ARTEP Development Function. The goal of this function is to estimate the effects of a new weapon system on unit training plans as described within Army Training and Evaluation Program (ARTEP) documents, ARTEP Mission Training Plan (AMTP) and Drill documents. A unit training plan includes:

- collective training objectives
- guidance for integrating individual task training with collective training
- guidance for integrating collective training across echelons
- guidance for integrating collective training across unit missions
- guidance for applying the progressive, building block approach to unit training.

Sub-functions/Outputs. ARTEP documents are the primary source of information about the collective tasks to be performed by units. AMTP and Drill documents integrate the traditional "what to train" guidance of the ARTEP with "how to train" guidance (Hiller, Hardy and Meliza, 1984; TRADOC Regulation 310-2) to provide unit training plans which progress from individual skills training through a series of collective training exercises. The information from AMTP and Drill documents relevant to the design of integrated training device strategies includes guidance for integrating individual task training with collective task training, collective task training across echelons, and collective task training across unit missions. The output of the ARTEP function relevant to the design of training devices includes the existing unit training plan for the unit receiving a new weapon, modified to reflect the features of the new weapon.

AMTP and Drill documents provide two types of information about how to integrate individual skills training with training on specific collective tasks. First, these documents identify the individual tasks which should be mastered before training on a particular collective exercise. Second, they identify individual tasks which can be safely trained in the context of particular collective exercises without detracting from collective training. By virtue of the fact that AMTP and Drill documents address the skills of individuals across duty positions and Military Occupational Specialties (MOS), these documents also provide information about integrating training across duty positions.

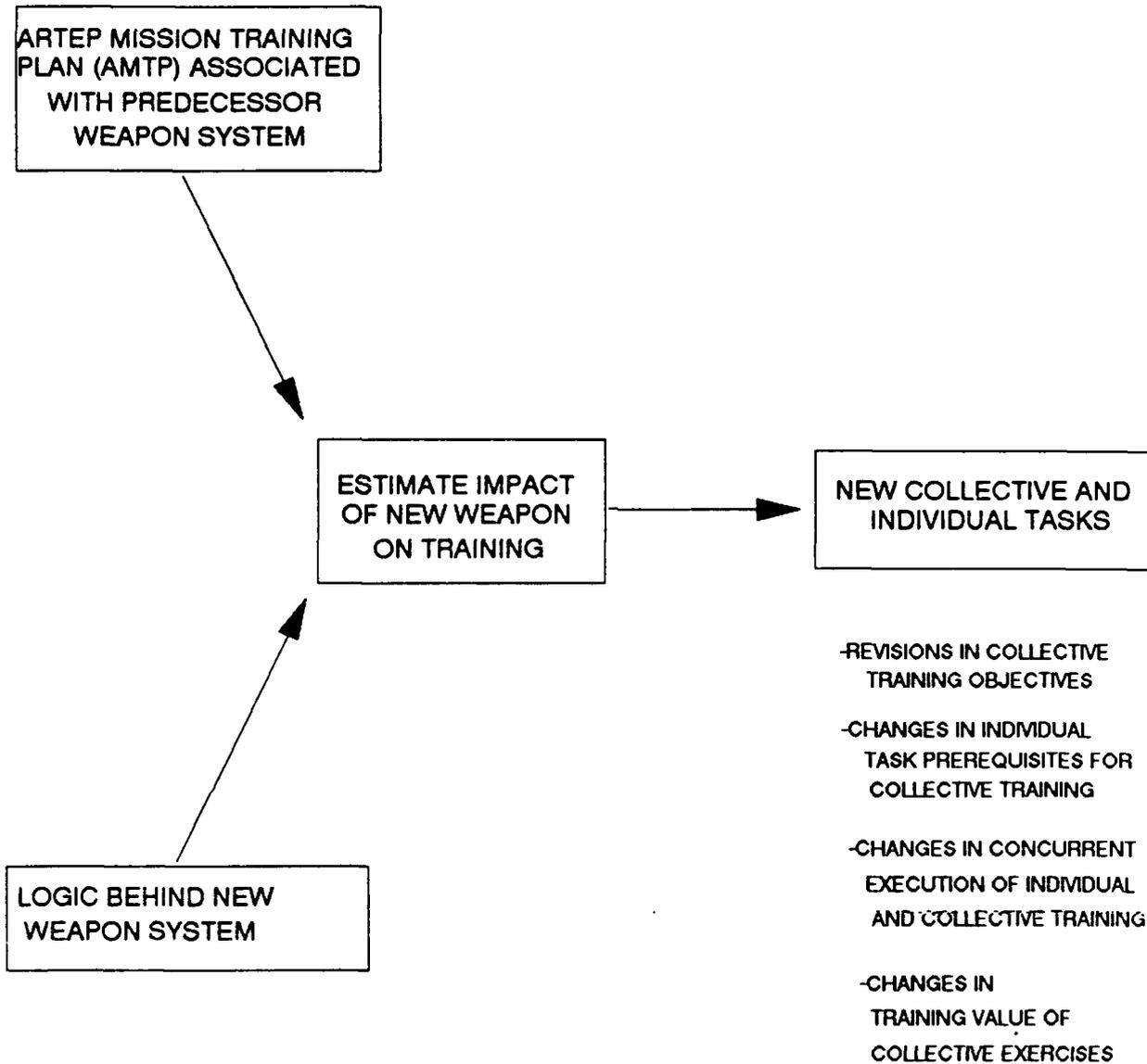


Figure 3. ARTEP Function for Estimating the Effects of a New Weapon on Unit Training Requirements.

ARTEP, AMTP and Drill documents define relationships between collective task training at one echelon and collective task training at the next higher echelon. For example, these documents indicate squad level collective tasks which support specific platoon level collective tasks.

Collective training exercises begin with basic collective tasks which warrant training in a repetitive Drill-like fashion and progress to Situational Training Exercises (STXs) which may contain multiple collective tasks and Drills. The most complex collective training events are called Field Training Exercises (FTXs). Each FTX contains a combination of STXs. Drills and STXs have a high pay-off in terms of progressive training value, because each exercise addresses skills which apply to many unit missions. The use of Drills and STXs as training vehicles helps to integrate collective training across unit missions.

With those rare exceptions where the fielding of a new weapon is associated with major deletions and additions of the collective tasks performed by a unit, unit training plans remain the same as with the predecessor system. The integration of individual and collective training, the scope and training value of Drills, and the scope and training value of STXS remain intact. In cases where the new weapon system is expected to enhance the capability of a unit, one would expect the enhancement to be reflected by changes in selected performance standards.

Drill and STX standards should require some revision if a new weapon is being fielded to help a unit address the threat situation more effectively. Such revisions are generally tied to the justification for the new weapon.

Input. The most important inputs for this function are the ARTEP and AMTP documents for units using the predecessor weapon system. The ARTEP and AMTP documents for a unit with a new weapon system are expected to be "cut and paste" versions of the previous unit documents. The new documents may differ from the old in terms of revision of selected standards, deletion of selected collective tasks, and addition of collective tasks.

Other important inputs for this function are those documents which describe the logic behind the decision to develop the new weapon system, because the logic is used to decide which collective tasks and which task standards need to be modified. The documents containing the logic behind new weapon systems should provide such information as a description of "how, what, when and where the system will be used on the battlefield and how it will interface with other systems" (Army Training Support Center, 1988). These logic documents include the Battlefield Development Plan (BDP) and the Organizational and Operational

(O&O) Plan for the new weapon system(s). The BDP (TRADOC Regulation 11-15, 1989) and O&O Plan (Army Training Support Center, 1988) are required to be developed by TRADOC very early in the formulation of the concept for a new weapon system.

Benefits Analysis. The benefits which accrue if the activities of the ARTEP function are carried out in a timely manner are listed below.

- It focuses the training device design process on preparing units to perform their missions, the bottom line of Army training.
- It helps to integrate individual task training across duty positions.
- It helps to insure that individual skills training is effectively integrated with collective training exercises.
- It defines individual tasks with a high pay-off in terms of progressive training value (tasks which apply to many collective tasks).
- It defines collective training exercises with a high pay-off in terms of progressive training value (exercises which apply to many unit missions).
- It helps to insure that collective task training will be effectively integrated across echelons and across unit missions.
- It insures that standards are available for measuring collective task performance.

Developmental Risk Analysis. The developmental risks associated with this function are minor. A previously unreported cooperative effort among ARI, the Ninth Infantry Division, and the U. S. Army Infantry School resulted in the preparation of ARTEP documents for each of three experimental organizations; the Mobile Assault Gun Battalion, the Light Attack Battalion, and the Motorized Infantry Battalion. These documents were prepared in less than two months in the form of "cut and paste" versions of the existing ARTEP document for Mechanized Infantry Battalions. These three Battalions differed from mechanized infantry units, and from one another, in terms of tactical doctrine, weapon systems and organizational structure. Information taken from draft doctrinal manuals regarding how each of these units were intended to fight was used in deciding which collective tasks needed to be deleted or added, and this information was also used to decide which collective task standards required revision.

The work to create three "cut and paste" versions of new ARTEP documents, described above, was accomplished a number of years ago. Two more recent events, implementation of the AMTP/Drill concepts and the Automated Systems Approach to Training (ASAT), should make it easier to update ARTEP documents to reflect new weapon systems, tactical doctrine and organizational structure. AMTP and Drill documents facilitate the revision process by providing a more economical description of training requirements than is provided in traditional ARTEP documents. For example, the same collective task may be contained within many different unit missions. While the traditional ARTEP document repeatedly described the same task within each mission context, the improved ARTEP essentially describes the task one time and indicates the missions to which the task applies. Bloedorn et al (1985) developed a concept for applying computer technology to facilitate the preparation and revision of AMTP and Drill documents. Science Applications International Corporation (1988) prepared draft functional specifications and database requirements for a prototype ASAT and completed the prototype in 1990. TRADOC will be producing the next version of ASAT in the 1991-92 time frame, and ASAT should be fielded by mid-decade.

Front End Analysis Function

Goal. Figure 4 indicates the inputs and outputs of the Front End Analysis (FEA) Function. The FEA Function, when used with the ARTEP Function, should provide most of the information about specific individual and collective tasks needed to decide what training devices might be employed to train each task. The goals of the function are to prepare FEA data for new individual and collective tasks and to identify FEA data for existing tasks that can be used in developing and comparing training strategies. Figure 4 is not intended to imply a strict left-to-right sequence of activities. The process is instead iterative and recurring. New tasks are input to MANPRINT Product 4; and new tasks, safety requirements, and estimates of time required to train tasks are inputs to OSBATS.

Sub-functions/Output. This function provides more information about tasks to be trained than does the ARTEP Function. Although the ARTEP Function provides information about how to best train collective tasks in the field using operational equipment, additional information is needed to support decisions about whether it is most cost-effective to train those tasks using operational equipment, embedded training, full mission simulators, part task trainers, or some other method.

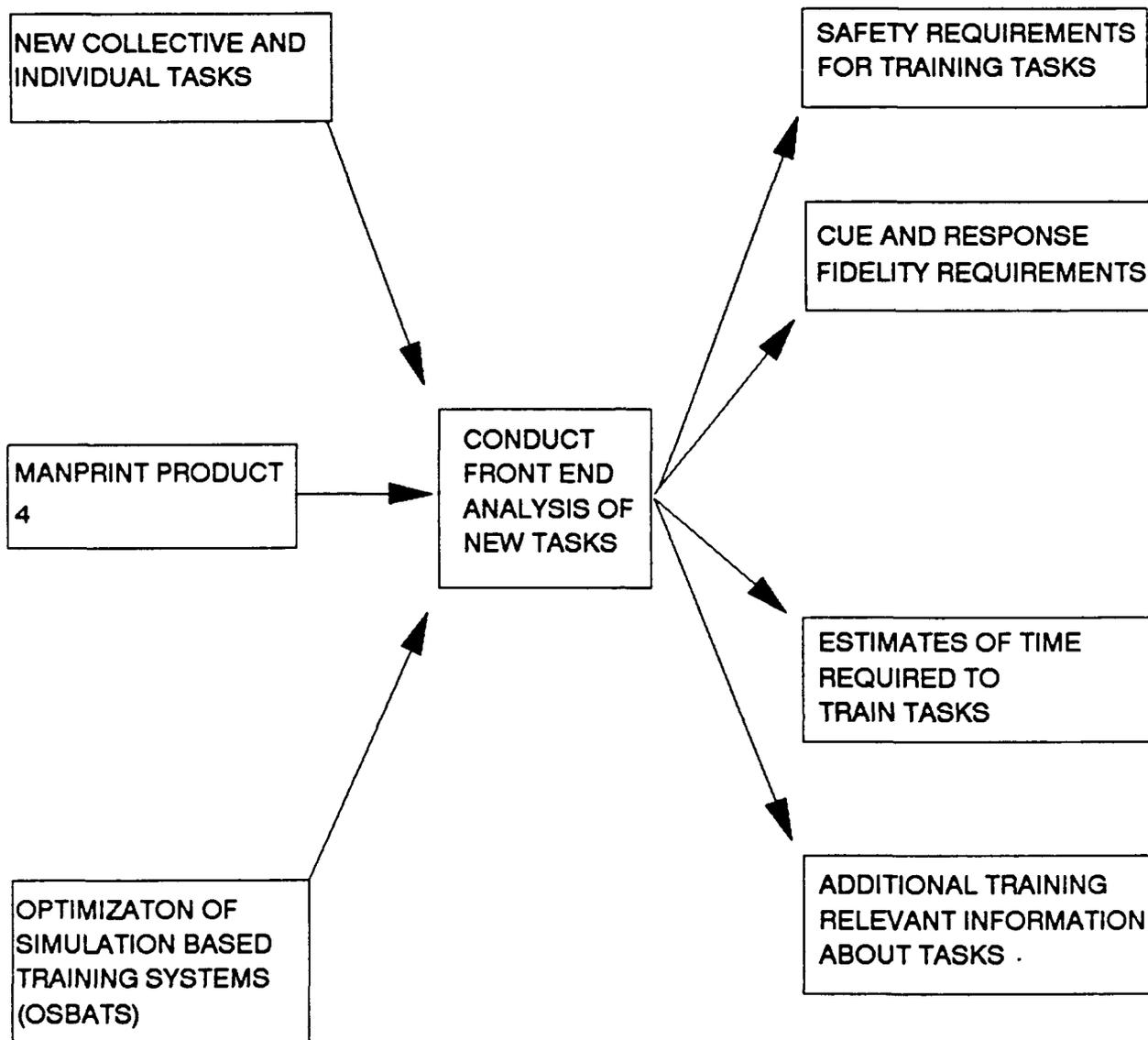


Figure 4. Front End Analysis Function for developing training relevant information about tasks.

The information required to choose among training options is growing as new types of training methods and products are made available. Since the Army currently has limited experience with many training device options, such as embedded training and collective training devices, a complete list of all factors to consider, and therefore of all desirable FEA outputs, is not readily available.

Cost and safety are the most important factors to consider when selecting among training device options. At times, they can override all other factors. For example, safety considerations prohibit training aircraft emergency procedures in the actual aircraft, and cost considerations severely limit the firing of actual air defense missiles for training purposes. Another important factor is the cue and response fidelity requirements of each task, that is, how similar to real life mission situations the training must be to provide meaningful opportunities for practice and performance feedback. Fidelity is a complex multidimensional factor which may, for example, encompass considerations of which of the six degrees of movement need to be employed, visual resolution requirements, field of view requirements, and interactions between motion and visual issues. The importance of fidelity is not surprising, given the substantial increases in cost associated with higher levels of visual, motion, auditory and tactile fidelity (Meliza and Lampton, in preparation).

Beyond those three factors, there is little agreement among members of the training community on the relative importance of other information about tasks. This other information includes the time required to train the task to standard, and requirements for providing feedback. These additional elements must be considered to insure that training is truly effective and to enhance the efficiency of training.

Benefit Analysis. This function provides information about tasks needed for the Training Strategy Development Function and the Training Strategy Comparison Function to perform their functions. The benefits of the FEA Function are realized in these other two functions.

Inputs. The ARTEP Function should provide input to the FEA Function to insure that individual task analysis is integrated with collective task analysis. A top down approach to task analysis (TRADOC Regulation 350-7, 1985) requires that collective task analysis precede and provide input to individual task analysis.

The FEA Function should also make use of information about related or predecessor weapon systems, including training objectives. In preparing these new training objectives and other

information, the FEA Function would again draw upon information from related or predecessor tasks, because the new training objectives and information would likely take the form of a "cut and paste" version of the old material. The sources of information which might be used to gather FEA material should include Training Performance Data Center (TPDC) databases, and similar weapon systems to which the OSBATS and ET guidelines have previously been applied. The initial results of the FEA would of course require updating to reflect changes in the concept for a new weapon system.

Developmental Risk Analysis. For this function to support subsequent functions in training device design effectively, the complete set of FEA outputs must be defined, and the outputs must be developed and readily available for use. Risks associated with these steps will be discussed in the following paragraphs.

The Army continues to identify new FEA requirements as it explores the use of new training technologies and new applications of existing training technology. For example, recent experience with the use of semi-automated forces (SAFOR), such as the computer simulation of friendly forces in the simulated networking environment, have raised questions about the types of tasks which SAFOR can perform without detracting from the realism of exercises and without overburdening the instructor/operators who help to control SAFOR actions. A hidden developmental risk lies in the ability of subsequent functions in early training estimation to address a growing variety of FEA input data when developing and comparing training strategies. That is, the subsequent functions need to be open-ended.

The process by which FEA output is developed must evolve to meet the information needs of training designers. Current FEA output does not satisfy all of the information requirements of existing decision rules for designing training devices. An effort to assess the availability of FEA material required to compare the cost-effectiveness of training device options using OSBATS found that some required information was not available in either schools or elsewhere (Willis, Guha, Hunter, 1988). A recent examination of the training device concept formulation process within PM TRADE found that some of the most critical information about tasks, fidelity requirements are difficult to obtain (Meliza and Lampton, in preparation). These observations were made even in situations where the fidelity issues were independent of the design features of a new weapon system (i.e., fidelity issues which applied to the predecessor system and its training devices). There is a need to impress training analysts with the importance of these FEA outputs, and there is a need to facilitate the preparation of these outputs.

Substantial progress has been made in developing procedures which make it easier to locate appropriate FEA output from predecessor systems. MANPRINT Product 4, for example, will make it easier to identify tasks comparable to those associated with new weapons. OSBATS contains FEA output within its database. Increased application of OSBATS to training device design, and the accumulation of OSBATS data in a centralized database, would greatly increase the extent to which such data are readily available.

Another important variable to consider in terms of quality of FEA outputs is the level of expertise of analysts. Army schools can use the selection process and training to increase the level of expertise of task analysts.

Training Strategy Generation Function

Goal. The goal of this function is to generate multiple training strategies for a new weapon system. Each strategy generated should meet certain criteria (such as being affordable) to warrant further consideration (see Figure 5). Multiple strategies are necessary to allow for subsequent comparison of the strategies to select the one which is most cost-effective (or most effective at or below a given cost).

Each training strategy defines the mixes of training products and devices required to provide effective individual and collective training on a new weapon system. This macro strategy, discussed in this section, should be distinguished from the micro strategies which describe how each training device option is to be used to achieve specific training objectives (US Army Training support Center, 1988). The early development of a training strategy involves specifying the training device options (operational equipment, embedded training, full mission simulator, networked simulations, and part task trainer) or combination of options to be employed within each strategy. For example, one training strategy might call for all individual and collective tasks to be trained using embedded training in institutions and units, while a second strategy might use a combination of training on operational equipment, part task trainers and networked simulation to address the same tasks as the first strategy.

Sub-functions/Outputs. The purpose of this function is to generate a group of training strategies for a new weapon system. Each strategy should address all of the tasks to be trained.

In addition to defining a mix of training products and devices, a good training strategy should meet additional criteria. First, a strategy must indicate where each task is to

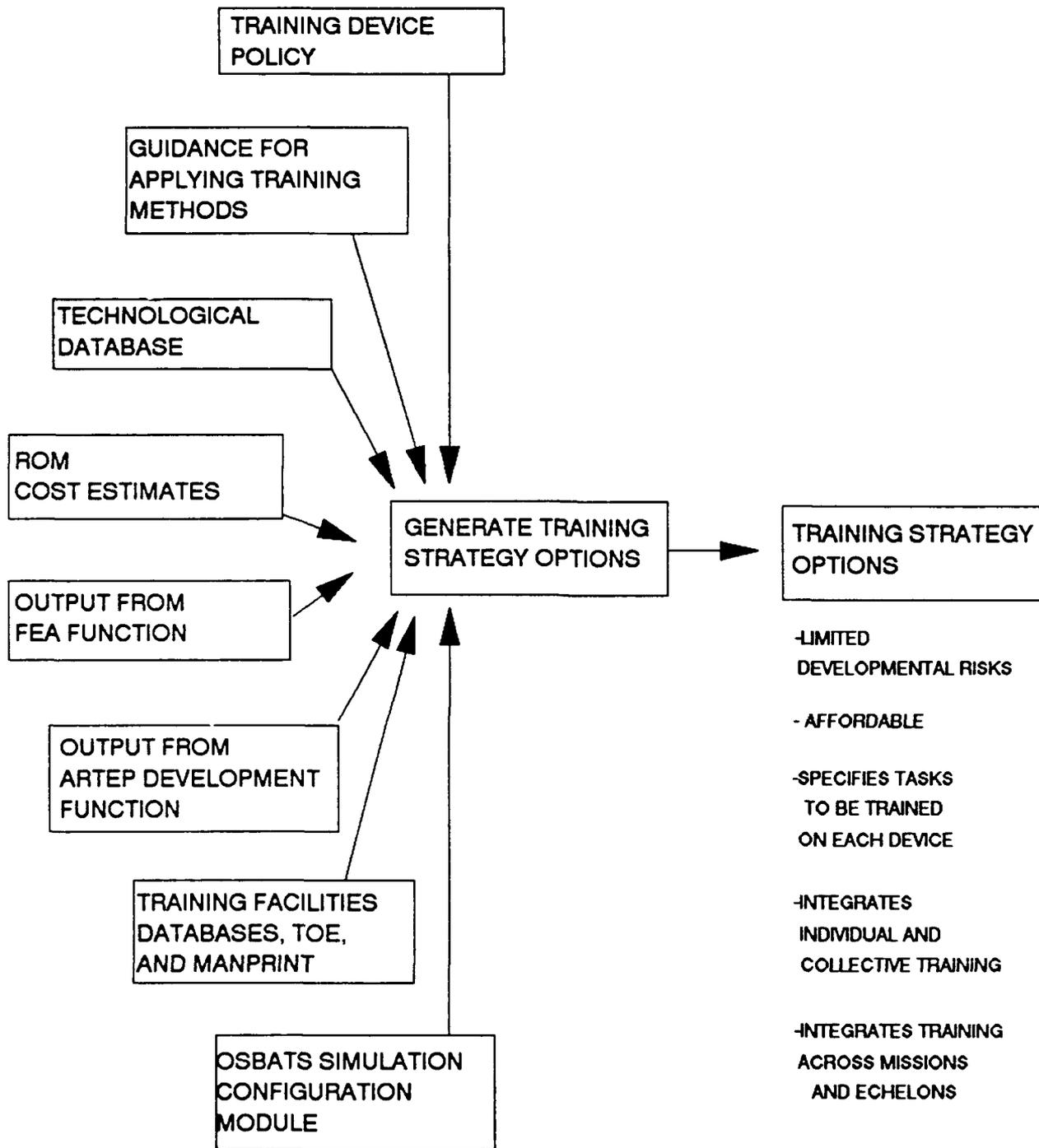


Figure 5. Training Strategy Generation Function for developing feasible and practical training strategy options.

be trained for the first time (institution or unit). Second, a strategy should be presented in sufficient detail to indicate which groups of individual and collective tasks are to be addressed by each specific training device. This is necessary to insure that all parties will understand the scope of the device. Third, the implementation of each strategy should involve minimal developmental risks. No strategy should call for applications of technology that are impossible given the state of the art or which are so novel that insufficient information is available to assess the potential for success. Fourth, a training strategy should reflect the integration of individual and collective training, collective task training across unit missions, and training across echelons.

Benefits Analysis. The type of training strategies described above:

- insures that there will be minimal duplication among training devices and products in terms of training objectives addressed, because devices and products are linked to specific training objectives;
- provides the level of detail required for accurate estimation of the cost of implementing training strategy options;
- increases the likelihood that all devices being considered are technical'v feasible; and
- insures an overall efficiency of training by integrating the various training requirements.

Inputs. The inputs to this function are used to insure that any training strategies developed are feasible and practical. To be practical and feasible the strategies must be in compliance with training device design policies, affordable, safe, technologically feasible, and compatible with the training environment. These strategies must integrate individual and collective training, and they must integrate training across missions and echelons. Finally, the strategies must be thorough and specific in describing the tasks to be trained by each device. The inputs required to develop strategies which meet all of these criteria are discussed below.

A major input to the training strategy development process is the current Department of the Army (DA) policy concerning embedded training as it is defined in a policy and guidance letter dated March, 1987 and signed jointly by the Vice Chief of Staff and the Under Secretary of the Army. This letter states that "an embedded training capability will be thoroughly evaluated and considered as the preferred alternative among other approaches to the incorporation of training subsystems in the

development and follow on Product Improvement Programs of all Army materiel systems". This policy was interpreted by Strassel, Dyer, Roth, Alderman, and Finley (1988) to mean that "ET will be included in all new and developing Army systems unless there are valid and compelling reasons not to do so". The potential targets of opportunity for ET include collective training. For example, the Systems Training Plan for the Main Battle Tank (MBT) Block III states "embedded training will include one or more stand-alone modules for force on force simulation" (U. S. Army Armor School, 1989).

Training device policies may apply to many different weapon systems, or they may apply to a single weapon system (Hinton et al., in preparation). DA guidance to consider ET as the preferred alternative among other approaches is an example of a policy which influences virtually all efforts to develop training devices for new weapon systems. Policy may also be specific to a given weapon system or family of weapon systems. For example, a policy might state that the training devices must be modular and reconfigurable to allow the same basic device to be employed for each member of a family of weapon systems.

Guidance is also required about how to apply specific training methods. For example, Volume 2 of the ET training development guidelines (Strassel et al., 1988) contains rules for deciding which tasks and subsystems of a weapon system are appropriate to be addressed by ET. The ET guidance considers such issues as the likelihood that ET can be provided without interfering with the weapon system's operational capabilities. These rules are currently being expanded to provide more detailed guidance, in the form of logic flowcharts and accompanying explanations, for making early ET decisions (Witmer and Knerr, in preparation).

The application of simulation networking to combined arms training has added a new set of policies to be considered when developing training strategies. For the simulators which support training on weapon system to be networked with simulators for other weapon systems in combined arms training exercises, these simulators must be designed to be interoperable. A DOD level standard to support interoperability in the simulation networking environment is in a late stage of development (McDonald, Pinon, Glasgow, and Danisas, 1990).

It is important to identify problems in the technological feasibility of device options as early as possible. The identification of such problems is part of the job of PM TRADE engineers, and PM TRADE is responsible for maintaining a technological database to support the identification process (U.S. Army Materiel Command and U.S. Army Training and Doctrine Command, 1988).

Information is required which can be used to estimate the cost of implementing the various strategies. Given the fact that these estimates are to be made early in the formulation of training strategies for new weapon systems, these estimates are unlikely to be based on the thorough and rigorous procedures used by PM TRADE engineers in preparing a Baseline Cost Estimate (BCE). Instead, these estimates are more likely to take the form of the rough order of magnitude (ROM) estimates developed by these engineers (PM TRADE, 1986).

The output from the FEA Function should also provide input to the development of training strategies. The FEA output describes the individual tasks to be trained and provides training-relevant information about both the collective and individual tasks to be trained. This training-relevant information includes safety considerations, estimates of the time required to train each task, and other information needed to decide which training device options can be applied appropriately to each task.

The output from the ARTEP Development Function also provides input to the design of training strategies. One of the most important inputs to training strategy generation are the unit training plans from the ARTEP. These plans provide the information needed to develop strategies which integrate individual and collective training, and training across unit missions and echelons. Such information is important in developing strategies in which individual skills training supports rather than disrupts collective training. The ARTEP also describes the collective tasks to be trained, and is describes collective training exercises (Drills and STXs). In some ways the collective training exercises provide a more accurate description of training requirements than do mere descriptions of collective tasks, because the exercises reflect previous consideration of training-relevant information about collective tasks. For example, the STX concept reflects the fact that certain collective tasks cannot be trained and performed separate from other collective tasks.

The job of generating a training strategy also requires information about the trainee population and the environment or environments in which training is to be conducted. Such information can be obtained from Tables of Organization and Equipment (TOEs), MANPRINT analyses, and the DoD Training Performance Data Center's database of DoD Installation Ranges and Targets. The number of soldiers to be trained, the time available to conduct training, and the resources available to support training are important variables in developing training strategies.

The OSBATS offers potential as a tool in generating multiple training strategies for a new weapon system by considering such factors as safety issues concerning training on operational equipment, overlaps among tasks in terms of the stimuli necessary to provide meaningful opportunities for practice (fidelity requirements), and device development cost. The Simulation Configuration Function of the OSBATS contains decision rules and databases which help to categorize individual tasks into clusters based upon similarity of cue and response fidelity requirements and safety concerns. The outcome of the application of the OSBATS Simulation Configuration Module is in the form of a macro training strategy which indicates the tasks to be trained on each of three training device options (operational equipment, full mission simulator, or part mission simulator. In addition, the Simulation Configuration Model gives the training designer the capability to develop variations of a training strategy by, for example, varying the importance of cost as a strategy determining variable. This feature allows the training designer to generate multiple training strategies in terms of the tasks assigned to each training device.

Developmental Risk Analysis. The process of defining a training strategy generation function represents a tremendous challenge. Problems to be faced include: (a) the lack of a universally accepted process for generating a training strategy; (b) the need to generate an initial training strategy very early in the design of a new weapon system; and (c) the requirement to consider unit training in detail. These problems are discussed below.

The overriding consideration is that a universally accepted process for generating training strategies does not exist. This is illustrated by the fact that at least two reports regarding training strategies have been prepared recently (Army Training Support Center, 1988; Perceptronics, 1988). These reports differ in terms of decision rules and information required to apply rules. The lack of a universally accepted process for generating training strategies is due, in part, to the fact that the Army has yet to learn how to best employ many of the "newer" training options, such as embedded training.

The TRASER model provides an overall framework for training strategy decisions but lacks detailed procedures for integrating existing tools. OSBATS and ET guidelines require integration to insure that the full range of device options can be defined within a single training strategy. This integration might take the form of applying OSBATS modules to embedded training candidates (e.g., to create strategies involving different mixes of training on operational equipment, embedded full mission simulators and embedded part mission trainers) or expanding the OSBATS to include embedded training as an option. Developmental risk is considered low to moderate.

The first problem is compounded by a second. The early generation of a training strategy is dependent upon adequate FEA input. Although much of this FEA input would be derived from data on comparable systems, adequate FEA data on comparable systems are often not available. This problem was discussed under the description of the FEA Function.

The third and most difficult problem is that the unit training environment is much more complex than the institutional training environment, and training environments vary greatly among units. Certain of the variables which need to be considered when developing a training product for use in units (i.e., personnel turbulence, personnel shortages, trainer experience and garrison/administrative distractions and the strategies used by units to address these problems) were identified in the course of a study of training detractors conducted within five Army divisions (Funk, Johnson, Batzer, Gambell, Vandecaveye and Hiller, 1980). The unit training environment has since become more complex due to the advent of Army Combat Training Centers (CTCs), such as the National Training Center (NTC) at Fort Irwin, California. CTCs are an extension of the unit training environment which provide units with the opportunity to conduct leader and collective training which often cannot be accomplished at home station due to resource constraints. CTCs have expanded the unit training environment, and, at the same time, CTCs have become a major variable influencing the unit training environment at home-station (Fobes and Meliza, 1989).

Guidelines and procedures need to be developed for considering the unit training variables listed above when developing unit training strategies. These procedures and guidelines should also consider two unique aspects of collective training which are expected to influence training device selection and design. First, many of the cues which initiate and guide performance are produced by other participants in the collective task. It is therefore more difficult to control the situational cues required for effective training, and it is more difficult to provide feedback to training participants. Second, the standards for performing higher level collective tasks must afford more latitude than those for an individual task to accommodate the fact that alternative task steps might be performed when executing a collective task. In addition, variations of the exact situation under which a collective task is performed also influences the range of responses which might be considered acceptable.

The Army also requires decision rules and databases for use in deciding when it is appropriate to use simulation networking (SIMNET) as a training device option. SIMNET-Training (SIMNET-T) represents a prototype or test-bed for future collective and combined arms training devices. Drucker, Campshure and

Campbell (1988) and Burnside (in preparation) have analyzed SIMNET-T to identify specific tasks and standards which can be trained effectively in SIMNET without modifying SIMNET hardware and software. This information can be directly applied to the development of training strategies which encompass collective and combined arms training. Further, SIMNET-T may serve as a tool in answering additional questions relevant to collective and combined arms training.

The number of distinct training strategies which might be generated for a weapon system might be excessively large, but selecting training which are feasible and practical helps to reduce the number of options. Further the current problem with the number of training strategies is that there are far too few strategies. Quite often only two strategies are considered with one of these being training on operational equipment (Meliza and Lampton, in preparation).

Training Strategy Comparison Function

Goal. This function (Figure 6) attempts to address two goals. The first goal is to collect additional information for use in comparing training strategy options. This approximates the Trade-Off Determination (TOD) process performed by PM TRADE engineers (PM TRADE SOP 66, 1986). The second goal is to analyze the information collected to identify the most cost-effective strategy, or to identify which strategy is most effective at or below a given price. This second goal approximates the Trade-off Analysis (TOA) performed by schools to select device options for development.

The second goal might be considered to be too ambitious, given the inadequate information available about tasks to be trained early in the concept formulation process for a new weapon system. A more conservative view of the goal of early comparison of device options has been presented by Sticha, Blacksten, Morrison, and Cross (1988). These authors suggest that it is critical for the early comparison of device options to identify bad device options and less critical that the comparison identify the best device option. This conservative approach was applied in the Training Strategy Generation Function of the current model. In the Training Strategy Generation Function, then, the emphasis is on the development of feasible training device options. In the Training Strategy Comparison Function, the emphasis is on the identification of the "best" option.

Sub-functions/Outputs. This function must serve as a tool for analyzing all of the information obtained about training strategy options to make sure that the option selected is cost-effective and affordable. An ideal feature of this function would be to provide training designers with the capability to assess rapidly the effects of varying the design features of a device on its relative cost-effectiveness. The cost of a device or mix of devices can be reduced by designing it to increase the efficiency of training, thereby reducing the number of devices required. For example, instructional support features can be included in the design of a device to increase its efficiency by reducing administrative "down time".

The information which must be derived from this function to support fully the comparison of training device alternatives is listed below. This list reflects both the ideal goal of selecting the best option and the more practical goal of avoiding the more inferior options.

- An estimate of the life cycle cost of implementing particular training strategies
- Comparisons of the relative costs of implementing strategy options

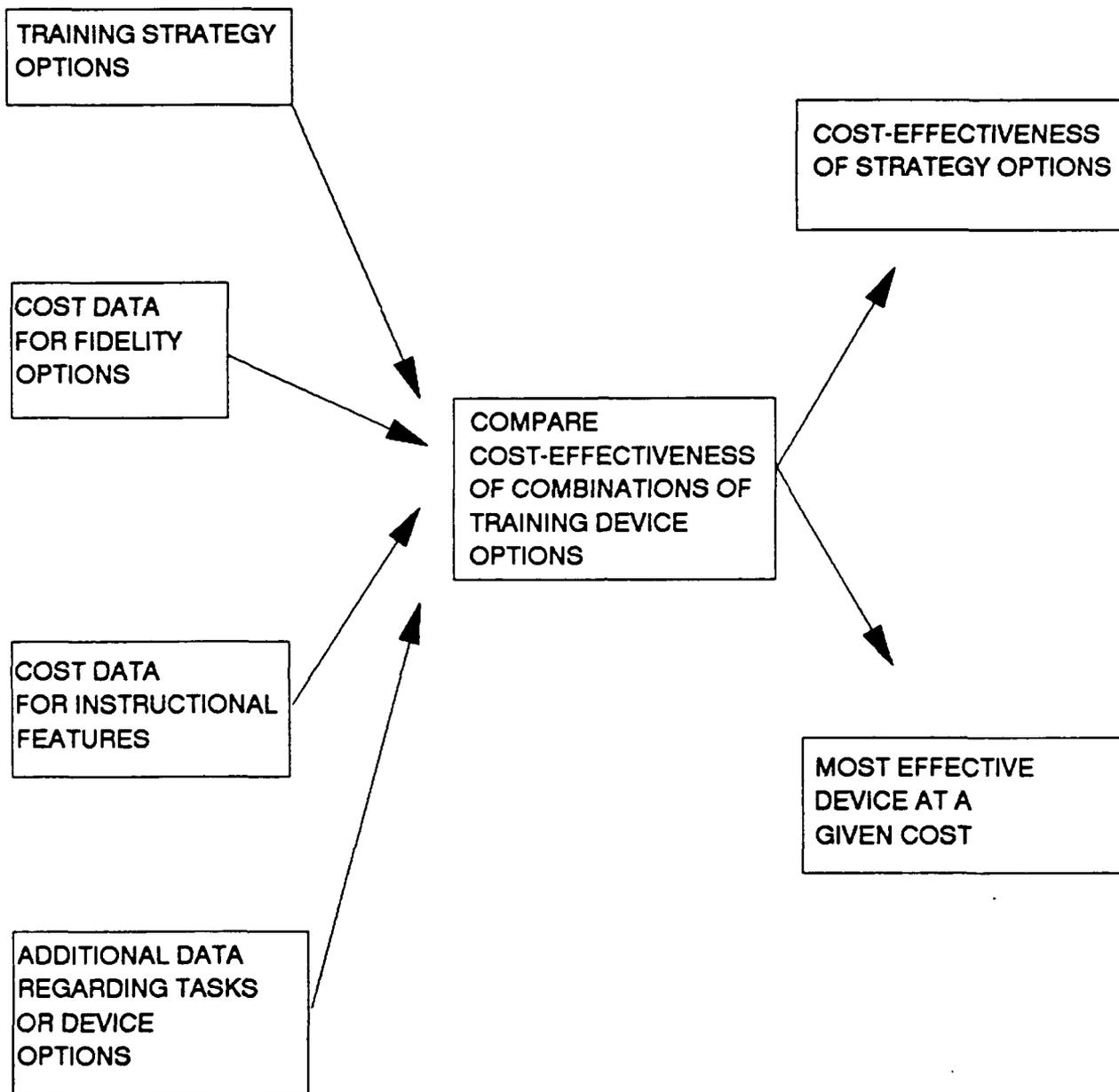


Figure 6. Training Strategy Comparison Function for estimating relative cost-effectiveness of training strategies.

- Changes in the cost of implementing a training strategy resulting from shifting selected tasks from one training device to another
- Changes in the cost of implementing a training strategy resulting from the addition or deletion of instructional support features.

Benefit Analysis. The Training Strategy Comparison Function will contain data bases and decision rules which can be used to:

- compare cost estimates of alternative training strategies which include major training device options;
- provide reasonably valid estimates of the cost of training on a new system for incorporation within budgeting requests; and
- identify strategies which tend to be the least cost-effective

Inputs. In order to price various training strategies and compare their effectiveness, this function must be capable of accepting from other sources, storing, or developing data on the amount of time and resources required to meet training objectives using various training devices and products. In addition, this function must be able to access or store information about the environments in which training products and devices are expected to be used. Information such as number of students and course length is required to estimate the number of training devices required.

Data from the FEA Function would also be used by the Training Strategy Comparison Function. Data currently produced by the FEA process include information such as estimates of frequency with which soldiers must be trained on specific individual and collective tasks to sustain performance. Such information is critical in determining annual resource requirements for training.

Finally, this function again requires life cycle cost estimates of training device options, fidelity levels, and instructional support features.

Developmental Risk Analysis. It is within the Training Strategy Comparison Function that the interface with existing training development aids is greatest. OSBATS, in particular, performs many (but not all) of the activities required. The following activities, however, are not performed by any existing aids and would need to be developed.

- A tool is required to compare the cost-effectiveness of embedded training with other options. This should include both fully embedded training (all training hardware and software are a relatively permanent part of the operational weapon system) and strap-on embedded training (training hardware and software temporarily interface with the operational weapon system).
- A tool for estimating the cost of collective training must be developed. A substantial portion of information requirements unique to collective training which are needed to accomplish this expansion are in the form of outputs of the ARTEP Development Function (such as information regarding the integration of specific individual and collective tasks). The Standard Army Training System (SATS), when developed, may at least partially satisfy this need (U.S. Army Training and Doctrine Command, 1989)
- Tools for training device selection and resource allocation must be developed which include the unit, as well as the institutional, training environment. This expansion is necessary to insure that accurate estimates of the number of training devices required will be developed. For example, the Resource Allocation portion of the OSBATS constructs schedules based upon training methods and resources available within an institution, and these resources and methods differ between schools and the operational environment. Further, training constraints and practices vary among operational units in ways which influence both the need for training devices and products and the ability to use these devices. A tool is required which incorporates unit training variables which influence the relative cost-effectiveness of device options.
- Techniques for developing life cycle cost estimates instead of, or in addition to, developmental costs are required.

Work Required to Implement Model

Implementation of the Early Training Strategy Development Model requires that research first be conducted to answer the questions listed below. As indicated in parentheses, most of these issues are already being addressed by various ARI Field Units.

- What are the unit training environment variables that influence individual and collective training in units, and what are the effects of these variables? (The Presidio of Monterey and Fort Benning Field Units are addressing these issues in the context of efforts to examine the relationships between home-station and CTC training.)
- What general approach should be taken to integrate ET guidelines with the OSBATS concept?
- What device options and instructional support features support the integration of individual and collective training?
- What device options and instructional support features aid in the conduct of combined arms training? (This issue is being addressed by the Fort Knox and PM TRADE Field Units.)
- What rules should guide the application of semi-automated forces in the design of collective training devices? (The Fort Knox Field Unit may address this issue in future years.)
- What are the fidelity requirements for conducting collective and combined arms training in a simulation networking environment, and which collective and combined arms tasks can be trained cost-effectively in a simulation networking environment? (The Fort Knox and PM TRADE Field Units are addressing these issues.)
- What general approaches should be taken to integrate decision rules and databases regarding additional training device options with the OSBATS? (This issue is being addressed by the ARI PM TRADE Field Unit)

Summary

A truly top-down approach to defining a training system architecture must be directed towards supporting collective performance in the field. The scope of the architecture must reflect a consideration of practical concerns such as the large number of individual and collective training requirements to be addressed, integration of training device design with weapon system design, integration of individual and collective training, the compatibility of training devices and products with the complex training environment, and cost constraints.

Consideration of alternative training devices and device design features early in the development of a new weapon system should insure that affordable and cost-effective training device options are selected. No mechanism exists to support such considerations early or otherwise, due to gaps in available decision rules and databases. However, the ASAT, OSBATS, ET guidelines, and MANPRINT Product Four provide an important beginning to the development of the needed mechanism. Refinement of the concept described in this report will help to make early training strategy development a reality.

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