

Technical Report 645

# A Critical Review of Front-End Analysis Procedures Employed in the Army Maintenance Training and Evaluation Simulation System (AMTESS)

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U. S. Army

Research Institute for the Behavioral and Social Sciences

July 1984

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARI Technical Report 645	2. GOVT ACCESSION NO. AD A159362	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) A CRITICAL REVIEW OF FRONT-END ANALYSIS PROCEDURES EMPLOYED IN THE ARMY MAINTENANCE TRAINING AND EVALUATION SIMULATION SYSTEM (AMTESS)		5. TYPE OF REPORT & PERIOD COVERED Final Report June 1982-June 1984
		6. PERFORMING ORG. REPORT NUMBER SAI 84-01-178
7. AUTHOR(s) John C. Woelfel, Paul J. Duffy, Kenneth W. Unger, and Robert W. Swezey (SAI); Robert T. Hays and Angelo Mirabella (ARI)		8. CONTRACT OR GRANT NUMBER(s)  MDA 903-83-C-0101
9. PERFORMING ORGANIZATION NAME AND ADDRESS Science Applications, Inc. 1710 Goodridge Drive McLean, VA 22102		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS  2Q263744A795
11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Army Research Institute for the Behavioral and Social Sciences 5001 Eisenhower Avenue, Alexandria, VA 22333-5600		12. REPORT DATE July 1984
		13. NUMBER OF PAGES 90
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)  --		15. SECURITY CLASS. (of this report)  Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE --
16. DISTRIBUTION STATEMENT (of this Report)  Approved for public release; distribution unlimited		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)  --		
18. SUPPLEMENTARY NOTES  Angelo Mirabella, Contracting Officer's Representative.		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number)  Front-end analysis procedures      Maintenance training AMTESS      Guidelines Generic training simulators		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number)  This report is divided into two parts. Part I contains a detailed critical review of the AMTESS front-end activities performed by the government and by government contractors. Part II contains a set of guidelines to assist government agencies in designing and implementing front-end activities in developmental efforts similar to AMTESS.		

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**Office, Deputy Chief of Staff for Personnel  
Department of the Army**

**July 1984**

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**Army Project Number  
2Q263744A795**

**Training and Simulation**

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## FOREWORD

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↖ In 1977, the Army conducted an investigation of the feasibility of using reduced-physical-fidelity training devices for maintenance training rather than the actual equipment then in service (Durall, Spears, & Prophet, 1978). The results of that effort indicated that reduced-physical-fidelity trainers were appropriate for training a number of maintenance tasks. The positive recommendation for reduced-physical-fidelity trainers led the Army to embark on development of the Army Maintenance Training and Evaluation Simulation System (AMTESS), an effort designed to provide the Army with more cost- and training-effective maintenance simulators.

By 1981, the Army had received two prototype maintenance simulators. In a previous report, Criswell, Unger, Swezey, and Hays (1983) provided an historical review of the AMTESS effort. The purpose of this report is to provide a case study of the front-end analytic activities which led to the construction of prototype AMTESS simulators. Based on this case study, the report suggests improvements in the front-end analysis procedures which can be used to guide future AMTESS-like efforts.

*Edgar M. Johnson*

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Technical Director

see p 4

# A CRITICAL REVIEW OF FRONT-END ANALYSIS PROCEDURES EMPLOYED IN THE ARMY MAINTENANCE TRAINING AND EVALUATION SIMULATION SYSTEM (AMTESS)

## EXECUTIVE SUMMARY

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### Requirement:

The Army Maintenance Training and Evaluation Simulation System (AMTESS) represents an initiative to develop generic maintenance training simulators which are cost effective and training effective. The purpose of this report is (1) to review and evaluate the front-end analysis (FEA) procedures performed in Phase I of the AMTESS project, and (2) to provide a series of general guidelines for conducting front-end analyses for future maintenance training device development.

### Procedure:

The procedure used in this report involved a thorough review of existing AMTESS documentation as well as pertinent training literature. In particular, three types of documentation were reviewed including government documentation (e.g., military training device doctrine and related studies), AMTESS requirements documents and reports, and pertinent device evaluation reports. The major focus on this review was upon the FEA activities performed by four AMTESS contractors (Grumman Aerospace Corporation, Honeywell Systems and Research Center, Hughes Aircraft Company, and a consortium composed of Seville Research Corporation and Burtek, Inc.) and by the Army. This review of FEA activities was guided by the following four criteria: (1) clarity of requirements, (2) completeness of performance, (3) effectiveness of coordination, and (4) preparation for device construction (AMTESS Phase II) and evaluation.

### Findings:

With respect to clarity of requirements, it was found that all four contractors developed very similar device concepts, suggesting that the initial requirements were clear. The major area in which the AMTESS 1 Request for Proposal (RFP) lacked clear guidance was task selection which, in turn, had a serious impact on device evaluation. Also, the RFP specification that AMTESS would be an "adjunct" to and "supplement" conventional maintenance training appeared to cause confusion regarding task selection.

In terms of completeness of performance, the results showed that two contractors, Grumman Aerospace Corporation, and Honeywell Systems and Research Center, produced all that was requested in the AMTESS Phase I effort. Seville Research Corporation also was responsive, with the exception of providing a device evaluation plan (although Seville previously had provided such a plan in its preliminary feasibility study prior to AMTESS Phase I). Hughes' performance was marked by a task analysis which was only somewhat responsive.

Also, Hughes did not provide a mini-program of instruction and specific 3-D training modules as required.

The results showed that effectiveness of coordination was very good in AMTESS Phase I, but coordination appeared to be less effective during subsequent stages of the project due to increases in the number of agencies involved, personnel turbulence, unanticipated delays, and shortcomings in coordination procedures.

AMTESS Phase I demonstrated that the concept of generic maintenance training simulators is sound, and detailed device designs were produced. However, in terms of preparation for subsequent development, it was found that only a general plan for device acceptance existed, which did not provide sufficient guidance for in-plant inspections of the devices. Also, there was no detailed evaluation plan for determining the training effectiveness of the devices agreed upon by the government.

#### Utilization of Findings:

Part II of this report presents guidelines within each of seven types of FEA procedures, some of which were conducted in AMTESS and some of which were not performed in AMTESS. These guidelines are not presented as step-by-step procedures for use in training device development efforts. Rather, they provide useful guidance to a range of FEA activities, which may be applicable to future development efforts such as AMTESS.



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PART I

Review of Front-End Analysis Activities

## A. Introduction

The Army Maintenance Training and Evaluation Simulation System (AMTESS) represents an attempt to define new concepts in the area of maintenance training (Dybas, 1981; 1983; Evans & Mirabella, 1982; Hofer, 1981). Traditionally, Army students receive maintenance training on operational equipment. However, this type of training may be counterproductive for several reasons:

- Equipment may be damaged during training.
- Students may be injured during operation of hazardous equipment.
- Availability of operational equipment for training purposes is often limited.
- Actual equipment trainers (AET) may be less cost effective than simulated maintenance equipment.

As an effort to investigate the entire process of specifying, designing, and procuring training devices, the AMTESS program had several objectives. One of the Army's objectives for the AMTESS program was to develop a family of simulators for maintenance training so that some of the problems which occur with operational equipment training would be relieved. Another objective was to develop generic trainers which could be used to train and evaluate maintenance procedures and tasks for all major maintenance functional areas. Other objectives were to develop cost-effective, training-effective, generic maintenance trainers which would:

- Support introductory training in a school setting
- Support proficiency training
- Provide self-paced, flexible training
- Provide feedback
- Record and display performance data

- Provide for automatic administration of skill qualification tests (SQTs)
- Adapt to a range of Army needs
- Use recent advancements in microcomputers, video storage, and interactive graphics

The AMTESS project was sponsored by the Army's Project Manager, Training Devices (PM TRADE). PM TRADE's AMTESS developmental program consisted of two phases. During the first phase, new training device concepts were developed. During the second phase, prototype devices were constructed and evaluated. As a part of Phase II, the U.S. Army Research Institute (ARI) was tasked to conduct an evaluation of the prototype models. This evaluation was undertaken as part of a larger effort termed SIMTRAIN. This was accomplished by a contractor team originally consisting of Honeywell, Inc. and Science Applications, Inc. (SAI), and later by SAI alone (Evans & Mirabella, 1982; Unger, Swezey, Hays, and Mirabella, 1984)

The Army's first SIMTRAIN project (termed SIMTRAIN I) centered around issues involved in the acquisition of training devices. More specifically, SIMTRAIN I had the following objectives:

- Develop better methods for determining training device requirements and characteristics (Kane & Holman, 1982),
- Establish procedures to integrate training devices into training systems and develop procedures for determining simulation fidelity requirements (Baum, Riedel, Hays & Mirabella, 1982), and
- Perform an empirical AMTESS transfer-of-training evaluation (Unger, Swezey, Hays, and Mirabella 1984).

An expanded effort, termed SIMTRAIN II, continues the evaluation and includes systematic extensions of previous AMTESS experiments. The present report is the second report of the SIMTRAIN

II project. The first report (Criswell, Unger, Swezey, and Hays, 1983) recounted the history of AMTESS from the first RFP to evaluation of the training devices developed as part of the project.

The Criswell, Unger, Swezey and Hays (1983) report was broad in scope tracing the entire history of the AMTESS experience and describing the role and evaluation of the performance of participating organizations including government agencies, device contractors, and evaluation contractors. The present report is more focused in scope. The purpose of this report is to examine the front-end analysis (FEA) procedures performed by the government agencies and contractors involved in the AMTESS effort and to measure their impact on the performance and utility of the AMTESS training devices.

#### B. Purpose of This Report

AMTESS represents a departure from traditional training device procurements, since AMTESS was an experimental research and development effort designed to develop new insights into the process of device acquisition. While front-end analysis is important in all new training efforts, it is particularly critical for the AMTESS situation, since this is such a new training concept. The AMTESS training devices are generic training devices in which combine two-dimensional media (e.g., CRT monitors, video-disc projectors) with three dimensional "plug-in" mock-ups of actual equipment driven by a common microprocessor.

The purpose of this report is to examine the front-end analysis procedures performed for AMTESS. The report has the following major objectives:

- Review and evaluate FEA procedures performed in the AMTESS efforts as a basis for the second objective
- Develop general guidelines for FEA procedures for future training device development procurements



This report is not confined to traditional FEAs such as task analysis and training requirements analysis. Rather, the report considers a variety of activities performed both by the government agencies and the contractors involved in the AMTESS project which helped prepare for the construction and evaluation of AMTESS prototype devices. The timeframe for this report spans the period from Spring 1977 when a feasibility study about AMTESS was conducted to the Summer of 1980 when the contracts to develop the devices were awarded.

The guidelines presented in this report are intended to be broad guides for future front-end analysis in AMTESS-like simulator development efforts. The guidelines are not intended to be detailed procedures for carrying out specific front-end analysis procedures such as task analysis. Other efforts have addressed such issues [see for example Demaree (1961), Miller (1973), Smith (1965), and Wheaton, Rose, Fingerman, Korotkin, Holding, and Mirabella (1976)]. Moreover, numerous guidelines already exist such as the Army's Instructional Systems Development (ISD) model (U.S. Department of the Army, 1975) and the Training Device Requirements Documents Guide (PM TRADE and Army Training Support Center, 1979). Also, the Seville-Burtek Phase II reports (Garlichs, Miller, and Davis, 1983a,b,c) provide a detailed description of their AMTESS specific front-end analysis activities. The strategy of the present report was to develop some general, easy to understand "do's" and "don'ts" based upon a case study of the AMTESS FEA's. While this report is specifically confined to the AMTESS experience, many issues raised here may also be appropriate for other types of projects designed to develop training systems.

The remainder of this report contains the following two parts:

#### Part I

- Overview of relevant FEA literature
- Procedures employed in the present effort
- Results
- Discussion

## Part II

- FEA Guidelines

### C. Overview of Front-End Analysis

The purpose of this section is to provide a brief overview of front-end analysis (FEA) procedures and their role in training device development. This overview provides the context with which to review the AMTESS project.

#### Definition of FEA

A recent workshop of participants selected from several organizational levels from all of the military services and appropriate civilian organizations (Seidel and Wagner, 1980) produced the following definition of FEA:

Front-end analysis (FEA) is a process that evaluates requirements for manpower, personnel and training (MP&T) during the early stages of the military systems acquisition cycle. Its purpose is to (1) determine manpower, personnel and training requirements under alternative system concepts and designs, and (2) estimate the impact of these MP&T requirements on system effectiveness and life cycle costs. Its end-product should be the information needed to assure that effective resources (human, equipment, materiel) will be available when and as required for each system to achieve its intended contribution to military readiness and effectiveness (p. 1).

The results of this workshop also noted that recent policy initiatives (OMB Circular A-109, DoD Directives 5000.1 and 5000.2) are intended to force the timely application of FEA procedures within the overall materiel acquisition process with particular attention to life cycle support.

## ISD Approach to FEA

Training establishments of all military services, including the Army, have adopted the Instructional Systems Development (ISD) model as an overall approach to design, development, implementation, and control of virtually all military training. ISD is intended to be a comprehensive and systematic approach to training. The ISD model involves an interlocking series of five phases (U.S. Department of the Army, 1975). These phases are:

- Analyze
- Design
- Develop
- Implement
- Control

At a molar level, this model is eminently straightforward in concept and intent. One of the key features of the ISD approach is to place appropriate emphasis upon systematic analysis of the entire job performance situation of interest in order to assure that all training solutions are focused on well-documented performance needs.

Within the ISD framework, front-end analysis is a term referring to job and task analysis, selection of tasks for training, and development of job performance measures (U.S. Department of the Army, 1975). Generically, the term FEA is applied to a wide variety of purposes, activities, and products, all of which ostensibly occur early in the ISD process. These FEA activities are critically important to the eventual outcome of applying the ISD model since "if a performance requirement is overdefined or underdefined based on analyses of field conditions, a new weapons system, or other source, the ISD procedures will tend to exaggerate the error" (U.S. Department of the Army, 1975, p. 2).

A variety of types of FEA are available and are conducted, as appropriate, in selected training situations. Among the types of FEA

are the following:

- Task analysis
- Job analysis
- Training requirements analysis
- Fidelity analysis
- Human engineering analysis
- Organization analysis
- Person analysis
- Reliability-Availability-Maintainability analysis
- Safety engineering analysis
- Cost effectiveness analysis
- Training effectiveness analysis

The last phase of the ISD model is referred to as Control. The Control phase includes both an internal evaluation component and an external evaluation component. The internal evaluation component is intended to provide the basis for determining whether the training developed as a consequence of the FEA activities achieved its objectives. The external evaluation component is intended to assure that those who complete the training meet the requirements of the job situation as determined by the findings from the FEA.

In particular, planning for both internal and external evaluation must begin at the earliest stages of the ISD approach in concert with the FEA activities. For instance, internal evaluation requires input from each of the preceding phases of the ISD approach, and the external evaluation requires the internal evaluation results as well as the FEA results. Thus, although evaluation nominally marks the final phase of the ISD approach, it is linked directly to the initial FEA activities.

#### Reviews of FEA Procedures

Wheaton, Rose, Fingerman, Korotkin, Holding and Mirabella (1976) reviewed the diverse and somewhat fragmented literature on

training device effectiveness models, including the FEA procedures involved in these various approaches. They found that most models were prescriptive of training device design based on the FEA procedures employed. For instance, Miller (1954) began by breaking down an operational situation into missions, which were then analyzed to enumerate tasks with respect to their chronological sequence and similarity of content. These tasks were then arranged along one dimension of a matrix and training strategies along the other dimension. Another model which is based on an initial task analysis is that offered by Shettel and Horner (1972), which identified significant learning elements in terms of behavioral categories and then identified training techniques related to each behavioral category. Although both of these methods offer a systematic approach to FEA procedures, they rely upon ambiguous definitions of task detail, and the basic models place heavy reliance on expert judgment.

Apart from the task-analytic approaches noted above, Caro (1970) has presented a method which is designed to identify the commonality between the stimulus-response conditions in a training device and the stimulus-response conditions in an operational situation. This approach requires a detailed analysis of these stimulus-response connections followed by a comparison of the rated degree of fidelity between the training device and the operational situation. Another stimulus-response based model is offered by Altman (1970) from which can be derived an index of net transfer (from training to operational situation). This net transfer index is an algorithmic summation of the various probabilities associated with the stimulus and response elements in both the training and operational situations.

After reviewing these and other models, Wheaton, Rose, Fingerman, Korotkin, Holding, and Mirabella (1976) concluded that:

- None of the models adequately considers both acquisition and transfer aspects.

- Definitions and procedures for data collection and processing tend to be complex and ambiguous.
- There is a tendency to oversimplify the problem, both in terms of the numbers of pertinent factors and the level of analysis.

In addition, their efforts to address these issues resulted in TRAINVICE, a training system model predictive of transfer of training based upon task, device, learning deficit, and instructional feature variables (Tufano and Evans, in press; Knerr, Nadler, Dowell and Tufano, 1983; Swezey, 1983; Swezey and Evans, 1980). Also developed were scales for measuring these variables and a formula for combining the measures into an index value of transfer of training. Other examples of work addressing these issues are the efforts of Schulz and others (Schulz, 1979; Schulz, Underhill and Hargan, 1979; Schulz, Underhill, Hargan and Wagner, 1979; Schulz and Farrell, 1980a,b,c,d,e,f; Schulz and Wagner, 1981).

#### Air Force FEA Procedures

The Air Force has implemented the ISD process through its Handbook for Designers of Instructional Systems (U.S. Department of the Air Force, 1978). This handbook is a detailed, proceduralized guide on how to implement the ISD model with particular emphasis upon task analysis and setting criterion objectives since these two topics often present difficulty. With respect to task analysis, this handbook breaks this process into two principal steps:

- Identifying job performance requirements
- Identifying training requirements

Job performance requirements describe what people must do to perform their jobs. This step is accomplished in the following systematic manner.

- Collect information
- Identify duties, tasks, and subtasks
- Determine which tasks require instruction
- Describe tasks and their activities

Once the job performance requirements have been identified, the next step is to identify training requirements which are specified in terms of the knowledges and skills required to satisfy the job performance requirements. These training requirements represent new knowledges, skills, and proficiency levels which trainees must acquire in order to achieve the job performance requirements. Analysis then identifies those training requirements which require practice and therefore represent training standards.

In general, the Air Force ISD process begins at a very global level (i.e., the job and how it fits within a broad mission) and it is successively refined in greater detail to the specification of training requirements and associated training standards. Underlying this entire process is the orderly compilation and development of information about the job and its components. Included among the sources for this information are:

- Statements of system requirements and functions
- Listings of duties, tasks, and subtasks
- Task data
- Descriptions of task activities and performance standards
- Listings of skills and knowledges
- Resource and personnel data

One of the major differences between the FEA procedures used by the Air Force relative to the other services is a greater emphasis on occupational surveys of job incumbents for identifying the tasks included in a job as well as indicators of activity distribution and criticality of these tasks.

The Air Force has conducted a great deal of work in the area of maintenance training simulators. In common with the other military services, Air Force policy requires application of ISD procedures (including FEA) to development and procurement of maintenance training simulators (Purifoy and Benson, 1979). Although the Air Force prescribes the application of FEA procedures to the development of training simulators, several problems have been identified. For example, the Air Force has found that, in practice, there is a lack of both procedural guidance in performing FEA as well as a lack of detailed task analysis data, particularly for existing weapon systems. In addition, there is a tendency to develop major overall simulators rather than part-task, or lower fidelity devices regardless of the FEA results or general learning principles. With respect to evaluation, Air Force procedures make it a part of the acquisition process, but again, little, if any, systematic guidance is provided on how the evaluation activities are linked to the FEA activities.

#### Navy FEA Approaches

The Navy has also implemented the ISD model, including FEA procedures, in a manner very similar to the other military services (MIL-T-29053, 1977). The Navy's approach includes somewhat more reliance upon subject matter experts (SME) as a principal source of job and task data than do the other services.

#### Additional Sources of FEA Procedures

A recent compendium of procedures, methods, and tools applicable to FEA represents a reasonably complete collection of references on FEA throughout the weapon system acquisition process (Dynamics Research Corporation, 1982). A total of 444 references are reviewed within the following 12 categories.

- Acquisition Process
- Cost
- Equipment



- Front-End Analysis
- Human Factors
- Logistics
- Manpower
- Manpower, Personnel, and Training.
- Personnel
- Software
- Training
- Data Bases

As noted, this compendium was assembled against the backdrop of the overall weapon system acquisition process.

As documented by the references in this compendium, there are a variety of methods and procedures which can be applied in the execution of FEA. For instance, there are automated procedures and non-automated procedures, and some procedures are highly structured while others are less structured. Also, ARI is involved in an ongoing effort designed to develop an automated procedure for extracting information from SME's to aid training designers and course developers in making decisions about what to train, where to train, and how to train. In general, however, these various procedures are intended to determine the specific need for training, identify the task/skill areas to be trained, select from alternative methods of instruction, and make a preliminary assessment of the cost and training effectiveness of the alternative chosen.

Of more direct relevance to the current report is the Training Device Requirements Documents Guide (PM TRADE and Army Training Support Center, 1979). Major portions of the TRAINVICE model noted above were implemented in this guide. The purpose of this guide is to present the structured procedures for responsible project officers within TRADOC schools who prepare training device requirements documents. Included among these procedures are FEA activities. The FEA activities documented in this Guide are concerned with evaluating a training need to determine if it is a training requirement, and

specifying these training requirements in terms of tasks, skills, and objectives. Following specification of training requirements, a media selection analysis is performed to determine if a training device requirement is appropriate.

After identifying the general requirements for a training device, the following analyses are conducted to identify what kind of training device is required:

- task commonality analysis
- physical similarity analysis
- functional similarity analysis
- skill and knowledge requirements
- task training difficulty analysis
- training device effectiveness analysis
- cost analysis

The outputs of these various analyses then are evaluated in greater detail to determine which of the following requirements documents are appropriate:

- Training Device Letter of Agreement (TDLOA) or a Commercially Available/Fabricated Training Device Requirement (CAFTDR) document
- Training Device Requirement (TDR) or a Training Device Letter Requirement (TDLR)

The choice between each of these pairs of requirements documents is based on specified cost and scheduling parameters, and the various choices result in different levels of approval authority and budgetary authorizations. These decisions also establish the broad decision criteria for whether a Joint Working Group should be formed to articulate issues and outline developmental strategies. Essentially, the procedures in the Training Requirements Documents Guide are directed at the formulation of training device requirements

documents with minimal reference to actual development and eventual evaluation of the device itself.

Among the conclusions reached by the various participants in the invitational workshop noted previously (p. 6) were the following (Seidel and Wagner, 1980):

- There are major differences among the service efforts in maturity of effort, level of detail, and applicability.
- There is a substantial need for standardized definitions of such terms as task analysis, measures of effectiveness, measures of cost, and transfer of training.
- The services have substantial information about FEA which should be compiled and made more available.
- No FEA's have been validated.
- Managerial and institutional aspects of FEA deserve more attention to include recognizing and strengthening the incentives for program managers to identify roles for R&D managers and training developers.

In summary, although there is a relative abundance of information on the topic of FEA, the area nonetheless is in some disarray. There is basic agreement on the need for several principal FEA components such as task analysis, training requirements analysis, and fidelity analysis (in the case of training devices). However, there exists a variety of methods for performing these activities. These methods often vary in the level of detail and systematization required for their execution. More importantly, FEA activities typically are focused primarily on the design and development of training rather than on providing a clear linkage to evaluation activities. Portions of the SIMTRAIN I project were designed to address this absence of procedural guidance (Eberts, Smith, Dray and Vestewig, 1982), and ARI research to close this gap further is underway.

This section has presented a brief overview of FEA procedures from a theoretical as well as operational perspective in order to show the importance of their role in system acquisition and training device development. In subsequent sections of this report, the FEA procedures which were performed in the AMTESS project are reviewed and discussed.

#### D. Procedures

Since this report addresses AMTESS FEA activities which occurred as many as 6 years ago, the principal method employed was a review of existing AMTESS documentation. This section describes the documents which were reviewed for this task and the procedures employed for analyzing this information.

##### 1. Documents Reviewed

Three types of documents were reviewed for this report. These were:

- Relevant Army doctrine and related government documentation
- AMTESS requirements documents and reports
- SIMTRAIN requirements documents and reports

Each of these sources is discussed in more detail below.

a. Government Documentation. Although this report deals exclusively with FEA within the context of the AMTESS development process, the overall AMTESS initiative exists within the broader context of military training procedures (e.g., U.S. Department of the Army, 1975) and training device development (e.g., PM TRADE and Army Training Support Center, 1979). Thus, existing documentation regarding Army doctrine applied to training device development procedures was reviewed. Also, this source of information included related studies

and analyses on the topic of training device development (Dynamics Research Corporation, 1982).

b. AMTESS Documents. The second source of information included relevant documentation from the AMTESS initiative itself. For example, the Request for Procurement (RFP) and associated Statements of Work (SOW) for the AMTESS I effort was included in the review. This category also included the complete final reports of the four AMTESS I contractors (i.e., Grumman Aerospace Corporation, Honeywell Systems and Research Center, Hughes Aircraft Company, and a consortium consisting of Seville Research Corporation and Burtek, Inc.). Other relevant documentation items included in this category were the recorded minutes of advisory group meetings as well as notes and working file materials from individuals involved in the AMTESS effort. (These latter materials, due to their informal nature, were used primarily for background information).

c. SIMTRAIN Documents. The third category of information included the following two documents:

- Draft final report of the SIMTRAIN I transfer-of-training evaluation effort (Unger, Swezey, Hays, and Mirabella, 1984)
- Task 1 report of the SIMTRAIN II effort. (Criswell, Unger, Swezey, and Hays, 1983)

The second of these documents, the SIMTRAIN II Task 1 report, is based on a series of interviews with various individuals and organizations involved in the entire AMTESS effort, and as such, represents the only primary information for the present study.

All documents reviewed in the present study are listed in the References section of this report.

## 2. Analysis Procedures

In reviewing these materials, the major focus was upon the FEA activities prescribed by the AMTESS I contract and conducted by the contractors (i.e., Grumman, Honeywell, Hughes, and Seville-Burtek). Given that FEA procedures are a component of the entire ISD process (and, therefore, the training device development process), this review extends beyond FEA activities themselves which were performed primarily by the contractors to include activities performed by the government.

The criteria chosen to guide this review were:

a. Clarity of Requirements. This criterion is applied exclusively for reviewing the performance of the government in laying out the requirements for AMTESS I in the AMTESS I RFP. Clarity of requirements deals with the extent to which the RFP provided sufficient and appropriate guidance based on the deliverables produced at the completion of AMTESS I.

b. Completeness of Performance. This criterion is applied primarily for reviewing the performance of the AMTESS device development contractors since their performance was designed to fulfill the terms of their contract. The standard applied to completeness of performance in this context is the extent of compliance with contractual requirements.

c. Effectiveness of Coordination. Given the scope and implications of the AMTESS initiative, there are a number of separate organizations which are, or have been, involved in AMTESS, including the FEA activities. Therefore, the third criterion addressed matters of coordination among these organizations.

d. Preparation for AMTESS II/SIMTRAIN I. The main purpose of AMTESS I was to develop device concepts for the development of the prototype training devices (AMTESS II) and their evaluation (SIMTRAIN

1). Since at the end of the AMTESS I effort only a portion of the overall developmental process had been completed, it is therefore necessary to examine AMTESS I within the broader context of both AMTESS I and II. Essentially, this means assessing the relationship between what was done in AMTESS II and what was produced in AMTESS I.

## E. Results

This section describes various front-end analytic activities implemented prior to and during the AMTESS I project. As noted earlier, the scope of this effort has been defined broadly to include various aspects of FEA beyond task analysis and training requirements analysis. The events covered in this section encompass the period from May 1977 (the initial study advisory group (SAG) for maintenance training meeting) and July, 1980 (the delivery of AMTESS I final reports by the contractors).

The section begins with a brief history of the activities during this period (see Criswell, Unger, Swezey and Hays, 1983 for more detail). It then provides a discussion of key documents produced during the period.

### 1. History of AMTESS Front-End Activities

This section outlines events which took place prior to the building of the prototype AMTESS training devices, and which set the stage for the construction of these devices. Table 1 contains a summary of these events.

Government activities leading up to the procurement for the prototype devices can be traced back at least as far as the Spring of 1977 when an RFP was issued to conduct a study of the feasibility of using reduced physical fidelity trainers for maintenance training. In May of 1977 the initial Maintenance Training Study Advisory Group (SAG) meeting was held to review the proposals received in response to the RFP. The SAG consisted of members of PM TRADE and the U.S. Army Training Support Center (USATSC).

TABLE 1  
PRE-AMTESS II MILESTONES

	1977	1978	1979	1980
Jan			AMTESS schedule revised due to delay in RFP - now scheduled to end in Sept 1981	ARI evaluation plan submitted to FM Trade
Feb				
March		SAC* expended to include Armor and Ordnance school	AMTESS I RFP issued	FM Trade responds to evaluation plan. AMTESS I results briefing.
April				
May	1st SAC* reviews RFP feasibility proposals	USATSC maintenance training conference. FM Trade announced as AMTESS project leader. Missile training requirements letter prepared by Missile Munitions Center & Air Defense School	AMTESS I proposals reviewed by JWC*	AMTESS II proposals reviewed by JWC*
June				
July		12 agencies invited to join AMTESS JSAC* project scheduled for completion January 81		AMTESS I final reports completed by contractor and submitted to FM Trade
Aug	Seville RFP feasibility study begins			
Sep		Seville final report on RFP feasibility study submitted to FM Trade	AMTESS I begins - Grumman, Honeywell Hughes, and Seville. Brief JWC* about work plans	
Oct				
Nov				
Dec				

\* The acronyms SAC, JSAC and JWC refer veriously to the group(s) convened to oversee and advise FM TRADE in the AMTESS efforts.



A contract was awarded to the Seville Research Corporation to develop alternative conceptual designs of reduced physical fidelity trainers that might be cost effectively substituted for actual equipment trainers. During the course of Seville's effort, periodic SAG meetings were held to review findings. During this period, the SAG was expanded to include both the original two agencies, PM TRADE and USATSC, and representatives from the Armor School and Ordnance Center.

In May of 1978, USATSC sponsored a maintenance training requirements conference at Ft Lee, VA. The conference activities included a discussion of reduced physical fidelity trainers as substitutes for Actual Equipment Trainers (AET). There were two important outcomes of this meeting. One outcome was that U.S. Army Air Defense School (USAADS) and U.S. Army Missile Munitions Center and School (USAMMCS) developed a letter requirement for maintenance trainers for an Improved Hawk maintenance trainer. The letter contained a statement of maintenance training needs and the principal characteristics desired in a modular training device for Improved Hawk Equipment. This letter became an input for the AMTESS I RFP. A second outcome was that PM TRADE was announced as the agency to coordinate and manage the contract designed to procure the initial reduced physical fidelity trainers.

In July of 1978, PM TRADE invited a number of agencies to send representatives to a Joint Study Advisory Group (JSAG) to assist with the procurement for the training devices. An initial schedule released at this time indicated that the prototype devices would be delivered by September, 1980 with subsequent evaluation of these devices completed by January, 1981.

The first JSAG meeting was held in August of 1978. The major agenda item was to agree upon objectives for the AMTESS I RFP. The RFP was released subsequently in March of 1979. Since the release date of the RFP was several months behind the previously scheduled release date of October, 1978, the project schedule was revised to

reflect prototype delivery in April, 1981 and completed evaluation by September, 1981. It should be noted that in the Fall of 1978 the JSAG was retitled the Joint Working Group (JWG).

Prior to the release of the AMTESS I RFP (January, 1979), PM TRADE had circulated a Memorandum of Understanding (MOU) for signature by representatives of the following agencies:

- PM TRADE - Project Manager Training Devices
- USAADS - U.S. Army Air Defense School
- USATSC - U.S. Army Training Support Center
- USMMCS - U.S. Army Missile Munitions Center & School
- USOC&S - U.S. Army Ordnance Center and School

The MOU was intended to outline the respective tasks of the JSAG member agencies and to formalize their relationships. No fully signed copy of the MOU could be obtained, therefore, it is not clear which agencies actually signed the MOU.

The proposals for the RFP were evaluated in June of 1979 and the contracts began in September with oral project plans presented by the four winning contractors, Grumman Systems and Research Center, Honeywell Aerospace Corporation, Hughes Aircraft Company, and a team of Seville Research Corporation and Burttek, Inc.. At this time, another revised project schedule was released. This schedule projected prototype delivery in July of 1981, with evaluation complete by December of 1981. Subsequent to the award of the AMTESS I contracts, the U. S. Army Research Institute (ARI) agreed to participate in preparing an evaluation plan for evaluating the prototype devices. In December of 1979, ARI officially accepted a role in the evaluation of the devices by signing the MOU although ARI was not involved in the initial planning for the development and evaluation of the devices. In January of 1980, ARI delivered to PM TRADE their proposed evaluation plan. (This plan is described in a subsequent section of this report).

In March of 1980, the contractors presented oral briefings of the results of the AMTESS I effort. By July, 1980, all contractors had submitted their final reports, thus completing the front-end activities leading up to the development of the prototype simulators.

The next part of this section provides reviews of the seven key documents produced prior to AMTESS II along with a summary of a critical coordination event, the "kick-off" meeting for the official AMTESS I contractual effort.

## 2. Review of Key Documents

a. Seville Feasibility Study. Seville was contracted by PM TRADE prior to the preparation of the AMTESS I RFP to conduct exploratory research concerning reduced physical fidelity trainers. According to the final report for that project (Durall, Spears, & Prophet, 1978) the effort had the following two purposes:

- Develop conceptual descriptions for a variety of reduced physical fidelity training devices that might be cost effectively substituted for AET, and
- Develop an evaluation methodology for determining the training effectiveness of the conceptual devices should they be developed and provided by the Army.

The first task Seville undertook in the effort was to investigate the use of AET's in maintenance training and to identify those potential AET replacement areas. Based on these findings, Seville then evaluated existing reduced physical fidelity alternatives and began the development of the new reduced physical fidelity concept.

Seville's examination of current Army maintenance training was confined to automotive, track vehicle, and heavy equipment maintenance training. One key finding in this area was that there was an overlap

of training across some of these areas. In particular, automotive (MOSs 63H10 and 63H20) and heavy equipment mechanics (MOSs 62B10 and 62B20) receive training in maintenance of both wheeled and tracked vehicles. Furthermore, MOS 63C10 (track vehicle mechanics) received training on wheeled vehicles.

Based on their analysis, Seville recommended four areas be addressed in examining reduced physical fidelity alternatives. These four areas included the following:

- Troubleshooting engines and related systems
- Troubleshooting track vehicle track/suspension systems
- Removal/replacement of engine and power packs
- Troubleshooting turret electrical and hydraulic systems

The first three of these areas are the responsibility of wheel and track vehicle maintenance personnel while the fourth is the responsibility of the turret mechanic.

Seville next examined existing reduced physical fidelity alternatives for training in these areas. Surprisingly, they uncovered only one reduced physical fidelity device to be in current use, the flat panel systems simulator (FPSS). According to Seville "these devices are used primarily in teaching system troubleshooting tasks in maintenance training and in teaching procedural tasks for operator training (Durall, Spears, and Prophet, 1978, p.19)." Seville found that FPSSs are infrequently used for teaching motor and cognitive tasks of the type performed in the equipment maintenance tasks they had reviewed.

The Seville report suggested that FPSS would have some utility for AET substitution in troubleshooting engines and turret electrical and hydraulic systems. However, they saw much more limited utility for tasks such as engine removal or troubleshooting track/suspension systems.

With this review complete, Seville set out to develop new reduced physical fidelity concepts. The strategy of the reduced physical fidelity device was to "bridge the gap" between AET which is the primary vehicle for hands-on training and simulators which primarily train diagnosis and troubleshooting. The reduced physical fidelity device would be a hybrid containing a 3-D mock-up of the equipment (for training motor tasks) a FPSS for troubleshooting (e.g., inspecting gauges, reading meters), and a microprocessor for coordinating all instruction. This basic system would have the capability of training many maintenance tasks, although each of the three components would not necessarily be required for training each task.

Seville designed a straightforward method for evaluating the reduced physical fidelity devices. The basic strategy was to evaluate the reduced physical fidelity device relative to AET and relative to alternative reduced physical fidelity devices. The design was a three way analysis of variance which included training device (reduced physical fidelity, AET, other), mode of instruction (lock-step, individually paced), and trainee characteristics (2 to 4 levels). The major criteria for trainee characteristics were aptitude and experience. Seville felt that trainees could be stratified into two to four levels on these characteristics. Seville also noted that a technique for assigning instructors would need to be developed and suggested that a control for training site might be required.

The criterion measures for evaluating the devices fell into the following three categories:

- Specific measures taken in close approximation to the training
- Actual performance on the job
- User acceptance of the devices

Seville's evaluation plan did not treat sample sizes required or amount of time required, nor did it discuss potential problems related to testing in a field environment.

b. AMTESS I RFP. The AMTESS I RFP (DAAK51-79-Q-0018) laid the foundation for the prototype devices delivered during AMTESS II. The purpose of AMTESS I was to "conceptually design a modular maintenance trainer" and to "provide an economic impact assessment of the effects of the introduction of the AMTESS into the Army maintenance program" (p. 26). The RFP prescribed the front-end analysis procedures to be conducted for the conceptual design of the training device, although no reference was made to any particular method or model (e.g., ISD) for conducting the FEA.

The RFP for AMTESS I was specific in terms of the type of training device desired. The device was to be computer-based with flexible, easy to operate, easy to program software. The device was to include a hands-on-training capability. The device was to be modular so that components could be interchanged easily.

The RFP pointed out the Army's philosophy for the use of AMTESS. It stated that the AMTESS concept "is seen as an adjunct to primary instruction" and as such "it should be designed to be a cost and training effective system supplementing/modifying the maintenance training presently taught" (p. 26).

The RFP presented three specific tasks to be performed "prior to" the design of the training device. The three traditional front-end analysis procedures included task analysis, training requirements analysis, and fidelity requirements analysis. A fourth task, design of the device concept, was to include an initial plan for evaluating the device and an economic assessment of the device in terms of life-cycle costs over a 15 year period. Each of the four tasks is described in more detail below.

(1) Task Analysis The purpose of the task analysis was to select two sets of tasks, one set from three automotive maintenance MOSs (63B, C, and H) and the other set from two missile maintenance MOSs (24C and K). These tasks would be the tasks to be tested on the prototype device.

The instructions in the RFP were to perform two separate task commonality analyses, one for each maintenance specialty (automotive and missile). Contractors were tasked to "classify into sets those tasks that require the same, or very similar behaviors with the same class of equipment" (p. 28). For each set of common tasks, contractors were instructed to "select sample tasks to represent the whole set" (p. 28). From these sample tasks, contractors would select a sufficient number to be taught during AMTESS II using the prototype training device. The RFP indicated that lists of tasks could be derived from government furnished data such as Soldier's Manual, Commander's Manual, applicable maintenance manuals, and Program of Instruction.

The RFP did not define what constituted "commonality" for purposes of classifying tasks. The only guidance offered for selecting sample tasks from the common classifications was to select tasks that "from a cost and training effective viewpoint, best lend themselves to simulation" (p. 28).

(2) Training Requirements Analysis. The purpose of this task was to "structure a mini-program of instruction (MPOI) to be used in the test and evaluation" (p. 28) of the training devices. Essentially, the MPOI was to be designed to train the maintenance tasks selected during the task analysis. The MPOI, according to the RFP, should interface with present instruction. However, the MPOI was not required to parallel the existing POI. The primary purpose of the MPOI was to "support the test of the hardware concept."

The MPOI was to describe the role of the student, the role of the instructor, and the role of the simulator. It also was required to include how the time of instruction would be spent by the student.

(3) Fidelity Requirements Analysis. The purpose of this task was simply to determine the degree and kinds of simulation fidelity required by the training device to train the tasks selected in Task 1 following the MPOI outlined in Task 2.

(4) Design of Modular Systems. The final task of the effort was to "develop a cost and training effective concept for a modular maintenance training system to be used at institutional and unit training" (p. 29). Along with the design of the device, the contractors were instructed to provide the following three additional pieces of information:

- Recommendations on how the prototype model of the concept can be evaluated
- Economic assessment of the device over 15 years and
- Trade-off analysis concerning the fidelity, expectations of transfer of training, and the relative costs involved with the concept

c. AMTESS I Kick-off Meeting. This meeting was held over the three day period 18-20 Sep 79. A major agenda item entailed each contractor presenting its contract performance plan to the Joint Study Advisory Group members. During their presentation, contractors were encouraged to raise any concerns or questions about the AMTESS I effort. Contractors, in turn, were made aware of the procedures for obtaining relevant documents and information from the Army, particularly from the schools. Contractors were cautioned about following advice from government representatives except for authorized contracting agents. Indeed, it was stressed to the Contractors that the government was not going to give directions and that the Contractors' charge was to make decisions based on cost and training effectiveness as ascertained by them during the course of the contract.

The kick-off meeting also discussed contract milestones and prototype test issues. Concerning this latter item, the JSAG agreed that test issues should be identified early in AMTESS I to insure an adequate test plan.



d. ARI Evaluation Plan. ARI agreed to be involved in the evaluation of the AMTESS training devices and acknowledged this agreement by signing a Memorandum of Understanding with PM TRADE on 7 December 1979. ARI was provided with a general overview of the prototype devices and the general conditions under which they were to be evaluated and responded on 22 January 1980 with a preliminary test plan for evaluating the training devices. The plan entitled "Training Effectiveness Testing for AMTESS I" was a necessarily general plan which proposed a test design encompassing 80 groups. In the absence of a specifically agreed upon set of test objectives, the test plan assumed the evaluation would include two (2) simulator models, two (2) locations (unit and school), and instruction on four (4) pieces of equipment. The test plan proposed to test the following five groups of subjects:

1. Control group - A sample of subjects who had received no maintenance training at all.

2. Baseline group - A sample of subjects who had received current conventional maintenance training.

3. Treatment group I - A sample of subjects who had received training on a prototype device.

4. Treatment group II - A sample of subjects who had received current conventional training augmented by the use of methodological innovations incorporated in the simulator system that can be employed without the simulator hardware or software itself.

5. Expert group - A sample of "expert" mechanics used to ascertain the feasibility of the criterion tasks and to provide an upper edge to the distribution of the performance scores.

The test design included broad criteria for assigning subjects to test conditions, and a few criterion measures of performance.

PM TRADE recommended modifications to the ARI test plan (6 March 1980) in the following areas:

- Reducing the number of treatment conditions from 80 to a more manageable number for field testing.
- Developing a specific method for matching treatment group subjects.
- Developing a standardized performance based maintenance test to be used as a performance criterion for evaluating the tasks trained in AMTESS.

PM TRADE attempted to provide additional detail only with regard to reducing the number of treatment conditions. The ARI test plan assumed that two simulators would be evaluated at two levels (unit and school) with each simulator being used to train four pieces of equipment. Given these assumptions, each treatment or control group tested would actually result in 16 treatment conditions or cells in the design. PM TRADE suggested that the "Control group," Treatment group II," and the "Expert group" were unjustified and could be eliminated. That would leave two test groups for a total of 32 test conditions.

Specific methods for matching treatment group subjects or developing performance criteria were not advanced by PM TRADE at this time.

e. Grumman AMTESS I Reports. Grumman was one of the two contractors from AMTESS I who was selected to build a prototype model of their device concept. Grumman conducted the three FEA's prescribed in the AMTESS I RFP along with a cost effectiveness analysis and a brief recommendation for evaluating their device. The three primary FEA procedures, task analysis, training requirements analysis, and fidelity analysis are described below, along with a summary of the device concept Grumman proposed.

(1) Task Analysis. Grumman conducted a comprehensive task analysis. The task analysis consisted of the following six interrelated steps:

- Identify population of tasks
- Classify tasks based on behavior performed
- Assess current Army training needs
- Identify candidate tasks
- Identify equipment commonalities
- Select tasks

Grumman identified candidate tasks by reviewing pertinent government documents. For the automotive MOSs, they classified tasks on the basis of five functional classifications including Inspect, Troubleshoot, Test and Adjust, Remove/Replace, and Vehicle Operation. They identified 171 common tasks for the three automotive MOSs. Through discussion with training school personnel and observation of trainees, Grumman identified 79 tasks of the 171 common tasks which they defined as having the highest priority. From these 79 tasks they selected 31 which best lent themselves to simulation. These 31 tasks were selected for testing during AMTESS II on the Grumman breadboard simulator.

For the missile MOSs, a total of 30 tasks were identified. These 30 tasks could be divided generally into performance of operational checks, and troubleshooting and repair of transmitter circuits. The repair tasks were further subdivided by levels of difficulty and the five basic circuits of the transmitter.

A major finding of the missile maintenance task analysis was that the tasks examined did not consist of easily discriminable discrete tasks, but rather of a prescribed logical sequence of tasks. Therefore, Grumman selected five sequences of tasks for inclusion in the simulator. These task sequences were "selected carefully in order to insure that each of them could be generalized to other areas of the transmitter" (Campbell, Stonge, Cothran, Anaya, and Sicuranza, 1980).

It is important to note that in selecting the tasks, Grumman adopted the philosophy that "the initial implementation of AMTESS is intended to be supplementary to existing training" (Campbell, Stonge, Cothran, Anaya, and Sicuranza, 1980). As a result, many of the tasks selected were tasks with a high training priority which were not currently being trained at the schools. Table 2 contains a list of tasks selected by each contractor.

(2) Training Requirements Analysis. Grumman's training requirements analysis began with a needs analysis to identify major problem areas involved with existing training. Those problems for which AMTESS might provide a solution were identified and discussed. Following the needs analysis, separate curricula analyses, one for missile, and one for automotive, were conducted. The analyses compared and contrasted the current training procedures for each MOS including curriculum content, lesson organization, and teaching methodology.

Based on the training requirements analysis, Grumman developed an MP01 for implementation during AMTESS II. They selected a total of 9 automotive tasks (from the initial set of 31) and 6 missile tasks (from the initial set of 30) for training in the MP01. Grumman's discussion of the MP01 included an outline of the lesson specification training the selected tasks. The lesson included the following information:

- Objectives
- Tasks to be trained
- Relationship to currently trained curriculum
- Prerequisite skills and knowledges
- Allocation of media
- Management and administrative requirements
- Learning abilities
- Selected training strategies
- Estimated time for completion

TABLE 2

## AUTOMOTIVE TASKS SELECTED FOR SIMULATION BY CONTRACTORS

<u>Troubleshoot</u>	<u>Seville</u>	<u>Honeywell</u>	<u>Grumman</u>	<u>Hughes</u>
Engine	x	x		x(M60)
Cooling System	x			
Oil Filter	x			
Oil Pump	x			
Suspension (Track)		x		
Automatic Transmission		x		
Suspension (Wheel)		x		
<u>Remove &amp; Replace</u>				
Thermostat	x			
Water Pump	x			
Alternator	x	x		
Starter Motor	x			
Fuel Pump	x			
Tank Engine (M60)		x		x
Steering Hydraulic Hoses		x		
<u>Adjust &amp; Align</u>				
Water Pump Belt	x			
Alternator Belt	x			
Alternator Output	x			
Valves (M60)		x		x
Transmission Bands (M60)		x		
Power Steering Cylinder (M809)		x		
<u>Perform</u>				
DC Voltage Test (MM)	x	x	x	
Continuity Test (MM)	x	x	x	
DC Voltage Test (LUCT)	x	x		
DC Current Test (LUCT)	x	x		
Resistance (MM)		x	x	
AL Voltage Test (MM)		x	x	
<u>Inspect</u>				
Engine		x		
Brakes		x		
Track Vehicle Suspension System		x		
Gas Filter System		x		

TABLE 2 (Cont.)

## MISSILE TASKS SELECTED FOR SIMULATION BY CONTRACTORS

<u>Troubleshoot</u>	<u>Seville</u>	<u>Honeywell</u>	<u>Grumman</u>	<u>Hughes</u>
Transmitter RF Generation	x		x	
Transmitter Noise Generation	x			
Transmitter Modulation Filament	x			
Transmitter Group Low Voltage	x			
High Voltage Power Supply			x	
Transmitter Test Set			x	
Low Voltage Power Supply			x	
Degeneration Rack			x	
Transmitter				x
<u>Remove/Install</u>				
Power Amplifier Filament				
Power Supply	x	x		
Master Oscillator Filament				
Power Supply	x			
High Voltage Regulator	x	x		
Amplifier Modulator Oscillator	x			
Power Amplifier Tube	x			
Master Oscillator	x			
<u>Adjust</u>				
Master Oscillator Frequency	x			
Transmitter				x
<u>Test</u>				
Power Amplifier Filament				
Power Supply	x			
High Voltage Regulator	x			
Master Oscillator	x	x		
<u>Repair</u>				
Range & Coding Amplifier Oscillator		x		
Low Voltage Power Supply		x		
Transmitter Circuits		x		
Transmitter Function Circuits		x		
Bridge Milling Amplifier and Cavity Tuner		x		
<u>Maintain</u>				
Noise Cancellation Circuits		x		
Modulation Circuits		x		
<u>Perform</u>				
Weekly Operation Checks		x	x	

While Grumman provided outlines of lesson specifications, it left to AMTESS II the actual development of detailed lesson plans.

(3) Fidelity Requirements Analysis. Grumman considered five major factors in the fidelity analysis including:

- Degree of dimensionality,
- The types of cues the AMTESS trainer must provide the student, and the inputs it must receive from the student
- Relative importance of those cues and inputs to the trainee's ability to learn the task
- The fidelity required in cue presentation to permit trainees to make necessary discriminations and
- Dynamic response fidelity required

Each of the tasks selected in the task analysis was examined separately with respect to these criteria. The results indicated that virtually all tasks could be simulated using a 2-D media presentation.

(4) Device Concept.

i. Hardware Design. Grumman identified three alternative configurations for the simulator device. One design included a set of student substations feeding off a central instructor station consisting of a computer, mass storage, terminal, and printer. Student substations would contain no independent computing power, so all processing would take place in the central processing unit of the instructor station. A second system design was similar to the first except that the student substations would include computing power. The central processing unit would be used primarily for information storage.

Grumman determined that flaws existed with each of these system concepts. Hence, a third configuration was devised, a stand-alone unit. The stand-alone unit included a 2-D workstation consisting of a computer, student input and display subsystem, an instructor CRT and printer, a mass storage unit and a 3-D simulation subsystem. The 2-D trainer had the following components:

- Microcomputer
- CRT
- Videodisc & TV monitor with speakers
- Touch panel and keyboard
- Floppy disc
- Hard disc
- Printer
- Standard RS232 interfaces
- Parallel data address bus to interface with 3-D simulator

Grumman planned two 3-D simulator modules, one for the automotive MOSs and one for the missile MOSs. The automotive simulator was designed to allow checking, diagnosing and troubleshooting the engine, electrical system, starter, battery, generator, regulator, and representative wiring and gauges for an automotive system. The missile simulator was designed to permit transmitter checks and hands-on diagnosing and troubleshooting for the Improved High Power Illuminator (IHIPIR). Table 3 contains a summary of the key device features proposed by each of the four contractors.

ii. Evaluation Plan. Grumman's plan for evaluating their device involved the basic elements of an experimental design. Students taking part in the evaluation would be matched on prerequisites to be determined at a future date. Students would be randomly assigned to one of three groups: a control group, treatment group 1, and treatment group 2. Treatment group 1 would receive existing training, and treatment group 2 would receive AMTESS training. The control group would not receive existing or AMTESS training (note that Grumman's approach was to be supplemental of



TABLE 3

## ANTESS I Device Concepts\*

Function	Grumman	Honeywell	Hughes	Seville-Burtek
Computer	Microcomputer (16 bit)	Microcomputer (DEC LSI-11)	Microcomputer (DEC LSI-11/23)	Microcomputer (LSI-11)
Visual/Audio I/O	Videodisc	Videodisc	Random access Video cassette recorder	Random access 35mm slide projector
	TV monitor	Color CRT	Digital audio synthesizer	Projection display unit CRT
	CRT	B/W terminal & keyboard	Color Graphics Display	Trainee response panel
	Touch panel & keyboard	Touch screen	Interactive panel	
Mass Storage	Floppy disc	Dual tape cartridge drive	Winchester hard disc (streaming tape unit back-up)	Dual drive floppy disc
		Hard disc	Floppy disc	Hard disc
Permanent Record	Printer	Printer	Printer	Printer (TI 743RO)
3-D Modules • Automotive	Engine electrical systems	Automotive valve adjustment Power steering cylinder Tank transmission gear servo	None Proposed	Cummins 250 Diesel Engine
• Missile	IHIPR Transmitter	Radar servo adjust- ment	None Proposed	IHIPR Transmitter

\* Actual brand names are indicated when proposed by contractors.

existing training.) Following training, all students would be required to perform tasks (to be determined) on actual equipment. Criterion measures for evaluating this performance would be developed, and the results would provide evidence of transfer-of-training.

iii. Economic Assessment. Grumman used a threefold approach to estimate device costs over a fifteen year life cycle. First, based upon their preliminary system engineering design, Grumman identified a number of potential "off-the-shelf" components for use. Next, these alternative components were evaluated on the basis of anticipated performance and estimated costs associated with that performance, including design, production, and maintenance costs.

In evaluating the alternative device components, anticipated performance was measured via a rating scheme developed by Grumman which included a user evaluation component. The relative costs of each component were measured according to a life cycle cost model which Grumman termed the AMTESS Cost Model System (ACMS). This model is a "linked and graded" model first developed for the U.S. Navy. A "graded" model is one which becomes increasingly complex to reflect the quality and quantity of data available. The term "linked" refers to the fact that the models may be related to one another at different grades.

The third step in the economic assessment involved solutions of the ACMS for the specific device components selected. The model included estimates of Research and Development Costs, Investment Costs, Operating and Support Costs, Consumption Costs (e.g., fuel), Depot Maintenance, Other Direct Support Operations, and Indirect Support Operations. The economic assessments were made under the assumption of producing 300 2-D workstations, and 20 each of 15 different kinds of 3-D modules. Life cycle is defined as 15 years. The average life cycle cost per system including software was estimated at \$93,943 in 1978 dollars.

f. Honeywell AMTESS I Reports. Honeywell participated in AMTESS I but was not selected to develop a prototype device based on their AMTESS I concept. In response to the AMTESS I RFP, Honeywell performed the task analysis, training requirements analysis, fidelity analysis, and they developed a device concept complete with an evaluation plan. These are detailed below.

(1) Task Analysis. Honeywell enumerated all the tasks involved in the five MOSs and classified them into the following categories: (See Behm, Johnson, Graf, Hirshfeld, & McAleese, 1980a&c)

Automotive

Troubleshooting  
Align and Adjust  
Remove and Replace  
Inspection

Missile

Fault Isolate and Repair  
Align and Adjust  
Inspect and Service

In conducting the commonality analysis, Honeywell used the Generalizable Job Proficiency Matrix (GJPM), a technique they had developed previously. The GJPM identifies major areas of commonalities across tasks and provides a systematic and efficient basis for selecting tasks and sub-tasks appropriate for training.

Following a training analysis to identify important training tasks and a cost analysis to determine cost effective training tasks, Honeywell developed a simulator value index for the tasks. Using the index, Honeywell selected the specific automotive and missile tasks for their MP01. (See Table 2).

(2) Training Requirements Analysis. Honeywell developed 26 individual lesson modules for the automotive tasks and 46 for the missile tasks. Each module in the MP01 was presented, at a minimum, with a lesson title, performance criterion for the module, enabling objectives (i.e., maintenance requirements necessary to support the performance criterion), and a time estimate for completing the module.

Some of the modules were developed to supplement existing training while others were designed to replace it. Honeywell presented a detailed matrix showing the relationship between their MP01 and the current P01. Honeywell also provided a discussion of the roles of the student, instructor, and the simulator in AMTESS.

(3) Fidelity Requirements Analysis. The heart of Honeywell's fidelity requirements analysis was a fidelity algorithm developed for a previous contract (Plocher and Koch, 1979). Generally, the algorithm entailed analyzing tasks with regard to the following decision points:

- What must be learned:
  - procedural sequence?
  - motor skill?
  - both?
- Do manipulations involve:
  - simple motor skills?
  - complex perceptual-motor skills?
- Is the stimulus display:
  - discrete?
  - dynamic?

The analysis also took into account information on requirements in the areas of olfactory, auditory, visual, tactile, and kinesthetic cues for purposes of developing simulation realism.

Honeywell divided fidelity into seven categories ranging from simple 2-D fidelity using a video CRT driven by a computer to high fidelity 3-D simulators. The fidelity analysis entailed examining each task selected for the MP01 with regard to the decision points and classifying each task into one of the seven fidelity categories.

The results of the fidelity requirements analysis indicated that more than 85 percent of all tasks could be trained using 2-D media with 10 percent requiring a low level 3-D fidelity. Only 5 percent of the automotive tasks and 1 percent of the missile tasks were found to require high fidelity 3-D simulators.

(4) Device Concept.

i. Hardware Design. The Honeywell device included a computer system (Primary AMTESS) with "plug-in" 3-D modules which attach to the Primary AMTESS (Behm, Johnson, Graf, Hirshfeld, McAleese, 1980b). The Primary AMTESS had the following components: (See also Table 3)

- Microcomputer - (DEC LSI-11)
- Videodisc
- Color CRT
- Touch screen/digitizer
- Black & white CRT with keyboard
- Dual cartridge tape drive
- Hard disc drive (5.2 megabytes)
- Dot matrix printer
- Interfaces

Honeywell proposed four 3-D simulators including the following:

- Radar Servo Adjustment
- Automobile Valve Adjustment
- Power Steering Cylinder
- Tank Transmission Servo

ii. Evaluation Plan. Honeywell sketched out a brief evaluation plan which involved comparing AMTESS trained performance with the current Army training. Honeywell estimated that about twelve weeks would be required at an installation to train with and evaluate each device using two devices at an installation.

iii. Economic Assessment. Honeywell's approach to the economic assessment was similar to Grumman's in a number of respects. First, based on the preliminary system engineering design, Honeywell developed a list of possible design components. These possible components were subjected to a trade-off analysis which addressed the component's reliability, estimated cost, and the module's capability to satisfy the greatest number of requirements of the system.

Following the selection of the superior components of the system via their trade-off analysis, Honeywell identified an appropriate military life cycle cost model for application at the current stage of the AMTESS Program. Honeywell selected a model developed by the USAF ASD/AFALD LCC/DTC at Wright-Patterson Air Force Base, Ohio.

In general the model estimates the development, procurement, and ownership costs of the system. Honeywell's estimates assumed the production of 300 systems and estimated life cycle costs over 15 years. Honeywell estimated an average system cost of \$87,562 in 1978 dollars. These costs could be subdivided into approximately \$3,084 for development, \$51,739 for procurement, and \$32,739 for ownership.

g. Hughes Aircraft Company AMTESS I Reports. Hughes participated in the AMTESS I effort, but was not selected to develop a prototype device in AMTESS II. To arrive at their device concept in AMTESS I, Hughes performed the three prescribed FEA's and provided an evaluation plan for the devices. These activities are described in detail in the following paragraphs.

(1) Task Analysis. Hughes reviewed the list of tasks performed for each of the five MOSs. Hughes identified one general factor encompassing all tasks, a Test/Operate factor; and three "active clusters" defined as "Inspect/Troubleshoot", "Remove/Replace/Install/Service", and "Adjust/Align(sic)" (Dickson, Phillips, Queen, and Toth, 1980 (a).

Based on the clustering activities, four tasks were selected representing "the total universe of tasks adequately" (Dickson, Phillips, Queen and Toth, 1980 (a)). These four tasks were:

- Trouble Shoot Vehicle Engine - Automotive
- Remove Power Plant - Automotive
- Adjust Transmission Band Services - Automotive
- Trouble Shoot and Adjust Transmitter - Missile

Three tasks were automotive tasks selected to represent all tasks performed in the three automotive MOSs. One task was a missile task selected to represent all missile tasks from the two missile MOSs. (See Table 2).

(2) Training Requirements Analysis. Hughes training requirements analysis encompassed essentially four components. These included a "microdecomposition" of the four tasks into their basic elements, determination of training media, outline of functional training requirements, and discussion of the role of the instructor.

"Microdecomposition" entailed splitting tasks into basic learning elements and simulation elements. Basic learning elements were defined as the enabling skills and processes a trainee needs in order to perform a particular maintenance task. Simulation elements were defined as those sensory cues required to perform the maintenance activity. Sensory cues include initiating stimuli, overt responses of the trainer, and equipment responses to the trainees' inputs.

Hughes "microdecomposed" the four tasks selected in the task analysis into 338 individual elements. Hughes further analyzed these elements and found that most (72.5 percent) required cognitive skills, while only 27.5 percent required a motor skill.

Based on this analysis, Hughes decided that the primary training medium could be a generic 2-D trainer. This 2-D trainer would be a computer-based audio-visual system. This device concept is

described in more detail later.

Hughes then listed several functional requirements for the training program. Among these requirements were the following:

- Training should be learned and applied immediately rather than learned and not applied for a long period of time.
- Training should be sequenced from simple to complex tasks.
- Training should be self-paced based on trainee's performance.

Basic instruction would include four modes:

- Preview the task
- Practice the task
- Testing of trainee on task
- Periodic review of task

Hughes' training requirements analysis concluded with several scenarios for the instructor. It is important to note that Hughes did not present an MPOL in their report. Instead, they delayed a comprehensive curriculum review and MPOL development until AMTESS II.

(3) Fidelity Requirements Analysis. Hughes' fidelity analysis considered both physical and psychological fidelity. Psychological fidelity was defined as how fully the training environment exercises mental skills required in performing job tasks. Hughes' philosophy was to reduce or eliminate non-essential elements of physical fidelity while retaining high psychological fidelity.

Hughes' approach to the fidelity analysis was to examine each of 338 individual elements and rate the fidelity needed along nine general and 30 specific fidelity dimensions. The results of the fidelity analysis indicated that most fidelity requirements could be achieved using a generic 2-D trainer. Six subtasks were identified



which would require an additional piece of equipment with a higher degree of fidelity beyond the generic 2-D trainer.

The fidelity analysis confirmed the findings of the task analysis and training requirements analysis that most tasks could be trained on a 2-D computer-based trainer.

(4) Device Concept.

i. Hardware Design. Hughes envisioned that their AMTESS training system would encompass a family of four components. The workhorse of the family would be a generic 2-D trainer which would be used for 87 percent of training. It would be supplemented by three additional components, a Generic Tactile Trainer, Hardware Specific Tactile Trainers, and Actual Equipment (Dickson, Phillips, Queen, Toth, & Desantis, 1980).

In selecting equipment for the AMTESS device, Hughes' primary concern was that the majority of the hardware components were to be military or commercial off-the-shelf items with proven reliability, availability, size, weight, and compatibility with approved military hardware. Hughes also tended to prefer equipment with which they had previous working experience.

Based on their analysis, Hughes designed the 2-D trainer to include the following components. (See also Table 3).

- DEC LSI-11/23 microcomputer
- Winchester hard disc for permanent mass storage
- Streaming tape for removable mass storage
- Serial and parallel input/output interfaces
- Floppy discs for removable mass storage
- Color graphics display
- Random access video recorder for removable video/audio storage
- Digital audio synthesizer
- Interactive panel

- Printer
- Instructor's terminal such as a Diablo printer/keyboard terminal
- General purpose interface bus to interface with the hardware specific tactile trainer
- Training software

Generic Tactile Trainer - The purpose of this component was to assist in training motor skills which require tactile training. This would include tasks such as the use of selected tools (e.g., wrenches, calipers) and selected general actions such as soldering. The actual configuration of the Generic Tactile Trainer was left for the future until "further classification of the tasks to be trained is made" (Dickson, Phillips, Queen, and Toth, 1980a). While specification of the actual configuration was postponed, Hughes did note that the Generic Tactile Trainer would not be computer-based.

Hardware Specific Tactile Trainers - These items constituted special pieces of hardware to be used in only a few, limited circumstances. They would be developed only for those few motor skill tasks which meet several conditions. Hughes did not provide specifications for this component because of the uncertainty of the tasks to be trained. The Hardware Specific Tactile Trainers were not expected to be computer-based.

ii. Evaluation Plan. Hughes' evaluation plan consisted of descriptions of various scenarios supplemented by evaluation recommendations. Hughes clearly anticipated a number of difficulties in evaluating the AMTESS devices. These difficulties ranged from availability of subjects, to the comparison of devices between contractors, to the specification of evaluation objectives.

Hughes noted that the major problem in evaluating AMTESS was troop support considerations for "fielding sufficient training hours on AMTESS." Hughes pointed out that the existing POI for one automotive MOS, 63H, included 360 hours of instructional time. They

argued that even 10 hours of AMTESS instruction would only amount to 3 percent of the existing plan of instruction (POI).

A second problem Hughes foresaw, was how to make a fair comparison between AMTESS and conventional training. Hughes proposed two possible designs. One design would involve using students who had completed the initial part of the existing POI. These students would be randomly assigned either to continue with the current POI or to take a parallel POI offered on AMTESS. Subsequent to completing the POI, students in both groups would be compared to determine which training situation (AMTESS or conventional) produced the superior student.

A second design would involve development of an MPOI unrelated to the existing POI. Trainees would learn all the relevant material using either AMTESS or in a "control condition" using training methods similar to the existing POI.

Hughes indicated that they were unclear as to whether the government evaluation effort would compare devices between contractors. They noted that if such comparisons were to be made, the devices should provide training on at least one common task.

iii. Economic Assessment. Hughes used the RCA Price 84 Program for estimating life cycle costs. Their estimates were confined to the 2-D trainers since the engineering design for the 3-D trainer had not been completed at that time. The RCA Price 84 Program uses inputs for engineering and manufacturing costs both during development and production of the 2-D system. The model also takes into account predictive estimates of the system's performance such as mean time between failures, support removable units, and support effort requirements.

Hughes estimated that the life cycle cost of the 2-D trainer would be approximately \$75,000 in 1978 dollars. While Hughes did not estimate the costs associated with the 3-D trainer, they did indicate

that these costs would be relatively small when compared to the 2-D trainer.

h. Seville-Burtek AMTESS I Reports. Seville-Burtek, a consortium consisting of the Seville Research Corporation along with Burtek, Inc., was one of two contractors selected from the four AMTESS I competitors to develop a working device in AMTESS II. Seville was the primary contractor in these activities, while Burtek provided engineering and design support. During AMTESS I, Seville-Burtek performed the three prescribed FEAs (task analysis, training requirements analysis, and fidelity analysis). They also provided a preliminary design of the device along with cost effectiveness documentation. Seville-Burtek did not provide a systematic evaluation plan in their report, but they did provide a brief recommendation concerning evaluation. A summary of the front-end analysis activities is provided below. A complete description of the design and development of the Seville-Burtek device is presented in their final reports for AMTESS II (Garlichs, Miller and Davis, 1983a,b,c).

(1) Task Analysis. Seville-Burtek's approach to the task analysis was to group tasks into categories such that the training designed for any one task in the group would apply to all tasks in the group. Seville-Burtek identified the following categories into which tasks from both automotive and missile MOSs could be grouped.

- Inspect
- Troubleshoot
- Remove
- Replace/Install
- Adjust/Align
- Service
- Test

It should be stressed that while these categories applied to both automotive and missile MOSs, the tasks from each area were classified separately into these categories. Once the tasks were

grouped into common categories, Seville-Burtek selected candidate tasks for incorporation into the MPQI. In selecting tasks, Seville-Burtek chose a set of tasks which could be trained using a single, simulator module. As noted in their report, Seville-Burtek intended the implementation and evaluation of their device to be straightforward:

Criteria for task selection were the amenability of tasks to development of a unified block of instruction to facilitate evaluation, the minimization of resources required for course development, and the logistics involved in implementation (Long, Miller, & Garlich, 1980a).

Seville-Burtek selected 23 automotive tasks and 22 missile tasks as suitable for performance with AMTESS. (See Table 2).

(2) Training Requirements Analysis. Seville-Burtek began their analysis by reviewing current training requirements, procedures, and operations. This review included examination of school documents, discussions with training personnel, and observation of training.

Unlike Grumman, who believed that the simulator initially would fill a supplementary training role, Seville-Burtek believed that the simulator would assume the identical role of the actual equipment trainer (AET) it simulates. That is, it would be a substitute for the AET. Based on this philosophy, and on the goal of being able to implement the simulator in a straightforward manner, Seville-Burtek concluded that "the most desirable situation would be a course organization and structure that would allow one-to-one substitution of simulator training tasks for existing tasks" (Long, Miller, and Garlich, 1980a). Therefore, Seville-Burtek developed two courses (one for the missile speciality, and one for the automotive speciality), each of which could be substituted directly for specific portions of existing training.

The automotive MP01 was designed for the Cummins diesel engine and taken specifically from MOS 63H10. The MP01 was presented in considerable detail and included objectives for the various lessons, student prerequisites, lesson plans, and actual practice exercises.

The missile MP01 was designed generally for the Improved Hawk Firing Section Equipment Maintenance Course and specifically maintenance on the IHIPR. The MP01 presentation included the objectives of each lesson along with practical exercises and tests.

(3) Fidelity Requirements Analysis. Rather than confine their fidelity analysis to the tasks selected for training (as indicated by the RFP), Seville-Burtek decided to conduct their analysis on all maintenance tasks. In the analysis, they considered the fidelity of tools and training support materials. Fidelity was examined along two primary dimensions, physical characteristics (e.g., size), and operational characteristics (e.g., audible outputs).

The principal conclusion of the fidelity analysis was that the simulator hardware must look like the equipment it simulates, disassemble like the actual equipment, but the simulator did not have to operate like the equipment.

(4) Device Concept.

i. Hardware Design. The Seville-Burtek device concept featured a 2-D computer based simulator coupled with a 3-D system training module (Long, Miller, and Garlich, 1980b). The 2-D simulator was designed to include the following components.

- DEC LSI-11 microcomputer
- CRT video terminal
- Floppy disc
- Hard disc
- Printer (TI 743 R0)
- Trainee video terminal

- Trainee response panel
- Random access 35mm slide projector

Seville-Burtek developed a 3-D simulator for both the automotive tasks and the missile tasks. The automotive training module was a stylized, full scale mock-up of the NHC-250 Diesel Engine. The missile system module was a stylized, full scale mock-up of the radar transmitter assembly with a simulated housing and all panel assemblies. (See Table 3 for a summary of features).

ii. Evaluation Plan. Seville-Burtek did not present a systematic evaluation plan in its reports. However, there were references in the reports to the evaluation of their device.

The Seville-Burtek recommendation was to develop a block of instruction for the simulator. Two groups would be trained using this block of instruction, an experimental group, and a control group. The experimental group would use the simulator in training while the control group would train using the equivalent actual equipment trainer.

iii. Economic Assessment. Seville-Burtek developed a Logistic Support cost (LSC) model for estimating life cycle costs which was based on the AFLC Logistics Support cost model. The model is comprised of five equations dealing with equipment replacement, equipment maintenance, inventory management, and cost of support equipment. Total life cycle costs are obtained by adding the Logistics Support cost to the original acquisition cost.

Seville-Burtek recommended exercising the model a minimum of every three months in order to take advantage of more specific information concerning the composition of the devices. Seville-Burtek did not actually solve the model they developed since they did not feel there was sufficient information to input to the model.

### 3. Summary of Contractors' FEA Procedures

This section summarizes the foregoing discussion of contractor FEA procedures. All four contractors used similar methods for conducting the task analysis, fidelity analysis, and the training requirements analysis. In general, the contractors reviewed information available at schools such as applicable manuals, the Programs of Instruction, and interviewed subject matter experts. With regard to the task analysis, the contractors enumerated the population of tasks and classified them into common categories. In general, the contractors identified similar categories such as Inspect, Troubleshoot, Remove, Replace, Install, Adjust, and Test. The procedures for assigning tasks to categories relied most heavily on expert judgment.

In selecting tasks from the categories for testing on the prototype devices, the contractors were guided by considerations of both cost and training effectiveness in a simulation training mode. Once again, the contractors relied heavily on expert judgment which was guided by the contractors philosophy or beliefs concerning how the device would be used. There appeared to be differences among the contractors in their philosophies.

Grumman, for instance, explicitly saw the devices as being supplementary to existing training and, therefore, they selected high training priority tasks not currently being trained. Honeywell implicitly viewed the devices as being both supplementary to existing training in some instances and replacing it in others. Therefore, they selected some tasks currently being trained and others not being trained. Seville saw the devices as replacing current training, and therefore, they selected tasks currently being trained. Hughes apparently was under the impression that the training tasks would be identified in AMTESS II, so they did not select a complete set of tasks for training on their devices.



For the training requirements analysis, the contractors relied on their review of appropriate manuals and interviews with subject matter experts to identify particular training needs, and procedures. Based on these, they developed appropriate programs of instruction to train the tasks they had selected by means of the training device.

With regard to the fidelity analysis, the contractors followed the same procedures. First, they identified key factors of fidelity necessary for effective training maintenance tasks. Next, they examined the maintenance tasks with regard to fidelity factors to determine the degree of fidelity required. In contrast to the task analysis where the contractors used similar categories, the contractors differed widely on the major fidelity factors. Despite the differences in fidelity factors examined, despite the fact that the contractors made decisions independently based primarily on their own expert judgment, and despite the fact that the contractors were evaluating, for the most part, different tasks, their conclusions were remarkably similar. They all agreed that most tasks could be trained effectively using primarily 2-dimensional media.

## F. DISCUSSION

This section provides a critical examination of the document review activity undertaken in this effort. This examination is made within the context of the following four criteria which were described in Section D:

- Clarity of Requirements
- Completeness of Performance
- Effectiveness of Coordination
- Preparation for AMTESS II/SIMTRAIN

### 1. Clarity of Requirements

The AMTESS I RFP provided the stimulus for the entire AMTESS effort. For purposes of guiding contractor development of the

training devices, the RFP was clear. This is evidenced by the fact that all four contractors developed similar systems (in that they were computer-driven, modular, flexible, and provided for hands-on training). The primary differences in the systems were the specific features of the devices such as type of storage medium, type of video display, and specific equipment brand.

Nonetheless there were two areas where the RFP lacked clear guidance. One area was criteria for task selection. The RFP prescribed a standard task analysis, yet allowed that "Justification for task classifications and for sample selections shall be provided by the contractor (p. 26)." Given that over 500 tasks were analyzed, it is not surprising that there was very little overlap in the tasks selected by contractors. (See Table 2). This had a decidedly negative effect on the evaluation of the AMTESS devices.

A second area of the RFP lacking in clarity was the specific purposes for which the devices were to be employed. While the RFP was clear that AMTESS training would be "adjunct" to, and "supplementing" maintenance training, it was unclear as to what this supplemental role actually meant. That is, does supplemental entail remediation, practice on tasks currently trained, training of tasks not currently trained, or something else? This lack of specificity apparently influenced contractor task selection and resulting MPOL development.

Seville-Burtek, for example, indicated concern about the ability to evaluate a device if the device did not offer an MPOL equivalent to conventional training. If an MPOL does not parallel a block of the current POL, then Seville-Burtek reasoned that there would be no convenient conventionally trained group against which to evaluate the device. As a result, Seville-Burtek developed an MPOL that could be substituted for a block of current instruction. Grumman, on the other hand, developed an MPOL which was supplemental to the current training. Honeywell's MPOL included both supplemental and directly substitutable training, and Hughes postponed both task selection and MPOL development until Phase II of the AMTESS effort.

One requirement of the RFP which may be construed as vague, stated that "the Contractor shall also provide recommendations on how the breadboard model in his proposed concept can be evaluated during the demonstration and validation phase (p. 29)." This statement elicited varying contractor responses ranging from Seville-Burtek's brief discussion of evaluation to Hughes' considerably more elaborate presentation. Since the government had agreed to have an independent agency (ARI) evaluate the devices, there appears to have been no need to saddle the contractors with this extra requirement.

## 2. Completeness of Performance

This section provides a discussion of the activities of the contractors. It includes consideration of the feasibility study conducted by Seville, as well as the AMTESS I efforts performed by Grumman, Honeywell, Hughes, and Seville-Burtek.

a. Seville Feasibility Study. The Seville feasibility study was one of the first steps in the development of the AMTESS devices. It documented the feasibility of reduced physical fidelity for maintenance training as well as the feasibility to develop potential reduced physical fidelity designs. It also pointed the way toward maintenance tasks most susceptible to reduced physical fidelity training.

The evaluation methodology described by Seville was a straightforward experimental design. In hindsight, one could criticize the plan for making no reference to potential problems which might result from conducting a field experiment. The plan made no reference to the time commitment and troop support requirements which would be required from field agencies.

Despite this shortcoming, the Seville evaluation plan, was, for the most part, responsive to the objectives of the procurement and an important first step in the development of the AMTESS devices.

b. AMTESS I Contractor Efforts. The AMTESS I RFP outlined a sizable effort. According to the ISD model, front-end analysis activities are essential for the development of an effective training device. This section provides a comment on the contractors' performance in response to the RFP. This evaluation does not include the quality of the contractors' performance. This purpose would require data collection and analysis beyond the scope of the present effort. What this section provides is an indication of the completeness of the contractors' performance. Table 4 contains an indication of the completeness of each contractors' performance on the major tasks (or subtasks) requested in the RFP.

As the table shows, Grumman, Honeywell, and Seville-Burtek were generally very responsive to all RFP requirements. The single area not addressed by Seville-Burtek was the development of an evaluation plan for their device. However, Seville-Burtek was cognizant that an evaluation would be conducted, and they attempted to develop a device which lent itself to easy evaluation. Moreover, Seville had prepared an evaluation plan in its feasibility study which ostensibly would apply to the device they planned to design in Phase II.

Only Hughes, of the four contractors, failed to respond completely to a number of RFP requirements. Hughes, for instance, devoted only five pages of text to the task analysis. Honeywell, in contrast, devoted 48 pages of text and approximately 70 pages of appendices to the task analysis. As a result of an incomplete task analysis, Hughes did not develop an MPDI nor did it develop a concrete 3-D training module. These activities presumably were to be postponed until the AMTESS II effort was awarded.

As for the other three contractors (Grumman, Honeywell, and Seville-Burtek), the completeness of their design appeared to allow for the construction of comprehensive and detailed training devices in the AMTESS II effort.

TABLE 4

## COMPLETENESS OF AMTESS I CONTRACTOR PERFORMANCE

Task Analysis	Grumman	Honeywell	Hughes	Seville-Burtek
Enumerate Tasks	*	*	+	*
Classify Tasks	*	*	+	*
Select Tasks	*	*	+	*
Training Requirements Analysis				
Develop MPOI	*	*	0	*
Discuss Role of Instructor, Student/Device	*	*	*	*
Fidelity Requirements Analysis	*	*	*	*
Device Concept				
PSED	*	*	*	*
Device Evaluation	*	*	*	0
Economic Assessment	*	*	*	*

## LEGEND:

\* Very Responsive  
+ Somewhat Responsive  
0 Unresponsive

It is interesting to note that, while Hughes was the least responsive contractor in many respects, it was the most responsive in developing an evaluation plan. Moreover, Hughes was the first organization to point out the major potential logistical problems of availability of subjects in the evaluation phase.

### 3. Effectiveness of Coordination

A previous report (Criswell, Unger, Swezey and Hays, 1983) contained summarized comments by representatives of agencies involved in the AMTESS effort concerning interagency coordination. These comments indicated mixed opinions concerning effectiveness of that coordination. However, one comment about the Joint Study Advisory Group and Joint Working Group is particularly pertinent. The Task I report states that "one interviewer commented that the JWG was stronger early in AMTESS than in the later time period" (p.24).

PM TRADE, the agency with the locus of responsibility for the effort, and USATSC which was involved from the early stages of the effort, both took a number of appropriate steps to insure effective coordination of the project. When the feasibility of the reduced physical fidelity trainers was established by Seville, PM TRADE and USATSC began to actively involve other agencies in the AMTESS effort. Various Army schools were invited to present training requirements and to become members of the JSAG. ARI was identified as the agency responsible for evaluating the prototype devices, and was invited to join the JSAG.

All JSAG members were invited to provide input to the AMTESS I RFP and to evaluate AMTESS I proposals. Instructions were provided to contractors regarding how to interact with various government agencies (primarily Army schools), such as whom to contact, what to expect, and what not to expect. Periodic JSAG/JWG meetings were held to keep participants informed and involved. Moreover, Memorandums of Understanding (MOU) were circulated describing the roles and duties of government agencies. These MOUs requested that agencies formalize

their relationships via appropriate signatures.

While interagency coordination appeared relatively effective during the timeframe covered by this report, there are some obvious reasons why it may have become less effective (as suggested by some AMTESS participants) later in the project. First, as Table 5 shows, the number of agencies involved in AMTESS multiplied rapidly during the first two years of the effort. Second, while the number of agencies proliferated, considerable personnel turbulence of AMTESS participants occurred. As Criswell, Unger, Swezey and Hays (1983) point out, only 2 of the 16 people who attended the August 1978 JSAG meeting were active through delivery and evaluation of the prototype devices. The personnel turbulence issue could have been ameliorated had formal minutes of the JSAG/JWG meetings been recorded and maintained. However, the only records of these meetings appear in Memorandums for Record submitted by individual members to their own organizations but not necessarily disseminated to or approved by other members.

Third, the timeframe for AMTESS expanded beyond initial expectations. Indeed, final evaluation of the devices was not completed until approximately 30 months later than projected in a 1978 schedule. Fourth, while formal MOUs were circulated to participating agencies, the process had shortcomings, the most important of which was the fact that several agencies did not sign MOUs. (Since no fully signed MOU could be obtained, it is unclear which agencies signed and which did not). If an agency did not sign an MOU, PM TRADE could not necessarily expect that agency to provide the necessary support when requested. Moreover, the responsibilities assigned to the agencies named in the MOUs were vague. For instance, the Ordnance, Air Defense, and Missile schools were given the task of providing all facilities, test support personnel, and resources for the test of the prototype devices. However, since a formal test plan had not been prepared when the MOU was circulated, it was unclear what the scope of this requirement actually entailed. It is possible that the vagueness of the MOU requirement kept some agencies from signing it.

TABLE 5

## AGENCIES ATTENDING SELECTED SAG, JSAG &amp; JWG MEETINGS

June 1977	September 1977	August 1978	September 1979
PM Trade USATSC	PM Trade USATSC Naval Training Equipment Center HQDA Seville	PM Trade USATSC USAOC&S USAADSS ARI Logistics Center (USALOGCEN) Aviation & Research Development Command (AVRADCOM)	PM Trade USATSC ARI USAOC&S USAADS USAMCS TRADOC Liason (USATL) Logistics Management College (USALMC) Grumman Honeywell Hughes Seville-Burtek



#### 4. Preparation for AMTESS II/SIMTRAIN

Ultimately, front-end analysis procedures can be judged in terms of how well they prepared the AMTESS players (both government and contractors) for actual development and implementation of the devices. Table 6 lists major objectives of AMTESS II/SIMTRAIN and shows the status of the effort relative to these objectives at the end of AMTESS I.

Table 6

##### Correspondence Between AMTESS II/SIMTRAIN Objectives and AMTESS I Products

AMTESS I Products	AMTESS II/SIMTRAIN Objectives
Detailed Prototype Designs	Contractors Develop Prototypes
General Acceptance Plan	Government Accept Prototypes
Draft, Incomplete Evaluation Plan	Government Evaluate Prototypes

At the completion of AMTESS I, at least two major accomplishments were available. The first was evidence that the reduced physical fidelity training device concept had applicability to a number of training situations. The second was actual detailed designs concerning how reduced physical fidelity trainers should be configured and how they would operate.

However, the government had not prepared a detailed plan tailored to the AMTESS devices for inspecting and accepting the devices, at least as far as can be ascertained from the AMTESS II RFP (N61339-80-R-0091). The RFP set forth a general set of procedures for the initial inspection and acceptance of the devices (p. 6-7; Exhibit A). These procedures included timing, general acceptance procedures, areas within which testing might be conducted, and reporting formats for documenting the audits. However, specifics of the device acceptance such as in-plant tests to be conducted prior to acceptance

were left for development after award of the AMTESS II contracts. As Criswell, Unger, Swezey and Hays (1983) strongly recommend, in a project such as this, precise device specification should be made available to device contractors and criteria for device acceptance should be "comprehensive, precise, and fully understandable by all parties." This level of specificity was never achieved resulting in problems both with the tasks trained on the devices and with device dependability.

Perhaps the major shortcoming at the end of AMTESS I was absence of a detailed, written evaluation plan which was acceptable to all government agencies. One reason for the lack of a detailed evaluation plan can be traced to the uncertainty of what was to be evaluated. For instance, when ARI was first requested to prepare an evaluation plan, the tasks to be trained had not yet been determined. As a result, ARI could not provide a complete evaluation plan. Another reason for the lack of a detailed evaluation plan was that most parties associated with AMTESS appeared to feel that the evaluation would be a relatively straightforward process. Seville's evaluation plan presented in their feasibility study proposed a classical experimental design and raised no issues concerning implementation difficulties. Neither did ARI's initial plan treat the odds of complications in fielding the evaluation plan. Honeywell and Grumman both saw evaluation as a straightforward exercise. Only Hughes, based on the documents reviewed, foresaw potential problems with the evaluation.

From the perspective of hindsight, it is easy to identify major problem in conducting the evaluation: i.e., uncertainty regarding which tasks would be trained on the devices. This issue was compounded since there were two devices and two separate maintenance areas being trained. In effect, there were potentially four separate evaluations, each requiring different subjects and different criterion measures.

The "tasks trained" problem was further magnified by the changing of the POI at USAOC&S and the switch in the curriculum at USAADS from a self-paced to a lock-step method of presentation. (See Criswell, Unger, Swezey, and Hays, 1983, for a discussion of this issue).

The final topic to be considered here was apparently overlooked in AMTESS. Presumably the objective of the task analysis was to classify common tasks and then to select representative tasks from each analytic classification. The intended consequence of this step was that if the simulator could effectively train the selected tasks, it should be able to train all the tasks from which the simulator tasks were selected. While this is a reasonable objective, some safeguards were required to insure that the tasks selected actually represented the category of tasks from which they were selected. The AMTESS effort did not attempt to do this. As a result, there is no necessary indication that, even if the devices were proven effective in transfer of training that they would also be effective if configured to train other tasks from the same MOSs.

5. Summary of Front-End Analysis Lessons Learned. The AMTESS effort to date appears to be successful (Dybas, 1983) and it will be continued and perhaps expanded to other maintenance areas. However, in spite of its success, it is clear that the effort did not proceed as smoothly as was expected. This section summarizes some of the lessons learned from AMTESS I.

From our perspective there were two major problems which occurred during AMTESS I which hampered the subsequent AMTESS effort. First, some of the key government agencies taking part in AMTESS did not have specific assignments which they formally agreed to undertake. Second, the tasks which the AMTESS prototypes were to train were not finalized until several months after AMTESS II had begun. Some other issues in the AMTESS I effort included the following:

- The major purposes for which the prototypes were to be used were vague. These purposes must be made more explicit at the outset of a procurement like AMTESS.

- The various study advisory groups used during AMTESS were very useful. To help coordinate these groups, the membership should be kept only to necessary agencies, formal agendas should be used and sent in advance of meetings, and written minutes of the meetings should be taken and disseminated to members.

- Evaluation of the training devices was not given a high enough priority.

The next section of this report presents some guidelines concerning the conduct of FEAs of the type examined here. The guidelines section is based both on the results of the case study of AMTESS I presented here as well as an earlier report (Criswell, Unger, Swezey, and Hays, 1983) which contains a more extensive review of AMTESS II.

## PART II

### Front-End Guidelines

## A. Introduction

If an analysis of the two prototype AMTESS devices indicates that the type of training provided by the device can be both cost- and training-effective, then it is likely that the Army will seek to improve these devices and procure additional (or similar) devices. Both government agencies and contractors involved in future efforts of this sort can profit from an examination of the lessons learned from AMTESS Phase I activities. The purpose of this section of the report is to present lessons learned in the form of a set of organized guidelines for FEA activities. These guidelines are not comprehensive in that they do not provide a step-by-step list of procedures to be followed during device development. They do, however, provide useful guidance which may be applicable to a wide range of procurements other than AMTESS.

Guidelines have been developed for each of the three FEA's performed by the contractors:

- Task Analysis
- Training Requirements Analysis
- Fidelity Analysis

In addition, guidelines have been developed for analyses which were not conducted during the AMTESS I effort, but which may be useful during subsequent AMTESS efforts. These analyses include:

- Reliability and Maintainability (RAM) Analysis
- Organization Analysis
- Human Factors Analysis
- Person Analysis

Each guideline is first discussed in a general manner; that is, the discussion may apply to a range of procurement efforts. Following this general discussion, the guideline is discussed in reference to the AMTESS effort.

## B. Task Analysis Guideline

1. THE INITIATING AGENCY SHOULD ASSUME RESPONSIBILITY FOR SELECTING TASKS.

a. Discussion: The task analytic activities conducted during the front-end of a training device procurement provide the major input to selecting the particular tasks to be trained by the device. These activities may be conducted by the device contractor or the government. Regardless of who conducts the task analysis, the initiating agency should make the selection of tasks to be trained. Relinquishing responsibility for task selection, either in specifying task selection criteria, or in actually selecting tasks, reduces the initiating agency ability to evaluate device contractor performance.

In selecting tasks, the initiating agency should strive to select critical tasks which are planned to be trained in the same MOS for several years in the future. It is further recommended that if several alternative devices are being developed, they should train the same tasks to facilitate comparison of the devices.

b. AMTESS Reference: The two contractors who were commissioned to develop training devices selected the tasks to be trained on the devices. The differences in the tasks they selected were considerable. This proved to be a significant burden for the device evaluation. Moreover, it turned out that many of the tasks to be trained were eliminated from the school curriculum less than five months after they had been selected. Problems such as these could have been avoided or minimized if the initiating agency had played a greater role in selecting tasks to be trained.

### C. Training Requirements Analysis Guidelines

1. WHEN FEASIBLE, SOLICIT THE OPINIONS OF SEVERAL (RATHER THAN ONE) SUBJECT MATTER EXPERTS (SMEs).

a. Discussion: The principle of obtaining data from a panel of experts is not unique to front-end analysis activities. Panels of experts are frequently consulted in a variety of fields in order to identify differences of opinion between experts, and to resolve those differences. Although the number of experts available is usually limited by practical constraints, heavy reliance on a single expert may produce results which are incomplete or inaccurate, or which are biased by the expert's opinions and preferences.

b. AMTESS Reference: Both contractors relied heavily on the expertise of a single SME to develop the radar transmitter simulator. This expert was highly knowledgeable about the subject matter, having functioned in the role of instructor and course writer. While this expert provided a great deal of valuable information to the device contractors, some of the information may have been biased. Consultation with other SMEs could have resulted in different tasks or different troubleshooting techniques being included in the contractors' plans of instruction.



## 2. IDENTIFY AND RESOLVE DIFFERENCES BETWEEN TECHNICAL MANUALS AND SUBJECT MATTER EXPERTS

a. Discussion: Frequently, serious differences exist between official procedures as described by technical manuals and course syllabi, and the procedures that actually are practiced by instructors and students. Exclusive reliance on either written materials or subject matter experts to develop a plan of instruction is likely to lead to a training device which includes unnecessary and inaccurate courseware, and which omits important relevant courseware. A thorough review of existing written materials should be compared with knowledge obtained from subject matter experts in order to identify conflicts and gaps in information required to develop courseware.

b. AMTESS Reference: Although the Seville-Burtek device at Aberdeen, MD included instructions for operating STE/ICE (Simplified Test Equipment/Internal Combustion Engine), no instructions were provided for the prerequisite skills of set-up and check-out of this device. Apparently, official course syllabi indicate that students have mastered these skills during a prior training course. However, none of the students and few of the instructors using the Seville-Burtek simulator had any prior experience with STE/ICE and were therefore unprepared to operate this important piece of equipment. Had Seville-Burtek sought to determine the skill level of students and instructors by querying those individuals instead of relying on course syllabuses, the problems could have been avoided.

Training on the use of STE/ICE on the Grumman device is also less than optimal, due to heavy reliance on technical manuals. Although the Grumman device teaches set-up and check-out of STE/ICE, procedures for troubleshooting with this equipment are derived from inappropriate technical manuals. Consultation with subject matter experts could have resulted in a simple solution to this problem.

Responsibility for the STE/ICE problems must also be accepted by government agencies. The requirement to incorporate this piece of

equipment into the MP01 came well after front end analysis activities had been initiated. Had the device contractors been forewarned of the STE/ICE requirement, repercussions could have been minimized.

3. DETERMINE IN ADVANCE THE SPECIFIC TRAINING REQUIREMENT  
TO WHICH A DEVICE WILL BE ADDRESSED

a. Discussion: In developing training requirements, it is imperative that consideration be given to the specific requirement(s) to be satisfied by a training device. This, to some extent, is compatible with the task specification requirement stated earlier. Devices should be designed to fill known training gaps and these gaps should be specified in advance.

b. AMTESS Reference: In the course of the AMTESS device development activities, the contractors were allowed to select not only the tasks to be trained, but also the training use to which their device would be applied. Consequently, one device (Seville-Burtek) was designed to replace (or substitute for) the use of actual equipment in the training curriculum, while the other (Grumman) was designed to be an adjunct device which provides supplemental training. This caused major confusion in subsequent efforts to evaluate the devices.

#### D. Fidelity Analysis Guidelines

1. THE INITIATING AGENCY SHOULD ALLOW THE RESULTS OF THE FIDELITY ANALYSIS TO INFLUENCE THE DESIGN OF THE DEVICE.

a. Discussion: Although there are many problems associated with contracts that contain too few explicit requirements, one must also avoid contracts that limit or reduce the effectiveness of contractor efforts by improperly focusing the scope of work.

b. AMTESS Reference: PM TRADE sought to develop a simulator which included both 2-D and 3-D components. The results of the contractors' fidelity analyses, however, revealed that most of the tasks in the MOSs under study did not require a 3D component. It may have been more appropriate for the contractors to design a simulator that did not include a 3-D component, or to analyze other MOSs in an attempt to identify tasks that were more suitable to 3-D simulation.

2. DETERMINE FIDELITY REQUIREMENTS BY EXAMINING THE RANGE OF VARIABLES ENCOUNTERED IN TRAINING ENVIRONMENTS.

a. Discussion: Hays (1981) identifies numerous variables which interact with simulator fidelity to produce given levels of training effectiveness. These variables include: task type, task difficulty, specific skills required to perform a task, trainee sophistication, stage of training, training context, incorporation of a device into a plan of instruction, user acceptance, and the use of instructional features.

Although resources are usually too scarce to examine all of these variables exhaustively, preliminary consideration of these variables is usually possible and is likely to lead to more effective decisions concerning fidelity of simulation.

b. AMTESS Reference: Most of the fidelity analyses conducted by the contractors concentrated on the type of task to be performed, task difficulty, and the specific skills required to perform the task. Although these are critical factors, examination of other variables described above also seems warranted.

## E. Reliability and Maintainability (RAM) Analysis Guidelines

1. CONDUCT A RAM ANALYSIS TO PREDICT FREQUENCY AND TYPE OF MAINTENANCE REQUIREMENTS FOR HIGH-TECHNOLOGY EQUIPMENT.

a. Discussion: Reliability refers to the probability that a system will be free of failure for a prescribed period of time under prescribed conditions of performance. A common quantitative measure of reliability is the probability of failure-free operations for each million hours. A second widely used measure of reliability is mean time between failures (MTBF) which is calculated by dividing total system operating time by the number of system failures.

Maintainability refers to the ease with which maintenance procedures are performed on a system. A common quantitative measure of maintainability is the mean time to repair (MTTR).

A related concept, availability, refers to the probability that a system will be operating at any particular time. It can be defined as:

$$\frac{\text{MTBF}}{\text{MTBF} + \text{MTTR}}$$

where: MTTR = mean time to repair, and

MTBF = mean time between failures

Although there are a variety of other measures of reliability and maintainability they need not be addressed here. The point to be made is that some estimate needs to be made of the types of maintenance activities that will be required to keep the system operational. If these estimates can be made by the contractor during early development phases of the effort, then assessments can be made regarding the acceptability of these failure rates. If these rates seem unacceptable, then engineering changes can be made early in the effort to alleviate the problem. In addition, the initiating agency can make concrete plans for servicing the system if it knows:

- the components that are most likely to fail,
- the type of maintenance personnel required to service the system, and
- maintenance procedures.

b. AMTESS Reference: Use of AMTESS devices could have been enhanced if effective RAM analyses had been conducted. However, since useful estimates of system reliability were not available, the schools had little notion of how well the devices would perform. If estimates of reliability had been available, troops may not have been expected to receive training on the device within confined time restrictions. Also evaluation of the devices could have been planned more effectively if it had been known how often the devices would fail.

A maintainability analysis could have indicated the skills required to service the AMTESS devices. Had this information been known, users could have determined if they could repair the device themselves, or if contractor representatives would be necessary.

2. PROVIDE SCHEMATICS OF THE DEVICE TO THE USER

a. Discussion: The number of people who can effectively troubleshoot a complex piece of equipment is significantly increased when schematics are available. When schematics are not available, the ability to repair equipment may be limited to those individuals who developed the equipment.

b. AMTESS Reference: The AMTESS devices may have been maintained more effectively had schematics been available to users. Since they were not available, users were forced to rely on the device manufacturers for maintenance support.



3. CONDUCT AN ANALYSIS TO DETERMINE THE ENVIRONMENTAL RIGORS TO WHICH THE DEVICE WILL BE EXPOSED

a. Discussion: Although prototypes cannot be expected to be as durable as production models, they must be durable enough to withstand manual use during an evaluation period.

b. AMTESS Reference: Had the contractors considered the environment in which the prototypes would be operated, the prototypes could have been designed to operate much more reliably. For example, it was suspected that the Grumman device at Fort Bliss failed repeatedly because of excessive dust in the operating environment. Dust storms are common in the spring in West Texas. It seems likely that a RAM analysis could have anticipated and solved this problem by either building the device to withstand the dust or describing preventative measures that could have been taken to reduce dust infiltration. Similarly, problems with the Grumman videodisc arose because instructors handled the disc with dirty hands. Procedures could have been developed to avoid these problems if they had been identified in a RAM analysis. Further, steps should be taken to ensure that device contractors are cognizant of, and in compliance with, all relevant military specifications which are applicable to the device under procurement.

## F. Organization Analysis Guidelines

1. CONDUCT AN ORGANIZATION ANALYSIS TO ENSURE THAT THE GOALS OF PARTICIPATING ORGANIZATIONS ARE COMPATIBLE WITH THE INITIATING AGENCY'S GOALS FOR THE DEVICE.

a. Discussion: In order for a training device or system to be effective, consideration must be given not only to the immediate organization in which it resides, but also to the larger organizational environment. Since the training device does not operate in a vacuum, it must be designed so that it fits into a particular organization or designed with flexibility so that it can fit into a variety of organizations. Identification of conflicting goals is an essential part of such an organization analysis.

b. AMTESS Reference: Several examples from the AMTESS effort serve to illustrate the importance of specifying an organization's goals. First, it appears that one of the important goals of instructors in the wheeled vehicle repair unit at Aberdeen, MD was to train soldiers as quickly as possible. Quality of instruction was as important as speed of instruction because the unit was under a great deal of pressure to graduate large numbers of trainees on time. Since this was the case, instructors had little time to train students on how to operate the Seville-Burtek simulator. Students frequently received less than 15 minutes of instruction on how to operate the device, even though a one to two hour introduction to the simulator is required. Consequently, students received far less than optimal training on the device since they could not operate it properly. Had an organization analysis been conducted, the importance of training time could have been discovered and the courseware could have been designed accordingly.

An organization analysis may also have revealed changing attitudes concerning self-paced versus lock-step instruction. The Grumman device is relatively inflexible in terms of its ability to adapt to a change in instructional techniques or PDI. An organization

analysis would have revealed the extent to which changes in PQI are required, and may have led the contractor to develop a more flexible, and therefore a more useful, training device.

A third example of the importance of the specification of organizational goals involves the objectives of the entire AMTESS effort. While most organizations participating in the project viewed AMTESS as an R&D effort, others expected the project to produce production quality training devices. This source of confusion plagued the effort from beginning to end.

2. CONDUCT AN ORGANIZATION ANALYSIS TO ENSURE THAT THE RESOURCES OF THE USER ORGANIZATION ARE COMPATIBLE WITH DEVICE REQUIREMENTS.

a. Discussion: This guideline is similar to the one described above in that it seeks to ensure that the training device and user organization are compatible. In this case, the point is to determine if the training system will require resources which the user organization cannot deliver. Here, resources may refer to such things as manpower, facilities, support equipment, and procedures.

b. AMTESS Reference: Both AMTESS devices were designed to allow an instructor to teach one or two students at a time. However, the student-instructor ratio for conventional training in the wheeled and tracked vehicle repair MOSs at Aberdeen, Md. is typically six-to-one, and occasionally higher. Although special arrangements were made (with great difficulty) to evaluate the device using a two-to-one ratio, the devices could not be used unit-wide with such a ratio since there is a severe shortage of qualified instructors. An organization analysis could have identified this problem and helped to design the device so as to minimize this problem.

## G. Human Factors Analysis Guidelines

1. CONDUCT A HUMAN FACTORS ANALYSIS TO ENSURE THAT THE DEVICE IS EASY TO OPERATE.

a. Discussion: The increasing complexity of weapon systems is reflected in the complexity of weapon system training devices. Complexity of the task which the device performs may or may not be desirable depending on training requirements. However, students should not have to learn a complex set of procedures simply to operate the training device. The effectiveness of the device is likely to increase if ease of use is increased.

b. AMTESS Reference: Although Seville-Burtek attempted to simplify the operation of their device through the use of a student responder panel, this panel was confusing to students. In addition, students also were required to look at a slide projector unit, a CRT, a 3-D module, technical manuals, and test equipment. Similar problems occurred with the Grumman device's video-disc capability. Many students seemed overwhelmed by all of the information that was presented. Had the devices been pretested with pilot students prior to delivery, they may have been redesigned in order to make them easier to operate.

2. CONDUCT A HUMAN FACTORS ANALYSIS TO ENSURE A SATISFACTORY MAN-MACHINE INTERFACE.

a. Discussion: There are a variety of documents that describe the development of human engineering program plans and human engineering design criteria (MIL-H-46855B, 1979; MIL STD 1472C, 1981). Among other topics, these documents provide guidelines for designing controls, displays, crew stations, and individual work stations. The guidance provided in these documents is appropriate to the design of training devices. Failure to use human engineering principles in the design of a training device may result in a wide variety of problems which will degrade the effectiveness of the device.

b. AMTESS Reference: Student performance on the Grumman device at Aberdeen could have been improved if human engineering principles had been incorporated into the device. For example, students were required to identify and use a number of cables attached to the STE/ICE device. However, since the cables were not labelled (as they are on the operational equipment), students spent excessive amounts of time attempting to identify the cables that were appropriate for each procedure.

Students also reported that the CRT on the Grumman device and the slide projector unit on the Seville-Burtek device were too small, i.e., details of the materials presented could not be identified. Further, the Grumman CRT was too low to be viewed comfortably while standing, and since neither the Grumman CRT nor the Seville-Burtek slide projector unit swiveled, students could not look at the CRT while they were working on the 3-D module. Problems such as these could have been identified and corrected following a human factors analysis.

## H. Person Analysis Guideline

1. CONDUCT A PERSON ANALYSIS TO IDENTIFY PERTINENT SKILL LEVELS OF THE TARGET POPULATION.

a. Discussion: The previous guidelines on human factors analysis stressed the importance of designing a device which incorporates basic principles of human engineering. In addition, it is necessary to design and to accommodate certain pertinent readiness skill levels of the target population. An example of such a skill would be reading. Another example might be general task attention. Selection of readiness skills to assess in a person analysis might be based on discussion with instructors and direct observation of ongoing training.

b. AMTESS Reference: The AMTESS contractors completed portions of a person analysis. Instructors and evaluators reported that the reading level of the materials was appropriate for the target population.

With respect to general task attention, however, some problems occurred during device testing. Many instructors noted that the devices did not hold students' attention well. Special attempts at holding student attention may be particularly important in military training. In the tracked vehicle repair course at Aberdeen, MD, students were observed exploiting the HELP feature of the device in order to leave the device as quickly as possible each day. Students discovered that they could rapidly complete instructional sequences by frequently using the HELP feature which would quickly tell them answers to questions. Thus, students did not have to search for answers themselves. Speedy progress is important in a training course, but not at the expense of omitting crucial training. Apparently, the actual instructional progress of some students was mitigated because the device failed to hold their attention. Observation of students in training prior to device construction might have pointed out special needs for holding students' attention.

## 1. SUMMARY OF GUIDELINES

The front end analysis guidelines described in the preceeding sections are summarized below:

### 1. TASK ANALYSIS GUIDELINE

The initiating agency should assume responsibility for selecting tasks.

### 2. TRAINING REQUIREMENTS ANALYSIS GUIDELINES

a. When feasible, solicit the opinions of several (rather than one) subject matter experts (SMEs).

b. Identify and resolve differences between technical manuals and subject matter experts.

c. Determine in advance the specific training requirement to which a device will be addressed.

### 3. FIDELITY ANALYSIS GUIDELINES

a. The initiating agency should allow the results of the fidelity analysis to influence the design of the device.

b. Determine fidelity requirements by examining the range of variables encountered in training environments.

### 4. RELIABILITY AND MAINTAINABILITY (RAM) ANALYSIS GUIDELINES

a. Conduct a RAM analysis to predict frequency and type of maintenance requirements for high-technology equipment.

b. Provide schematics of the device to the user.



c. Conduct a RAM analysis to determine the environmental rigors to which the device will be exposed.

#### 5. ORGANIZATION ANALYSIS GUIDELINES

a. Conduct an organization analysis to ensure that the goals of participating organizations are compatible with the initiating agency's goals for the device.

b. Conduct an organization analysis to ensure that the resources of the user organization are compatible with the device requirements.

#### 6. HUMAN FACTORS ANALYSIS GUIDELINES

a. Conduct a human factors analysis to ensure that the device is easy to operate.

b. Conduct a human factors analysis to ensure a satisfactory man-machine interface.

#### 7. PERSON ANALYSIS GUIDELINE

Conduct a person analysis to identify pertinent skill levels of the target population.

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