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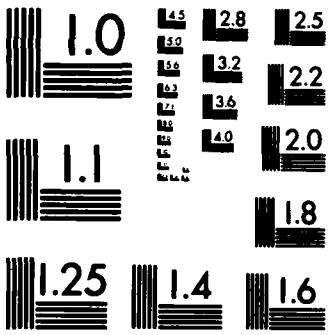

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TAXONOMIC CONSIDERATIONS IN THE ACQUISITION OF MAINTENANCE SIMULATORS

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Maintenance simulators are playing an increasingly important role in many training programs, particularly in the military. The military constantly trains large numbers of young and inexperienced personnel with the aid of simulators to maintain various avionics, weapon, and equipment systems. Such training can be both cost- and training-effective. Although many attempts have been made to classify such simulators, none has been very satisfactory. This paper presents a taxonomy of maintenance simulators, along with other useful information, whereby managers and trainers can make pertinent acquisition and training decisions. Maintenance simulators can be classified as being one of four types: (a) Stimulated Actual Equipment, (b) Model Simulators, (c) Panel Simulators, and (d) Interactive Video Display Trainers (IVDTs). Cost comparisons among various types of maintenance simulators are presented to demonstrate the efficacy of this simulator taxonomy.

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SUMMARY

The use of simulators for training maintenance personnel is becoming increasingly important, particularly in the military where large numbers of young and inexperienced personnel must learn to maintain complex avionics, weapon, and equipment systems. Maintenance simulators have been found to be both cost-effective and training-effective for these purposes. Because of their proliferation, and the variety of available types of simulators that exist, it has become necessary to have a means of distinguishing one from another. This paper presents a taxonomy of maintenance simulators and other useful information designed to assist managers and trainers in making pertinent acquisition and training decisions. In this taxonomy, maintenance simulators are classed as: (a) Stimulated Actual Equipment, (b) Model Simulators, (c) Panel Simulators, and (d) Interactive Video Display Trainers (IVDTs). Each is described, and cost comparisons among the four types are provided in a manner which demonstrates the usefulness of this taxonomy.

PREFACE

This technical paper relates to Project 2361, Simulation for Maintenance Training, Project 1121, Technical Training Development, and other Air Force Human Resources Laboratory (AFHRL) projects that deal with simulator training devices. The author wishes to acknowledge Applied Science Associates' (Valencia, PA 16059) many contributions to the field of maintenance simulator acquisition, particularly the work accomplished under Contract No. F33615-78-C-0019. Appreciation for the hard work accomplished under this contract is expressed to Applied Science Associates staff members, Lisa A. Thocher, J. Thomas Roth, and especially the project manager, Robert J. Carroll. Appreciation is also expressed to Nancy J. Allin, and other AFHRL staff members, who professionally devoted their time and talents to ensure that even the most minute details were taken care of in the preparation of this paper.

The primary objective of this paper is to familiarize Air Force and other DoD managers/trainers with the necessary knowledge and skills for effective acquisition of simulator training devices. A single simulator procurer, effectively employing the information presented in this paper, could save the DoD hundreds of thousands or even millions of dollars. As DoD's manpower, equipment, and funding resources become increasingly limited, the importance of maximally optimizing defense resources cannot be overemphasized.

TAXONOMIC CONSIDERATIONS IN THE ACQUISITION OF MAINTENANCE SIMULATORS

Maintenance simulators are playing an increasingly important role in many training programs, particularly in the military, where large numbers of young and inexperienced personnel must be trained. With the proliferation of maintenance simulators, a great deal of confusion has arisen as to what really constitutes a "maintenance simulator." This general term covers a wide range of training devices, varying widely in their resemblance to the actual equipment in terms of physical and/or task fidelity. When people speak of maintenance simulators, they may have in mind any number of alternatives, based upon their own unique experiences, preferences, or perhaps even biases. It is, therefore, incumbent upon military managers and training personnel to be aware of the spectrum of available maintenance simulator alternatives, lest they be convinced by vendors and others that only one type of simulator will meet their training needs. An effective taxonomy for maintenance simulators would go a long way toward eliminating the existing confusion.

Perhaps the most common research method for classifying maintenance simulator devices is by using some form of fidelity dimension. Rouse (1982-83) defined fidelity as "the precision with which the simulator reproduces the appearance and behavior of the real equipment" (p. 104). Hays (1981) proposed a similar definition: the degree of similarity between the training simulator and the equipment being simulated in terms of its physical and functional characteristics. Hays further noted in his extensive literature review, a wide diversity of terms being employed by simulator researchers. Nevertheless, there appear to be two basic types of fidelity: physical and non-physical. The most ambiguous or difficult to define is the non-physical-fidelity construct. Psychological fidelity, functional fidelity, task fidelity, and behavioral fidelity are among the terms used for this complex construct (Hays, 1980). Unfortunately, research taxonomic definitions derived from these constructs tend to be context specific and often involve the use of complex psychometric measures. In summary, trainers and managers have little or no pragmatic use for taxonomic schemata based on such constructs.

The Air Force Human Resources Laboratory (AFHRL), in conjunction with Applied Science Associates,[1] has developed a maintenance simulator taxonomy based on both the physical and functional characteristics of computer-driven maintenance simulator trainers. This taxonomy was especially designed for use by managers and trainers. Maintenance simulators can be categorized, from the highest to the lowest fidelity trainer, as follows: (a) Stimulated Actual Equipment, (b) Model Simulators, (c) Panel Simulators, and (d) Interactive Video Display Trainers (IVDTs).

Stimulated Actual Equipment (SAE) is equipment stimulated or directed by a computer and/or other interface device(s). In many cases, it may be difficult to perceive the difference between the simulator trainer and the actual equipment. SAE simulators typically consist of actual equipment components (racks, cabinets, dials, testing devices, etc.), some interface devices, and a signal generator (or source for signal input; e.g., from a computer disk). Unlike the actual equipment, an SAE trainer does not receive its input from real equipment devices such as line replaceable units (specialized electronic boxes) but rather, from a computer-generated signal source via some interface device(s). This generated signal source is typically controlled such that specific signals are sent only under certain conditions.

[1] This maintenance simulator research was accomplished under Contract No. F33615-78-C-0019 with Applied Science Associates, Valencia, PA 16059.

Model simulators are like SAE trainers in that portions of the simulator are three-dimensional replicas of the actual equipment. However, unlike SAEs, model simulators typically contain operational replicas only for those displays and controls essential to the tasks being trained. Nonessential displays or controls (dials, lights, racks, levers, etc.) are represented visually by etched drawings or nonfunctional displays/controls. Although model simulators are typically full-scale mock-ups of actual equipment, they can also be under- or over-scaled units that meet certain training needs. Like all simulator devices addressed in this study, model trainers are supported by a microcomputer that drives the simulation exercises.

Panel simulators resemble actual equipment even less than model simulators, since a large portion of system components may be entirely omitted or merely represented by graphic/etched drawings on a flat panel device. A typical panel simulator would have full-size components (some functional and others represented by graphic drawings), with drawings depicting the location of those components as they appear on the real equipment. Various actual test equipment devices (e.g., ohmmeter, oscilloscope, voltmeter) may be built into the flat panel, along with various test points for testing of system components associated with that particular weapon, aircraft, or equipment system. As in the model simulator, nonessential displays of controls are represented visually by etched drawings or nonfunctional controls/displays. Also, panels can be used to represent large units reduced, small units enlarged, or full-scale units. Multiple interchangeable panels depicting different systems (e.g., radar, navigation, hydraulic) are also a prevalent feature of panel trainers. In general, panel simulators are selected for training when it is desirable to have a student practice on a device that resembles certain equipment components in appearance, but does not require that many of the systems and components be either present or actual in size.

Unlike the other types of simulator trainers, with IVDTs, the ability to perceive or physically touch an actual-size component is not an important consideration. IVDTs are simulators that utilize computer-generated graphics or computer-controlled videodisc images, or a combination of these, and display equipment systems or components on a cathode-ray tube (CRT) monitor. An IVDT typically consists of a microprocessor, a video display monitor, an input device (e.g., light pen, touch panel, keyboard, joystick), and sometimes a videodisc player that generates still or motion displays. Although the videodisc-based IVDTs' pictorial clarity is high, the component size distortion due to CRT screen size limitations is frequently substantial. IVDTs may also be difficult to distinguish from Computer-Based Training (CBT) systems on the basis of hardware, since CBT systems many times use the same hardware. A better way of differentiating between the two, although more difficult to assess, is on the basis of their computer software or simulation characteristics. In essence, IVDTs employ sophisticated computer algorithms to accomplish fairly complex types of simulations. On the other hand, the more sophisticated CBT authoring systems do possess the capability to develop simple types of simulation.

It should be noted that these classifications may not be completely independent. A few maintenance simulators might be considered "hybrids" of the above simulator types (e.g., a simulator that utilizes both a model and separate panels). In such cases, the instructional features and characteristics of both could apply. Despite the potential for some overlap, this classification schema appears to be far more objective and meaningful for managers and trainers than those developed by other research studies.

Despite their varying capabilities, probably one of the most important considerations in selecting the type of trainer for a particular application is cost. In one AFHRL contract study,[1] cost data were obtained on 16 simulators (three IVDTs, five Panels, four Models, and four SAEs) that were used to train maintenance technicians during the January 1984 through June 1984 time period. Figure 1 shows a representation of the mean acquisition costs for the different types of maintenance simulators, arranged from the lowest to the highest fidelity

trainer type. The lowest mean acquisition cost was approximately $23,000 for IVDT simulators; the highest was $2,000,000 for SAEs. The average per unit costs for Panel and Model trainers were $377,000 and $833,000, respectively. These data indicated that the higher the trainer's fidelity, the more expensive it was to acquire. Although this study's sample size was small (because cost information is difficult or impossible to obtain on many simulator trainers), this same fidelity-cost relationship has also been substantiated by AFHRL in other more experimentally oriented research (Cicchinelli, Harmon, & Keller, 1982; Pieper, Richardson, Harmon, Keller, & Massey, 1984).

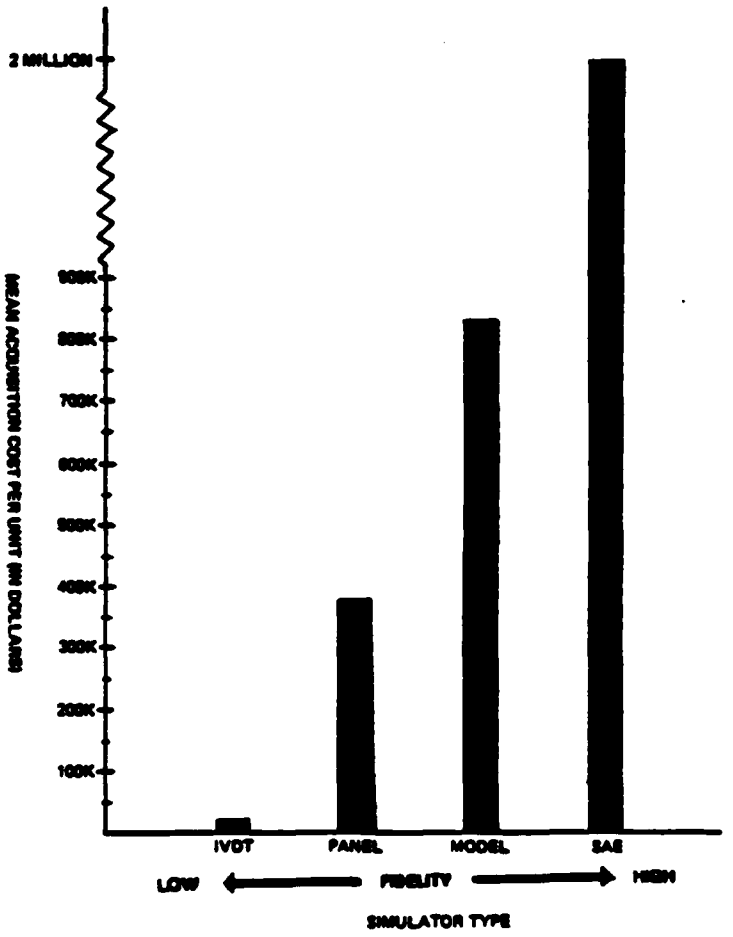

Figure 1. Mean Acquisition Cost Per Unit by Simulator Type.

Maintenance simulators continue to increase in their importance and range of training applications because of several significant factors. They are more advantageous than the Actual Equipment Trainers (AETs) - actual equipment being used as a trainer - in that "they reduce costs, are more reliable, provide safer training, and have greater capability to insert malfunctions" (Jarvis, Winter, & Bucciarelli, 1983). In terms of acquisition costs, Orlansky and String (1981) have found that the acquisition cost was substantially less for maintenance simulators than AETs. They found that the initial development and fabrication of the initial prototype was 60% of the AET cost in 7 of 11 cases, with additional fabricated units costing less than 20% of the AET cost in 9 of the 11 cases examined. (Figure 1 data suggest that the

acquisition cost would be a function of the type of trainer acquired.) In more experimentally oriented studies (Cicchinelli et al., 1982; Pieper et al., 1984), both acquisition and maintenance logistical support costs were found to be much lower for maintenance simulators than for AETs. Pieper also demonstrated that an IVDT-type trainer was superior to the AET in training troubleshooting skills. In view of the many advantages and cost benefits, as well as the rapid geometric increase in weapon sophistication, it is anticipated that maintenance simulator trainers will continue to proliferate and increase in importance in the military training environment.

Does this imply that managers/trainers should rush out and procure a maintenance trainer? If the answer is "Yes," one should perform an adequate front-end analysis and become familiar with the complex procurement aspects of obtaining effective training devices. Maintenance trainers, when not properly designed and procured, can be more of a training liability than a training asset! The following AFHRL documents may be helpful to those desiring to procure such trainers:

Maintenance training equipment: Design specification based on Instructional System Development (AFHRL-TP-84-43, AD-A149 405).

Maintenance training simulators: Logistical support cost considerations in design and acquisition (AFHRL-TP-84-49, AD-A152 168).

Maintenance training simulators prime item development specification: Model specification and handbook (AFHRL-TP-84-44, AD-A154 108).

Indeed, the acquisition of effective simulator trainers is no simple endeavor; it requires a great deal of time, hard work, and specialized knowledge.

This paper has covered only one small aspect of maintenance simulator acquisition: initial acquisition cost based on simulator taxonomic type. Evidence suggests that simulators will become increasingly more prevalent among all the Armed Services in meeting training and defense readiness requirements in the future. Nevertheless, the most important question is, "How effectively will they be procured?" As manpower, equipment, and funding resources become ever more limited, the need to maximally optimize defense resource allocations is mandatory. The procurement decisions of today's managers and training personnel will be sowing the seeds for the future growth or demise of an exceptionally promising technology - Maintenance Simulators.

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