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Army Maintenance Training and Evaluation Simulation System (AMTESS) Device Development and Features

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An overview of the development and testing of AMTESS devices was presented. This history was based on AMTESS documents and data gathered in structured interviews of 16 participants in the AMTESS project. Opinions about specific device features were presented along with experts' ratings of the features. Experts' ratings were subjected to a multi-attribute utilities analysis. Guidelines for similar future device development efforts were offered.

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FOREWORD

The Training and Simulation Technical Area of the Army Research Institute for the Behavioral and Social Sciences (ARI) has supported the Army Project Manager for Training Devices (PM TRADE) in its research program to develop new methods for designing and procuring maintenance training devices. The Army Maintenance Training and Evaluation Simulation System (AMTESS) project is an effort to build modularized maintenance training devices and also to develop new approaches to the maintenance trainer procurement process.

This report is a review of the developmental history of the AMTESS project. It documents the activities of the agencies involved in the project and traces how these activities led to specific training device hardware designs. It also documents how the evaluations of the prototype devices proceeded. This documentation of "lessons learned" from AMTESS can be used to improve future procurements of maintenance training devices.

This report may be used by the training community to help avoid previous mistakes as well as to recognize procedures that work. It can sensitize the representatives of interacting agencies in the training device procurement process to pitfalls, which, if avoided, will facilitate the process. In addition, this report can be used by researchers to help them prepare for the contingencies they will encounter in future training device evaluations.

Edgar M. Johnson

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Technical Director

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ARMY MAINTENANCE TRAINING AND EVALUATION SIMULATION SYSTEM (AMTESS) DEVICE DEVELOPMENT AND FEATURES

EXECUTIVE SUMMARY

Requirement:

This report includes a discussion of (1) processes in the development of two Army Maintenance Training and Evaluation Simulation System (AMTESS) breadboard (first-run) generic training devices, and (2) the specific features on each device. One goal of this report is to document several years of interaction among government agencies, device contractors, and evaluation contractors for the purpose of elucidating strengths and weaknesses in the process of developing, acquiring, and testing generic training simulators. A second goal is to identify strengths and weaknesses in specific, generic training device features. A third goal is to offer recommendations, based on AMTESS experiences, for similar future efforts. The AMTESS project may be seen as a case study in training simulator development.

Procedure:

First, a number of documents were examined to develop a chronology (1977 to 1983) of government and contractor participation in the AMTESS project. Second, key participants representing the government and contract firms were personally interviewed for their opinions about the AMTESS development and testing process and specific device features. Data from the first and second sources concerning AMTESS project development were collated, displayed in figures, and discussed. Next, opinions about device features were summarized. Finally, experts rated specific device features, and ratings were subjected to a multi-attribute utilities analysis.

Findings:

An examination of AMTESS documents and interviewee opinions revealed that problems arose during AMTESS device development, acquisition, and testing. Most of these problems centered on the need for (1) more frequent, more precise communications, (2) clearer definitions of the explicit responsibilities of each agency, both government and contractor, (3) more explicit mechanisms for quality control of the devices, (4) greater anticipation of disruption contingencies, and (5) the need for more high-level administrative and financial resources appropriate to the responsibilities imposed on program personnel than were available during the AMTESS project.

Two devices were tested during AMTESS: one developed by the Seville Research Corporation and the Burtek Corporation and the other by the Grumman Aerospace Corporation. Interviewees and experts felt that many device features were based on sound instructional concepts. Implementation problems, however, especially disrepair, plagued both devices. Some of the most

valued features of the Seville/Burtek device were its high fidelity 3D module and comprehensive student performance record. The 3D module with its high fidelity parts and easy access design was especially valued on the Grumman device.

Recommendations are offered concerning future device development and evaluation efforts. These recommendations center around more frequent communication among participants and greater specificity concerning participants' responsibilities.

Use of Findings:

The findings of this report will be of interest to the training device development field. This report will be useful in planning the development of maintenance training simulators, particularly generic maintenance simulators.

ARMY MAINTENANCE TRAINING AND EVALUATION SIMULATION SYSTEM (AMTESS) DEVICE DEVELOPMENT AND FEATURES

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INTRODUCTION

The Army Maintenance Training and Evaluation Simulation System (AMTESS) represents an attempt to define new concepts in the area of maintenance training. Traditionally, Army students receive maintenance training on operational equipment. However, this type of training may be counterproductive for several reasons. Often, training equipment is unlike field equipment, and training is unlikely to generalize to field equipment. Frequently, faults used for diagnostic training are only a small subset of malfunctions found in the field. In addition, equipment may be damaged during training, or students may be injured during operation of hazardous equipment. Finally, availability of operational equipment is limited. The AMTESS project has sought to develop maintenance training devices to alleviate some of the problems encountered in actual equipment training.

As stated in the Request for Proposal (RFP) for the first phase of the AMTESS project, device design, the AMTESS project had three objectives:

1. Conceptually design a modular maintenance trainer that could be used for hands-on training and testing at the institution and unit levels.

2. Provide economic impact assessment of the effect of the introduction of AMTESS devices into the Army maintenance program.

3. Fabricate a breadboard (first-run) working model for evaluation.

The initial RFP also included several features which should characterize AMTESS devices:

- Adjunct to primary instruction
- Individualized, self-paced instruction
- Hands-on, actual practice capability
- Low cost

- Easily producible
- Modular, with easy interchange of modules
- Flexible, adaptable to changes in school curricula, including an editing system for school personnel to use for updating
- Instructor and student stations
- Easily transportable
- Complete software

Automotive and missile maintenance tasks were to be taught by the first AMTESS devices, but more devices were envisioned in the "family of maintenance trainers." Those future devices included aviation, electronics, heavy equipment, armor and artillery maintenance training simulators.

The AMTESS project was sponsored by the 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 written. During the second phase, breadboard devices were constructed.

Phase I of the AMTESS development program was aimed at the definition of conceptual designs for a modular maintenance trainer. To arrive at a conceptual design, five major tasks were performed by each of four device contractors:

1. Task analysis,
2. Training requirements analysis,
3. Fidelity requirements analysis,
4. Design of a modular system, and
5. Assessment of potential economic impact.

Phase II of the AMTESS research and development program involved the fabrication of breadboard models of two of the four designs developed during Phase I. The Grumman Aerospace Corporation, and a consortium of Seville Research Corporation and Burtek, Inc. produced these breadboard models.

The Army Research Institute (ARI) sponsored the project which included AMTESS device evaluation. This project was called SIMTRAIN I. SIMTRAIN I included three tasks. The first task involved the identification of methods for evaluating device requirements (Heeringa, Baum, holman, & Peio, 1982; Kane & Holman, 1982) and development of new methods of evaluating effectiveness (Eberts, Smith, Dray, & Vestewig, 1982; Klein, 1982; Tufano & Evans, 1982).

Task 2 involved the specification of simulation fidelity (Baum, Riedel, Hays, & Mirabella, 1982; Hays, 1980; Hays, 1981). Task 3 involved a field, transfer-of-training evaluation of the two AMTESS breadboard simulators (Unger, Moyer, Cole, & Swezey, 1983).

The present report is an evaluative effort in the SIMTRAIN II project. (SIMTRAIN II continues the AMTESS evaluation and includes systematic extensions of previous AMTESS experiments.) One goal of this report is to document several years of interaction among government agencies, device contractors, and evaluation contractors for the purpose of elucidating strengths and weaknesses *in the process of generic training* simulator development and testing. A second goal is to identify strengths and weaknesses of specific AMTESS device features. A third goal is to offer guidelines for future device development efforts.

This report has three sections. Section I describes the development of the AMTESS project. The procedures used in gathering a relevant data base are discussed. Important events and relationships in the history of AMTESS are displayed graphically and discussed.

Section II describes specific features of two breadboard devices. The data base for this section includes the personal opinions of personnel representing nine organizations involved in AMTESS and quantitative ratings by a small panel of device experts.

Section III summarizes all the findings and offers suggestions for future efforts in the development of generic maintenance simulators.

I. RECORDING THE HISTORY OF THE ARMY MAINTENANCE TRAINING AND EVALUATION SIMULATION SYSTEM (AMTESS)

A. Procedures

Information about the history of AMTESS came from two sources: documents and structured interviews.

1. Documents. A large number of formal and informal documents was examined. Appendix A contains a list of all documents reviewed. Information extracted included the dates and participants in AMTESS events.

2. Structured interviews. Key personnel representing the government, device contractors, and the evaluation contractor (SAI) were interviewed. Two interviewers conducted each interview.

Table 1 presents a list of all interviews conducted. It gives descriptive information about each interview, identifies each interviewee, and presents the date and location of each interview.

Eighteen people representing nine organizations were interviewed. Those nine organizations were judged to be the most heavily involved in the AMTESS program. Personnel representing other organizations (Honeywell, Hughes, USAMMC&S, and USALOGCEN, for example) were not interviewed because their scope of involvement in AMTESS was less than that of those organizations interviewed, and time and financial constraints dictated that not every participant could be interviewed.

The structured interview protocol was written by SAI. This protocol contained three sections of questions. The sections concerned the history of AMTESS, front end analysis, and device features. Appendix B contains a copy of the protocol.

Each interview began with introductions of interviewee and the two interviewers. The interviewee was told that the purpose of the interview

TABLE 1. INTERVIEW INFORMATION

ORGANIZATION	NUMBER OF INTERVIEWEES	INTERVIEW LOCATION	INTERVIEW DATE
PM TRADE Orlando, FL	1	Ft. Bliss	24 May 1983
ARI, Simulation Systems Technical Area Alexandria, VA	2	ARI Ft. Bliss	9 June 1983 23 May 1983
USAOC&S Aberdeen, MD	2	Aberdeen	6 May 1983
USAADS Ft. Bliss, TX	1	Ft. Bliss	23 May 1983
TRADOC, ATSC Ft. Eustis, VA	1	Ft. Eustis	3 May 1983
Grumman Bethpage, NY	2	Bethpage	14 June 1983
Seville Research Corp. Pensacola, FL	2	Pensacola	5 May 1983
Burtek, Inc. Tulsa, OK	3	Tulsa	16 May 1983 17 May 1983
Science Applications, Inc. McLean, VA	4	McLean	2 May 1983 6 June 1983 10 June 1983 29 June 1983

was to learn about the AMTESS development process so similar future efforts might be improved. The primary interviewer then conducted the interview and took notes as much as possible. The second interviewer took extensive notes and occasionally requested clarification. Interviewees were asked to respond in depth to those questions about which they were knowledgeable and to give no comment if unfamiliar with the topic. Care was taken to put interviewees at their ease. Average interview duration was about two hours.

Individuals interviewed were assured that their comments would not be attributed to them by name. Interviewees' opinions are not to be construed as the official position of their employers. Interviewees' opinions reflect personal judgments based on experience in the AMTESS program.

After each interview, the interviewers discussed the interviewee's response to each question. During this time, the interviewers reached agreement about the interviewee's responses and drew connections between responses.

3. Data Reduction and Display Procedures. From the extensive chronology extracted from AMTESS documents, key events were selected. This information was organized around two figures (presented and discussed in Section I.B. of this report).

Information from structured interviews aggregated around five topics: objectives of AMTESS, performance of organizations involved, coordination of effort, the device evaluation, and the future of AMTESS. All responses were collated question-by-question within each issue and then summarized. The discussion of structured interview responses is presented in Section I.C. of this report.

Although interviewees were questioned about their front end analysis activities, very little information was obtained. Most interviewees were not involved in the AMTESS effort during the front end analysis portion of the project. Front end analysis is not treated as a separate topic in this report, but will be thoroughly discussed in a subsequent report.

B. Results: A Brief History of the AMTESS Effort

1. Overview. This history of AMTESS begins in May 1977 with the proposal review for a maintenance training study and ends in June 1983 with the conclusion of the first AMTESS device evaluation. During these six years, five major contracts were awarded. Five government agencies and six contract firms were key players. These organizations were based in New York, Maryland, Virginia, Florida, Arkansas, Texas, Oklahoma, and Minnesota.

Figure 1 presents the major events in the AMTESS project and includes an overview of the relationships among the principal participants.

The Study Advisory Group was organized by PM TRADE and originally included representatives from PM TRADE and USATSC. Later, representatives from USALOGCEN, USAADS, and USAOC&S were added. As shown in Figure 1, the Study Advisory Group awarded to the Seville Research Corporation a contract to investigate the concept of using simulators in maintenance training. From 1977 to 1979, PM TRADE developed the AMTESS concept with the help of the Study Advisory Group and with input from Seville.

Late in 1979, PM TRADE awarded Phase I AMTESS contracts to four firms: Grumman Aerospace Corporation, Honeywell Systems and Research Center, the Seville Research Corporation, and Hughes Aircraft Company. Figure 1 shows this branching out to the four contractors. Each firm was to conduct a front end analysis and then posit a conceptual design for a generic AMTESS device. The AMTESS device was generic in the sense that it was to include one core component and various 3D modules relating to different MOSs.

The Phase I front end analysis included three main components: task commonality analysis for selected automotive and missile MOSs, training requirements analysis, and fidelity analysis. Other requirements in Phase I included life cycle cost estimates and a preliminary system design. All four contractors submitted Phase I final reports by July 1980 as shown in Figure 1.

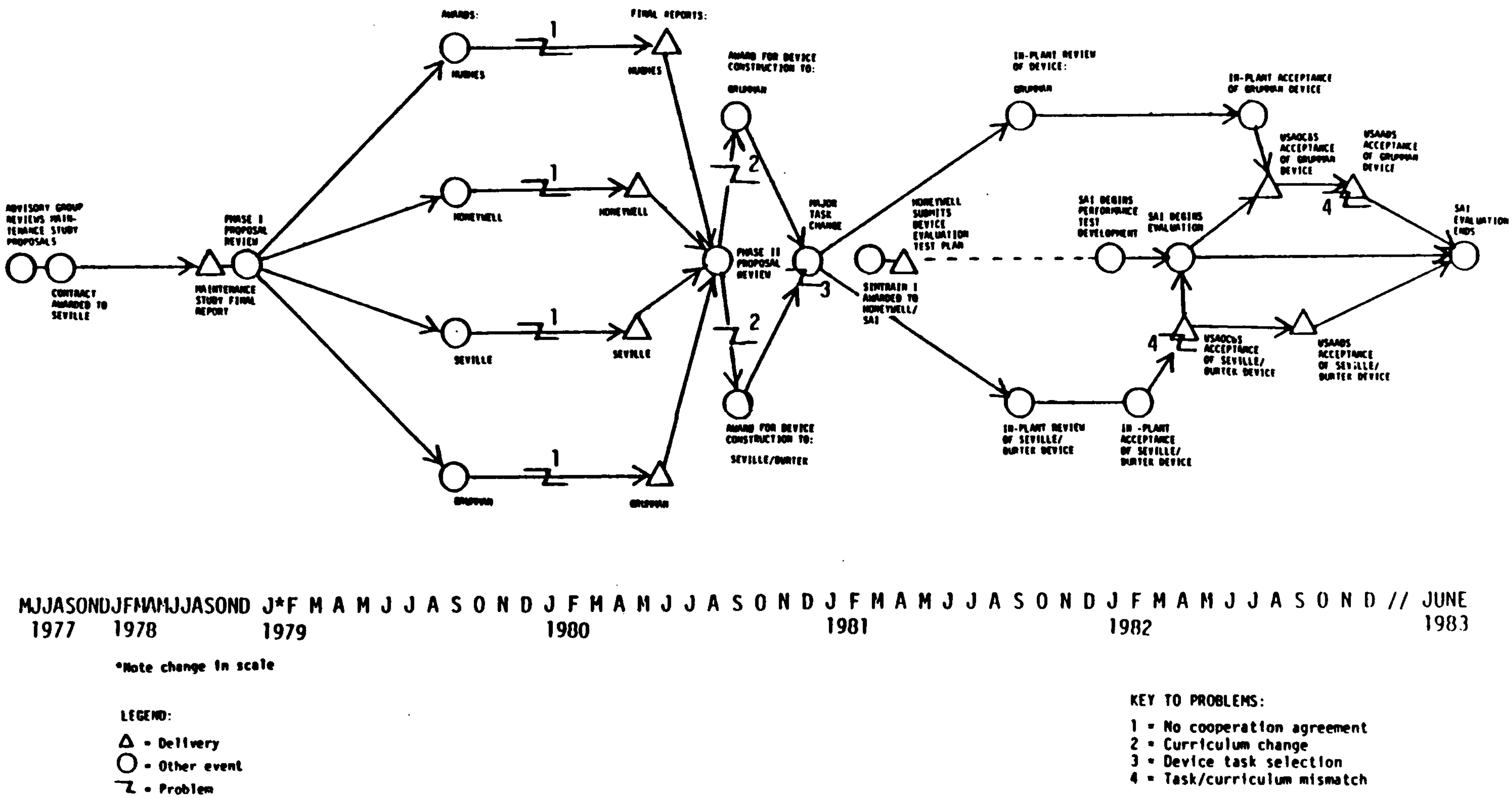

Figure 1. AMTESS milestones.

As shown in Figure 1, several problems occurred during Phase I. These problems remained unsolved and carried over into Phase II. The problems included lack of a cooperative agreement among participants, and poorly documented school-contractor contacts.

Phase II of AMTESS began in September 1980 with PM TRADE's contract awards to Grumman Aerospace Corporation and a team consisting of Seville Research Corporation and the Burtek Corporation. In Phase II, these two contractors were to construct breadboard models of the devices they designed in Phase I. These two contractors were selected, in part, because their device designs were quite different from each other. Each contractor would construct two devices, one for each of the two test schools (USAADS and USAOC&S). The devices would address the MOSs selected by each school.

The selection of skills to be taught by the devices turned out to be one of the largest problems in Phase II. As shown in Figure 1, a problem in this regard occurred after Phase II proposals had been submitted, but before Phase II award. Three of the five MOSs from which skills had been drawn were dropped from the curriculum at USAOC&S. Thus, at the time of award, the government could not specify a skill list for the contractors. Several meetings occurred, and by December 1980, the tasks were specified. However, Figure 1 shows that a major problem with the task selections still existed: the tasks selected were different for each device, thereby making invalid any experimental comparisons that might have been made between them.

Shortly after the Phase II award, as shown in Figure 1, ARI awarded to Honeywell a contract called SIMTRAIN I. Honeywell's involvement in SIMTRAIN I is largely out of the scope of this report, but Honeywell's subcontractor, SAI, had the task of conducting an empirical evaluation of the Grumman and Seville/ Burtek devices. SAI, with ARI's guidance, began developing during the time of device development (in mid-1981) test plans and actual performance tests for use in the evaluation. These simultaneous and related efforts are shown in Figure 1.

Finally, from mid to late 1982, the devices arrived at the test schools. Figure 1 again shows a problem, this time with device acceptance. The tasks taught by two devices did not match either the tasks selected in December 1980, the tasks used by the test schools and SAI to develop performance tests, or the school's conventional curriculum which was to serve as control training. At the last minute, new performance tests were developed and the evaluations began. SAI completed its evaluation of both devices in June 1983.

The following sections, I.B.2. and I.B.3., discuss the AMTESS device developmental process in detail.

2. AMTESS Phase I. Figure 2 presents the 11 main groups involved in the AMTESS project and events critical to their participation. Figure 2 shows the tasks performed by single groups and illustrates how activities of different groups overlapped in time. (Some groups such as USALOGCEN and USAMMCS have not been listed separately in Figure 2. These agencies participated in the various advisory groups, listed in Figure 2 as Advisory/ Working Groups.)

The AMTESS concept was developed during 1977 and 1978. During this time, PM TRADE sponsored a study to survey maintenance training devices used by the Army, other services, and private schools and industry. PM TRADE organized a Study Advisory Group (SAG) in September 1977 to oversee the study. The Seville Research Corporation conducted the survey. The main goal of the study was to recommend state-of-the-art alternatives to actual equipment training. Seville's final report was submitted in September 1978. Clearly, Seville is the one contract firm which has been involved in AMTESS since 1977, and one of its employees who was involved in the survey study is still involved in AMTESS.

In June 1978, a group of 28 government personnel met at ATSC to discuss various points of view about the development of maintenance trainers. Two Army schools, USAADS and USAMMCS, submitted a statement of their needs and requirements for a generic maintenance training device. According to notes

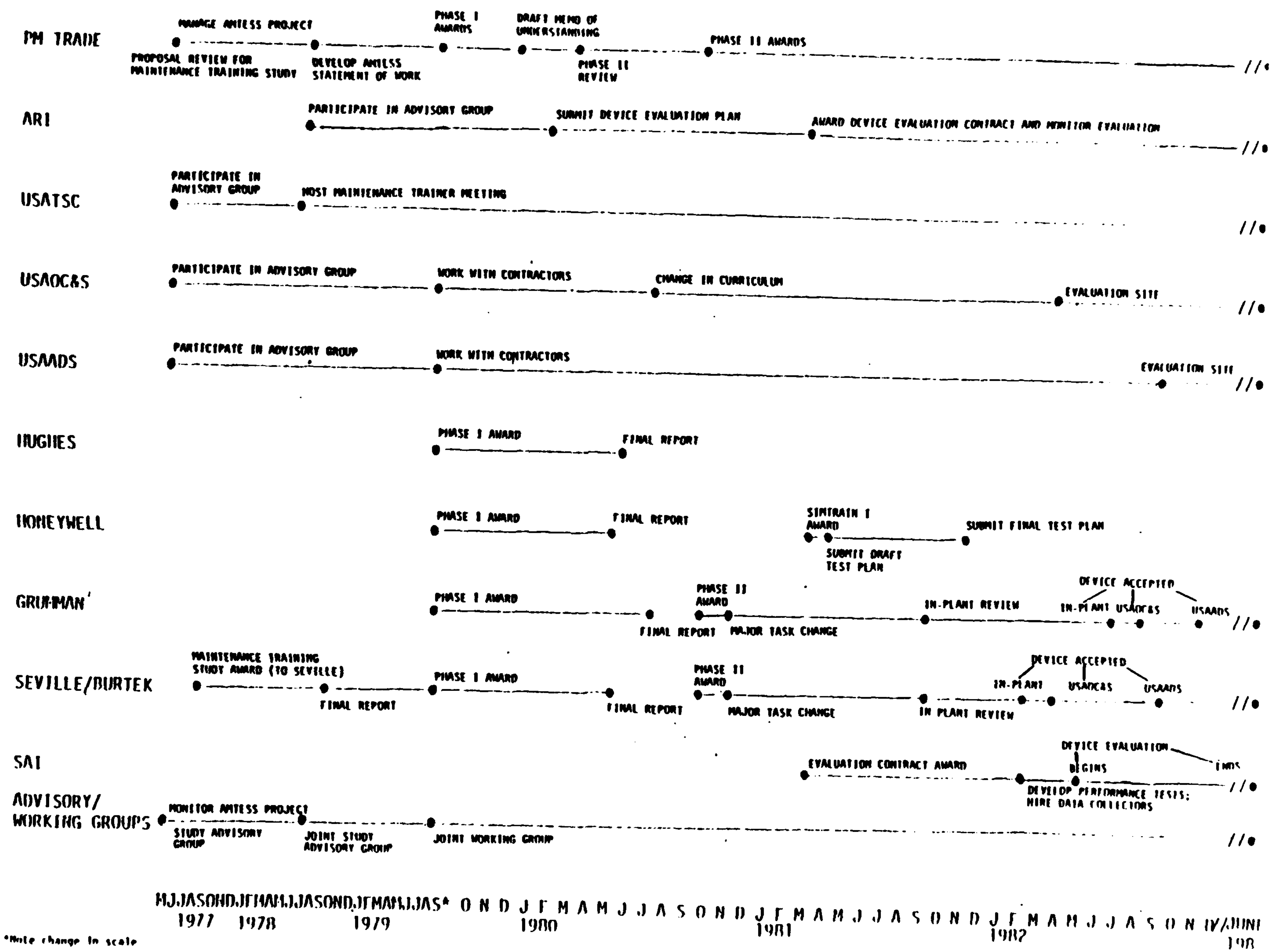

Figure 2. Critical events in the AMTESS project.

from one USAADS employee, the schools wanted improved training devices. The extensive research and development envisioned by several agencies was not envisioned by the schools at that time. Thus, a problem with mismatched goals might have been born during this time. The group affirmed that PM TRADE would develop a request for proposal concerning development of maintenance trainers, and manage the subsequent contract.

Accordingly, in July 1978, PM TRADE formed a coordinating organization, the Joint Study Advisory Group (JSAG). Specific organizations invited to participate were PM TRADE, ARI, USATSC and nine schools, USAIS, USAOC&S, USAAMMC&S, USASIGS, USAFAS, USAARMS, USAADS, USATSCH and USALOGCEN. The primary objectives of this group were to develop the AMTESS concept, develop long-range maintenance training plans, and develop the statement of work for AMTESS Phase I. Government personnel directly involved in AMTESS have changed substantially since the first JSAG meeting in August 1978. Of the 16 individuals at that meeting, only two were active through AMTESS Phase II and device evaluation.

Later in 1978, the JSAG was restructured. The new group was called the Joint Working Group (JWG).

The Phase I contracts were awarded in September 1979 (about nine months later than planned). Of the 11 individuals on the proposal review committee, again, only two remain active in AMTESS. Phase I contracts were awarded to four contractors: Grumman, Hughes, Honeywell, and Seville.

In December 1979, PM TRADE authored a memorandum of understanding between itself (a DARCOM organization) and USATSC (A TRADOC organization), supported by USAOC&S, USAMMC&S, USADDS, and ARI. The responsibilities of each organization were spelled out in general. It is uncertain, however, if the document was finalized and signed by all parties.

As mentioned earlier, the goals of Phase I were: (1) to conduct a front end analysis including task commonality analysis, training requirements analysis, and fidelity analysis; (2) estimate life cycle system costs;

and (3) design a high technology generic maintenance trainer. Personnel at USAADS, USAOC&S, USAAS, and USAMMC&S were asked to provide the contractors with as much information as possible about their curricula. Contractor and school contacts during Phase I are not well documented, and few personnel remain to report the details of Phase I activity.

It is not the purpose of this report to document and discuss activities in the front end analysis. A report on AMTESS front end analysis activities is the subject of another report (under the SIMTRAIN II contract, Task 2) due in 1984.

Final Phase I briefings were presented by all four contractors at PM TRADE on March 26, 1980. Grumman proposed a generic training device consisting of a 2D module with computer, video disc, and CRTs, which linked to a 3D computerized, simulated piece of equipment that was scaled down in size. Honeywell's and Hughes's devices were also designed with a video disc. Seville proposed a device of 2D component with computer, random access slide projector, and CRT. Seville's 3D component was to be a full size computer-activated piece of equipment.

Final reports were submitted by Honeywell, Seville, Hughes, and Grumman in May, May, June, and July 1980, respectively.

3. Phase II and Device Evaluation. PM TRADE developed the statement of work for Phase II in 1979 and 1980. The major tasks in Phase II were to be the construction and acceptance of breadboard generic maintenance training devices. These devices had been designed in Phase I.

Coordination of Phase II activities was the responsibility of PM TRADE and the Joint Working Group (JWG). This group was organized by PM TRADE in late 1978. Agencies in the JWG were PM TRADE, ARI, ATSC, USALOGCEN, USAOC&S, USAADS, and USAAMCS. Contractor representatives were invited to attend JWG meetings as appropriate. The JWG coordinated activities through Phase II, the device evaluation, and remains active still.

In January 1980, as shown in Figure 2, ARI submitted a device evaluation plan to PM TRADE. The evaluation plan was complex, included 80 cells, and was substantially simplified before implementation.

The MOSs used in the Phase I task commonality analysis were 63B, C, and H in automotive systems, and 24C and K in missile systems. Plans made for the devices were based on those MOSs. Unfortunately, problems arose in July 1980, after the Phase II proposals were evaluated, but before the contracts were awarded. The 63B, C, and H MOSs were dropped from the curriculum at USAOC&S; therefore, the tasks to be taught by the devices changed. This meant that some portion of Phase I device planning was no longer applicable. Further, changes in school curricula meant that control (conventional) training had changed. Clearly, a reassessment with respect to device development and evaluation was in order. Perhaps at that point, because of the extensive changes that had occurred in task selection, the contract process should have been delayed until the schools and ARI decided on a task list that would fit with the school's curriculum and lend itself to performance testing for purposes of device evaluation. Then, perhaps another task commonality analysis should have been conducted.

The AMTESS Phase II contracts were awarded in September 1980, before the task selection problem was solved. Shortly after contract award, the Phase II contractors, Seville/Burtek and Grumman, met with the government, but did not agree on task selection. Then, at a JWG meeting in November 1980, contractors were told that they needed to add training in the use of the STE/ICE (Standard Test Equipment for Internal Combustion Engines) device. The task selection problem was thereby magnified.

Contractor and school personnel finalized task selection by December 1980. For USAOC&S, the Grumman simulator was to be based on tasks from the 63D30 MOS, and Seville/Burtek's simulator on 63W10. For USAADS, both devices would be based on the 24C10 MOS, but the overlap in tasks taught by the device was only partial. (Date of USAADS task selection is unknown.) The contractors and schools would work closely together for the next 15 months of device development.

ARI was informed of task selection for each device in December 1980. ARI expressed reservations about the selection because ARI's device evaluation plans, submitted to PM TRADE nearly one year earlier, called for a comparison between the two devices on measures of transfer of training from the simulators to the actual equipment. Such a comparison would be invalid if the devices did not teach the same tasks. ARI communicated their concern to PM TRADE, but PM TRADE did not insist that the devices teach the same tasks.

Shortly after the task list was specified, in March 1981, ARI awarded to Honeywell, with SAI as a subcontractor, a contract to support the AMTESS device evaluation. AMTESS device evaluation was one task of a large device evaluation project called SIMTRAIN I. Honeywell submitted a draft test plan to ARI in April 1981 taking into account the changes in task selection and removing experimental comparisons of the devices. Discussion of the test plan occurred at JWG meetings over the subsequent seven months, and Honeywell submitted a final test plan to ARI in November 1981.

In the meantime, device development and construction were underway. The schools provided the contractors with lesson plans and course material which was to be incorporated into the devices. Contractor representatives spent time at both schools, meeting with instructors and subject matter experts. However, construction of both devices fell behind the original schedule. Contractors report that slippages were due to the extensive changes required following the changes in task selection <u>after</u> front end analyses and <u>after</u> contract award.

In September 1981, one year after the Phase II awards, the JWG conducted In-Plant Reviews of both devices. The Seville/Burtek device was not assembled nor had courseware been developed, but the companies projected a January 1982 delivery date (three months behind schedule). Grumman demonstrated hardware, software, and courseware, but also anticipated late deliveries. They projected a delivery to USAOC&S in February 1982 and one to USAADS in April 1982.

It was thought at the time of the In-Plant Reviews that both device deliveries might be even later than expected, and that the device evaluation contract (SIMTRAIN I) might actually end before the devices could be evaluated. Honeywell submitted its final test plan in November 1981, and SAI, as subcontractor to Honeywell, continued to plan for the device evaluation. Device delays persisted, and in mid-1983, ARI awarded a contract (SIMTRAIN I Extension) to SAI to collect and analyze data, and to submit the evaluation report. Honeywell completed its work on the SIMTRAIN I project and is no longer involved in the AMTESS effort.

Problems began developing at the other test site, USAADS, in October 1981, nearly a year before any device would be delivered there. Conventional training changed from a self-paced to a lock-step mode and the school was unwilling to provide self-paced conventional training to subjects in the evaluation. The primary experimental comparison in the device evaluation was that of conventional to simulator training. Now the validity of that comparison was threatened. Again, as when major curriculum changes occurred at USAOC&S, perhaps the process should have been halted and a new school chosen which could provide conventional training that met evaluation requirements.

In February 1982, the JWG conducted the In-Plant Acceptance of the Seville/Burtek device. According to an ARI trip report, the acceptance involved a demonstration of the missile configuration and visual inspection (but no demonstration) of the automotive configuration. The fact that a mismatch existed between tasks actually taught by the devices and tasks expected was not uncovered at that time.

Also in February 1982, expecting device deliveries in the near future, SAI hired and trained its data collectors. During the next several months, SAI continued to develop performance tests and prepare for the evaluation. ARI restricted SAI's access to the contractors so that the evaluation would be conducted by a totally independent party.

In April 1982, the Seville/Burtek device was delivered to USAOC&S. When it arrived, it was discovered that the tasks for which the performance tests had been developed were not included and that the tasks taught by the device were actually from the 63H MOS originally planned. Not only were the tasks taught by the device a surprise, the tasks pertained to a different type engine than was expected. At the last minute, SAI developed new performance tests to match the device, and the evaluation began in early May 1982. Seville/Burtek was not pleased with the evaluation plans and protested because not all the tasks taught by their device were included in the evaluation. In response to the protest, the performance tests were revised and a new criterion was added. The new criterion was the extent to which subject matter experts felt the device covered the required program of instruction.

The final In-Plant Acceptance of the Grumman device occurred in July 1982, and was accepted at USAOC&S in August 1982.

In September 1982, Seville/Burtek delivered its device to USAADS. This device matched what was expected, and the evaluation at USAADS began in October 1982.

The Grumman device was delivered to USAADS in November 1982. Again, there were problems. Performance tests for some of the skills taught by the device could not be implemented because the skills were too dangerous to perform on actual equipment because of high voltage. Therefore, testing occurred on the simulator. Further, use of the device was clearly supplemental to conventional training. This fact, coupled with the problem created by the change in conventional training from self-paced to lock-step, prevented a comparison of control and experimental training.

More problems arose at USAADS concerning the evaluation of the Grumman device. The experimental plan called for 10 students each in the simulator and conventional training groups. The school, however, did not make 24C10 (entry-level) students available for the evaluation, apparently because their participation in the study would interfere with their training in mechanics which was the school's responsibility to provide. The school instead provided 10 advanced students from other MOSs for simulator training and provided no students from conventional training for testing. Thus, no experimental comparison between the Grumman device and conventional training was conducted at USAADS.

SAI completed the evaluation of both devices at both schools by mid-June 1983. The complete report on the device evaluation is in progress.

4. Summary. During Phase I, PM TRADE, the schools, the advisory group, and the contractors worked together well enough that the four contractors conducted front end analysis, designed devices, and delivered final reports in a timely manner. Several problems arose during Phase I, however, which were unresolved and carried over into Phase II. First, no memorandum of understanding bound PM TRADE, ARI, the contractors and schools. Second, government monitoring of the frequent contractor and school contacts either did not occur or is not documented. This practice continued on into Phase II with schools and contractors meeting but without close monitoring. Third, the goal of the schools was to obtain better maintenance training programs, and the schools apparently did not officially agree to cooperate fully with device research. Finally, ARI did not assume any special role during Phase I, yet ARI would administer the device evaluation projects.

Phase II and the device evaluation seemed to be characterized by misunderstanding. Even before the Phase II contracts were awarded, changes in device specifications threatened problems. The first changes in planning for task selection for the devices were required in July 1980. In spite of all the meetings, phone calls, and trips between schools and contractors that occurred over a 21-month period, the first device delivered (and subsequently two more device deliveries) did not teach the tasks many agencies thought it should. Unexpected changes in both the schools' conventional training programs threatened the validity of the device evaluation. The device evaluation was conducted, but the evaluation was able to address only a portion of the questions it sought to answer.

C. Outcomes of the AMTESS Experience

In section I.B. above, a chronology of AMTESS project events was presented. In this section, a summary of key participants' opinions about the AMTESS process is presented. All opinions came from structured interviews described in sections I.A.2. and I.A.3. above. The opinions presented here do not represent official views of organizations.

This discussion is organized around five topics:

1. Objectives of AMTESS
2. Performance of organizations involved
3. Coordination of effort
4. The device evaluation
5. The future of AMTESS

1. Objectives of AMTESS. Table 2 presents a summary of opinions of the nine organizations concerning the primary objectives of AMTESS. The data in Table 2 suggest that there was good agreement among organizations that the primary AMTESS objective was to develop concepts, then using the concepts, produce a breadboard (or forerunner) generic maintenance trainer. The trainer was to include a common core and various 3D modules.

Some organizations (PM TRADE, ARI, and SAI, for example) added that the development of front end analysis procedures that might apply to the development of other training simulators was a second AMTESS objective. Most organizations, however, did not mention this objective.

In spite of general agreement about the primary AMTESS objective, representatives from seven of the nine organizations stated that the objectives and process for AMTESS were unlike other device development processes because of the lack of specificity received from the Army. According to interviewees, the development process for most devices is usually more clearly spelled out than it was for AMTESS devices. The AMTESS objective was very general.

TABLE 2. OPINIONS OF ORGANIZATIONS' REPRESENTATIVES CONCERNING AMTESS OBJECTIVES

ORGANIZATION REPRESENTED	PRIMARY AMTESS OBJECTIVE	HAS AMTESS PROCESS DIFFERED FROM OTHER DEVICE PROCUREMENT PROCESSES?
PM TRADE	Develop generic maintenance trainer that allows for broad spectrum of training and transfer to any maintenance training area.	Same as other 6.2 programs.
ARI	Develop general model of a generic maintenance trainer which includes a core module and MOS-specific 3D modules.	Yes; this was R&D.
USAOC&S	To challenge industry to develop a generic maintenance trainer involving 2D and 3D modules.	Yes; Army is usually more specific in its desires.
USAADS	Develop maintenance training concepts and then develop appropriate hardware.	Yes; this was R&D.
ATSC	Develop a generic way to train maintenance.	Yes; this was R&D.
GRUMMAN	Develop conceptual design and then the hardware to be a forerunner of a universal maintenance training device.	Yes; much was unspecified.
SEVILLE	Develop family of hands-on maintenance trainers.	This was like any R&D effort.
BURTEK	Verify cost and training effectiveness of a maintenance simulator which includes common core hardware and 3D modules applicable to many MOSs, especially "low-end" MOSs.	Yes; usually receive more specifications.
SAI	Design and build modular, reconfigurable low-cost breadboard generic maintenance trainer.	Yes; this device was generic.

2. Organization Performance. This section includes a discussion of participants' comments about the performance of the organizations involved in AMTESS. Interviewees commented on organizations' performance in general, and with respect to pertinent critical tasks. The goal of this discussion is to present general themes, not to specifically identify the author of each comment discussed.

a. PM TRADE. Several interviewees felt that PM TRADE had done a good job developing the AMTESS concept; however, most participants felt that the statements of work (SOWs) pertaining to the concept were too open-ended with too much interpretation left to the contractors. Only a few interviewees commented on PM TRADE's proposal review process, but apparently the majority felt that a standard review process was followed. Most felt that PM TRADE should have been more of a presence in monitoring in-plant development of both devices. Similarly, the interviewees felt that PM TRADE should have been more active in monitoring the device evaluation. Several interviewees commented that PM TRADE should have provided more leadership in general to the AMTESS project. However, PM TRADE was generally pleased with its performance.

b. ARI. Most interviewees did not comment on ARI's performance in the proposal review process; standard procedures were followed. One interviewee felt the device evaluation award to Honeywell was "improper" because Honeywell was a potential bidder in future AMTESS procurements.[1] With respect to ARI's SOW for the device evaluation, two interviewees felt it was vague; one of those interviewees, however, felt the SOW was acceptable.

Representatives of all organizations which commented felt that ARI's in-plant monitoring of device development was good. ARI participated both in In-Plant Reviews and Joint Working Group meetings.

[1] Exclusion of bidders is not ARI's prerogative. ARI acts as an agent for the Defense Supply Service in contract awards.

Most interviewees felt that ARI's test plan was too general, but many felt that ARI did a good job monitoring the device evaluations. ARI representatives felt that limited funds for travel prevented ARI personnel from visiting Ft. Bliss as often as they would have liked.

One interviewee remarked that ARI's approach to AMTESS was too academic and therefore impractical. Representatives from two organizations felt that a stronger relation between ARI and PM TRADE would have helped the project.

c. Schools. Opinions were about evenly divided on the schools' work with the contractors during the front end analyses. About half said the schools could have worked more closely with the contractors and about half felt the schools and contractors worked adequately with each other.

In general, interviewees felt that the schools', or the subject matter experts', roles in both the in-plant monitoring of device development and device acceptance had not been clearly specified by the Joint Working Group. However, most individuals felt that the schools did well with device development monitoring. Most interviewees also felt that a much stronger relation between subject matter experts and the schools would have improved device development.

Opinions were mixed regarding the schools' cooperation with the device evaluation. Generally, the schools cooperated as best they could, but the evaluation lacked support from top school administrators. Therefore, no one deeply involved in AMTESS had sufficient authority over school personnel (instructors, subject matter experts, course writers, for example) to get the cooperation required for a fully successful evaluation. The schools' intentions were good, but there was no official cooperative agreement.

d. Contractors. Both contractors were pleased with their front end analyses, preliminary systems engineering design, and life cycle cost estimates. Most interviewees did not comment on those aspects of contractor performance.

In general, most interviewees, especially the contractors, were satisfied with the devices. According to some device contractor representatives, the contractors received little direction from the Army, were faced with mid-stream changes in device requirements, yet both contractors produced working hardware and software. However, one spokesman was disappointed in both devices because they were not stimulating and were cumbersome; representatives from two organizations pointed out the problems caused by late device deliveries; several interviewees mentioned major problems caused by disrepair.

Both contractors were satisfied with their device maintenance service during the evaluation. Grumman provided telephone consultation and Seville/Burtek provided a technician on-site. Although both contractors employed a maintenance plan, a clear majority of interviewees felt the on-site technician provided better service.

e. SAI. Most organizations felt that, under the difficult circumstances, SAI developed satisfactory performance tests for the device evaluation. While ARI was pleased with SAI's test plans, several representatives did not see copies of the test plan as it was revised. Thus, several interviewees did not know that test plans existed.

As for the qualitative and quantitative data gathered by SAI in the device evaluation, some individuals did not comment because the evaluation report is not written. Most interviewees were pleased with data collection saying SAI did well given the constraints. The strong efforts of SAI's two on-site data collectors were praised. The TRAINVICE evaluation (a portion of device evaluation involving user ratings of device features), while being relevant and appropriate, was criticized by both schools as being too long.

One organization commented that SAI did a good job and was flexible in their planning. SAI was pleased with its own performance.

f. ATSC. ATSC, as a member of the Joint Working Group, was to represent TRADOC's perspective. Nearly all individuals commenting on ATSC felt that ATSC representatives took an active role in AMTESS.

3. Coordination of Effort. Interviewees were asked to identify the locus of responsibility for coordination of AMTESS efforts and to characterize the coordination between organizations.

First, all interviewees stated that PM TRADE was responsible for managing AMTESS. Individuals were mixed in opinions concerning the adequacy of PM TRADE's authority and resources to manage AMTESS.

Representatives from about half of the organizations felt that PM TRADE had inadequate authority and/or resources to manage AMTESS. However, many representatives felt that PM TRADE had sufficient authority and resources.

Several interviewees felt that limited resources and/or authority presented problems for PM TRADE's management effort. However, representatives of two organizations felt that PM TRADE's management was satisfactory. PM TRADE was satisfied with its own participation in AMTESS.

Related to PM TRADE's responsibility is the responsibility of the Joint Working Group (JWG) and the effectiveness of JWG meetings in coordinating AMTESS activities. Several interviewees said that the JWG did not provide clear directions to the organizations involved. Rules, meeting objectives, and minutes might have strengthened the JWG's effectiveness in the opinion of several interviewees. One interviewee commented that the JWG was stronger early in AMTESS than in the later time period. One representative felt that the JWG worked well.

Problems in coordination of activities among the organizations involved were the result of lack of direction from the JWG according to a few interviewees. Two interviewees viewed coordination as satisfactory.

Interviewees were asked to characterize the coordination between their organization and each other organization. Most interviewees felt that their organization had contact with PM TRADE only through JWG meetings; thus, most felt that coordination with PM TRADE was not as good as it should have been. Some individuals pointed out that PM TRADE was always available by phone.

The coordination between ARI and SAI was judged to be satisfactory by representatives of both organizations. The schools felt that a stronger relation between themselves and ARI would have been helpful although both schools had frequent telephone contact with ARI.

Most interviewees commenting felt that coordination between their organization and the schools was satisfactory. Representatives from one organization commented that coordination was better with subject matter experts than with top school administrators.

Most interviewees felt that coordination between their organization and the contractors was minimal and that more contact was needed. Where contacts were frequent between the contractors and schools, apparently monitoring of the contacts was needed. In general, participants felt that the problems surrounding device delivery and evaluation might have been avoided had coordination and leadership been more apparent.

Coordination with SAI was satisfactory according to representatives of several organizations. However, one representative of USAADS felt that more frequent on-site contact with a senior SAI staff member would have helped. From SAI's point of view, cost prohibited more frequent travel to USAADS.

All individuals commenting felt that coordination with ATSC at the JWG meetings was satisfactory.

4. Device Evaluation. It is not the purpose of this report to summarize the results of the device evaluation. The report presenting the results of the empirical device evaluation is separate from this report. This section contains opinions about the evaluation (which was still in progress at the time of the interviews).

Interviewees were asked to comment on several aspects of device evaluation. Among those aspects were selection of test tasks and the comprehensiveness and validity of the evaluation.

Most representatives felt that ARI was responsible for asking the schools to select the tasks used in device evaluation. Many interviewees did not know who selected tasks to be taught. A few thought the schools (with contractor input) actually selected the tasks to be taught by the devices.

Most interviewees felt that the validity of the evaluation has been compromised. Two important reasons mentioned were too few tasks tested and an insufficient number of students. However, one interviewee remarked that the problems encountered are typical in field studies.

5. The Future of AMTESS. Interviewees were asked if they felt that the AMTESS concept, embodied in the prototypes, has lived up to expectations. They were also asked if the AMTESS concept is worth pursuing.

Opinions were mixed concerning the prototypes' representation of the AMTESS concept. Most interviewees, especially contractor representatives, felt that the devices had "proven" the concept and/or surpassed expectations. Those people who felt the devices did not live up to expectations most often mentioned operational problems with the equipment.

Agreement was widespread that the AMTESS concept is worth pursuing. Individuals varied widely, however, in their opinions of how AMTESS should be pursued. Most felt that more research is needed. Several felt that the 3D modules should be designed to reflect general maintenance tasks, not specific (and frequently changing) MOSs. Some contractor interviewees offered some questions needing answers. For example, is the sophisticated integration of 2D and 3D components necessary to teach very simple skills? How can one core component be designed to support many different 3D modules? Is remove/replace capability as important as troubleshooting capability? Are the simulators supposed to replace or supplement existing training?

The tone of interviewee comments about the future of AMTESS was hopeful. In spite of problems encountered during AMTESS, the need for tested AMTESS devices is clear to all the participants.

D. Summary

The preceding sections have presented a brief history of the AMTESS project and participants' opinions about critical events in the AMTESS project. Perhaps the largest problem, which arose during Phase I and carried over into Phase II, was the absence of a memorandum of understanding. Many organizations did not appreciate their specific responsibilities to the program, and gaps in performance were evident. Progress made during Phase I might be attributed to agreement about general project goals and adequate cooperation between schools and contractors. Phase I final reports were submitted in a timely fashion.

During Phase II, coordination and communication suffered as the number of participants increased and the interfaces between participants became more complex. Two simultaneous efforts, device construction and device evaluation, should have been more interactive than they were. However, interaction was insufficient, and as a result, the devices did not meet all the schools' expectations.

In spite of the problems encountered, participants in the AMTESS project felt that many project goals were accomplished. Participants shared the idea that generic maintenance training simulators will be important in Army training. Most also felt, however, that the devices developed during AMTESS need considerable improvement before they are ready for classroom use.

II. AMTESS DEVICE FEATURES

This section presents interviews opinions and expert judgments about the features of the device. First, the procedures used to collect opinions and judgments are described. Next, a summary of opinions is presented, first the Seville/Burtek device, then for the Grumman device.

A. Procedures

The data for this section come from two sources: structured interviews and device feature ratings from a small panel of experts.

1. Structured Interviews. Opinions about device features were obtained in the structured interviews mentioned in section I.A.2. above. The reader is referred to that section for interview procedures.

All interviewees were asked to comment on the concept and implementation of specific device features. They were also queried about the overall functioning of the devices. Contractors were also asked to comment briefly on the rationale behind device features.

2. Expert Ratings. Quantitative ratings of device features were obtained to augment the qualitative data collected in the structured interviews. Ratings were obtained from four experts, all unbiased and knowledgeable about both devices. Three SAI and one ARI personnel rated the devices. One SAI and one ARI personnel rated features of both devices used at both USAADS and USAOC&S. Another SAI employee rated features of both devices used at USAADS and a third SAI employee rated features of both devices used at USAOC&S. Thus, three sets of ratings were obtained for both devices at each school.

The training device features evaluation form given to each judge was designed such that the ratings could be easily subjected to a multi-attribute utilities analysis (Swezey, 1979). Multi-attribute utilities analysis is an applied technique useful to combine quantitative subjective data about several different attributes from several judges. This technique is particularly applicable when attributes may be evaluated on different dimensions of value. The ratings for each attribute are weighted according to a constant derived from each dimension of value. Then the weighted ratings for each attribute are summed. The sum for each attribute represents its value with respect to all the dimensions. Using these sums, attributes may be rank ordered.

For example, each dimension of value is assigned a weight based on its importance, in the judges' opinions, relative to all other dimensions. Each judge rates each attribute along each dimension. To illustrate, an attribute might receive a 20 on one dimension and an 80 on another. The 20 and 80 are multiplied by the weights for their respective dimensions. Then, those two numbers are summed. The sums for all judges are summed, then the attributes rank ordered. This procedure is explained in detail below.

The ratings form used contained three sections. A copy of the form appears in Appendix C. In the first section, judges were asked to rank four dimensions of value in order of their importance as criteria for features in a generic maintenance training simulator. Judges were instructed to rank the least important dimension "10," then rank the other dimensions in relation to the least important dimension and in relation to each other. For example, a dimension rated "30" is three times more important than the dimension ranked "10" and half as important as a dimension ranked "60." Each judge's ranks summed to 100.

The four dimensions and their descriptions are listed below:

Concept - Is the concept behind the feature important in a generic maintenance training simulator? (For example, the concept behind both a video disc and a slide projector may be the same, that of automatic presentation of visual material. The concept dimension asks if the concept is important.)

Implementation - Does the feature truly embody and express the concept behind it?

Operation - Is the feature easy to use and in good working order?

Motivation - Is the feature appealing and does it capture interest in learning?

In the second section, judges were asked to rate ten Grumman device features along each of the four dimensions. Judges were asked to consider a typical trainee and the MOSs taught. Judges were asked to use a scale of 0 to 100, with 0 minimal and 100 maximal. Ratings were orthogonal and did not have to sum to 100. Grumman device features at USAOC&S were rated separately from the Grumman device at USAADS. The ten features rated were:

- 3D module
- Student performance record
- Instructor CRT
- Video disc
- Touch panel, student CRT
- Editing system
- Request help
- Repeat lesson option
- Mandatory instructor call after two errors
- Performance feedback

In section three, judges rated 13 features of the Seville/Burtek device using the same procedures as for the Grumman ratings described above. The 13 features are:

- 3D module
- Student performance record
- Instructor CRT
- Slide projector unit

- Student response panel
- Editing system
- Student CRT
- Instructor control panel
- Remove/replace capability
- Random malfunction selection
- Performance feedback
- Troubleshoot only mode
- Sound effects

The first step in data analysis was assigning a weight to each of the four dimensions of value. This was done by summing the ranks of all judges on each of the four dimensions of value. The sum for each dimension was divided by the sum of the sums (400) and multiplied by 100. These numbers were used as the dimension weights. (Raw data for each judge are presented in Appendix D.)

According to our experts, the most important dimensions in evaluating features in generic maintenance training simulators are, in order, concept, operations, implementation, and motivation. The weights for these dimensions are 32.5, 28.8, 23.8, and 15.0, respectively. These weights suggest that concept and operations are highly valued and close in value, and motivation is clearly the least important criterion.

Next, each judge's ratings for each feature on each dimension were weighted. Then, the four weighted ratings (one of each dimension) for each feature were summed. Finally, ratings for each feature were summed across judges (or across three sets of ratings). As mentioned above, two experts rated both devices at both schools. A third and fourth expert rated devices used at USAADS and USAOC&S, respectively. Thus, three complete sets of ratings were available. The third set combines judgments from the third and fourth experts. The grand sum obtained represents feature value taking all four dimensions of value into account.

The results of the multi-attribute utilities analysis are presented below in section II.B.2. for the Seville/Burtek device and section II.C.2. for the Grumman device.

B. Results: The Seville/Burtek Device

1. Opinions about Features. Information in this section comes from structured interviews. The interview protocol contained 13 device features for interviewees to comment on. (It was considered inappropriate for device contractors to comment on each other's devices.) In addition, the protocol contained general questions about feature strengths and weaknesses.

a. 3D module. Almost all interviewees thought the 3D module was good, even excellent. The module was praised for its high fidelity, simplicity, and good operational record.

There was an assortment of criticisms. One interviewee commented that the module at USAOC&S was too specific, loud, and intimidating. One interviewee mentioned that many tasks are much easier to perform on the module than on the real equipment. That interviewee recommended increased fidelity in the 3D module to include improvements with the fuel line, the oil line and fittings, and addition of an oil dipstick. Further, an increase in difficulty of removing the starter and using the STE/ICE device was recommended. This interviewee also suggested that some tool usage skills were not of high enough fidelity. For example, bolts could not be torqued to specification because of risk of damage to the simulator.

Overall, representatives of all organizations commented that the concept behind the 3D module was good and implementation was successful. Several felt the realistic module was motivating to students.

b. Student performance record. This feature received unifc... ..igh praise for its completeness and dependability. Seville commented that the design of the record was based on the task analysis performed in the front end analysis.

A few organizations felt that some codes used on the record were difficult to interpret. Another criticism concerned a software problem. Occasionally, while working on the 3D module, the student would correctly push or pull on parts to repair them. However, this motion caused errors to register and these "errors" were reflected on the performance record.

c. Text presentation on student CRT. Text was presented on the student CRT. Text was praised as being well coordinated with the 3D module and technical manuals. Interviewees both praised and criticized the simplicity of the text presented. One interviewee noted that start-up safety training had been omitted from instruction; this omission could cause performance problems on actual equipment. However, the concensus was that this feature worked well.

d. Instructor CRT. This CRT presented screens to help the instructor set up the device. It also displayed student progress information. Representatives from all organizations found this feature good, even excellent, in its completeness and dependability.

e. Slide projector unit. Representatives from all organizations thought the use of a slide projector in a generic maintenance trainer was a good, if not excellent, feature. Implementation problems occurred, however. One interviewee felt the unit should be abandoned because of frequent malfunctions. Several organizations criticized its dependability and mentioned a chronic overheating problem. One interviewee mentioned a focusing problem. One interviewee commented that more photographs were needed on the slides; many slides were redundant with the technical manuals. One interviewee mentioned that many slides appeared backwards on the screen. However, another participant thought that material from the manuals on a slide held a student's interest more than the same material in the manual. Overall, most interviewees liked the flexibility and low cost of the slide projector.

f. Student response panel. Opinions were mixed about the response panel. Some individuals liked it more than a keyboard or touch panel; some liked it less. One criticism was that several buttons had to be pressed to enter one response, thus making entries complicated. A more specific criticism concerned problems with the service button on Task #18 in the remove/replace thermostat sequence. Generally, however, most interviewees liked its simplicity and dependability.

g. Editing system. The editing system allowed the instructor to change the instructional material. Participants from all organizations rated the simple-to-use editing system as good to excellent - a strong point to the system.

h. Remove/replace capability. Most interviewees reported that this feature was often in need of repair, but that the concept behind the feature was good. According to some interviewees, this feature was useful for beginning level students more so than for advanced students.

i. Random malfunction selection. This feature sets the device on a randomly selected malfunction. Interviewees thought this was a good feature although it was not used often at USAADS. One participant reported that malfunction selection might not have been truly random; some days the same malfunction would appear repeatedly.

j. Performance feedback. The feature provided feedback to the student. Most interviewees felt this feature was adequate.

k. Troubleshoot only mode. This feature gave the student a chance to practice troubleshooting. Participants thought this was a good, if not very good, feature. One individual commented that this feature is especially motivating and instructional for more advanced students.

l. Sound effects. Sound effects were included on the device at USAOC&S. Most interviewees thought the sound effects were realistic and good. One interviewee thought they were especially motivating. One interviewee felt the sound effects were not important.

m. Instructor contol panel. The instructor uses this panel to operate the device. Interviewees felt that this panel was a good idea, straightforward, and simple to use. Seville representatives commented that this panel was designed based on past experience and on the task analysis completed in the front end analysis. One participant commented that the pre-session system check feature was good.

n. Software. Burtek representatives felt that their software programmed in FORTRAN IV was an outstanding feature of the device. It was highly useful for writing programmed instruction, easy to troubleshoot during device development, and compatible with military requirements. Further, FORTRAN IV is easy for users and thus users might not be dependent on Burtek for updates.

Specific benefits of the programming were mentioned by some interviewees. According to one, the capability for the instructor to insert a malfunction was a powerful feature. In fact, this feature was said to make training more authentic than actual equipment training because instructors could program malfunctions they could never insert into the actual equipment.

2. Expert Ratings. A panel of experts was asked to rate features of the Seville/Burtek device and the ratings were subjected to a multi-attribute utilities analysis. Basically, each device feature was rated along each of four dimensions: concept, implementation, operations, and motivation. Procedures used for rating and data analysis are described in section II.A.2. above.

Table 3 presents each judge's weighted rating and the total rating for each device feature. As mentioned in section II.A.2., the third judge's ratings are a combination of the ratings from the expert who rated the USAADS devices and the one who rated the USAOC&S devices. The data in Table 3 are grand totals of the weighted ratings for the Seville/Burtek device at USAOC&S and USAADS. Thus, the data in Table 3 suggest how valued each device feature is, taking all four dimensions into account. Features in Table 3 are listed in descending order by rank.

TABLE 3. MULTI-ATTRIBUTE UTILITIES DATA, WEIGHTED RATINGS FOR SEVILLE/BURTEK DEVICE

FEATURE	J_1	J_2	J_3	J_{Total}
1. Student performance record	14,664	18,200	17,192	50,056
2. 3D module	14,778	18,349	16,504	49,631
3. Troubleshoot only mode	14,664	16,324	13,162	44,150
4. Performance feedback	12,231	16,603	14,462	43,296
5. Remove/replace capability	13,858	15,760	12,762	42,380
6. Student CRT	11,137	15,373	13,166	39,676
7. Random malfunction selection	15,052	14,829	8,762	38,643
8. Student response panel	12,764	12,506	9,540	34,810
9. Slide projector unit	11,956	11,036	11,138	34,130

J_{Total}:
Mean = 41,863.6
S.D = 5,697.7

Table 3 shows that, according to our experts, the student performance record and the 3D module are the most valued features in the Seville/Burtek device. The total value for these features exceeds one standard deviation above the mean of this distribution. Table 3 also shows that the student response panel and the slide projector are the least valuable features in the Seville/Burtek device. The total values for those two features fall more than one standard deviation below the mean.

In a very general way, the order of ranks in Table 3 parallels the subjective comments made by personnel who gave structured interviews. The student performance record and the 3D module received high praise. The slide projector received criticisms for operational problems.

Table 4 presents the multi-attribute utilities data for features of the Seville/Burtek device, separately, by school. Although judges' ratings were similar for the device at each school, differences were seen. Table 4 shows that at both schools the student performance record and the 3D module were rated the most valuable device features. Values for these features exceed one standard deviation above the mean. However, the least valuable feature at USAADS was the slide projection unit, and the response panel at USAOC&S. Those features had composite ratings less than one standard deviation below the mean. Nevertheless, the rank order of features on this device at both schools is very similar.

In addition to the features mentioned above, four device features, the instructor CRT, the editing system, the instructor control panel, and sound effects, were also included in the ratings protocol. However, the instructor CRT, editing system, and instructor control panel were not included in the analysis because the judges felt that the dimension of "motivation" did not apply to these features. Data for sound effects are not included in the analysis because sound effects were used only in the device at USAOC&S. Thus, data for these four features are incomplete.

Weighted ratings in a multi-attribute utilities analysis are global in the sense that any one rating reflects value along several dimensions taken together. However, the judges' unweighted ratings indicate where each feature falls on each separate dimension of value.

TABLE 4. MULTI-ATTRIBUTE UTILITIES DATA FOR THE SEVILLE/BURTEK DEVICE AT BOTH SCHOOLS

USAOC&S		USAADS	
FEATURE	TOTAL VALUE	FEATURE	TOTAL VALUE
Student performance record	24,568	Student performance record	25,488
3D module	24,268	3D module	25,363
Sound effects	23,994	Troubleshoot only mode	21,347
Troubleshoot only mode	22,803	Performance feedback	21,169
Performance feedback	22,127	Remove/replace capability	20,672
Remove/replace capability	21,708	Student CRT	19,710
Student CRT	19,966	Student response panel	19,536
Random malfunction selection	19,302	Random malfunction selection	19,341
Slide projector unit	18,344	Slide projector unit	15,786
Student response panel	15,274		
Mean = 21,235.4 S.D. = 2,993.3		Mean = 20,934.7 S.D. = 3,023.7	

Table 5 presents the judges' total unweighted ratings for features in the Seville/Burtek device along each dimension of value. By using these values, we may determine how features compare to each other on each dimension. For purposes of this discussion, a value is considered high or low if it falls at least one standard deviation above or below the mean.

For this device, of all features rated, the concepts behind the student performance record and 3D module are viewed by our experts as the most important concepts in a generic maintenance training simulator. Further, in the Seville/Burtek device, the implementation of concepts underlying the 3D module and student performance record is good compared to other features.

On the other hand, judges felt that the concepts behind the student response panel and the implementation of concepts in that feature were poor compared to other features. In addition, judges felt that concept implementation was poor for the performance feedback feature compared to other features.

For the operations dimension, judges rated the student performance record as the best and the slide projector unit the worst feature as compared to other features.

Finally, judges rated the 3D module the most motivating feature of the Seville/Burtek device. The slide projector unit and student response panel were seen as the least motivating features.

3. Summary. The preceding two sections presented a discussion of interviewee opinions and experts' quantitative judgments about a selection of features in the Seville/Burtek device. In general ways, the experts' judgments matched interviewee opinions about device features.

Of all the features, the 3D module and student performance record received the highest praise for design and performance. The device's troubleshoot only mode also received praise as a valuable and dependable device feature.

TABLE 5. TOTAL UNWEIGHTED RATINGS FOR FEATURES IN THE SEVILLE/BURTEK DEVICE ALONG FOUR DIMENSIONS OF VALUE

FEATURE	DIMENSION			
	CONCEPT	IMPLEMENTATION	OPERATION	MOTIVATION
3D module	510	530	465	470
Student performance record	550	510	485	405
Slide projector unit	355	440	275	280
Student response panel	300	400	425	220
Student CRT	355	430	455	320
Remove/replace capability	425	460	380	445
Random malfunction selection	355	450	400	325
Performance feedback	490	395	400	430
Troubleshoot only mode	450	455	420	440
Mean	421.1	452.2	411.7	372.8
S.D.	85.1	44.9	61.5	85.9

Several features fell into a middle range. Those features are performance feedback, remove/replace capability, student CRT, and random malfunction selection. In the opinion of interviewees and experts, those features were designed well and performed adequately.

Two features were found to be especially in need of improvement. Those features were the student response panel and slide projector unit. In general, the opinion was that the design of the response panel might be improved. The main problems with the slide projector unit were operational ones.

Interviewees felt the instructor CRT, instructor control panel and editing system were adequate in design and performance. These features were not rated by the panel of experts.

C. Results: The Grumman Device

1. Opinions about Features. Information in this section comes from structured interviews. The interview protocol contained 10 device features for interviewees to comment on. (It was considered inappropriate for device contractors to comment on each other's devices.) In addition, the protocol contained general questions about feature strengths and weaknesses.

a. 3D module. Nearly all interviewees approved of the concepts behind this feature and concept implementation as well. The component parts in the 3D modules are high fidelity. The fidelity of the arrangement of parts for the engine module is not as high. However, this layout was designed for easy access to the parts, a feature praised by several interviewees. Interviewees felt the Grumman 3D modules were "reasonable," "adequate," and even "excellent." The 3D module also received high marks for its operational record.

Several interviewees commented that this 3D module was highly interactive with the rest of the system. Only one felt that this high degree of interaction was not required.

The 3D module received basically one criticism. Some felt that the low fidelity component part arrangement, with its easy access design, oversimplified training. Slower students benefited from this arrangement, but faster students did not.

b. Student performance record. Almost all interviewees criticized this device feature because too little information was presented. Several interviewees added that what was presented, was difficult to interpret.

Grumman personnel stated that this feature was designed based on the recommendations of their instructional design staff.

c. Instructor CRT. Opinions were mixed regarding the instructor CRT. Most interviewees felt that more information displayed on the CRT would be helpful. Several interviewees commented that the information available on the instructor CRT concerned the system, not the student, and that the information presented about the student's progress was not especially informative. On the other hand, several interviewees commented that this feature worked well. One added that the pre-lesson system check was valuable.

d. Video disc. Most interviewees approved of the concept of a video disc feature in a generic maintenance training device. Benefits cited include high resolution and longevity of discs. One interviewee felt that this high technology feature made studying more interesting to students. Several interviewees stated that concept implementation was good for this feature.

Many interviewees had criticisms of the video disc. Several mentioned that the high cost and difficulty of producing discs make the device somewhat inflexible. New material is not easily added. Some interviewees felt the video disc's reaction time was too slow, and faster students became bored. Some interviewees mentioned the poor maintenance record of the video disc. One reported frequent disc drive jams, overheating and problems due to dust particles. Several interviewees felt that the video disc feature is a potentially powerful feature, but in this device it was not used to capacity.

Grumman commented that the choice of video disc was based in part on prior poor experiences with a slide projector unit in a simulator. They added that the video disc concept is state-of-the-art in video technology.

e. Student CRT and touch panel. Text from the video disc was presented on the student CRT. The touch panel, incorporated into the student CRT, was used by the student to enter responses. About half the interviewees felt the touch panel was easy to use, more user friendly than a keyboard, and about half felt it was unnecessary. One commented that the touch panel was especially motivating to students because of its novelty. A few commented that students had to touch the panel exactly in the right spot for it to work; thus, some students sat very closely to the CRT and too far away from the 3D module.

Related to this positioning problem, one interviewee mentioned that the student CRT was small and was mounted at an angle such that frequent turning was required on the part of the student to use both the CRT and the 3D module.

f. Request help. This feature on the student CRT allowed the student to request of the computer extra help with the lesson. A few interviewees offered criticisms: one felt the review information was not extensive enough; one felt some students overused the feature; one felt it worked too slowly. However, one interviewee felt the feature was motivating to students, and most interviewees felt it was a useful feature of the device.

g. Editing system. The editing system allows an instructor to change the program. Grumman commented that it was designed for ease of use.

According to interviewees at USAADS, personnel at their school were not taught how to use the Grumman editing system. Only very limited training occurred at USAOC&S. Thus, the editing system was rarely used during the evaluation.

h. <u>Repeat lesson option</u>. A student could repeat an entire lesson by using this feature. Grumman stated that a positive aspect of this feature is that it decreases dependence on the instructor.

Most interviewees felt that the concept of this feature is good and necessary in self-paced instruction. Two interviewees observed that few students used the option. One interviewee commented that simply repeating a lesson may not be adequate remedial instruction. However, the majority felt the feature worked well.

i. <u>Call instructor after two errors</u>. This feature automatically stopped the device when the student made two sequential errors. Grumman commented that this feature was recommended by its instructional system developers. Many interviewees liked the concept behind the feature. One interviewee commented that this feature helped students proceed in a productive manner.

The main criticism of this feature was that it sometimes scored errors incorrectly. Thus, it would occasionally, in error, lock students out of the program. Further, students did not know how to get back into the program. Small errors could, perhaps unnecessarily, activate the feature. So, in many cases, the feature fostered unnecessary dependence on the instructors.

j. <u>Performance feedback</u>. Performance feedback was given to the student on the student CRT. Most interviewees felt that the concept was good. Many of the interviewees commenting found the buzzer, which was a signal for the student to look at the CRT for feedback, distracting. A few interviewees said the buzzer mechanism occasionally malfunctioned. Some students incorrectly thought the buzzer was a punisher.

k. <u>Software</u>. Grumman device programming is written in Assembler language. Grumman chose this language based on previous good experience with it.

Two problems with inflexibility of software were mentioned several times. One problem related to the fact that an instructor could only begin a lesson at its beginning. Another related to the fact that it was difficult for an instructor to insert a malfunction.

2. Expert Ratings. A panel of four experts was asked to rate features of the Grumman device. The ratings were then subjected to a multi-attribute utilities analysis. Basically, each design feature was rated along each of four dimensions of value: concept, implementation, operation, and motivation. Procedures used for rating and data analysis are described in section II.A.2. above.

Table 6 presents each judge's weighted rating and the total rating for each device feature. The data in Table 6 are grand totals of the weighted ratings for this device at both schools. Thus, the data in Table 6 suggest how valued each device feature is, taking all four dimensions into account. Features in Table 6 are listed in descending order by rank. As mentioned earlier, the third judge's ratings are a combination of the ratings from the expert who rated the devices at USAADS and the expert who rated the devices at USAOC&S.

Table 6 shows that the most valued feature of the Grumman device was the 3D module; its value exceeded one standard deviation above the mean of this distribution. The performance feedback feature also earned a high value; its value was very nearly one standard deviation above the mean.

Two features scored values less than one standard deviation below the mean: the student performance record and the mandatory instructor call after two errors.

Table 7 presents, for both schools, aggregate ratings for each feature. The judges' ratings indicate that features of the Grumman device at USAOC&S were similar in value to features on the device at USAADS; however, one important difference emerged. As shown in Table 7, the most valued feature at USAADS was the 3D module, yet this feature was only third in value at USAOC&S. The request help feature was the most valued feature on the device at USAOC&S. For both devices, performance feedback was the second most

TABLE 6. MULTI-ATTRIBUTE UTILITIES DATA FOR THE GRUMMAN DEVICE

FEATURE	J_1	J_2	J_3	J_{Total}
1. 3D module	10,923	13,949	12,422	37,294
2. Performance feedback	5,530	16,741	14,762	37,033
3. Request help	6,582	18,394	11,162	36,138
4. Touch panel	10,008	14,146	6,332	30,486
5. Video disc	9,557	14,096	6,590	30,243
6. Repeat lesson option	4,880	13,526	11,162	29,568
7. Student performance record	2,528	12,386	8,490	23,404
8. Call instructor after two errors	6,656	9,929	1,764	18,349

J_{Total}:
Mean = 30,314.4
S.D. = 6,753.7

TABLE 7. MULTI-ATTRIBUTE UTILITIES DATA FOR THE GRUMMAN DEVICE AT BOTH SCHOOLS

USAOC&S		USAADS	
FEATURE	TOTAL VALUE	FEATURE	TOTAL VALUE
Request help	17,731	3D module	21,294
Performance feedback	17,465	Performance feedback	19,568
3D module	16,000	Request help	18,407
Touch panel	15,471	Video disc	17,559
Repeat lesson option	14,464	Repeat lesson option	15,104
Video disc	12,684	Touch panel	15,015
Student performance record	11,452	Student performance record	11,952
Call instructor after two errors	10,960	Call instructor after two errors	7,389
Mean = 14,528.4 S.D. = 2,606.0		Mean = 15,768.0 S.D. = 4,486.9	

valued feature; its rating at USAOC&S was more than one standard deviation above the mean and the value for the feature at USAADS was nearly one standard deviation above the mean.

For both Grumman devices, the student performance record and the mandatory call instructor after two errors feature were the two least valued features. The values for both features on the USAOC&S devices fell more than one standard deviation below the mean. On the USAADS device, the instructor call feature value fell below one standard deviation below the mean.

Two features, the instructor CRT and the editing system, were included in the ratings protocol. However, these features were not included in the analysis because judges felt the dimension of "motivation" did not apply to these features. In addition, personnel were not systematically trained to use the editing system, so ratings on the dimensions of implementation and operations were omitted by some judges. Thus, data for these two features are incomplete.

As mentioned earlier, ratings in a multi-attribute utilities analysis are based on all dimensions of value taken together. However, the judges' unweighted ratings indicate where each feature falls on each separate dimension of value.

Table 8 presents the judges' total unweighted ratings for features in the Grumman device along each dimension of value. Using these values, we may determine how features compare to each other on each dimension. A value is considered high or low if it falls at least one standard deviation above or below the mean of the distribution.

As shown in Table 8, judges considered the concepts underlying the 3D module more important than concepts behind other features. Judges also felt that concept implementation was better for the 3D module than for other features.

TABLE 8. TOTAL UNWEIGHTED RATINGS FOR FEATURES IN THE GRUMMAN DEVICE FOR FOUR DIMENSIONS OF VALUE

FEATURE	DIMENSION			
	CONCEPT	IMPLEMENTATION	OPERATION	MOTIVATION
3D module	480	370	260	360
Student performance record	400	90	240	90
Video disc	370	275	210	375
Touch panel	290	325	270	370
Request help	340	350	410	330
Repeat lesson option	320	280	330	200
Mandatory instructor call after two errors	220	195	160	130
Performance feedback	430	300	360	370
Mean	356.3	273.1	267.5	278.1
S.D.	82.3	91.3	92.5	119.0

Judges felt that the concepts behind the mandatory instructor call feature were less valuable than for other features. Judges also felt that this feature was low on both the operations and motivation dimensions.

Judges rated the request help feature higher than other features on the operations dimension.

The student performance record was rated lower than other features on the motivation dimension.

3. Summary. The preceding two sections presented a discussion of interviewee opinions and experts' quantitative judgments about a selection of features in the Grumman device. Based on the data presented, general summary statements about the features may be made.

Of all the features in the device, the 3D module received the most praise for design and performance.

Five features seemed to fall in a middle range. The repeat lesson option, request help, touch panel and performance feedback features were viewed as adequate in design and performance. The video disc was viewed as excellent conceptually, but had some problems practically.

Two features seemed in special need of improvement: the mandatory instructor call after two errors and the student performance record. The former was felt to foster dependence on the instructor and perhaps decrease motivation. Further, operational problems are associated with the feature. The student performance record was seen as inadequate because so few student progress data were presented.

Interviewees felt that the instructor CRT was adequate, but might be improved in comprehensiveness. Personnel did not test the editing system because they were not trained to do so.

D. Summary

Sections II.B. and II.C. above have presented a discussion of individual device features. In this section, comments are presented concerning the overall functioning and uses of the devices.

Interviewees were asked how well the components of each device were integrated into a working training system. Agreement was widespread that both devices function well as systems.

Three points relevant to device component integration were made. First, one interviewee mentioned that the AMTESS concept of integrating 2D and 3D components by computer is expensive. Further, for many basic MOSs, that level of sophistication may be unnecessary. In addition, during some lessons, a student may spend most of his or her time watching the CRT or reading technical manuals; during this time the costly integration of 2D and 3D components is unused. Thus, it may be that this complex a device is unnecessary on a widespread basis. Research on this problem might test the efficiency and effectiveness of a networked, real time system that would allow one student to work on the 2D component while another student uses the 3D component.

Related to this point, another interviewee commented that the Grumman components were so tightly integrated, that if the video disc was down, students could not progress. However, if Seville/Burtek's slide projector was down, students could progress using the technical manuals for text presentation. This interviewee felt that integration might be regarded an undesirable quality given the high frequency of disrepair for both devices.

Third, one interviewee noted that the Grumman device contains one computer for the 2D component and a second computer with each 3D module. In contrast, the Seville/Burtek device contains one computer which operates the 2D component and any 3D module. Further study is in order concerning the economy and efficiency of one versus two computers per device.

Next, several school personnel and the SAI data collectors gave their opinions on how best each simulator could be used in order to gain maximum benefits from it. The majority of interviewees felt that both devices would function best as supplemental or remedial training. Only one interviewee felt that the Seville/Burtek device might directly replace actual equipment training.

Interviewees gave several reasons for their opinions about optimal use of the Seville/Burtek device. Two interviewees commented that the troubleshooting exercises are geared toward entry level students. Indeed, as presented earlier in Table 1, Burtek personnel designed the device to accommodate "low-end" skills training. One interviewee commented that some advanced students found some remove/replace exercises elementary and of too low fidelity to be useful. One interviewee added that some critical tasks are not taught by the devices. Thus, for several reasons, interviewees felt that the Seville/Burtek device would best be used as supplemental or remedial training for slow students.

As for the Grumman device, several interviewees commented that this device was geared toward remedial training because of the slow rate of material presentation. Others noted that because of limited remove/replace capability, this device functions as supplemental training. As with Seville/Burtek's device, some critical tasks are not taught with the Grumman device.

Most interviewees felt that the two contractors had indeed designed and constructed devices whose components were integrated, functioning, and at some level, effective in training. Certainly, both contractors were pleased with their devices. Perhaps the greatest problem with both devices is their dependability. Down-time plagued the device evaluation. Certainly, the maintenance records of these breadboard devices would be unacceptable in a production model. On the other hand, it may have been somewhat unrealistic to subject breadboard models to transfer of training studies. In general, however, participants felt that these devices were adequate.

III. DISCUSSION

This report has included two discussions. First, the development of AMTESS devices was presented and second, a summary of opinions about the features of two AMTESS devices was presented.

A. Device Development

AMTESS device development grew out of the Army's need for simulators to replace or supplement actual equipment used in maintenance training. AMTESS device conceptual designs were first developed, then two breadboard devices were constructed. Problems arose during device construction stemming from changes in government requirements for the devices, particularly in the school settings. Due to serious lack of communication between the government and the contractors, the devices did not meet all the schools' requirements. The delivered devices were subjected to formal experimental evaluation, but the evaluation did not proceed as planned. The evaluation suffered because the devices did not perform as the schools and the evaluation team had expected and because adequate numbers of subjects were not available for testing.

The problem encountered in device development reflected unclear communications among the agencies involved. Some agencies communicated frequently among themselves and other communicated less often, yet regardless of the communication frequency, costly misunderstandings occurred. Communication between project administration and those actually developing and testing devices seemed especially poor. Although many interview participants noted that administrators were always available by phone, the contacts with administration in many cases did not produce concrete plans.

One area in which high-level adminstrative support seemed lacking was with the schools. Fortunately, personnel at each test site school were involved in AMTESS for several years. Unfortunately, however, high-level school administrative personnel were not involved. In addition, many different types of school personnel were involved (instructors, course writers, subject matter experts, for example), but they were not all under the authority of the schools' points-of-contact for AMTESS. When changes occurred in the schools' curricula or training procedures, the AMTESS representative may not have been in a position to counter the changes.

Not only was administrative support concerning agency assignments and coordination frequently lacking, but financial support may have been a problem as well. As government device requirements changed, so contractor financial requirements increased. In addition, limited travel funds restricted some agencies from monitoring device development and evaluation as needed.

Kane and Holman (1982) applied the Army Life Cycle System Management Model to the process of developing and acquiring training devices. Kane and Holman (1982) identified seven important steps in the training device process:

1. Gather data on existing training systems; select tasks to be taught; select training modes.
2. Award contract for device concept development.
3. Demonstrate and validate device-based training concepts.
4. Improve device requirements based on #3.
5. Develop detailed predictions of the training effectiveness of alternative device models; award contract to build the device.
6. Major test of prototype simulator transfer-of-training effectiveness.
7. Construct and evaluate production model device.

In the case of the AMTESS procurement, Step 1 was accomplished in 1978 by the Seville maintenance training survey. PM TRADE completed Step 2 in 1979. In 1980, four contractors submitted final design reports based on front end analyses. As for Step 3, the four contractors' reports demonstrated concepts, but did not empirically validate them. The extent to which the government completed Step 4 (improving device requirements) is unknown, but the Phase II device construction proposals were submitted before final Phase I reports were submitted. In light of the problems that developed surrounding task selection, too little attention to Step 4 activities may have prevented the evaluation from proceeding as originally designed.

In the AMTESS project, some Step 5 prediction was accomplished. A new type of prediction method was tested although this did not occur until after device construction (Klein, 1982). The government awarded device construction contracts in September 1980.

The Step 6 device evaluation was completed in 1983. In the case of the AMTESS devices, further experimentation is planned. Production models have not been ordered.

B. Device Features

The problems in communication during the AMTESS device development are not clearly related to opinions about the features of the devices. However, two substantial problems with the devices noted by participants may relate to unmatched expectations between the contractors and the government.

One of these problems concerns the Grumman device's student performance record. Nearly all participants felt that this record is inadequate because it gives too little information. Perhaps this performance record would have been more complete had Grumman been more aware of government requirements in this regard.

The second and much more important problem concerns the high frequency with which the devices were in disrepair during device evaluation. The contractors were supposed to construct first-run, breadboard models, but at the same time, the devices should have been strong enough to withstand testing. Perhaps rigorous testing should not be planned for breadboard devices, or provisions for ensuring device reliability and maintainability should be implemented.

Comments made by some interview participants suggested factors that might be considered in designing device features. First, if devices are designed for entry level students for low-skill MOSs, high physical fidelity of parts and ease of access are desirable. As a Burtek representative pointed out, advanced students do not need to practice simple tasks on an expensive simulator; those students often profit from reading or following schematics. Devices designed for entry level, low-skill MOSs should provide ample opportunity for direct shaping of the skill by the device. In addition, instructional material for low-skill MOSs may need to be in simpler English than material for more advanced MOSs.

The level of student and MOS level considerations mentioned above raise the issue of how generic a maintenance training simulator can be. Some interview participants suggested that the simulator be generic across skills, not across specific MOSs. Simulator training designed in this way would be supplemental to conventional Army courseware which is designed around MOSs. It may be necessary in a generic skill simulator to reduce physical fidelity. The usefulness of a low fidelity simulator should be carefully examined with respect to entry level, low-skill MOS students. Generally, training for these students needs to be concrete.

The question concerning the relative importance of troubleshoot (diagnosis) versus remove/replace (repair) can only be answered by examining the skills or MOSs to be taught by the device. The front end analysis would determine which of these features should be included in the device.

Because the devices could not be fairly compared to each other, the merits of individual features were not assessed. Research on the efficacy of device features is planned.

IV. CONCLUSIONS

This section presents guidelines for future device development. These guidelines are based on the AMTESS experiences discussed in this report.

1. Project leadership should take an active role in overseeing the activities of all agencies involved. Meetings should have specific agendas. Minutes of all meetings should be taken and distributed to all participants. Minutes should be thorough and spell out who should do what next.

Documentation of project activities is particularly important when projects are lengthy, personnel change frequently, and participants are separated by long geographical distances. Such was the case with the AMTESS project. Several participants in the AMTESS project mentioned that the JWG would have been more successful in its coordination of AMTESS activities had specific minutes been taken at JWG meetings. Another instance where documentation was apparently lacking in the AMTESS project were the contacts between school and contractor personnel. Such documentation if made available to the JWG might have alerted the JWG to the problems discovered at device delivery.

2. Formal memorandums of understanding should be signed which officially link all participants needed in the project. The responsibilities of each organization, both government and contractor, should be clear to all participants.

In the AMTESS project, cooperative agreements were needed in at least three directions. First, participants in AMTESS Phases I and II, notably the schools, contractors, and PM TRADE, needed some agreement to guide hardware and software development. Second, participants in that portion of SIMTRAIN I which included device evaluation needed an agreement concerning how they would conduct the evaluation. Those participants were ARI, schools, and the evaluation team. Finally, the evaluation effort needed an official link to AMTESS Phase II. In the AMTESS project, this third link may have been the weakest connection. As discussed earlier in this report, evaluation plans were developed without contractor input.

3. The coordinating group should include personnel with authority over people whose cooperation is needed in each participating agency.

As mentioned by one interviewee, problems in this regard occurred in the AMTESS project with the schools. In many instances, important work was performed without proper supervision.

4. Project administration should plan with flexibility to accommodate disruptions.

Problems in the AMTESS project resulted in device delivery delays which affected the evaluation time schedule and created a need for additional funds. When changes were required in the tasks to be taught by the devices, no administrative mechanism was in place to direct the changes. As discussed earlier, the contractors and schools planned major device changes and informed the other organizations later. A preplanned administrative mechanism for making unexpected changes might have produced decisions with better consequences than was the case with AMTESS.

Several interviewees commented that disruptions created the need for additional money. Provisions should be made for modification in contracting procedures to facilitate compatibility with changing device requirements.

5. Frequent and precise communication should characterize the relationship between the government, contractors, and the evaluation team.

Many interviewees felt that communication was a problem in AMTESS. As several interviewees noted, for example, the device contractors knew little about the evaluation process, and the evaluation team knew little about the devices. Perhaps an expedient course would have been to require frequent communication between the contractors and the evaluation team to ensure that evaluation plans were appropriate and fully understood.

6. The government should carefully choose the MOSs from which tasks are selected for inclusion in the devices. Those MOSs should be stable. Preferably, complete performance tests would be available for those MOSs and be in use in conventional training.

The Phase II disruptions described earlier illustrate the point that selection of MOSs and tasks to be taught turned out to be one of the largest problems in the AMTESS project. Had the MOSs not changed during the project, much of the confusion surrounding task selection might have been avoided.

Complete performance tests did not exist for the tasks taught by the devices. The available performance tests, however, were helpful in designing the comprehensive tests necessary to study transfer of training in the device evaluation.

7. Precise device specifications should be made available to the device contractors. These specifications should include a general list of device features, the intended use of the simulator in training, the level of students involved, and the demands of any planned evaluations.

As representatives of all involved organizations noted, the AMTESS project was a research and development effort. For Phase I, many device requirements were not specified. Specifications were needed, however, for Phase II devices. The contractors needed more information about how devices should perform to ensure a successful evaluation.

8. An explicit mechanism for quality control of the devices should be instituted. This mechanism should track devices from construction, to delivery, through evaluation.

Device construction should be carefully monitored both by sponsoring agency and user agency personnel. Careful monitoring should ensure that the devices meet all requirements.

Careful AMTESS device construction monitoring might have been expensive because of the geographical locations of the organizations involved. As device requirements changed, monitoring should have increased. Instead, as mentioned earlier, no one had responsibility for carefully checking that the devices were being appropriately changed.

The quality control mechanism should ensure that devices are designed for dependability and ease of maintainability. Devices should be sturdy enough to withstand testing. As discussed above, many device features were criticized for poor maintenance records. Disrepair caused delays in the device evaluation. (More information regarding device malfunctioning will be presented in the SIMTRAIN I Extension final report.)

9. The criteria for device acceptance should be comprehensive, precise, and fully understood by all parties. If criteria are not met, the devices should not be accepted.

In the AMTESS project, the weaknesses in acceptance criteria were in the area of task selection and device dependability. The absence of acceptance criteria in the areas of maintainability and reliability effectively forces the government to accept devices regardless of their performance along these dimensions.

10. Instructor training in the use of the devices should be required and monitored.

As mentioned earlier, instructor training was not provided for the Grumman device at USAADS, and only brief training for personnel at USAOC&S. One unfortunate consequence of this omission was that instructors did not use the Grumman editing system and it could not be evaluated.

Although numerous problems occurred, the AMTESS project may be judged successful in at least three very important ways. First, functioning, effective devices were constructed. These devices did in fact provide substantial capability for maintenance training beyond existing approaches. Second, the concept of generic maintenance training device development and implementation appears vindicated. Third, and perhaps as important, the project offers valuable lessons in how to improve similar future device developmental efforts.

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APPENDIX A

LIST OF SOURCE DOCUMENTS

Army Research Institute:

AMTESS training effectiveness evaluation, 9 December 1982. (A briefing)

Army Research Institute representative's AMTESS files

PM TRADE:

Army Maintenance Training and Evaluation Simulation System (AMTESS), *I/ITEC Proceedings*, Orlando, FL: November 1981. (Dybas, R. T.)

USAADS:

USAADS representative's AMTESS files

ATSC:

ATSC representative's AMTESS files

GRUMMAN:

AMTESS 1 program presentation (Interim Report), January 1980.

AMTESS 1 program presentation (End of Contract Report), March 1980.

AMTESS 1 final report, April 1980.

AMTESS final report, July 1980.

AMTESS program presentation, 20 May 1981.

Trainer test procedures and results report for AMTESS, 8 June 1982.

SEVILLE/BURTEK:

AMTESS - A modular system for Army maintenance training, March 1980.

AMTESS - A modular system for Army maintenance training, appendices, March 1980.

AMTESS - Preliminary systems engineering design, March 1980.

AMTESS - A modular system for Army maintenance training (AMTESS 1 final report), May 1980.

AMTESS 1 final report, May 1980.

AMTESS 1 final report appendices, May 1980.

AMTESS II program review, 21 May 1981.

Trainer test procedure and results report for AMTESS II, Vol. I, December 1981.

Hughes:

AMTESS 1 final report, June 1980.

Honeywell:

SIMTRAIN task 1 work plan description, March 1981.

Task 2 interim report - SIMTRAIN research on guidelines for training device and simulation development, 31 August 1981. (Baum)

A test plan for the experimental evaluation of the Army maintenance training and evaluation simulation system (AMTESS), November 1981. (Smith, D. A. and Hirshfeld, S. F.)

SAI:

Research on guidelines for training device and simulation development, technical proposal task 3 only, 1 December 1980.

Revised test plan, May 1982. (Unger, K.)

SAI correspondence files

Data collectors' logs

APPENDIX B

STRUCTURED INTERVIEW PROTOCOL

HISTORY

	Target
1. When did you begin work on AMTESS? - What was your role? - Did it change? How?	ALL
2. Have you participated in any activities that led to the development of the AMTESS concept? - If yes, what were these activities?	ALL but SAI
3a. What do you believe are the overall objectives of the AMTESS initiative? - To what extent are these objectives understood by other organizations involved in AMTESS? - What changes, if any, have there been in these objectives over time? Why? - What impacts resulted?	ALL
3b. What do you believe are the objectives of the AMTESS procurement? - To what extent do other organizations involved in AMTESS share these objectives? - Have these objectives changed for you or any other organization during the course of AMTESS? - If so, how and why?	ALL
4a. Please identify what you consider to be critical tasks in the implementation of AMTESS. Identify both critical tasks which your organization performed and which other organizations involved in AMTESS performed. (Probe: Ask respondents to evalute performance of each task named.)	ALL
4b. List of critical tasks. Have respondents evaluate performance of each task not discussed in 4a.	ALL

A. PM TRADE

1. Develop AMTESS concept.
2. Write SOWs for AMTESS.
3. Review proposals.
4. Monitor development of devices at Tulsa/Bethpage.
5. Review contractor reports.
6. Monitor device evaluation.

Target

B. SCHOOLS — ALL

1. Review proposals.
2. Work with contractors during FEAs.
3. Monitor development of devices at Tulsa/Bethpage.
4. Government acceptance of devices at Ft. Bliss/Aberdeen Proving Grounds.
5. Assist ARI/SAI in evaluating devices.

C. ARI

1. Review proposals (contractors and Honeywell).
2. Prepare SOW for device evaluation.
3. Develop test plan.
4. Monitor development of devices at Tulsa/Bethpage.
5. Monitor device evaluation.

D. ATSC

1. Review proposals.
2. Monitor development of devices at Tulsa/Behtpage.
3. Monitor device evaluation.

E. CONTRACTORS

1. Perform FEAs.
2. Develop PSED.
3. Develop life cycle cost estimate.
4. Develop hardware.
5. Develop software.
6. Maintain devices during evaluation.

F. SAI

1. Develop performance tests.
2. Modify test plan.
3. Collect qualitative data.
4. Collect quantitative data.

5. Were there any tasks you consider critical to AMTESS which were not performed at all? — ALL

   (Probe: Why were they not performed?)

6. In your opinion, which organization was actually responsible for managing the AMTESS effort? — ALL

   - Did they manage it well?
   - Did they have adequate authority and resources to manage the project well?

		Target
7a.	How would you characterize the coordination among the various organizations involved in AMTESS?	ALL
7b.	Please describe the nature of your coordination with each of the organizations you were involved with in AMTESS and evaluate the effectiveness of that coordination. 1. ARI 2. Schools 3. PM TRADE 4. ATSC 5. SAI 6. contractors	ALL
7c.	Please describe the effectiveness of the Joint Working Group meetings for planning and coordinating AMTESS activities.	ALL
8a.	Please describe how the tasks to be used during the device evaluation were selected.	ALL
8b.	Who had the principal responsibility for selecting these tasks?	ALL
8c.	What coordination was involved in this task selection procedure? - What made that coordination effective/ineffective?	ALL
9.	What are your opinions about the evaluation of the AMTESS devices being conducted at Aberdeen Proving Grounds and Ft. Bliss? o Valid evaluation of transfer of training? o Comprehensive? o Suggestions for improving this type of evaluation?	ALL
10.	I would like you to comment on the performance of each of the organizations involved in AMTESS. Please describe what they did well and what they did poorly. 1. ARI 2. Schools 3. PM TRADE 4. ATSC 5. SAI 6. Contractors	ALL
11.	Do you feel that the AMTESS concept, embodied in the prototypes has lived up to expectations?	ALL

		Target
12.	Is the AMTESS concept worth pursuing?	ALL
13.	How does the AMTESS procurement process compare to that of other training devices?	ALL

FRONT END ANALYSIS

1.	What do you believe were the objectives of the front end analysis? - To what extent do other organizations share these objectives? - Did these objectives change for you or other organizations during the project?	ALL
2.	Describe your organization's involvement in the front end analysis activities.	ALL
3a.	Describe the activities conducted during each of the following phases of the FEA. - Task analysis - Training requirement analysis - Fidelity analysis	ALL
3b.	Did your company perform any FEAs that were not called for in the SOW?	CONTRACTORS
3c.	Were the same personnel involved in all of the FEAs?	CONTRACTORS
3d.	What are the backgrounds of the individuals who conducted the analysis?	CONTRACTORS
3e.	How were the results of the various analyses integrated into the design of the simulator?	CONTRACTORS
3f.	How important was the FEA in the selection of specific device features?	CONTRACTORS
3g.	What procedures/decisions/mechanisms insured that requirements identified in the FEA would be addressed by the simulator?	CONTRACTORS
3h.	How closely did the results of the FEA match up with the final system design?	CONTRACTORS
4.	How would you evaluate the performance of your organization and the performance of other organizations in each of the tasks of the FEA?	CONTRACTORS

		Target
5.	Were there any aspects of the FEA which you consider critical which were not performed at all?	CONTRACTORS
6.	Describe the extent to which you and your organization were able to coordinate FEA activities with other organizations.	ALL
7.	How did the FEAs for AMTESS differ from FEAs for other training devices, if at all?	ALL
8.	In hindsight, what would characterize an optimal FEA?	ALL

FEATURE ANALYSIS

1. Describe the strengths/weaknesses of each of the following features as concepts, and then describe how well they actually worked in the devices. ALL

GRUMMAN	Concept	Implementation
1. 3D module		
2. Student performance record		
3. Instructor CRT		
4. Video disc		
5. Touch panel		
6. Request help on CRT		
7. Editing system		
8. Repeat lesson option		
9. Call instructor after 2 errors		
10. Performance feedback		

SEVILLE/BURTEK

1. 3D module
2. Student performance record
3. Student CRT
4. Instructor CRT
5. Slide projector unit
6. Student response panel
7. Editing system
8. Remove/replace capability
9. Random malfunction selection
10. Performance feedback
11. Troubleshoot only
12. Sound effects
13. Instructor control panel

		Target
2.	What other features do you consider to be highly important? - What are their strengths/weaknesses? FEATURE CONCEPT IMPLEMENTATION	ALL
3.	For those features you consider to be ineffective, what would you suggest to improve or replace those features?	ALL
4.	How well does the device integrate the various features to operate as a system?	ALL
5.	Are there training requirements which have not been addressed by the device at all?	ALL
6a.	Why was video disc chosen?	GRUMMAN
6b.	Why was a touch panel chosen?	GRUMMAN
6c.	What thinking guided the amount and type of information given on instructor station?	GRUMMAN/ S/B
6d.	What thinking guided the amount and type of information given on the student performance record?	GRUMMAN/ S/B
6e.	Whay is programming written in Assembler?	GRUMMAN
7a.	Why wasn't video disc chosen?	SEVILLE
7b.	Why programmed in FORTRAN IV?	SEVILLE
7c.	Why is a student response panel used instead of a standard keyboard?	S/B
8a.	What are the features of the simulator that are applicable to the school's training course?	SCHOOL
8b.	What are the features of the simulator that are not applicable to the school's training course?	SCHOOL
8c.	In your opinion, what features of the simulator helped make the lesson interesting to the students?	SCHOOL
8d.	What features of the simulator made it more effective than conventional training?	SCHOOL
8e.	How would you employ the simulator in order to gain maximum benefit from it?	SCHOOL
8f.	What were the features that made this simulator easy to operate?	SCHOOL

	Target
8g. What features made this simulator difficult to operate?	SCHOOL
8h. What types of problems did students have with any feature?	SCHOOL

APPENDIX C

TRAINING DEVICE FEATURES EVALUATION RATINGS FORM

TRAINING DEVICE FEATURES EVALUATION

We are interested in your expert judgments about training device simulators in general and specifically about the Grumman and Seville/Burtek simulators used in Phase II of AMTESS. The judgments of a small group of experts will be useful in preparing a report on AMTESS device features. This questionnaire survey has three sections:

Section 1 - Ranking simulator dimensions
Section 2 - Ranking Grumman device features
Section 3 - Ranking Seville/Burtek device features

SECTION 1 - DIMENSIONS

Please consider the four dimensions of training simulators listed below. Next, rank the dimensions in relation to each other. Rank the least important dimension "10." Rank the other three dimensions in relation to the least important dimension and in relation to each other. For example, if you rank a dimension as "50," it is five times more important than the least important, and only half as important as a dimension ranked "100." Note: Your ranks have to sum to 100.

Dimension		*Rank*
Concept:	Is the concept behind the feature important in a generic maintenance training simulator or is it unnecessary?	
Implementation:	Does the feature truly embody and express the concept(s) behind it or does it depart too far from the concept(s)?	
Operations:	Is the feature easy to use, does it work reliably, or is it unwieldly and frequently down?	
Motivation:	Is the feature appealing, does it capture interest in learning, or is it overly difficult and intimidating?	

SECTION 2 - THE GRUMMAN DEVICE - USAADS

For the Grumman simulator, consider the MOS it teaches and a typical trainee. Please rate each of the following features of the device along each of the four dimensions. Use a scale of 0 to 100. Zero (0) is minimal and 100 is maximal. You should refer to the definitions of the dimensions presented in Section 1. Ratings are orthogonal and need not sum to 100.

Evaluate the Grumman device along the four dimensions below. Do not compare it to the Seville/Burtek device.

Feature	Concept	Implementation	Operations	Motivation
1. 3D module				
2. Student performance record				
3. Instructor CRT				
4. Video disc				
5. Touch panel				
6. Editing system				
7. Request help				
8. Repeat lesson option				
9. Mandatory instructor call after two errors				
10. Performance feedback				

SECTION 2 - THE GRUMMAN DEVICE - USAOC&S

For the Grumman simulator, consider the MOS it teaches and a typical trainee. Please rate each of the following features of the device along each of the four dimensions. Use a scale of 0 to 100. Zero (0) is minimal and 100 is maximal. You should refer to the definitions of the dimensions presented in Section 1. Ratings are orthogonal and need not sum to 100.

Evaluate the Grumman device along the four dimensions below. Do not compare it to the Seville/Burtek device.

Feature	Concept	Implementation	Operations	Motivation
1. 3D module				
2. Student performance record				
3. Instructor CRT				
4. Video disc				
5. Touch panel				
6. Editing system				
7. Request help				
8. Repeat lesson option				
9. Mandatory instructor call after two errors				
10. Performance feedback				

SECTION 3 - THE SEVILLE/BURTEK DEVICE - USAOC&S

For the Seville/Burtek device, consider the MOS it teaches and a typical trainee. Please rate each of the following features of the device along each of the four dimensions. Use a scale of 0 to 100. Zero (0) is minimal and 100 is maximal. Ratings are orthogonal and need not sum to 100.

Evaluate the Seville/Burtek device along the four dimensions below. Do not compare it to the Grumman device.

Feature	Concept	Implementation	Operations	Motivation
1. 3D module				
2. Student performance record				
3. Instructor CRT				
4. Slide projector unit				
5. Student response panel				
6. Editing system				
7. Student CRT				
8. Instructor control panel				
9. Remove/replace capability				
10. Random malfunction selection				
11. Performance feedback				
12. Troubleshoot only mode				
13. Sound effects				

SECTION 3 - THE SEVILLE/BURTEK DEVICE - USAADS

For the Seville/Burtek device, consider the MOS it teaches and a typical trainee. Please rate each of the following features of the device along each of the four dimensions. Use a scale of 0 to 100. Zero (0) is minimal and 100 is maximal. Ratings are orthogonal and need not sum to 100.

Evaluate the Seville/Burtek device along the four dimensions below. Do not compare it to the Grumman device.

Feature	Concept	Implementation	Operations	Motivation
1. 3D module				
2. Student performance record				
3. Instructor CRT				
4. Slide projector unit				
5. Student response panel				
6. Editing system				
7. Student CRT				
8. Instructor control panel				
9. Remove/replace capability				
10. Random malfunction selection				
11. Performance feedback				
12. Troubleshoot only mode				
13. Sound effects				

APPENDIX D

TRAINING DEVICE FEATURES EVALUATION

RAW DATA

DIMENSIONS OF VALUE RATINGS

DIMENSION	JUDGES			
	J_1	J_2	J_3	J_4
CONCEPT	20	50	40	20
IMPLEMENTATION	35	20	30	10
OPERATIONS	35	20	20	40
MOTIVATION	10	10	10	30

RAW DATA FOR "CONCEPT" DIMENSION

SEVILLE/BURTEK DEVICE - USAADS

FEATURE	JUDGES		
	J_1	J_2	J_3
1. 3D module	70	90	100
2. Student performance record	80	100	100
3. Slide projector unit	60	50	50
4. Student response panel	60	20	80
5. Student CRT	50	50	70
6. Remove/replace capability	65	70	60
7. Random malfunction selection	80	30	60
8. Performance feedback	60	90	100
9. Troubleshoot only mode	80	70	60

RAW DATA FOR "IMPLEMENTATION" DIMENSION

SEVILLE/BURTEK DEVICE - USAADS

FEATURE	JUDGES		
	J_1	J_2	J_3
1. 3D module	80	95	100
2. Student performance record	70	90	100
3. Slide projector unit	60	80	90
4. Student response panel	70	70	90
5. Student CRT	60	80	80
6. Remove/replace capability	70	80	90
7. Random malfunction selection	75	70	90
8. Performance feedback	60	70	50
9. Troubleshoot only mode	70	70	90

RAW DATA FOR "OPERATIONS" DIMENSION

SEVILLE/BURTEK DEVICE - USAADS

FEATURE	JUDGES		
	J_1	J_2	J_3
1. 3D module	75	70	90
2. Student performance reçord	70	80	100
3. Slide projector unit	55	50	10
4. Student response panel	70	80	90
5. Student CRT	60	80	90
6. Remove/replace capability	60	40	90
7. Random malfunction selection	70	50	90
8. Performance feedback	60	50	90
9. Troubleshoot only mode	70	50	90

RAW DATA FOR "MOTIVATION" DIMENSION
SEVILLE/BURTEK DEVICE - USAADS

FEATURE	JUDGES J_1	J_2	J_3
1. 3D module	70	70	100
2. Student performance record	70	60	70
3. Slide projector unit	60	40	20
4. Student response panel	50	10	70
5. Student CRT	55	50	50
6. Remove/replace capability	70	70	70
7. Random malfunction selection	75	20	50
8. Performance feedback	60	80	60
9. Troubleshoot only mode	70	80	50

RAW DATA FOR "CONCEPT" DIMENSION
SEVILLE/BURTEK DEVICE - USAOC&S

FEATURE	JUDGES		
	J_1	J_2	J_3
1. 3D module	70	90	90
2. Student performance record	80	100	90
3. Slide projector unit	65	50	80
4. Student response panel	60	20	60
5. Student CRT	50	50	85
6. Remove/replace capability	70	70	90
7. Random malfunction selection	80	30	75
8. Performance feedback	60	90	90
9. Troubleshoot only mode	80	70	90

RAW DATA FOR "IMPLEMENTATION" DIMENSION

SEVILLE/BURTEK DEVICE - USAOC&S

FEATURE	JUDGES		
	J_1	J_2	J_3
1. 3D module	80	95	80
2. Student performance record	70	90	90
3. Slide projector unit	60	80	70
4. Student response panel	70	70	30
5. Student CRT	60	80	70
6. Remove/replace capability	70	80	70
7. Random malfunction selection	75	70	70
8. Performance feedback	60	70	85
9. Troubleshoot only mode	70	70	85

RAW DATA FOR "OPERATIONS" DIMENSION

SEVILLE/BURTEK DEVICE - USAOC&S

FEATURE	JUDGES		
	J_1	J_2	J_3
1. 3D module	75	70	85
2. Student performance record	70	80	85
3. Slide projector unit	60	50	50
4. Student response panel	70	80	35
5. Student CRT	60	80	85
6. Remove/replace capability	75	40	75
7. Random malfunction selection	70	50	70
8. Performance feedback	65	50	85
9. Troubleshoot only mode	70	50	90

RAW DATA FOR "MOTIVATION" DIMENSION

SEVILLE/BURTEK DEVICE - USAOC&S

FEATURE	JUDGES		
	J_1	J_2	J_3
1. 3D module	70	70	90
2. Student performance record	70	60	75
3. Slide projector unit	55	40	65
4. Student response panel	50	10	30
5. Student CRT	50	50	65
6. Remove/replace capability	80	70	85
7. Random malfunction selection	75	20	85
8. Performance feedback	65	80	85
9. Troubleshoot only mode	70	80	90

RAW DATA FOR "CONCEPT" DIMENSION

GRUMMAN DEVICE - USAADS

FEATURE	JUDGES		
	J_1	J_2	J_3
1. 3D module	70	90	100
2. Student performance record	10	100	100
3. Video disc	80	50	70
4. Touch panel	60	20	50
5. Request help	30	50	90
6. Repeat lesson option	20	50	90
7. Mandatory instructor call after two errors	40	10	30
8. Performance feedback	30	90	100

RAW DATA FOR "IMPLEMENTATION" DIMENSION

GRUMMAN DEVICE - USAADS

FEATURE	JUDGES		
	J_1	J_2	J_3
1. 3D module	50	70	100
2. Student performance record	10	5	30
3. Video disc	40	20	100
4. Touch panel	30	50	90
5. Request help	30	50	100
6. Repeat lesson option	20	50	90
7. Mandatory instructor call after two errors	30	5	50
8. Performance feedback	20	40	100

RAW DATA FOR "OPERATIONS" DIMENSION

GRUMMAN DEVICE - USAADS

FEATURE	JUDGES		
	J_1	J_2	J_3
1. 3D module	50	20	90
2. Student performance record	20	20	80
3. Video disc	40	5	100
4. Touch panel	50	20	60
5. Request help	40	70	100
6. Repeat lesson option	30	70	70
7. Mandatory instructor call after two errors	30	10	30
8. Performance feedback	30	80	90

RAW DATA FOR "MOTIVATION" DIMENSION

GRUMMAN DEVICE - USAADS

FEATURE	JUDGES		
	J_1	J_2	J_3
1. 3D module	50	70	80
2. Student performance record	10	20	10
3. Video disc	45	70	90
4. Touch panel	60	50	90
5. Request help	30	50	90
6. Repeat lesson option	30	50	0
7. Mandatory instructor call after two errors	30	10	10
8. Performance feedback	30	80	80

RAW DATA FOR "CONCEPT" DIMENSION

GRUMMAN DEVICE - USAOC&S

FEATURE	JUDGES		
	J_1	J_2	J_3
1. 3D module	40	90	90
2. Student performance record	10	100	80
3. Video disc	60	50	60
4. Touch panel	60	20	80
5. Request help	30	50	90
6. Repeat lesson option	20	50	90
7. Mandatory instructor call after two errors	40	10	90
8. Performance feedback	30	90	90

RAW DATA FOR "IMPLEMENTATION" DIMENSION

GRUMMAN DEVICE - USAOC&S

FEATURE	JUDGES		
	J_1	J_2	J_3
1. 3D module	50	70	30
2. Student performance record	20	5	20
3. Video disc	20	20	75
4. Touch panel	30	50	75
5. Request help	30	50	90
6. Repeat lesson option	20	50	50
7. Mandatory instructor call after two errors	30	5	75
8. Performance feedback	20	40	80

RAW DATA FOR "OPERATIONS" DIMENSION

GRUMMAN DEVICE - USAOC&S

FEATURE	JUDGES		
	J_1	J_2	J_3
1. 3D module	60	30	10
2. Student performance record	10	20	90
3. Video disc	40	5	20
4. Touch panel	50	20	70
5. Request help	40	70	90
6. Repeat lesson option	30	70	60
7. Mandatory instructor call after two errors	30	10	50
8. Performance feedback	30	80	50

RAW DATA FOR "MOTIVATION" DIMENSION

GRUMMAN DEVICE - USAOC&S

FEATURE	JUDGES		
	J_1	J_2	J_3
1. 3D module	70	50	40
2. Student performance record	10	20	20
3. Video disc	40	70	60
4. Touch panel	60	50	60
5. Request help	30	50	80
6. Repeat lesson option	30	50	40
7. Mandatory instructor call after two errors	30	10	40
8. Performance feedback	30	80	70