NAVAL TRAINING SYSTEMS CENTER
ORLANDO, FLORIDA

TECHNICAL REPORT 88-006

MAINTENANCE TRAINING SIMULATOR INSTRUCTOR STATION AND STUDENT STATION DESIGN GUIDELINES

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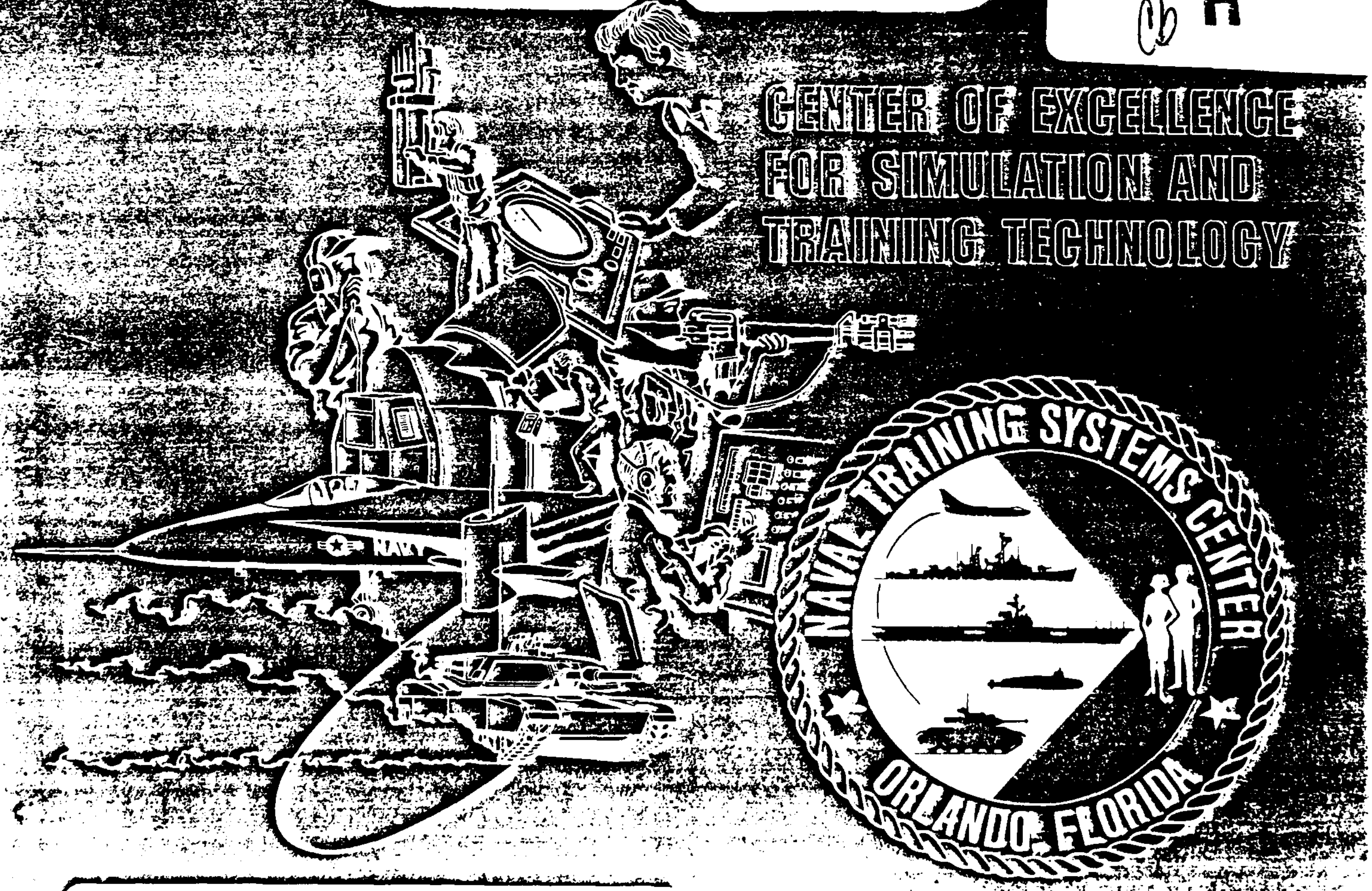

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This report discusses the methodology and results of a research effort that was conducted to derive a set of design guidelines for maintenance training simulator (MTS) instructor stations and student stations. The first step in collecting the information necessary for developing the design guidelines was to develop a classification scheme for categorizing different MTSs by type. Next, an attribute taxonomy was constructed to delineate the different features characteristic of MTSs. Then, a sample of 51 instructors was surveyed in order to determine the commonality of the attribute taxonomy features across 19 different MTSs. Finally, the same instructors were queried on their perceptions of the usefulness and training contribution of each of the critical features. The findings formed the foundation on which the design guidelines were based.

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EXECUTIVE SUMMARY

PROBLEM

The Navy considers Maintenance Training Simulators (MTSs) to be an effective means for providing maintenance training. Navy procurement of MTSs has risen steadily over the past several years, and it appears that this trend will continue. As at present, the majority of MTS characteristics will continue to be dictated by factors such as training requirements and end-equipment characteristics. Therefore, a variety of MTS types and configurations will be procured. From the standpoint of development, implementation, and logistics support, a wide variety of designs and implementation approaches is undesirable because of increased design costs, limited opportunity for spares standardization, and interference in the transfer of operator skills across MTSs. To the extent that commonality of critical features can be promoted across MTSs, these undesirable side-effects can be reduced.

OBJECTIVE

Although. the operational equipment which is being simulated will largely drive the physical appearance of the MTS, designers have much more freedom in the design, configuration, and especially the functional capabilities of the simulator's instructor station (IS). This is also true, though perhaps to a lesser extent, when components such as a visual display unit (VDU) and keyboard serve as an auxiliary student station (SS). The purpose of this research was to develop guidelines to support the development of those portions of MTS specifications devoted to IS and SS design. The guidelines will assure appropriate consideration will be given to the incorporation of critical functional capabilities during MTS design, and that the minimum required capabilities will be implemented in a common format across all MTS IS and SS designs.

APPROACH

The first step in collecting the information necessary for developing IS and SS design guidelines was to develop a classification scheme for categorizing different MTSs by type. Next, an attribute taxonomy was constructed to delineate the different features characteristic of MTSs. Then, a sample of 51 instructors was surveyed in order to determine the commonality of the attribute taxonomy features across 19 different MTSs. Finally, the same instructors were queried on their perceptions of the usefulness and training contribution of each of the critical features. The findings formed the foundation on which the design guidelines were based.

FINDINGS

The MTS classification scheme developed for this effort identified four different categories, or types, of MTSs: Interactive Video Display Simulators (IVDS), panel simulators, model simulators, and Stimulated Actual Equipment

(SAE). A commonality analysis, based upon the attribute taxonomy, revealed that MTSs share many high-level features (both within and between MTS types), suggesting that IS and SS design requirements can generalize across MTS types. At the implementation level, however, it was found that the features are often incorporated differently and operate in diverse ways. The survey results revealed that instructors gave high ratings to most (but not all) of the features that were assessed. The similarity of instructor responses across the different MTS types indicates that IS and SS design features are a function of the instructional requirements associated with providing sound maintenance training via simulation, rather than being determined by MTS physical characteristics. The design guidelines resulting from this effort are provided in a narrative format in Appendix C. The design guidelines are intended to support the development of those portions of the MTS specification devoted to IS and SS design.

CONCLUSIONS

The results of this effort suggest that, at a "macro" level, a great deal of feature commonality exists across different types of MTSs. At a "micro" level, however, they are frequently implemented in different formats and operate in diverse ways. The ways in which the features are designed and implemented in future MTSs can be standardized to some extent. While we are not advocating complete standardization whereby ISs and SSs are provided "off-the-shelf" as Government-furnished equipment, the design guidelines in this report can help the Navy move toward more standardization than in the past. The advantages of promoting more commonality of features across MTSs lies in reduced design costs each time a new MTS is procured, spares standardization across MTSs for enhanced logistics support, ensurance that training-critical instructional features are present in all MTSs, and a facilitation in the transfer of operator (user) skills across different MTSs.

RECOMMENDATIONS

The results of this effort are not a panacea. That is, the design guidelines provided in Appendix C will not resolve all of the difficulties associated with MTS procurement. They can, however, serve as an aid during the preparation of those portions of the MTS specification devoted to IS and SS design. Therefore, it is recommended that the guidelines generated as a result of this research be used to support the acquisition of future MTSs.

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INTRODUCTION

The maintenance of electronic, electromechanical, and hydraulic military equipment is a critical component of preparedness. Because of the continual loss of experienced technicians from the armed services, and the increased dependence on more junior, less experienced maintenance technicians, training has become an increasingly important concern during the past decade (Cicchinelli et al., 1982). According to Nauta (1985), the Navy, like other branches of the armed services, has realized "that the human element has become the most critical, problematic, and costly component of its war-fighting capability. At the same time, the hardware being developed and fielded is becoming increasingly complex." To meet the demands for cost-effective, yet high-quality training, simulators have long been proposed as alternatives to actual operational equipment used for training (Miller, 1974).

Although the concept of simulation has a long military history, there is still no universally accepted definition of a simulator. One of the earliest definitions, proposed by Gagne (1954), states that "a simulator is generally understood to be a kind of training device which has a high degree of resemblance to operational equipment, particularly with respect to the display, the controls, and the way one affects the other when in operation." Later Gagne (1961) elaborated on this definition by stating that all true simulators have three things in common: (1) an attempt to represent a real situation in which operations are carried out, (2) a provision for certain controls over the situation which represents the real operational situation, and (3) a design that deliberately omits certain parts of the real operational situation.

In a similar vein, Kinkade and Wheaton (1972) define a simulator as a highly complex training device that attempts to reproduce a large number of the operational characteristics of a system and includes the system's response to control actions. Orlansky and String (1981) contend that "maintenance simulators are synthetic training devices that appear to duplicate the performance characteristics of operational equipment under normal and many malfunction conditions . . . They incorporate some type of computer support to provide a large variety of malfunctions for instructional purposes, are designed to withstand abuse in a classroom, do not expose students to dangerous conditions, and can measure student performance for the information of both students and instructors."

For the purposes of this effort, maintenance training simulators (MTSs) are defined as maintenance trainers that represent actual equipment/systems via computer controlled emulation of equipment/system operation and responses to user inputs.

Since World War II, the military services have conducted considerable research on the development and application of simulators for maintenance training. These studies have demonstrated that simulators can be used to teach many maintenance skills. In particular, "it has been shown conclusively that the controls and external indicators, and the signal flow characteristics of electronic equipment can be simulated accurately enough so that the resulting simulators can be used to teach operator skills and the conceptual aspects of troubleshooting." (Fink and Shriver, 1978a).

At the same time, "it has become axiomatic among educational/training specialists that the complex processes of learning are not necessarily best served by "hands on" experience with real equipment . . . These processes may be better served by the (simulator), since it, unlike the operational equipment, can be specifically designed and employed to optimize such instructional features as feedback, scenario freeze and playback, sequencing of training events (i.e., easy to difficult materials) and finally, measurement of student achievement" (Wheaton et al., 1976).

Comparisons of actual equipment trainers (AETs) with MTSs have asserted that they are comparable in training capabilities, (Pieper et al., 1984) but simulators are advantageous in that they "reduce costs, are more reliable, provide safer training, and have greater capability to insert malfunctions" (Jarvis et al., 1983).

In addition to being widely-accepted and training effective, MTSs are cost-effective. In a study conducted by Orlansky and String (1981), the acquisition costs of maintenance simulators were typically found to be less than those of AETs. The cost to develop and fabricate one unit of a simulator was less than sixty percent of the cost of AETs in seven of eleven cases examined. The cost to fabricate an additional unit of a simulator was less than twenty percent of the cost of actual equipment trainers in nine of eleven cases. The one available life-cycle cost estimate showed that, over a fifteen year period, the cost to purchase and use a simulator would be only thirty eight percent of that for an AET.

Results from a life-cycle cost comparison of the F-111 Test Station AET (referred to as the "6883") with 2-dimensional and 3-dimensional test station simulators demonstrated that the cost per student-hour for AETs was $58, whereas the costs per student-hour for the 2-D and 3-D simulators were $23 and $16, respectively. The 15-year life-cycle costs were estimated to be $5.3 million for the actual equipment, $2.1 million for the 3-D simulator, and $1.6 million for the 2-D simulator (Cicchinelli et al., 1982). In a later study, Pieper et al. (1984) estimated the 15-year life-cycle cost of a videodisc trainer used for the same training purposes to be about half the cost of the 2-D simulator (i.e., approximately $800,000).

Because of the demonstrated capabilities of MTSs, the Navy will continue to design, develop, and procure simulators for both operational and developmental weapons systems. As at present, the majority of trainer characteristics will be dictated by such things as training requirements and end-equipment characteristics. Therefore, a wide variety of kinds of trainers will be procured, but most will have several common capabilities. These common capabilities pertain primarily to functions or capacities provided by instructor stations and, to a certain extent, student stations of MTSs.

PURPOSE

The purpose of this research was to develop guidelines to support the development of MTS instructor and student stations. The guidelines will assure that appropriate consideration is given to the inclusion of trainer-critical functional capabilities during design, and that at least the minimum required capabilities will be incorporated into all MTS instructor station and student station designs.

BACKGROUND

Recent advances in technology have spurred similar advances in the design of MTSs in general and MTS student and instructor stations in particular. Student stations with touch sensitive CRT screens and instructor stations capable of automatic student monitoring are becoming more common. Recently developed MTSs both take advantage of available technology, and drive the development ot new technology capabilities in response to identified needs for particular training features or desired characteristics. However, the scope of capabilities available through technology initiatives affords the opportunity for widely varying designs that implement various characteristics and technologies in unique ways. From the standpoint of development and procurement of MTSs, a wide variety of implementation approaches and designs is undesirable. There will be little or no commonality between different designs for MTS student and instructor stations' features if the design process is unconstrained.

This problem is not unique to MTSs. According to Hinton and Komanski (1982), who examined flight simulator instructor/operator stations, "the instructor/operator station (IOS) has been the recipient of much of the explosion of simulation technology. As technology has permitted higher fidelity simulation of more and more trainee tasks, it has also enabled expanded capabilities to control the simulation environment. These capabilities have been incorporated into the IOS. All too often selection and implementation of the capabilities have been based on insufficient analyses and data. As a result, IOSs and the associated software have been poorly designed."

Some studies have suggested that certain MTS characteristics could be standardized (Hritz and Purifoy, 1984; Carroll et al., 1984). Fink and Shriver (1978b) recommended the "continued investigation of various procedures which can be used to develop the functional specifications for maintenance simulators, to include both the tasks which should be simulated and the instructional features which should be incorporated into the trainer."

In a recent report dealing with these issues, Nauta (1985) recommends, among other things, that "specifications for general-purpose and generalized maintenance training equipment, including standardized modules for student and instructor stations" be developed.

The development and refinement of the instructional systems design (ISD) model appears to promise more effective MTS design. In fact, a handbook of procedures was developed to guide the application of ISD methodology to the development of MTS functional specifications (Hritz and Purifoy, 1984). These procedures and the current awareness of the importance of detailed training analysis in developing MTS specifications should result in MTSs with many common student and instructor station design attributes.

Given the large number and diversity of systems being simulated and the fact that MTS design in many cases follows advances in technology, it is not surprising to find a corresponding variety of student and instructor station designs. While one might argue that the diversity of systems being trained has led to the large number of different MTS designs in existence, the variety of student/instructor station designs is not easily justified. There is much commonality in the manner in which students interact with MTSs within a given class of MTSs, and the features and capabilities required by instructors are largely independent of the systems being simulated. Thus, it appears feasible that generic student station and instructor station design guidelines or principles can be developed that can be used for all MTSs or at least all MTSs within a particular MTS category.

Maintenance Training Simulator Classification

Numerous attempts have been made to assign maintenance training simulators to categories. While there is no universally accepted taxonomy of MTSs, various classification schemes have been developed.

In a recent survey of maintenance training simulators, Carroll, Thocher, Roth, and Massey (1984) classified simulators according to physical appearance and function, resulting in a descriptive taxonomy. This taxonomy was chosen as a point of departure for this effort. The four classes of simulators in this taxonomy are:

1. Stimulated Actual Equipment (SAE).

2. Model Simulator.

3. Panel Simulator.

4. Interactive Video Display Simulator (IVDS).

SAE refers to actual equipment which is stimulated or directed by an auxiliary computer and other interface device(s). Typically, such a simulator consists of actual equipment, some interface device(s), and a signal generator (or source for signal input; e.g., from a computer disk). Some SAE utilizes actual equipment with some simulated components. The actual equipment does not receive its input from normal sources, but rather from the signal source via some interface device(s). Typically, the signal source can be controlled such that specific signals are sent under certain conditions. An example of a very simple SAE is a trainer used to teach oscilloscope skills. The trainer consists of an oscilloscope (the actual equipment), a signal generator (a device that sends the appropriate signals to the oscilloscope to produce the various waveforms), and a processor of some sort. The processor is used to program the generator to produce various waveforms (i.e., to send the correct signal at the proper time).

Model simulators are three-dimensional replicas of the actual equipment. They are typically full-scale mock-ups of the actual equipment, but can also be under-scale or enlarged mock-ups. Like SAE, model simulators allow the student to see the spatial relationships of components as they appear on the actual equipment. Unlike SAE, typical models contain operational replicas of only the displays and controls essential to the tasks to be trained. For example, a model simulator representing an aircraft cockpit may include operational three-dimensional replicas of the throttle, fuel/pressure gauges, and other components used during a particular task. These operational components allow student input to be sensed by the simulator's computer, which in turn generates the appropriate responses (e.g., meter readings and indicator lights). Displays and controls that are not essential to training are replicated visually (i.e., represented by etched drawings or nonfunctional replicas of the displays and controls). The component locations and size relationships are commonly the same as on the actual equipment, although this may be provided via a full-scale, under-scale, or over-scale model or mock-up. Like other training simulators, the model simulator is supported by a computational subsystem that drives the instructional exercises.

Panel simulators are used to provide maintenance trainees with the opportunity to practice maintenance procedures and perform troubleshooting tasks on simulated equipment that resembles the actual equipment, although the system components are often represented by etched drawings. Some panel simulators have full-sized components (some functional, others represented by graphic drawings, silkscreens, or photographs) displayed on a flat panel, with drawings to show where the components are found on the real equipment.

The displays, knobs, switches, etc. that the trainee uses on the panel simulator are usually functional and highly realistic. The ones not used are often graphically represented on flat panels. For example, of four heat-sensing indicators on an actual equipment system, only one of them might be made functional on a panel simulator. The other three indicators would be made the same size, but nonfunctional. To fully simulate the other indicators would be redundant for training purposes. Thus, they would add to the cost but not to the training value of the simulator. Panels can be used to represent large units reduced, small units enlarged, or full-scale units.

IVDSs include simulators that utilize random-access slide systems, computer-generated graphics, computer-controlled videodisc images, or any combination of these. Typically, IVDSs are under the control of a stand-alone microcomputer and consist of a keyboard, mouse, touch pad, or touch-sensitive screen for data entry, and a video display unit for information display. A videodisc maintenance training simulator typically contains a videodisc player, a computer, an interface device (e.g., CRT screen), and an input device (e.g., touch panel, keyboard, or joystick). The two most common types of IVDSs are computer videodisc simulators and computer-generated graphics simulators; both are discussed below. Newer IVDSs incorporate both videodisc and computer-generated graphics to produce highly sophisticated, high-fidelity interactive representations of equipment and functions.

The computer videodisc simulator (the first type of IVDS) presents images relating to the equipment the student is learning to maintain. The simulation may display motion sequences (e.g., actual equipment in motion, dials moving) or, more frequently, static image sequences which are played frame by frame. Videodisc images can be line drawings, charts and graphs, pages of text, photographs of the actual equipment, selected frames of film or videotape of the equipment during operation, animated sequences, etc.

Computer-generated graphics simulators (the second type of IVDS) provide computer graphic representations of actual equipment components on a video display and provide high psychological fidelity, but low physical fidelity (i.e., provide two-dimensional pictorial representations of actual equipment). An extensive database and flexible software allow graphic simulators to display a variety of informational visual presentations. These simulators include a video display, a computer with a graphics generator, a device for interacting with the trainer, and complex software.

In general, video display trainers of the types described above are interactive trainers. Controlled by the computer, they can present the student with a variety of situations, choices, and information. These presentations or instructional exercises are designed to teach maintenance principles or procedures to the student. The student interacts with the trainer via a keyboard or other input device (Carroll et al., 1984).

Maintenance Training Simulator Attributes

Certain attributes are common to virtually all maintenance training simulators. Although various authors refer to these different characteristics in a general way, none has developed a classification scheme for delineating attributes. To facilitate the conduct of this research, MTS attributes were classified into four major areas:

1. Information/Training Management.

2. Instructional Features.

3. Human Factors Design and Layout.

4. Computer System Characteristics.

Information/Training management. This attribute refers to those trainer capabilities which enable the instructor or course manager to perform training administration functions such as student monitoring, performance scoring, and student recordkeeping via the simulator's computer system. The following eight characteristic features of this attribute were derived from the comprehensive coverage of these features (under the title "Instructional Features") in a handbook of ISD procedures for designing and acquiring maintenance trainers developed by Hritz, Harris, Smith, and Purifoy (1982).

1. Initialization.
2. Performance Monitoring.
3. Performance Measurement.
4. System Monitoring.
5. Report Generation.
6. Student Recordkeeping.
7. Student Tutoring.
8. Training Exercise Control.

Instructional features. This attribute includes those trainer capabilities which enable the instructor to control critical aspects of the training environment by exercising options such as malfunction selection/ insertion, system freeze capability, and augmented feedback messages. The following nine features which comprise the Instructional Features attribute were derived from the ISD handbook mentioned in the previous paragraph, the results from a recent survey of over thirty maintenance simulators (Carroll, Thocher, Roth, and Massey, 1984), and two MTS design and acquisition specifications and handbooks which have been updated and used in the acquisition of several MTS devices by the Air Force (Hritz, Purifoy, and Fitzpatrick, 1984; Hritz and Purifoy, 1984).

1. Student Sign-in Capability.
2. Malfunction Insertion/Selection.
3. Freeze Capability.
4. Augmented Feedback Capability.
5. Next Activity Control.
6. Cue Enhancement.
7. System Parameter Control.
8. Training Mode Control.

Human factors design and layout. Human factors design and layout addresses the user (student/instructor) interface; i.e., the simulator hardware and software which effects the manner in which the student/instructor receives stimuli from and makes responses to the simulator. The features that comprise this attribute were derived from several sources. The primary sources of the user-hardware interface considerations (i.e., controls and displays) were Van Cott and Kinkade (1972), Woodson and Conover (1973), and McCormick (1976). The user-software interface features were taken from the comprehensive guidelines developed by Smith and Mosier (1984). The features of human factors design and layout are:

1. Input/Control Devices.

2. Display Devices.

3. Workstation Design and Layout.

4. User-System Software Interface.

Computer system characteristics. Computer system characteristics refer to the configuration and functioning of the simulator's computer system and subsystems hardware and software. This information was collected and compiled into a comprehensive list by a group of engineers who have been actively involved in writing maintenance trainer procurement specifications for many years. This information was incorporated into a procurement model specification and handbook (Hritz et al., 1984). The computer system characteristics listed below were derived from the detailed computational system section of the handbook (Hritz et al., 1984). Computer system features include:

1. Instructional Systems Software, which controls the presentation of instruction and exercises via the MTS hardware. Included in this software are the implementation of instructional features, malfunction selection, student and system monitoring, and other features critical to the presentation of instruction and exercises.

2. Computational Subsystem Hardware, which includes processors, memory, mass storage, and interfaces to the remaining MTS hardware, including instructor and student station hardware.

3. Computational Subsystem Software, which includes the computer operating system, language compilers, utility programs, diagnostics, device drivers, and other general support software capabilities. Also included in this category are simulation control logic, and mathematical models of the system being simulated or other systems or elements which must be modeled to provide a complete simulation.

4. Trainer Support Subsystems, including diagnostic software for elements of the MTS other than the computational subsystem, test and readiness assessment software, database management and exercise configuration control

software and databases, and records management software. Authoring or exercise modification capabilities are also classified as trainer support subsystem software.

All of the features of the attributes mentioned above must be considered when developing an MTS instructor station or student station design specification. The last attribute mentioned (Computer System Characteristics) is actually an attribute of the maintenance simulator. However, the maintenance simulator's computer system must support all of the other instructor station and student station features.

Once MTS types and MTS instructor station and student station attributes and features have been identified, an investigation can be conducted to determine the degree of instructor station and student station attribute/feature commonality among MTSs and to determine the relative importance of each feature with respect to training effectiveness. The remainder of this report describes such an effort, the result of which is a set of guidelines for developing MTS instructor station and student station design specifications.

Limitations of This Research

Just as the findings of a carefully controlled experiment may be limited in their generalization to the operational environment, the results of survey research conducted in the operational environment are limited in their ability to highlight cause-and-effect relationships. Although both approaches have their disadvantages and merits, survey research was the preferred method of achieving the goal of assessing instructors' perceptions of the training effectiveness of MTS instructor station/student station characteristics. The survey method allowed the examination of maintenance simulators and instructors as they function in the actual training environment. Thus, the conclusions drawn from this study reflect the attitudes held in various technical schools and operational environments.

To avoid some of the problems associated with the survey method (particularly of mail surveys), questionnaires were administered at the training site by project personnel. This virtually eliminated subject attrition; only two of fifty-three instructors surveyed chose not to complete the survey. Due to the specialized nature of courses that utilize maintenance simulators, the number of instructors was generally low for the devices surveyed. While requests were made to have at least four instructors per simulator participate in the study, more often only two instructors were available. This limits the ability to assess consistency of instructor responses within each device. However, instructor response reliability does not appear to be a problem since the results show considerable response consistency both between MTSs and within MTS types.

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TECHNICAL APPROACH AND FINDINGS

CLASSIFICATION OF MAINTENANCE TRAINING SIMULATORS

Since it was possible that some functional capabilities may have been peculiar to specific MTS types, it was necessary to partition MTSs into various categories. Consequently, the first phase of this effort involved the development of a classification scheme for categorizing MTSs by type. Existing taxonomies were first reviewed; their characteristics were then examined and isolated; and finally, the salient components of each were extracted and synthesized to construct a final MTS classification system.

Review Existing MTS Taxonomies

Existing MTS taxonomies were identified and examined to determine their classification dimensions, characteristics, and descriptions of MTSs that fit within the classification framework. Once the MTS taxonomies were reviewed, they were analyzed to determine which met the selection criteria presented below.

- Parsimony. Only the minimum number of dimensions and characteristics within dimensions needed to accurately discriminate all important categories of MTSs should be included in a taxonomy.

- Clarity. Each dimension and characteristic of the taxonomy must be explicitly defined, and the boundaries between characteristics accurately identified.

- Comprehensiveness. The taxonomy and its categories must address all significant classes and subclasses of MTSs.

- Ease of use. Classification of MTSs within the taxonomy must be straightforward and unambiguous; extremely subtle or difficult-to-determine criteria must be avoided, and simple algorithms or procedures must be provided for classification.

Examine Characteristics of Existing Taxonomies

The candidate MTS taxonomies (i.e., those that appeared to meet the selection criteria listed above) were further analyzed to determine (a) hardware dimensionality; (b) training objectives (i.e., types of tasks taught) addressed by each taxonomy category; and (c) functional fidelity levels of the MTSs within each category. These characteristics were examined to validate the comprehensiveness of each taxonomy and to compare characteristics of different taxonomies.

Synthesize Taxonomies and Construct Final MTS Taxonomy

The identified candidate dimensions were synthesized to develop an MTS taxonomy. The characteristics of all the classification dimensions were identified and listed. Combinations of characteristics were examined and evaluated against the following criteria:

- **Meaningfulness**. MTS types to be included in the taxonomy must be meaningful; that is, a particular description of a simulator type must represent a kind of trainer that is actually usable to support effective training. An example of a meaningful simulator type description is an AET designed to provide familiarization and practice in developing mechanical adjustment, rigging, and remove/replace skills. Both the design characteristics and the potential utilization of the simulator type in teaching maintenance skills were considered in judging whether candidate descriptions were meaningful.

- **True discriminations**. MTS type descriptions must represent true discriminations between types of simulators to be included in the taxonomy. For example, including a discrimination between panel simulators used for training hydraulic vs. electronic system function or task skills may add little or nothing to the taxonomy; in such a case, only a single, higher-level description (e.g., panels vs. AETs, etc.) was retained in the taxonomy.

- **Redundancy**. MTS types which were redundant were identified and collapsed into a single category in order to eliminate overlap and to enhance clarity and conciseness.

Findings

The taxonomies that came closest to meeting the requirements of this research were the taxonomy of maintenance training equipment developed by the Logistics Management Institute (1983) and the taxonomy of maintenance simulators developed by Carroll, Thocher, Roth, and Massey (1984). These taxonomies are presented in Tables 1 and 2, respectively. The taxonomy categories and the dimensionality represented by each category are presented as rows in the tables, and the types of tasks taught and the functional fidelity levels for each category are presented in columns. Table entries indicate whether or not a given type of maintenance task is taught on the trainers within each category. In some cases, the scope of the Diagnostic/ Troubleshooting and Theory of Operation Tasks is indicated. The psychological, physical, and task fidelity levels of the trainers that comprise each of the taxonomy categories are also indicated in the tables. It should be noted that the entries in these tables represent the authors' best estimates and are not intended to serve as definitive descriptions of the characteristics of each of the taxonomy categories. The tables were constructed to delineate the attributes of each taxonomy in order to facilitate the comparison of the different taxonomies.

Table 1

Characteristics of Maintenance Training Equipment Taxonomy
(Developed by Logistics Management Institute, 1983)

Maintenance Simulator Category*	Maintenance Tasks Taught					Fidelity**		
	Op. Checks	Manipulation	Diagnostic/ Troubleshooting	Familiarization and Structure	Theory	Psy	Phy	Task
TT								
I-level 2D	--	--	logical	Yes	Yes	H	L	L
3D			logical	Yes	Yes	H	L	L
GT								
I-level 2D			logical	Yes	Yes	H	L-H	L-H
3D	Yes	Yes	Yes	Yes	--	H	L-H	L-H
AET								
O-level 2D/3D	Yes	Yes	System Specific	Yes	--	L-M	H	L-M
3D	Yes	Yes	System Specific	Yes	--	L-M	H	L-M
I-level 2D/3D	Yes	Yes	System Specific	Yes	Sys. Spec.	L-M	H	L-M
3D	Yes	Yes	System Specific	Yes	Sys. Spec.	L-M	H	L-M
ERT								
O-level 2D/3D	Yes	--	System Specific	Yes	--	M-H	L-H	L-H
3D	Yes	Yes	System Specific	Yes	--	M-H	L-H	L-H
I-level 2D/3D	Yes	--	System Specific	Yes	Sys. Spec.	M-H	L-H	L-H
3D	Yes	Yes	System Specific	Yes	Sys. Spec.	M-H	L-H	L-H
GPT								
O-level 2D	Yes	--	Limited	Yes	Limited	L-H	L	L-M
2D/3D	Yes	Yes	Limited	Yes	Limited	L-H	M-H	L-H
I-level 2D	Yes	--	Limited	Yes	Sys. Spec.	L-H	L	L-M
2D/3D	Yes	Yes	Limited	Yes	Sys. Spec.	L-H	M-H	L-H

* TT = Technology Trainer; GT = Generalized Trainer; AET = Actual Equipment Trainer; ERT = Equipment Replica Trainer; GPT = General Purpose Trainer.

** L = Low, M = Medium, H = High.

Table 2

Characteristics of Maintenance Training Simulator Taxonomy
(Developed by Carroll, Thocher, Roth, and Massey, 1984)

Maintenance Simulator Category*	Maintenance Tasks Taught					Fidelity**		
	Op. Checks	Manipulation	Diagnostic/ Troubleshooting	Familiarization and Structure	Theory	Psy	Phy	Task
SAE								
O-level 2D/3D	Yes	Yes	System Specific	Yes	--	L-M	H	L-M
3D	Yes	Yes	System Specific	Yes	--	L-M	H	L-M
I-level 2D/3D	Yes	Yes	System Specific	Yes	Sys. Spec.	L-M	H	L-M
3D	Yes	Yes	System Specific	Yes	Sys. Spec.	L-M	H	L-M
PANEL SIMULATOR								
O-level 2D/3D	Yes	--	System Specific	Yes	--	M-H	L-H	L-H
I-level 2D/3D	Yes	--	System Specific	Yes	Sys. Spec.	M-H	L-H	L-H
MODEL SIMULATOR								
O-level 2D/3D	Yes	--	System Specific	Yes	--	M-H	L-H	L-H
I-level 2D/3D	Yes	--	System Specific	Yes	Sys. Spec.	M-H	L-H	L-H
IVDS								
O-level 2D	Yes	--	Limited	Yes	Limited	L-H	L	L-M
2D/3D	Yes	Yes	Limited	Yes	Limited	L-H	M-H	L-H
I-level 2D	Yes	--	Limited	Yes	Sys. Spec.	L-H	L	L-M
2D/3D	Yes	Yes	Limited	Yes	Sys. Spec.	L-H	M-H	L-H

* SAE = Stimulated Actual Equipment; IVDS = Interactive Video Display Simulator.

** L = Low, M = Medium, H = High.

As can be seen from the tables, the two taxonomies have much in common. This is not surprising since the taxonomy in Table 2 applies to maintenance training simulators which are a subset of maintenance training equipment. The taxonomy in Table 1 addresses maintenance training equipment in general. The SAE and IVDS categories in Table 2 appear to be identical to the AET and GPT categories in Table 1. Furthermore, the panel simulator and model simulator categories in Table 2 appear to be subdivisions of the equipment replica trainer (ERT) category presented in Table 1. It was determined that the maintenance training simulator taxonomy actually represents a subset of the more general taxonomy of maintenance training equipment.

The maintenance training simulator taxonomy appears to be the most appropriate for the purposes of this research; i.e., to develop guidelines for the development of student and instructor station design specifications. Although the maintenance training equipment taxonomy is a comprehensive and complete classification scheme for the broad range of maintenance training equipment in use, it includes categories of devices that are unlikely to have instructor or student stations (e.g., technology trainers) and the taxonomic dimensions are not descriptive and may be ambiguous to manufacturers and Navy acquisition personnel (e.g., generalized trainer and general purpose trainer). Conversely, the dimensions of the maintenance training simulator taxonomy are descriptive and easy to conceptualize.

The taxonomy developed and presented in Table 2 is believed to be a comprehensive and complete classification scheme for that subset of maintenance training equipment (MTE) which utilizes instructor and student stations. This taxonomy facilitated the goal of selecting a representative sample of maintenance simulators in order to examine the characteristics of their student and instructor stations.

SELECTION OF MAINTENANCE TRAINING SIMULATORS

A sample of MTSs, representative of the MTS types identified in the classification taxonomy, was selected in order to keep the number of simulators examined within a manageable range. The original candidate pool insisted of over 100 training systems drawn from the Directory of Cognizance 2 "O" training devices. The criteria presented below, were then applied in order to select a representative sample for further examination.

Selection Criteria

Dedicated maintenance simulator. The simulator must be dedicated to maintenance training. A device that is utilized to train both maintenance and operational tasks qualified for inclusion in the research, as long as its primary function was maintenance training.

Recent utilization. The simulator must have been utilized in a maintenance training course within the past six months. To help insure the validity of responses to the survey items, it was considered important to include only simulators with which instructors had recent experience.

Computer driven. The simulator must be computer driven for training purposes. A training device may include a computer system which is part of the actual equipment or system for which training is being provided. However, unless the computer included software specifically designed to provide training, then that device was not considered a maintenance training simulator for the purposes of this research.

Contribution. The simulator contributes to the goal of obtaining a representative sample of devices from each taxonomic category.

Classification. The simulator must not be a classified device.

Findings

Nineteen MTSs met each of the selection criteria. The remaining simulators were eliminated from further consideration. Of the nineteen MTSs selected, three were IVDSs, six were model simulators, six were panel simulators and four were SAE. The final sample is presented in Table 3.

It was found that the MTSs are often hybrids of the four defined taxonomy types, and thereby broaden the features available to the trainee. For example, Device 11G3 is primarily a model simulator with a stimulated actual equipment oscilloscope as an integral component. In cases of hybrid types, the MTSs were classified according to the type most predominant in their design.

DEVELOPMENT OF AN MTS ATTRIBUTE TAXONOMY

In order to organize the MTS functional capabilities within a conceptual framework, it was necessary to develop an attribute taxonomy. The approach was to decompose "macro" level attributes into component and subcomponent parts that would depict the hierarchical structure of each attribute. The specific steps taken are presented below.

Review and Examine Existing Taxonomies

The first activity in this task was to identify and abstract the attributes and features of all available MTS attribute taxonomies. This review concentrated upon identifying MTS attribute dimensions and features of each dimension and preparing clear statements of the defining elements of each attribute and characteristics from each taxonomy reviewed.

Select and Refine Dimension/Attributes for Taxonomy

When the review of existing MTS attribute taxonomies was complete, subsets of candidate attributes and their features were examined to identify and refine the most appropriate taxonomic hierarchies. Attributes/features/ elements were evaluated to identify the most parsimonious and complete set of descriptors of the characteristics and elements of each attribute.

Table 3

MTS Designator Code, Simulator Type, Military Service Branch, and Location

Designator	Type	Service Branch	Location
11B106A	IVDS	Navy	FTA School, Great Lakes
AN/WSC-3	IVDS	Navy	Electronics School, Norfolk N.S.
IGS	IVDS	Air Force	Lowry Air Force Base
11E15	MODEL	Navy	EM/C School, Great Lakes
19D2	MODEL	Navy	DGT School, Great Lakes
19E2	MODEL	Navy	DGT School, Great Lakes
A6E DRS	MODEL	Navy	NAMTRADET 1003, Oceana
11H102	MODEL	Marines	NAMTRADET 1038,
11H103	MODEL	Marines	NAMTRADET 1038, LeMoore
11G2	PANEL	Navy	FTC School, Naval Station San Diego
11G3	PANEL	Navy	FTC School, Naval Station, San Diego
A6 ECII	PANEL	Navy	NAMTRADET 1003, Oceana
CH53E	PANEL	Marines	NAMTRADET 1032, Tustin
SH60B1	PANEL	Marines	NAMTRADET 1067, North Island
OFA/UTU	PANEL	Marines	NAMTRADET 1078, El Toro
19D1	SAE	Navy	DGT School, Great Lakes
20H7A	SAE	Navy	DGT School, Great Lakes
F14MPD	SAE	Marines	NAMTRADET 1007, Oceana
SH60B2	SAE	Marines	NAMTRADET 1067, North Island

Synthesize Taxonomies

Each identified attribute, feature, and element derived from previous activities was evaluated against the initial taxonomy to determine whether it could be incorporated meaningfully.

Where particular descriptive elements were deemed appropriate, they were integrated into the initial taxonomy. Once all elements were incorporated into the initial taxonomy, the expanded taxonomy was examined for structural correctness and completeness.

Develop Detailed Attribute/Feature/Element Description

Detailed and comprehensive descriptions of each attribute, feature, and element of the taxonomy were developed in order to effectively communicate the exact relationships, purpose, and contents of each taxonomy category. A final review was made of the taxonomy after all definitions and descriptions were in place to ensure the clarity, comprehensiveness, and accuracy of the final taxonomy.

Findings

A review of the MTS literature did not reveal a single, comprehensive taxonomy of MTS attributes, per se. Consequently, the attributes of such a taxonomy were derived from various references in the literature, a preliminary attribute list in the contract Statement of Work, and the authors' experience in developing acquisition and design guidelines for maintenance trainers. This led to the identification of four major categories:

1. Information/Training Management.

2. Instructional Features.

3. Human Factors Design and Layout.

4. Computer System Characteristics.

Information/Training management. This attribute refers to those trainer capabilities which enable the instructor or course manager to perform training administration functions via the simulator's computer system. Eight characteristic features of this attribute (initialization, performance monitoring, performance measurement, system monitoring, report generation, student recordkeeping, student tutoring, and training exercise control) were derived from the comprehensive coverage of these features (under the title "Instructional Features") in a handbook of ISD procedures for designing and acquiring maintenance trainers (Hritz et al., 1982). Definitions of each of these features along with a listing and description of the elements which comprise them are presented in Appendix A.

Instructional features. This attribute includes those trainer capabilities which enable the instructor to control critical aspects of the training environment by exercising options such as malfunction selection/insertion, system freeze capability, and augmented feedback messages. The eight features which comprise the Instructional Features attribute (student sign-in capability, malfunction insertion/selection, freeze capability, augmented feedback capability, next activity control, cue enhancement, system parameter control and training mode control) were derived from the ISD handbook mentioned in the previous paragraph, the results from a recent survey of over thirty maintenance trainers (Carroll et al., 1984), and two MTS design and acquisition specification handbooks which had been updated and used in the acquisition of several MTS devices by the Air Force (Hritz et al., 1984; Hritz and Purifoy, 1984). Definitions and descriptions of these features and their associated elements appear in Appendix A.

Human factors design and layout. Human factors design and layout addresses the user (student/instructor) interface; i.e., the simulator hardware and software which effects the manner in which the student/instructor receives stimuli from and makes response to the simulator. The five features that comprise this attribute (input/control devices, display devices, workstation design and layout, user-system software interface, and maintainability) were derived from several sources (Van Cott and Kinkade, 1972; Woodson and Conover, 1973; McCormick, 1976; Smith and Mossier, 1984). Definitions and descriptions of these features and their associated elements appear in Appendix A.

Computer system characteristics. Computer system characteristics refers to the configuration and functioning of the simulator's computer system and subsystems hardware and software. This information was collected and then compiled into a comprehensive list by a group of engineers at Wright-Patterson Air Force Base who have been actively involved in writing maintenance trainer procurement specifications for many years. This information was incorporated into the procurement model specification and handbook mentioned earlier (Hritz et al., 1984). Four computer system features (instructional system software, computational subsystem hardware, computational subsystem software, and trainer support subsystem) were derived from the detailed computational system section of the aforementioned document. Definitions and descriptions of the taxonomy attributes, features, and elements are presented in Appendix A. A hierarchical listing of the taxonomy is presented in Table 4.

Table 4

Maintenance Training Simulator Attribute Taxonomy

Attributes	Features	Elements
Information/ Training Management	Initialization	Program Loading Verification Component Activation
	Performance Monitoring	Sensing Recording
	Performance Measurement	Performance Scoring Rating Criteria Control
	System Monitoring	Control Position Display Indications
	Report Generation	Summary Reports Statistical Profile
	Student Recordkeeping	Amount of Time Dangerous Actions Sequence Errors Helps Malfunctions Summary Data
	Student Tutoring	Lock Step Self-Paced
	Training Exercise Control	Training Exercise Selection Training Exercise Generation Training Exercise Modification
Instructional Features	Student Sign-in Capability	Student Identification Lesson Identification
	Malfunction Insertion/ Selection	Malfunction Creation Malfunction Selection
	Freeze Capability	Pre-Programmed Freeze Control Manual Freeze Control

Table 4 (Continued)

Attributes	Features	Elements
	Augmented Feedback Capability	On/Off Feedback Control Select Feedback Control Feedback Message Adjust
	Next Activity Control	Next Activity On/Off Control Next Activity Selection Next Activity Override Next Activity Modification
	Cue Enhancement	Stimuli Cue Enhancement Response Cue Enhancement
	System Parameter Control	Parameter Setting Capability Parameter Input Capability
	Training Mode Control	Lock Step Mode Self-Paced Mode Demonstration Mode
Human Factors Design and Layout	Input/Control Devices	Type Function Coding Resistance Feedback Control Display Ratio
	Display Devices	Function Intensity Contrast Resolution Frequency
	Workstation Design and Layout	Visibility Clearance Procedural Efficacy Physiological Factors Psychological Factors Dimensional Factors

Table 4 (Continued)

Attributes	Features	Elements
	User-System Software Interface	Data Entry Data Display Sequence Control User Guidance Data Transmission Data Protection
	Maintainability	Maintenance Concept Ease-of-Maintenance Reliability Repair Time
Computer System Characteristics	Instructional Systems Software	Training/Simulation Programs Instructional Features Programs Instructional Text Programs
	Computational Subsystem Hardware	Equipment Performance Characteristics Input/Output Hardware Interface Hardware Peripheral Equipment Spare Capacity/Growth Capability
	Computational Subsystem Software	Executive Program Input/Output Programs Maintenance and Test Programs
	Trainer Support Subsystem	Modification Support Hardware Modification Support Programs

MTS COMMONALITY ANALYSIS

In order to determine if certain MTS features were unique to particular MTS types, a commonality analysis was performed. This involved a determination of the frequency with which each of the features (identified in the MTS attribute taxonomy) appeared in the simulators examined. This determination was made via on-site administration of a survey questionnaire to fifty-one instructors, distributed across the nineteen MTSs examined. All instructors had utilized the MTS under study to teach a class within two months prior to the survey. The length of time operating a given MTS ranged from 4.0 to 32.4 months, with an overall average of 20.6 months. This assessment allowed not only an examination of feature commonality within MTS types, but also an assessment of feature presence across MTS types.

Gather Data on Selected MTSs

Initially, an attempt was made to collect data for the commonality analysis from Government-Furnished Information (GFI) and documentation gathered in earlier tasks. However, it soon became apparent that the available documentation, particularly the Prime Item Development Specifications and Functional Specifications which were obtained for the simulators, were not sufficiently detailed to determine whether or not specific features were included in a device. Consequently, it was decided to combine the data gathering for the commonality analysis with that planned to support the criticality assessment (discussed later). Thus, to determine the presence of design features for the selected MTSs, data were gathered via a survey instrument (questionnaire) administered on site, from instructors who had taught with the devices.

The questionnaire (which was specially developed for this effort) consisted of twentyfive items representing the attributes/features from the MTS attribute taxonomy previously developed (see Appendix B). The attribute taxonomy consisted of the four attributes: Information/Training Management, Instructional Features, Human Factors Design and Layout, and Computer System. The questionnaire addressed the features of the first three attributes. It was anticipated that instructors would not have the information necessary to give sufficient responses to questions addressing aspects of the MTS's computer hardware and software; therefore, the features of the fourth attribute, Computer System, were not included on the questionnaire.

For each of the 25 features on the questionnaire, a definition was provided. If an instructor indicated that a feature was present on the training device, the questionnaire required him to rate, using a seven-point Likert scale, the perceived training effectiveness and amount of utilization of that feature. When an instructor indicated that a feature was not included on the trainer, the questionnaire prompted him to rate the desirability of having the feature and to provide an estimation of the amount of utilization that the feature would be likely to receive if it were present. Three of the items on the questionnaire required the respondent to rank the relative importance of the features previously rated.

The survey questionnaire employed a seven-point Likert scale format to enable respondents to rate the effectiveness of MTS features for a given simulator. Ratings for negatively worded items were reversed prior to analysis. Thus, a rating above "4" indicated that the respondent perceived the feature to contribute to simulator effectiveness. Ratings below "4" indicated that the feature was not perceived to contribute to simulator effectiveness. Ratings of exactly "4" implied neutral opinion.

Prior to administering the survey questionnaire, the data gatherers requested a demonstration of the MTS and took notes on the student station and instructor station physical layout and control and display devices.

The survey questionnaires were administered to the instructors in groups. The survey administrator explained the purpose of the survey and reviewed the instructions for completing the questionnaire. Instructors were given 45 minutes to complete the questionnaire. The average time required to complete the questionnaire was approximately 30 minutes. The survey administrator was present to answer questions while the instructors completed the questionnaires.

As data were gathered from the survey site visits, the data were entered into a computer database for subsequent analysis. The analysis allowed an assessment of feature presence, commonality, and criticality.

Identify Design Features of MTSs

Based upon the data gathered via the questionnaires, matrices were constructed in order to identify which features were present in each simulator. Since the simulators were grouped by MTS types, an assessment of feature presence within MTS type (IVDS, panel, etc.) was also possible. The columns in the matrix represented the simulators studied and rows represented the MTS taxonomic features. For each simulator, an entry was made in each cell corresponding to the features that were found to be present in that simulator. This resulted in a profile of the "feature-makeup" of each simulator. The commonality within and between simulator types was determined by examining the pattern of matrix entries (the number and particular type of features present for each simulator as profiled by the entries in the matrix columns). The similarities and differences among MTSs were made readily visible by this method of presentation.

Findings

The results of the commonality analysis are presented in Table 5 (for instructor station features), and Table 6 (for student station features). The tables provide the simulator designator and the MTS type for each simulator along the top. The attributes, which are grouped into features, input devices, and display characteristics, are presented along the side.

The variation of features, input devices and display characteristics depicted in Tables 5 and 6 suggest that these "components" are not significantly constrained by MTS type. Instead, the commonality of the components appear to be independent of the grouping of MTS types. The lack of distinct sets of characteristics corresponding to simulator type can be partially attributed to the existence of combined or hybrid types.

Table 5

Instructor Station Feature, Input Device, and Display Commonality Matrix

	Training System	11B106A	IGS	AN/WSC-3 GMT	11G2	11G3	A6 ECII	CH53E	OFA/UTU	SH60B-1	11E15	11H102	11H103	19D2	19E3	A6E DRS	19D1	20H7A	SH60B-2	F14MPD
	Type	I	I	I	P	P	P	P	P	P	M	M	M	M	M	M	S	S	S	S
Feature	Initialization	●	●	●	●	●	●	●	●	●		●	●	●		●	●	●	●	●
	Performance Monitoring	●	●	●	●	●		●		●	●	●	●	●		●				●
	Performance Measurement	●	●	●		●	●	●	●		●	●	●		●		●		●	
	System Monitoring	●			●	●				●	●	●	●	●		●		●		●
	Report Generation	●	●	●		●				●			●			●				●
	Student Recordkeeping		●	●									●							
	Exercise Selection		●	●		●	●						●	●		●		●		●
	Exercise Modification		●	●									●	●				●		
	Malfunction Insertion	●	●	●	●	●	●		●	●	●			●	●	●		●		●
	Freeze					●				●		●	●			●		●		
	Next Activity		●			●	●	●					●	●		●				●
	System Parameter		●		●					●				●	●			●		
	Training Mode		●			●					●									
	Cue Enhancement	●	●		●					●			●	●						
Input Device Components	Keyboard	●	●	●		●	●			●						●	●	●		
	Keypad										●			●	●				●	●
	Toggle Switch				●				●											
	Pushbutton				●		●			●	●				●		●	●	●	
	Rotary															●				●
	Touchscreen	●	●																	
	Light Pen			●																
	Lever																			
	Thumbwheel							●		●							●			
Display Characteristics	Video Monitor	●	●	●	●	●		●		●	●	●	●	●	●	●	●	●	●	
	Information Light															●				
	Print Out				●															
	Digital Counter								●	●										●
	System Specific				●		●	●		●					●		●	●	●	

Table 6

Student Station Feature, Input Device, and Display Commonality Matrix

	Training System	11B106A	IGS	AN/WSC-3 GMT	11G2	11G3	A6 ECII	CH53E	OFA/UTU	SH60B-1	11E15	11H102	11H103	19D2	19E3	A6E DRS	19D1	20H7A	SH60B-2	F14MPD
	Type	I	I	I	P	P	P	P	P	P	M	M	M	M	M	M	S	S	S	S
Feature	Augmented Feedback	•		•	•	•	•	•						•						•
	Student Tutoring		•			•								•						
	Student Sign-In		•		•	•								•						
Input Device Components	Keyboard	•	•	•	•	•														
	Keypad							•												
	Toggle Switch					•	•	•	•	•				•		•				
	Pushbutton					•	•				•				•	•				•
	Rotary					•								•	•					
	Touchscreen	•	•																	
	Light Pen			•		•														
	Lever														•					
	Thumbwheel																			
Display Characteristics	Video Monitor	•	•	•	•	•														
	Screen Projection						•	•		•						•				
	Information Light						•									•				•
	Print Out																			
	Digital Counter																			
	System Specific				•	•	•		•	•	•			•	•	•				•

Additional observations regarding the commonality of MTS features are as follows:

- SAE typically lacks student stations and the associated features.
- IVDSs can be expected to incorporate keyboards and CRTs/video monitors.
- Toggle switches are common as student station input devices and uncommon in instructor stations.
- Input devices other than keyboards, toggle switches, and push-button are relatively uncommon.
- Display methods other than CRTs, video monitors, and system specific devices are uncommon.

These findings indicate that student stations do not have many features in common. Their characteristics more often reflect considerations of the equipment simulated. In such instances, the student interacts with the simulator directly and there is no separate student station (i.e., the simulator is the student station).

CRITICALITY ASSESSMENT

Data gathered via the questionnaire discussed above, were used to generate a criticality index for each feature. For each of the MTSs included in the effort, instructors were asked to rate two of the following four variables:

1. Training effectiveness. The instructor's perception of the training effectiveness of each feature present on the MTS.
2. Utilization. The frequency with which a feature is utilized on the MTS.
3. Desirability. The extent to which an instructor would desire to have a feature which is not currently present on the MTS.
4. Anticipated utilization. The extent to which an instructor anticipated utilizing a feature if that feature was provided.

If a given feature was present on a particular simulator, respondents rated the perceived effectiveness and utilization of that feature on the seven-point Likert scale. If the feature was not present on the simulator, the respondents rated the desirability of having and anticipated utilization of that feature.

Findings

Frequency of responses, means, and standard deviations were calculated for each of the survey items. The survey items were grouped according to the following set of variables:

- Perceived Effectiveness and Utilization.
- Desirability and Anticipated Utilization.

In addition, means were calculated for all items within an MTS type (e.g., for all panels) to facilitate comparisons between MTS types.

The seven-point Likert scale was utilized in order to provide for a range of responses. However, examination of the data revealed that there was not much variability in responses. Given the low variability of responses and the qualitative nature of the survey, it was decided that the only meaningful interpretation of the scale was to assign high (greater than 4), neutral (4), and low (less than 4) criticality ratings to each feature.

Table 7 shows the criticality ratings that were assigned to each of the MTS features studied. From the Overall Rating column in the table, it can be seen that only one of the features was given a low criticality rating, while three features were rated as neutral (i.e., neither high nor low), and the remaining 21 features were given high criticality ratings. These results are not surprising, since the features were pre-selected from features that are commonly found in MTS designs. Although there are few (if any) studies conducted to assess the training effectiveness of most of these features, they are increasingly being addressed in Instructional Systems Development (ISD) analyses of training device requirements and included in MTS design specifications.

Comments made by the instructors on their questionnaire forms suggest that while they like most of the features currently provided (and would like to have most of the features which were not present) on their simulator, they would have them designed to function differently than they do now. For example, several instructors commented that Student Performance Measurement was a desirable feature to have, but felt that the instructor still needs to be present.

They also took exception to the specific performance measurements that the automated feature was providing (e.g., number of replacements and time to accomplish a task). While they did not cite specific performance measures that would be desirable, the general tone of comments suggested that measures more diagnostic of students' reasoning or logical errors would be helpful. Similarly, several instructors generally liked the system monitoring feature, but did not agree with the selection of parameters that were monitored and available to them.

Table 7

Criticality Ratings for MTS Features

FEATURES	IVDSs	MODELS	PANELS	SAE	OVERALL RATING
Student Performance Monitoring	High	High	High	High	High
Initialization	Neutral	Low	Low	Low	Low
Performance Measurement	High	High	Neutral	High	High
System Monitoring	---	High	High	High	High
Report Generation	Neutral	High	High	---	High
Student Recordkeeping	Neutral	---	High	Neutral	Neutral
Training Exercise Selection	High	High	High	High	High
Training Exercise Generation/ Modification	High	High	High	High	High
Malfunction Insertion/Selection	High	High	High	High	High
Freeze Capability	Neutral	Neutral	---	High	Neutral
Next Activity Control	High	High	High	High	High
Cue Enhancement	High	High	High	---	High
System Parameter Control	High	High	High	High	High
Training Mode Control	Neutral	High	---	---	Neutral/ High

Table 7 (Continued)

FEATURES	IVDSs	MODELS	PANELS	SAE	OVERALL RATING
Instructor Station Control-Display/ Layout and Operation	High	High	Neutral	High	High
Instructor Station/ Operating Procedures	High	High	Neutral/ High	High	High
Instructor Station/ Input Devices	High	High	High	High	High
Instructor Station/ Display Devices	High	High	High	High	High
Student Tutoring	High	---	High	---	High
Student Sign-in/ Capability	High	---	High	---	High
Augmented Feedback Capability	High	High	High	High	High
Student Station/ Input/Control Devices	High	High	High	High	High
Student Station/ Display Devices	High	High	High	High	High
Student Station/ Operating Procedures	High	High	Neutral/ High	High	High
Student Station Control-Display/ Layout and Operation	High	High	Neutral/ High	High	High

Judging from instructor comments on trainer initialization procedures, the low rating appears to be due to lengthy and complicated initialization procedures. The few devices that were given high ratings on initialization, were described in terms such as "quick" and "easy" to use.

Table 7 also presents the criticality ratings for each MTS type. Ratings in the IVDS column are generally consistent with the Overall Rating column. One exception, Report Generation, was given a neutral rating for IVDSs, but a high overall rating. Report Generation was present but not currently functioning on one of the three IVDSs. This feature was criticized as producing long printouts displaying all steps, regardless of how trivial, on another IVDS. It appears that the low ratings given to Report Generation by this group were due more to the implementation of the feature than to any consideration specific to IVDSs.

The criticality ratings reported on the Model, Panel, and SAE columns were also generally consistent with those in the Overall Rating column in Table 7.

The homogeneity of criticality ratings in Table 7 strongly suggests that, in most instances, the criticality of MTS features can be generalized across all four MTS types. The preponderance of high ratings suggests that most of the MTS features considered by the instructors were important with respect to perceived training effectiveness.

The following paragraphs describe the results of the survey responses upon which the criticality assessment was based. Table 8 shows mean instructor responses to feature effectiveness/utilization items (greater than 4.5 = high training effectiveness/utilization, less than 3.5 = low trainer effectiveness/utilization, and a rating between 3.5 and 4.5 = a neutral response) and standard deviations for each MTS feature in each of the four types of MTSs. Table 9 shows the mean instructor responses for desirability of obtaining features not currently present on the given MTS. Tables 10 through 13 present the responses and number of respondents (N) for each of the MTSs within the four types. A definition of each MTS feature and the ratings for each feature are discussed below (see Appendix A for a more complete description of the features).

<u>Student performance monitoring</u>. This feature is a simulator computer system capability that automatically monitors (i.e., senses and records) student performance on a training exercise.

The total (unweighted) mean rating[1] (5.7) for this feature is within the effectiveness range of the scale. The small standard deviations in table 8 indicate that there is little variability in responses within MTS types and that the ratings are consistent across MTS types, as well. In fact, an examination of Tables 10 through 13 reveals that the only noneffective rating

[1] The total mean ratings reported in this section reflect unweighted means across the four MTS categories in Table 8. If no data were presented for a particular MTS category (in Table 8), the total mean rating was based on the remaining categories for which data was present.

Table 8

Mean Perceived Effectiveness and Utilization Ratings for MTS Features

SIMULATOR FEATURES		IVDS		MODEL		PANEL		SAE	
		X̄	S.D.	X̄	S.D.	X̄	S.D.	X̄	S.D.
STUDENT PERFORMANCE MONITORING	EFFECTIVENESS:	5	1.73	6.42	.787	6	1.12	5.5	1.29
	UTILIZATION:	4.5	2.38	6.6	.548	4.9	1.85	6.5	.577
INITIALIZATION	EFFECTIVENESS:	3.85	2.41	3.33	2.30	3.25	1.96	1.77	1.33
	UTILIZATION:	4.5	2.61	5.83	.752	4.95	1.75	6.44	.726
PERFORMANCE MEASUREMENT	EFFECTIVENESS:	5	1.41	6.5	.534	4.62	1.99	5.75	1.25
	UTILIZATION:	3.33	2.08	5	2.54	3.85	2.03	4.75	2.06
SYSTEM MONITORING	EFFECTIVENESS:	—		5	2.19	5	2.04	6	0
	UTILIZATION:	—		2.4	2.07	3.4	1.83	1	0
REPORT GENERATION	EFFECTIVENESS:	3.6	1.92	5.25	1.5	6	1.41	—	
	UTILIZATION:	4	2.19	5.25	2.87	4.5	3.53	—	
STUDENT RECORDKEEPING	EFFECTIVENESS:	4.08	2.22	X	X	5	0	4.5	2.12
	UTILIZATION:	4.6	2.07	2	0	3	0	4.5	2.12
TRAINING EXERCISE SELECTION	EFFECTIVENESS:	5.2	2.11	6.3	1.65	6.3	.956	6	1.26
	UTILIZATION:	2	1.26	2	2.23	2.1	1.58	3.5	2.58
TRAINING EXERCISE CREATION/MODIFICATION	EFFECTIVENESS:	6.66	.577	7	0	6	0	6.5	.707
	UTILIZATION:	6.66	.577	X	X	X	X	6	0
MALFUNCTION INSERTION OR SELECTION	EFFECTIVENESS:	6.2	.752	6.7	.487	6.8	1.15	5.5	2.25
	UTILIZATION:	2	1.41	2.25	2.5	1.90	1.15	1.5	.547
FREEZE CAPABILITY	EFFECTIVENESS:	4	0	4.1	1.92	—		6	0
	UTILIZATION:	3	0	1.75	.5	—		5	0
NEXT ACTIVITY CONTROL	EFFECTIVENESS:	6.16	1.16	5.66	.577	5.81	.750	5.33	1.15
	UTILIZATION:	5.6	2.07	5	1.73	5.45	1.12	5	1.73
CUE ENHANCEMENT	EFFECTIVENESS:	7	0	6	0	5.5	2.38	—	
	UTILIZATION:	1	0	X	X	2.5	2.38	—	
SYSTEM PARAMETER CONTROL	EFFECTIVENESS:	7	0	7	0	7	0	7	0
	UTILIZATION:	1	0	2	0	2	1.41	1	0
TRAINING MODE CONTROL	EFFECTIVENESS:	4	2.82	6.5	.707	—		—	
	UTILIZATION:	3.5	2.12	X	X	—		—	
CONTROL-DISPLAY LAYOUT AND OPERATION	EFFECTIVENESS:	6.14	.690	6	1.69	4.59	1.79	6.11	1.05
	UTILIZATION:	5.16	2.13	5.14	2.11	4.59	1.70	6.44	.527
INSTRUCTOR STATION OPERATING PROCEDURES	EFFECTIVENESS:	5	2.09	6	.5	4.47	1.47	5.88	1.05
	UTILIZATION:	6.16	.408	5.57	1.13	4.86	1.42	5.33	1.93
I.S. INPUT DEVICES	EFFECTIVENESS:	6.5	.707	6.33	.5	5.45	1.80	6.6	.547
	UTILIZATION:	—		—		—		—	
I.S. DISPLAY DEVICES	EFFECTIVENESS:	6	0	6	.632	6.5	.971	5.28	2.62
	UTILIZATION:	—		—		—		—	
STUDENT TUTORING	EFFECTIVENESS:	7	0	—		5.5	.707	—	
	UTILIZATION:	6	0	—		4	0	—	
STUDENT SIGN-IN CAPABILITY	EFFECTIVENESS:	5.8	1.09	—		6.75	.5	—	
	UTILIZATION:	5.75	1.25	—		6.57	.5	—	
AUGMENTED FEEDBACK	EFFECTIVENESS:	6.2	.752	5	1.41	5	2.07	5.5	2.12
	UTILIZATION:	2.33	1.50	1.5	.707	2.76	1.69	1.5	.707
S.S. INPUT DEVICES	EFFECTIVENESS:	6.25	.5	6.83	.408	5.23	1.89	5.2	1.92
	UTILIZATION:	—		—		—		—	
S.S. DISPLAY DEVICES	EFFECTIVENESS:	6.28	.487	6.28	.755	5.95	1.46	5.28	1.79
	UTILIZATION:	—		—		—		—	
STUDENT STATION OPERATING PROCEDURES	EFFECTIVENESS:	5.12	1.72	5.33	1.65	4.45	1.79	5.28	1.79
	UTILIZATION:	3.66	2.65	5	2	3.86	1.95	5.28	1.79
STUDENT STATION CONTROL-DISPLAY LAYOUT AND OPERATION	EFFECTIVENESS:	5	1.41	5.77	1.56	4.68	1.91	6	.816
	UTILIZATION:	4.14	2.34	4.71	1.25	4.09	2.11	5.42	1.71

Table 9

Mean Desirability and Utilization Ratings for MTS Features

SIMULATOR FEATURES		IVDS		MODEL		PANEL		SAE	
		X̄	S.D.	X̄	S.D.	X̄	S.D.	X̄	S.D.
STUDENT PERFORMANCE MONITORING	DESIRABILITY:	—		6	0	3.9	2.68	2.2	2.16
	UTILIZATION:	—		7	0	4	2.78	2	1.73
INITIALIZATION	DESIRABILITY:	—		—		—		—	
	UTILIZATION:	—		—		—		—	
PERFORMANCE MEASUREMENT	DESIRABILITY:	5	2.16	2	0	4.63	2.50	1	0
	UTILIZATION:	4.66	3.21	4	1.41	5.57	2.07	1	0
SYSTEM MONITORING	DESIRABILITY:	4.66	1.63	7	0	5.37	1.99	5	3.46
	UTILIZATION:	4.33	1.50	7	0	5.37	1.99	4	3.46
REPORT GENERATION	DESIRABILITY:	—		2.25	1.89	4.18	2.04	3.66	2.65
	UTILIZATION:	—		3	2.82	4.18	2.07	3.83	2.78
STUDENT RECORDKEEPING	DESIRABILITY:	—		3	2.26	4.04	2.03	4	2.94
	UTILIZATION:	—		4.4	2.30	3.95	2.13	4.25	3.20
TRAINING EXERCISE SELECTION	DESIRABILITY:	—		—		7	0	4	0
	UTILIZATION:	—		—		7	0	4	0
TRAINING EXERCISE CREATION/MODIFICATION	DESIRABILITY:	5	2.64	5.62	1.40	5.55	2.01	5.83	1.47
	UTILIZATION:	5	2.64	5.6	1.51	5.4	1.90	5.83	1.47
MALFUNCTION INSERTION OR SELECTION	DESIRABILITY:	—		6.5	.707	7	0	2.5	2.12
	UTILIZATION:	—		6.5	.707	7	0	2.5	2.12
FREEZE CAPABILITY	DESIRABILITY:	4.75	2.62	2.66	2.88	4	1.85	3.6	2.70
	UTILIZATION:	4.33	2.51	5	1.41	4	1.88	3.6	2.70
NEXT ACTIVITY CONTROL	DESIRABILITY:	2	0	5.75	.957	4.28	2.36	3.75	2.5
	UTILIZATION:	3	0	5	0	4.14	2.54	4	2.58
CUE ENHANCEMENT	DESIRABILITY:	4.83	2.22	3.5	2.25	4.82	1.81	3.8	2.28
	UTILIZATION:	4.25	2.62	3.6	2.07	4.64	1.72	3.8	2.28
SYSTEM PARAMETER CONTROL	DESIRABILITY:	4.4	1.51	4.42	2.22	5.14	2.0	5.14	2.19
	UTILIZATION:	4.6	1.67	4.6	2.30	4.95	2.08	5.14	2.19
TRAINING MODE CONTROL	DESIRABILITY:	5	2.64	5.2	1.64	3.68	1.98	4.85	2.19
	UTILIZATION:	5	2.16	4.33	2.16	3.90	2.04	4.85	2.19
STUDENT TUTORING	DESIRABILITY:	4	2.64	4.28	1.49	4.24	2.00	5.5	2.07
	UTILIZATION:	3.75	2.06	3.6	1.14	4.43	1.94	4.62	2.38
STUDENT SIGN-IN CAPABILITY	DESIRABILITY:	6	0	3.37	2.50	2.61	1.37	3.62	2.19
	UTILIZATION:	6	0	5.33	2.25	2.5	1.68	3.62	2.44
AUGMENTED FEEDBACK	DESIRABILITY:	—		3.8	2.16	6	1.73	3	2.30
	UTILIZATION:	—		5.66	1.15	5.8	1.30	2.75	2.06

Table 10

Mean Perceived Effectiveness and Utilization Ratings of MTS Features for IVDSs

FEATURES

SIMULATOR DESIGNATOR	STUDENT PERFORMANCE MONITORING		INITIALIZATION		PERFORMANCE MEASUREMENT		SYSTEM MONITORING		REPORT GENERATION		STUDENT RECORDKEEPING		TRAINING EXERCISE SELECTION		TRAINING EXERCISE CREATION/MODIFICATION		MALFUNCTION INSERTION/SELECTION		FREEZE CAPABILITY		NEXT ACTIVITY CONTROL		CUE ENHANCEMENT	
	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$	N
118108A EFFECTIVENESS	4	2	5.5	4	–		–		3.6	5	4.75	4	4	4	–		6	3	–		6	4	–	
UTILIZATION	3.5	2	3.2	6	–		–		4	4	6	3	2.66	3	–		2.5	2	–		5	3	–	
IGS EFFECTIVENESS	6	2	1.5	2	4	1	–		5.5	2	5.5	2	7	2	7	2	5.5	2	4	1	6.5	2	7	1
UTILIZATION	6	1	7	2	2.5	2	–		2	1	3	1	1	2	7	2	1.5	2	3	1	6.5	2	1	1
AN/WSC-3 EFFECTIVENESS	5	1	2	1	6	1	–		5	1	2	1	6	1	6	1	6	1	–		–		–	
UTILIZATION	5	1	6	1	5	1	–		6	1	2	1	2	1	6	1	2	1	–		–		–	

FEATURES

SIMULATOR DESIGNATOR	SYSTEM PARAMETER CONTROL		TRAINING MODE CONTROL		CONTROL-DISPLAY LAYOUT AND OPERATION		INSTRUCTOR STATION OPERATING PROCEDURES		I. S. INPUT DEVICES		I. S. DISPLAY DEVICES		STUDENT TUTORING		STUDENT SIGN-IN CAPABILITY		AUGMENTED FEEDBACK		S. S. INPUT DEVICES		S. S. DISPLAY DEVICES		STUDENT STATION OPERATING PROCEDURES		STUDENT STATION CONTROL-DISPLAY LAYOUT AND OPERATION	
	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$	N
118108A EFFECTIVENESS	–		–		5.8	5	4	3	–		–		–		6.33	3	5.7	3	6	1	6	4	5	5	4.8	5
UTILIZATION	–		–		4.66	3	6	3	–		–		–		6	2	3.33	3	–		–		2	3	2.75	4
IGS EFFECTIVENESS	7	1	4	2	7	1	6.5	2	7	1	–		7	1	5	2	7	2	6.5	2	7	2	6.5	2	6.5	2
UTILIZATION	1	1	3.5	2	6	2	6.5	2	–		–		6	1	5.5	2	1	2	–		–		7	2	7	2
AN/WSC-3 EFFECTIVENESS	–		–		7	1	5	1	6	1	6	1	–		–		6	1	6	1	6	1	3	1	6	1
UTILIZATION	–		–		5	1	6	1	–		–		–		–		2	1	–		–		2	1	4	1

Table 11

Mean Perceived Effectiveness and Utilization Ratings of MTS Features for Models

SIMULATOR DESIGNATOR	FEATURES																							
	STUDENT PERFORMANCE MONITORING		INITIALIZATION		PERFORMANCE MEASUREMENT		SYSTEM MONITORING		REPORT GENERATION		STUDENT RECORDKEEPING		TRAINING EXERCISE SELECTION		TRAINING EXERCISE CREATION/MODIFICATION		MALFUNCTION INSERTION/SELECTION		FREEZE CAPABILITY		NEXT ACTIVITY CONTROL		CUE ENHANCEMENT	
	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$	N
19D2 EFFECTIVENESS	—		—		—		—		—		—		7	1	7	1	7	1	—		—		—	
UTILIZATION	6	1	5	1	—		—		1	1	—		—		—		—		—		6	1	—	
19E3 EFFECTIVENESS	—		—		—		—		—		—		7	1	—		7	1	—		—		—	
UTILIZATION	—		—		—		—		—		—		6	1	—		6	1	—		—		—	
11E15 EFFECTIVENESS	7	2	—		7	2	3.5	2	—		—		4.5	2	—		6.5	2	—		—		—	
UTILIZATION	—		—		—		—		—		—		—		—		—		—		—		—	
ABE DRS EFFECTIVENESS	6.66	3	4	2	6.66	3	6.3	3	6	3	—		6.7	3	—		6.7	3	6.3	3	6	2	—	
UTILIZATION	7	3	6.33	3	6.66	3	1.33	3	6.66	3	—		1	3	—		1	3	1.66	3	4.5	2	—	
11H102 EFFECTIVENESS	5	1	2	1	6	1	4	1	—		—		1	1	—		—		3	1	—		—	
UTILIZATION	6	1	5	1	1	1	2	1	—		—		1	1	—		—		2	1	—		—	
11H103 EFFECTIVENESS	6	1	—		6	1	—		3	1	—		7	1	—		—		2	1	5	1	6	1
UTILIZATION	—		6	1	4	1	6	1	—		2	1	—		—		—		—		—		—	

SIMULATOR DESIGNATOR	FEATURES																									
	SYSTEM PARAMETER CONTROL		TRAINING MODE CONTROL		CONTROL-DISPLAY LAYOUT AND OPERATION		INSTRUCTOR STATION OPERATING PROCEDURES		I. S. INPUT DEVICES		I. S. DISPLAY DEVICES		STUDENT TUTORING		STUDENT SIGN-IN CAPABILITY		AUGMENTED FEEDBACK		S. S. INPUT DEVICES		S. S. DISPLAY DEVICES		STUDENT STATION OPERATING PROCEDURES		STUDENT STATION CONTROL-DISPLAY LAYOUT AND OPERATION	
	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$	N
19D2 EFFECTIVENESS	7	1	—		2	1	6	1	6	2	5.5	2	—		—		—		6.5	2	6	2	6	2	6	2
UTILIZATION	—		—		6	1	6	1	—		—		—		—		—		—		—		—		—	
19E3 EFFECTIVENESS	7	1	—		7	1	6	1	7	1	6	1	—		—		—		7	1	7	1	6	1	2	1
UTILIZATION	2	1	—		7	1	4	1	—		—		—		—		—		—		—		6	1	3	1
11E15 EFFECTIVENESS	—		6.5	2	6	2	6.6	2	6	1	6	1	—		—		—		7	1	7	1	6	1	7	1
UTILIZATION	—		—		—		—		—		—		—		—		—		—		—		5	1	5	1
ABE DRS EFFECTIVENESS	—		—		6.66	3	6	3	6	2	—		—		—		5	2	7	2	6	3	6	3	6.66	3
UTILIZATION	—		—		5.33	3	6.33	3	—		—		—		—		1.5	2	—		—		6	3	5.33	3
11H102 EFFECTIVENESS	—		—		7	1	5	1	7	1	7	1	—		—		—		—		—		1	1	6	1
UTILIZATION	—		—		1	1	4	1	—		—		—		—		—		—		—		1	1	6	1
11H103 EFFECTIVENESS	—		—		—		6	1	7	1	6	1	—		—		—		—		—		5	1	5	1
UTILIZATION	—		—		6	1	6	1	—		—		—		—		—		—		—		—		3	1

Table 12

Mean Perceived Effectiveness and Utilization Ratings of MTS Features for Panels

FEATURES

SIMULATOR DESIGNATOR	STUDENT PERFORMANCE MONITORING	INITIALIZATION	PERFORMANCE MEASUREMENT	SYSTEM MONITORING	REPORT GENERATION	STUDENT RECORDKEEPING	TRAINING EXERCISE SELECTION	TRAINING EXERCISE CREATION/MODIFICATION	MALFUNCTION INSERTION/SELECTION	FREEZE CAPABILITY	NEXT ACTIVITY CONTROL	CUE ENHANCEMENT
	X̄ N	X̄ N	X̄ N	X̄ N	X̄ N	X̄ N	X̄ N	X̄ N	X̄ N	X̄ N	X̄ N	X̄ N
11G2 EFFECTIVENESS	6.33 3	2 3	–	7 0	6 2	5 1	7 3	–	7 3	–	6 2	7 2
UTILIZATION	3.66 3	6.33 3	–	1.2 3	4.5 2	3 1	1 3	–	1 3	–	5.5 2	1 2
11G3 EFFECTIVENESS	6.5 2	3.5 2	7 1	–	–	–	7 1	6 1	–	–	–	–
UTILIZATION	–	3 2	–	–	–	–	–	–	–	–	–	–
A6 ECII EFFECTIVENESS	–	2.86 7	–	–	–	–	5.8 6	–	6.1 7	–	6.5 4	–
UTILIZATION	–	6 7	–	–	–	–	2 6	–	2 7	–	5.25 4	–
CH53E EFFECTIVENESS	5.4 5	3.86 7	3.83 6	4.5 6	–	–	6.2 7	–	5.4 7	–	6 5	–
UTILIZATION	5 5	4.57 7	3.33 6	4.2 6	–	–	2.29 7	–	2.57 7	–	6.6 5	–
OFA/UTU EFFECTIVENESS	–	5 2	–	–	–	–	6.7 3	–	7 3	–	–	4 2
UTILIZATION	–	3.5 2	–	–	–	–	1.33 3	–	1.33 3	–	–	4 2
SH60B-1 EFFECTIVENESS	6.5 2	2.66 3	7 1	3.5 2	–	–	–	–	7 2	–	–	–
UTILIZATION	6.5 2	6.66 3	7 1	3 2	–	–	–	–	1.5 2	–	–	–

FEATURES

SIMULATOR DESIGNATOR	SYSTEM PARAMETER CONTROL	TRAINING MODE CONTROL	CONTROL-DISPLAY LAYOUT AND OPERATION	INSTRUCTOR STATION OPERATING PROCEDURES	I. S. INPUT DEVICES	I. S. DISPLAY DEVICES	STUDENT TUTORING	STUDENT SIGN-IN CAPABILITY	AUGMENTED FEEDBACK	S. S. INPUT DEVICES	S. S. DISPLAY DEVICES	STUDENT STATION OPERATING PROCEDURES	STUDENT STATION CONTROL-DISPLAY LAYOUT AND OPERATION
	X̄ N	X̄ N	X̄ N	X̄ N	X̄ N	X̄ N	X̄ N	X̄ N	X̄ N	X̄ N	X̄ N	X̄ N	X̄ N
11G2 EFFECTIVENESS	7 2	–	6.33 3	6.66 3	6.33 3	7 2	–	6.5 2	7 1	6.33 3	6.33 3	6 2	4 3
UTILIZATION	2 2	–	5.66 3	6 3	–	–	–	6.5 2	1 1	–	–	4.66 3	4 3
11G3 EFFECTIVENESS	–	–	5 1	5 1	–	–	5.5 2	7 2	4 2	6.5 2	7 2	6.5 2	7 2
UTILIZATION	–	–	5 1	–	–	–	4 1	7 2	7 1	–	–	6 2	7 1
A6 ECII EFFECTIVENESS	–	–	3.83 6	4.83 6	–	–	–	–	4.3 6	4.14 7	4.66 6	3.28 7	4 7
UTILIZATION	–	–	5.16 6	5.5 6	–	–	–	–	2.4 5	–	–	3.42 7	3 7
CH53E EFFECTIVENESS	–	–	4.83 6	3.42 7	5 4	6.16 6	–	–	5.7 6	5.66 6	6.5 6	4.83 6	5.33 6
UTILIZATION	–	–	3.33 6	4.57 7	–	–	–	–	2.66 6	–	–	4.66 6	4.83 6
OFA/UTU EFFECTIVENESS	–	–	3.66 3	4.66 3	3.5 2	–	–	–	–	6 3	6 3	4.66 3	5 3
UTILIZATION	–	–	4.33 3	6 3	–	–	–	–	–	–	–	2 3	6 3
SH60B-1 EFFECTIVENESS	–	–	4.66 3	4.66 3	7 2	7 1	–	–	–	–	6.5 2	4.5 2	2 1
UTILIZATION	–	–	5 3	3 3	–	–	–	–	–	–	–	1 1	2 1

Table 13

Mean Perceived Effectiveness and Utilization Ratings of MTS Features for SAE

FEATURES

SIMULATOR DESIGNATOR		STUDENT PERFORMANCE MONITORING $\bar{X}$	N	INITIALIZATION $\bar{X}$	N	PERFORMANCE MEASUREMENT $\bar{X}$	N	SYSTEM MONITORING $\bar{X}$	N	REPORT GENERATION $\bar{X}$	N	STUDENT RECORDKEEPING $\bar{X}$	N	TRAINING EXERCISE SELECTION $\bar{X}$	N	TRAINING EXERCISE CREATION/MODIFICATION $\bar{X}$	N	MALFUNCTION INSERTION/SELECTION $\bar{X}$	N	FREEZE CAPABILITY $\bar{X}$	N	NEXT ACTIVITY CONTROL $\bar{X}$	N	CUE ENHANCEMENT $\bar{X}$	N
19D1	EFFECTIVENESS	–		1	2	–		–		–		–		7	1	–		–		–		–		–	
	UTILIZATION	–		6.5	2	–		–		–		–		7	1	–		–		–		–		–	
20H7A	EFFECTIVENESS	–		1.5	2	6	1	6	1	–		–		7	2	6.5	2	4	2	6	1	–		–	
	UTILIZATION	–		6.5	2	3	1	1	1	–		–		1	2	6	2	1.5	2	5	1	–		–	
SH60B-2	EFFECTIVENESS	–		1	1	–		–		–		–		–		–		–		–		–		–	
	UTILIZATION	–		7	1	–		–		–		–		–		–		–		–		–		–	
F14MPD	EFFECTIVENESS	5.5	4	2.5	4	5.66	3	–		–		4.5	2	3	3	–		1.75	4	–		5.33	3	–	
	UTILIZATION	6.5	4	6.25	4	5.33	3	–		–		4.5	2	4	3	–		1.5	4	–		5	3	–	

FEATURES

SIMULATOR DESIGNATOR		SYSTEM PARAMETER CONTROL $\bar{X}$	N	TRAINING MODE CONTROL $\bar{X}$	N	CONTROL-DISPLAY LAYOUT AND OPERATION $\bar{X}$	N	INSTRUCTOR STATION OPERATING PROCEDURES $\bar{X}$	N	I. S. INPUT DEVICES $\bar{X}$	N	I. S. DISPLAY DEVICES $\bar{X}$	N	STUDENT TUTORING $\bar{X}$	N	STUDENT SIGN-IN CAPABILITY $\bar{X}$	N	AUGMENTED FEEDBACK $\bar{X}$	N	S. S. INPUT DEVICES $\bar{X}$	N	S. S. DISPLAY DEVICES $\bar{X}$	N	STUDENT STATION OPERATING PROCEDURES $\bar{X}$	N	STUDENT STATION CONTROL-DISPLAY LAYOUT AND OPERATION $\bar{X}$	N
19D1	EFFECTIVENESS	–		–		4.5	2	5	2	–		1.5	2	–		–		–		–		7	1	7	1	7	1
	UTILIZATION	–		–		6.5	2	2.5	2	–		–		–		–		–		–		–		7	1	7	1
20H7A	EFFECTIVENESS	1	2	–		7	2	6	2	7	1	7	2	–		–		–		6.5	2	6.5	2	6	2	6.5	2
	UTILIZATION	1	2	–		6.5	2	6.5	2	–		–		–		–		–		–		–		6.5	2	6	2
SH60B-2	EFFECTIVENESS	–		–		7	1	7	1	7	1	7	1	–		–		–		–		–		–		–	
	UTILIZATION	–		–		7	1	7	1	–		–		–		–		–		–		–		–		–	
F14MPD	EFFECTIVENESS	–		–		6.25	4	6	4	6.33	3	6.5	2	–		–		2.5	2	4.33	3	4.25	4	4.5	4	5.5	4
	UTILIZATION	–		–		6.25	4	5.75	4	–		–		–		–		1.5	2	–		–		4.25	4	4.75	4

was a 4 (neutral) and that the instructors who used this simulator (device 11B106A) seldom used the feature (i.e., gave it a low utilization rating), while instructors using most of the other devices often utilized the feature.

It cannot be determined from the data whether low utilization caused the instructors to refrain from giving this feature an effective rating. It may be that the lack of perceptions that the feature was training-effective led to the low rate of utilization. Given the overall ratings, speculation would lead one to assume that this is the case. In any event, the overall results strongly imply that Student Performance Monitoring is an effective MTS feature.

Initialization. Simulator initialization refers to the procedures and functions performed by the instructor/operator to initialize, verify, and configure the maintenance simulator for training. Specific elements of initialization include: program loading, verification, and components (e.g., printer, CRT, panel) activation.

The total mean (3.1) for this feature is in the noneffective range of the scale. Table 8 shows that this low rating is consistent across MTS types. An examination of Tables 10 through 13 reveals that this feature was rated as effective on only two devices. The feature was rated as neutral on two devices, and for four model trainers no rating was given. For two of the model trainers, instructors indicated a desire to have effective initialization procedures for the MTS.

An interesting observation from Tables 10 through 13 is that initialization procedures are rated as being frequently utilized on most of the devices for which this feature was indicated to be ineffective, while with the simulators for which initialization was rated as effective, the feature was seldom used. It appears that simplified initialization procedures are rare, but are rated as effective, while complex initialization procedures are commonplace and rated as an ineffective MTS feature. The few instructors who rated these procedures effective used descriptions like "quick" and "easy" in their comments.

Given the overall ratings, the data strongly suggest that, in general, initialization procedures as they exist in current trainers are not an effective MTS characteristic.

Performance measurement. This feature is a simulator capability that utilizes the simulator's computer system to test and assess student responses.

The total mean (5.5) for this feature is within the effectiveness range of the scale. The small standard deviations in Table 8 indicate that the ratings are consistent within MTS types. Tables 10 through 13 reveal only two ratings were in the neutral range.

The responses in Table 9 made by instructors who did not have this feature available to them are varied, ranging from 1 for SAE to a 5 for IVDSs. This result may be attributed to the fact that instructors utilizing SAE seldom have many software enhancements on their trainers, in contrast to IVDS instructors who are teaching with a device that provides all equipment/system simulation through software control and are accustomed to software support features. Several instructors commented that although effective, this feature does not eliminate the need for the instructor to be present.

The overall ratings suggest that, in general, Performance Measurement is perceived by instructors to be an effective, but not frequently used, MTS feature. Perhaps if implemented more effectively, utilization would increase.

System monitoring. System monitoring capability provides the instructor with information about the control positions and display indications on the student station when a student error occurs.

The total mean rating (5.3) for this feature is in the effective range of the scale. Table 8 shows that there is very little variability among the rankings for the MTS types that possessed this feature. It is surprising to note that none of the IVDSs had this feature. However, Table 9 shows that IVDS instructors considered this feature to be in the high range of desirability. A review of Tables 10 through 13 reveals that when this feature was present, it was rated as effective on all but three devices. On one of the devices, the feature was rated as neutral; on the other two, it was rated as not effective. Many instructors commented that system monitoring was of limited utility because it monitored only a subset of the system responses/indicators needed for analysis of student performance. Most instructors seldom utilized the feature.

The overall ratings suggest that although Student Monitoring is not often used, it is perceived by instructors to be an effective MTS feature.

Report generation. This is a feature of the simulator that provides the instructor with a report of student responses or scores.

The total mean (5.0) for this feature is in the effectiveness range of the scale. However, as shown in Tables 10 through 13, the feature was present in only six of the nineteen simulators. All three IVDSs had this capability. The instructors on two of the IVDSs rated this feature as effective, while those on the other gave it a neutral rating. Two of the six models, one panel trainer and none of the SAE had this capability. The amount of utilization was not reported for two of the devices and varied widely for the remainder.

It appears that for those simulators that have Report Generation, it is more often than not perceived as an effective feature. However, these data are based on only a few MTSs, thus limiting the extent to which the findings can be generalized.

Student recordkeeping. This is a simulator computer system capability that provides a means for storage, retrieval, and review of student training performance.

The total mean rating (4.5) for this feature is in the neutral range of the scale. As shown in Tables 10 through 13, the feature was only present in five of the nineteen trainers. As with Report Generation, all three IVDSs had this capability; however, the mean rating for IVDSs is only 4.1. From Table 9, it appears that, for instructors who did not currently have the feature on the MTS, there was little desire to obtain the feature. Most of the comments written by instructors were critical of this feature (e.g., "Doesn't contribute much," "Would only cause more paperwork.").

The amount of utilization varied widely for the simulators. Given the high variability combined with the borderline overall mean rating and the small number of devices that have this feature, it is difficult to generalize the perceived effectiveness of this feature.

Training exercise selection. This is a simulator capability that enables the instructor to select an exercise from a set of preprogrammed exercises.

The total mean rating (6.0) for this feature is well into the effectiveness range of the scale. From Table 8, it is apparent that the mean ratings are consistent over MTS types. The relatively low standard deviations in Table 8 indicate that ratings are also consistent within MTS types. Examination of Tables 10 through 13 confirms this. Of the MTSs that have this feature, Tables 10 through 13 show that instructors only gave high utilization ratings to two simulators (Devices 19E3 and 19D1). Most of the instructor comments praised this feature, however it is unclear why the feature was infrequently utilized for many MTSs.

The ratings strongly suggest that, in general, Training Exercise Selection is an effective, although seldom utilized, MTS feature.

Training exercise creation/modification. This is a simulator capability that enables the instructor to create new training exercises or modify existing exercises.

The total mean rating (6.5) for this feature indicates that it is perceived by the instructors as a very effective MTS capability. Table 8 shows that the mean ratings are consistent between MTS types. The low standard deviations shown in Table 8 indicate that the high effectiveness rating is consistent within MTS types as well. However, an examination of Tables 10 through 13 reveals that these means are based on responses for only five MTSs. For these simulators, high utilization ratings were reported on three simulators; two simulators were not rated on this factor; thus, it is not possible to draw any inferences with respect to utilization of this feature. It is interesting to note that the preponderance of instructor comments, both from those who have this feature on their MTS and those who do not, were in praise of the feature.

From the responses obtained, it appears that Training Exercise Creation/Modification, although not commonly available, is regarded by instructors as a very desirable MTS capability. The small sample size precludes generalization.

Malfunction insertion/selection. This simulator capability enables the instructor to select the malfunctions to be presented to the student during an exercise.

The total mean rating (6.3) for this feature indicates that it is perceived by the instructors as a very effective MTS feature. From Table 8, it is clear that mean ratings are consistently high across MTS types. The low to moderate standard deviations shown in Table 8 indicate that this rating is consistent within MTS types. An examination of Tables 10 through 13 confirms this. Instructors who did not have this MTS feature available indicated a desire to have such a feature (see Table 9). From instructor comments, it appears that the feature is considered very valuable when it functions properly. Several instructors expressed frustration with malfunction insertion/selection features which functioned improperly on their MTSs.

Overall, it appears that Malfunction Insertion/Selection is perceived by instructors to be an effective MTS feature.

Freeze capability. This simulator feature causes the simulator to freeze (i.e., displays and controls stop in their present position) in response to certain student errors.

Although the total mean rating (4.7) technically falls within the effectiveness range of the scale, a closer examination of the data suggest that this feature may more appropriately be categorized as neutral. As Table 8 shows, the only mean rating that fell within the effectiveness range was for the SAE category (the rating was 6.0) and that this rating, as evident in Table 13, was based upon a single simulator and only one respondent. On the other hand, the mean responses for IVDSs and models were both in the neutral range, as seen in Table 8 (4.0 and 4.1, respectively), and these data were based on four simulators and six respondents (see Tables 10 and 11). None of the panels had this feature. Thus, this feature was given a neutral rating on the effectiveness scale.

Automatic Freeze Capability appears to be an uncommon feature among MTSs. Although it was generally rated as ineffective (or neutral), some instructors indicated a desire to have such a feature. Instructor comments were divided between observations such as, "Freeze Capability would benefit both student and instructor, allowing the instructor to assist the student at the place of his error and allowing the student to resume his operation where he left off when the error occurred" and statements such as, "When working on aircraft you don't have that option; if he replaces the wrong part he keeps on searching."

Overall, instructor ratings appear to indicate that Freeze Capability is not considered to be an effective MTS feature, and when it is present, utilization tends to be relatively low.

Next activity control. This feature is a simulator capability that enables the instructor to turn on or off the next activity preprogrammed for the student, or enables the instructor to select the next activity to be presented to the student.

The total mean rating (5.7) is in the effectiveness range of the scale. Table 8 shows that the mean ratings are consistent across MTS types. The standard deviations shown in Table 8 indicate that this rating is also consistent within MTS types. An examination of Tables 10 through 13 also shows that instructors frequently utilized (i.e., gave high utilization ratings to) this feature.

Given the overall ratings, the data strongly suggest that Next Activity Control is an effective, frequently utilized MTS feature.

Cue enhancement. This feature enables the instructor to highlight (i.e., magnify, intensify, or otherwise make more noticeable) specific cues such as trainer sounds or messages on a CRT screen.

The total mean rating (6.2) for this feature is well within the effective range of the scale. However, any generalization about the perceived effectiveness of this feature must be made with caution, since the mean was calculated from only one IVDS, one model, and two panel trainers. None of the SAE had this feature (see Table 8). Table 8 also shows that the feature is seldom utilized by instructors . Further, the ratings in Table 9 suggest that the instructors whose trainers did not have this feature were not enthusiastic about obtaining it. Ratings were in the neutral range for feature desirability.

The small sample of devices possessing this feature, and the low utilization rate, preclude generalizing the results beyond the particular devices for which the responses were obtained.

System parameter control. This feature enables the instructor to set or change the value of parameters of the simulated system such as pressure, temperature, voltage, force, etc., to set up the simulator for specific exercises.

The only mean rating (7.0) is at the extreme high end of the effective range of the scale. Table 8 shows that the mean ratings are consistent between MTS types. An examination of Tables 10 through 13 reveals that only a small number of devices were reported as having this feature (one IVDS, two models, one panel, and one SAE). Most instructor comments were positive about the feature with statements such as, "To be able to control them would help out tremendously," and "Makes simulation more like the actual equipment." One instructor felt that the feature "would over complicate things for the student." The consistently high ratings across MTS types suggest that this feature is considered to be a very effective training aid. This assessment is confounded, however, by the very low rate of utilization reported in Table 8. Instructors, whose MTS did not have the feature, reported neutral (IVDSs, models) to high (panel, SAE) desirability ratings (see Table 9). These seemingly contradictory results may be attributed to instructor difficulty in understanding the feature definition.

Overall, instructor ratings indicate that they consider System Parameter Control to be a highly effective MTS feature.

Training mode control. This simulator capability enables the instructor to select the training mode (lock step, self-paced, freeplay, or demonstration) in which the student will go through the training exercise.

The total mean rating (5.3) for this feature is in effectiveness range of the scale. Table 8 shows that mean ratings were reported for only two of the MTS types (IVDSs and models) and that the mean rating for IVDSs was in the neutral range (4.0) of the scale. An examination of Tables 10 through 13 reveals that only one IVDS and one model reported having this feature. Instructor comments tended to be negative with respect to the utility of this feature. However, the desirability of having this feature was rated high for all four MTS types (see Table 9). This sample is too small to allow an accurate assessment of this feature.

Instructor station control-display layout and operation. This refers to the arrangement and operation of controls (switches, knobs, keypads, etc.) and displays (CRTs, meters, signal lights, etc.).

While not a specific MTS feature, this survey item was included in the questionnaire to assess the general level of satisfaction/dissatisfaction with current MTS control-display configurations/functioning. This information is useful to determine the extent to which this area should be addressed in the MTS Student Station and Instructor Station Design Guidelines. The total mean rating (5.7) is in the effectiveness range of the scale. Table 8 shows that mean ratings are generally high for all four MTS types. The low standard deviations reported in Table 8 indicate that ratings were also consistent within MTS types. A few of the instructor comments suggested that the MTS operating instructions are either overly complicated (i.e., take too long to learn), or are nonexistent. Suggestions were made to develop better instruction manuals, and design more logical control-display layouts.

Since many of the MTSs had different control-display configurations, no assessment can be made of specific control-display arrangement. What can be inferred from these results is that current configurations/functions are generally considered satisfactory.

Instructor station operating procedures. This refers to the procedures that an instructor has to follow to operate the simulator's instructor station.

The total mean response (5.3) for these procedures is in the effectiveness range of the scale. The mean responses for each type in Table 8 vary only slightly from the total mean. Also, the standard deviations in Table 8 and the responses in Table 10 indicate only slight variation within IVDSs. The main criticism evident from the instructor comments is that instruction manuals are out of date, ambiguous, or nonexistent.

In general, there appears to be a consensus that while not perfect, Instructor Station Operating Procedures are deemed satisfactory by the instructors.

Instructor station input devices. The keypads, switches, touch screens, etc., that enable the instructor to make inputs to the simulator comprise this feature.

The time and size constraints of the survey questionnaire precluded gathering information on specific devices within this category. As with the preceding item, this item was included to probe a general area to determine if this area warranted special attention in the Guidelines. The total mean response (6.2) for Instructor Station Input Devices is well within the effectiveness range of the scale, with very little variation between and within MTS types. Although many instructor comments were recorded, they tended to be device descriptions, rather than criticisms or recommendations.

These results suggest that instructors are content with existing instructor station input devices.

Instructor station display devices. This category includes CRTs, meter indicators, signal lights, sound generators, etc., on the instructor station that present information to the instructor.

This item was not intended to elicit information on specific devices within this category, but was included to determine whether or not this area warranted special attention in the Guidelines. The total mean response (6.0) for Instructor Station Display Devices is within the effectiveness range of the scale, with very little variation between MTS types, but some variation within the SAE category. Again, instructor comments were more descriptive than suggestive (i.e., they described a particular MTS configuration).

The results appear to imply that instructors are content with the instructor station display devices that they are currently using.

Student tutoring. This feature is a computer-based instruction capability that provides preprogrammed remedial practice via the simulator's computer system.

The total mean rating (6.3) for this feature is in the effectiveness range of the scale. However, no generalization can be made about the perceived effectiveness of this feature, since the total mean was based on only one IVDS and one model MTS, and only the IVDS reported a high rate of utilization. Table 9 shows that, with the exception of SAE, instructors were not interested in obtaining this capability for their devices. Instructor comments offered no insight regarding instructor attitudes toward this feature. Thus, although instructors rated student tutoring as an effective MTS feature for the two devices that had the feature, there is insufficient data to draw any conclusions or generalization about this feature.

Student sign-in capability. Student sign-in is a simulator capability which uses the student's sign-in code (e.g., name or ID number) to identify the student. The student typically signs in by entering his/her name, ID, and, sometimes, a lesson number into the simulator's student monitoring program via a keyboard.

The total mean rating (6.3) for this feature is in the effectiveness range of the scale. The feature was rated by instructors for two IVDSs and two panel MTSs. The utilization means in Table 8 also indicate that the feature is frequently used by these instructors. While this represents a relatively small sample, there was little variance in the scores for the four devices (see Tables 10 and 12). The mean responses in Table 9 show that the instructors for the one IVDS considered the feature to be highly desirable, while low mean ratings for instructors using the other three types of MTSs indicate that they are uninterested in having this capability. This latter contention is reinforced by the number of negative comments, such as "I don't like sign-in codes," or "Unneeded function," provided by the instructors.

In summary, Student Sign-in Capability is frequently used and is considered a very effective MTS feature by those who use it. For those who do not have this feature, there appears to be no interest in obtaining it.

Augmented feedback. This is information (often a message on a CRT screen) given to the student, by the simulator, concerning the correctness of his/her responses on a particular exercise.

The total mean rating (5.4) for this feature is in the effectiveness range of the scale. All three of the IVDSs, four of the six panels, and one each of the models and SAE had the feature (Tables 10 through 13). The means for each MTS type were all in the effectiveness range (see Table 8). However, Table 8 shows that the mean utilization rate reported is surprisingly low for all four MTS types. For those MTSs that did not have an augmented feedback feature, Table 9 shows that instructors using panels consider it very desirable, while instructors using models and SAE panels do not. Instructor comments were generally positive and some suggestions were offered with respect to the implementation of this feature, such as "It would be best in the self-paced mode," and "It is important that the trainer informs the student when he/she makes a mistake . . ."

From the small sample of MTSs that have this capability, Augmented Feedback is considered to be an effective feature, but appears to be seldom utilized.

Student station input devices. This refers to the keypads, switches, touch screens, etc., on the student station that enable the student to make inputs to the simulator.

Again, the time and size constraints of survey questionnaire precluded gathering information on specific devices within the category. As with the Instructor Station input devices, this item was included to probe a general area to determine if this area warranted special attention in the Guidelines. Table 8 shows that the total mean response (5.9) for student input devices is within the effectiveness range of the scale, with little variation between and within MTS types. The instructor comments were descriptive of the Student Station Input Devices, but offer few insights or suggestions.

These results suggest that instructors are content with the various input devices that currently exist on their MTS student stations.

Student station display devices. These devices include CRTs, meter indicators, signal lights, sound generators, etc., on the student station that present information to the student.

This item was not included to elicit information on specific display devices within this category. The item was included to determine whether or not this area warranted special attention in the Guidelines. The total mean response (5.9) in Table 8 for Student Station Display Devices is well within the effectiveness range of the scale. The means for MTS types, and the standard deviations show little variation within types. Again, the comments were more descriptive than suggestive.

The results suggest that instructors are content with the display devices currently present on MTS student stations.

Student station operating procedures. This refers to the procedures that a student has to follow to use the simulator's student station.

The total mean response (5.0) in Table 8 for Student Station Operating Procedures is within the effectiveness range of the scale. The mean responses for each type vary only slightly from the total mean. Also, the standard deviations in Table 8 indicate that there is slight variation within MTS types. Only two instructors suggested that operating procedures impeded student performance (e.g., "Operating procedures are a big stumbling block," and "Student must be able to type") while other comments were generally favorable. Thus, there appears to be a consensus that Student Station Operating Procedures are effective for the MTSs studied.

Student station control-display layout and operation. This category includes the arrangement and operation of controls (switches, knobs, keypads, etc.) and displays (CRTs, meters, signal lights, etc.).

This survey item was included in the questionnaire to assess the general level of satisfaction or dissatisfaction with current MTS student station control-display configuration/functioning in order to determine the extent to which this area should be addressed in the Guidelines. The total mean rating (5.4) is within the effectiveness range of the scale. Table 8 shows variation in the means between MTS types, but they are generally within the effectiveness range, with little variation within MTS types. Instructor comments were both positive and negative (e.g., "The station control, indicators, test points, etc., are logical and to scale with the TTE"; "The layout is identical to the aircraft layout"; "They find it easy to learn, but sometimes hard to remember, especially the 'replace' and 'isolate' feature"; "The trainer should present itself more as an aircraft if that is what it is going to simulate."). It appears that comments are device-specific, rather than applicable to a class of MTSs.

Since many of the MTSs had different student station control-display configurations, especially between MTS types, no assessment can be made of specific control-display arrangements. What can be inferred from these results is that most instructors consider current MTS student station control-display configurations/functioning to be satisfactory.

Comparison of features. The last three items of the questionnaire required instructors to rank order the MTS features with respect to their relative importance. Since rank ordering all of the features would be too difficult a task for most respondents, the features were divided into three groups. Instructors rank ordered the features within each group (see Tables 14 through 16).

The rankings in Table 14 indicate that Malfunction Insertion/Selection is considered to be the most important of the six features in that group, while Student Recordkeeping was ranked last in the group. These results were, in general, consistent across the four MTS types. This is also consistent with the criticality ratings (Student Recordkeeping received only a neutral criticality rating).

Table 15 shows that Training Exercise Selection was tied with Malfunction Insertion for models, panels, and SAE as most important. These features were also tied with Training Exercise Creation/Selection for model MTSs. Training Exercise Creation/Selection was also ranked most important by IVDS instructors. Table 15 shows that Freeze Capability and Cue Enhancement were tied in rank as least important for all four MTS types with Next Activity Control, and tied in rank as least important for panels and SAE. Freeze Capability received a neutral rating in the criticality assessment, but the other features ranked as "least important" received high criticality ratings (see Table 7).

Table 14

Instructor Rank Ordering of Group 1 MTS Feature Importance

TYPE OF MTS	STUDENT PERFORMANCE MONITORING		PERFORMANCE MEASUREMENT		SYSTEM MONITORING		REPORT GENERATION		STUDENT RECORDKEEPING		MALFUNCTION INSERTION/ SELECTION	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
IVDS	3.06	1.68	3.9	1.1	4.3	1.5	3.1	1.02	4.2	1.59	1.33	0.58
MODEL	2.24	1.17	3.44	1.09	2.74	1.03	5.24	0.51	5.5	0.87	1.86	0.99
PANEL	2.7	0.98	3.75	0.7	3.03	0.65	4.1	0.97	5.47	0.76	1.95	0.93
SAE	3.9	0.98	3.6	0.96	3	0.87	4.6	0.32	4.7	0.26	1.17	0.29

Table 15

Instructor Rank Ordering of Group 2 MTS Feature Importance

TYPE OF MTS	TRAINING EXERCISE SELECTION		TRAINING EXERCISE CREATION/ MODIFICATION		MALFUNCTION INSERTION/ SELECTION		FREEZE CAPABILITY		NEXT ACTIVITY CONTROL		CUE ENHANCEMENT		SYSTEM PARAMETER CONTROL		TRAINING MODE CONTROL	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
IVDS	2.9	0.93	1.67	0.58	2.03	0.9	6.5	1.8	4.4	1.4	6	1.27	5.4	0.51	4.8	1.75
MODEL	2.14	1.06	2.54	0.62	2.74	1.03	7.26	1.18	4.4	0.96	7.14	0.77	5.05	1.23	4.54	0.99
PANEL	2.13	0.32	3.48	1.17	2.4	0.48	6	0.36	5.8	1.38	6.2	0.79	4.9	1	5.03	1.86
SAE	2	0.87	2.8	1.26	2.27	0.64	6.17	1.26	6.8	1.26	6.6	1.64	4.6	1.49	4.77	1.12

Table 16

Instructor Rank Ordering of Group 3 MTS Feature Importance

TYPE OF MTS	STUDENT TUTORING		STUDENT SIGN-IN CAPABILITY		AUGMENTED FEEDBACK		INPUT DEVICES		DISPLAY DEVICES		CONTROL-DISPLAY LAYOUT AND OPERATION	
	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD
IVDS	3.3	1.04	5.2	1.44	3.6	1.27	3.0	1	2.2	0.82	2.6	1.76
MODEL	4.95	0.64	4.5	2.21	4.05	1.1	2.3	0.88	2.7	0.75	2.47	1.81
PANEL	4.15	1.26	5.3	0.9	3.1	1.1	3.15	0.77	3.2	0.77	2.2	0.76
SAE	4.1	0.85	4.9	0.9	4.2	2.12	2.83	0.76	2.5	0.87	2.5	1.1

In the last grouping (Table 16), there is agreement across all four types that Control-Display Layout and Operation is the most important MTS feature. Tied with this was Display Device for IVDSs, models, panels and Input Devices for models and SAE. The feature ranked least important in this group was Student Sign-In Capability for all four MTS types, tied with Student Tutoring for models. These all received high ratings in the criticality assessment.

In general, the findings from this rank ordering of features appear to be consistent with the criticality assessment. However, all instructors ranked all features, while during the criticality assessment only instructors experienced with a feature rated its effectiveness. Consequently, criticality ratings based on effectiveness differ slightly from the ranking data. Where a disparity exists, the criticality rankings were used in the function allocation.

Inter-rater reliability. The small number of instructors surveyed for each MTS device precluded conducting statistical analyses of inter-rater reliability. However, the small standard deviations obtained for most of the means in Tables 8 and 9 indicate that most of the responses within MTS types lie close to the mean. Further, there was little variation in the mean responses between MTS types. This high consistency of responses within and between MTS types suggests that the inter-rater reliability is also high.

FUNCTION ALLOCATION

In addition to determining which design features are critical to the effectiveness and utilization of the various types or classes of MTSs, it is also necessary (in order to develop design guidelines) to identify the most appropriate implementation of the design features which are critical. In this case, implementation choices are limited to (1) instructor station, (2) student station, or (3) both instructor station and student station (i.e., the functional capability may be resident in one or both types of stations). In order to determine how the specific features should be allocated to the separate (instructor and student) stations, a set of allocation criteria were developed and applied to the MTS features.

Allocation Criteria

Accrual of benefit. The critical functional elements may influence the performance and effectiveness of the student, the instructor, or both. If a particular characteristic or element primarily benefits the student, it is sensible to have the functional element be implemented in the student station (e.g., graphics generation, freeze-on-critical-error capability); if a particular element primarily benefits the instructor (e.g., initialization and setup, malfunction selection, student records), it may be appropriate to locate that functional element in the instructor station. If benefits accrue to both instructor and student, functional capabilities may be divided between the instructor station and student station.

Operational function of features. If functional characteristics are primarily intended to enhance learning and retention, provide information presentation or practice capabilities, or otherwise enhance and support students' learning and performance, such characteristics are good candidates for student station design. Characteristics that pertain primarily to training management (e.g., student records, exercise selection) or training maintenance (authoring or addition of malfunctions/exercises) are candidates for instructor station design. Capabilities which lie between these extremes (student monitoring and performance measurement, etc.) may be candidates for sharing between both instructor and student stations or implementation in both stations.

Implementation feasibility and efficiency. Some functional characteristics of MTSs are inherently compatible in terms of implementation (e.g., presentation of information, stimuli, and feedback to students; malfunction selection and exercise sequencing for instructors), while other combinations of functional characteristics are relatively incompatible for recordkeeping. The entire set of function allocations to instructor station and student station must be considered as a whole in order to identify potential implementation problems and inconsistencies posed by the functions allocated to instructor station and student station and to resolve such problems by reallocation.

Findings

Table 17 identifies the applicability of each feature to instructor and student station as determined by applying the allocation criteria (accrual of benefit, operational function, and implementation feasibility and efficiency). The X's in the table indicate that the criterion applies for that specific feature-station combination. As the table shows, if a feature qualifies for allocation to instructor station or student station under one criterion, then it usually qualified under the other two criteria also.

The assignment of features to MTS instructor stations and student stations was derived by an analysis of the results in Table 17 and is presented here as Table 18. An X in an instructor station or student station column indicates allocation of the corresponding feature to that station. It should be noted that three features (initialization, student recordkeeping, and freeze capability) do not appear in Table 18 because their ratings fell within either the noneffective or neutral range of scale.

It is acknowledged that situations could arise which would necessitate the application of a set of criteria other than those which were applied here. However, this allocation appears to be the most logical and generalizable based on the data gathered. Table 18 will guide the discussion of MTS feature allocation in the MTS Instructor Station and Student Station Design Guidelines.

Table 17

Applicability of MTS Features to Instructor/Student Station

SIMULATOR FEATURES	BENEFIT IS	BENEFIT SS	OPERATIONAL FUNCTION IS	OPERATIONAL FUNCTION SS	IMPLEMENTATION IS	IMPLEMENTATION SS
Student Performance Monitoring	X		X		X	
Initialization			X		X	
Performance Measurement	X	X	X	X	X	X
System Monitoring	X		X		X	
Report Generation	X		X		X	
Student Recordkeeping	X		X		X	
Training Exercise Selection	X	X	X	X	X	X
Training Exercise Generation/ Modification	X		X		X	
Malfunction Insertion or Selection	X		X		X	
Freeze		X	X			X
Next Activity Control	X		X		X	
Cue Enhancement		X	X			X
System Parameter Control	X		X			X
Training Mode Control	X	X	X	X	X	X

Table 17 (Continued)

SIMULATOR FEATURES	BENEFIT IS	BENEFIT SS	OPERATIONAL FUNCTION IS	OPERATIONAL FUNCTION SS	IMPLEMENTATION IS	IMPLEMENTATION SS
Student Tutoring		X		X		X
Student Sign-in Capability	X			X		X
Augumented Feedback		X	X			X

IS = Instructor Station
SS = Student Station

Table 18

MTS Instructor Station and Student Station Feature Control Allocation

Instructor Station Only	Student Station Only	Both Instructor and Student Station
Student Performance Monitoring	Student Tutoring	Performance Measurement
System Monitoring	Student Sign-in	Training Exercise Selection
Report Generation		Training Mode Control
Training Exercise Generation/ Modification		Operating Procedures
Malfunction Insertion/ Selection		
Next Activity Control		
Cue Enhancement		
System Parameter Control		
Augmented Feedback		

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CONCLUSIONS

A MTS can be conceptualized as consisting of three major parts: the maintenance simulator computer system, instructor station, and student station. The student station is primarily the training device (e.g., stimulated actual equipment, panel, model, or interactive video display). However, a case can be made for providing a visual display unit and keyboard as an adjunct to the training device to facilitate the integration of the student station with the critical features identified in this research. In other words, the keyboard and VDU adjunct would provide student sign-on capability (which enables the computer to establish a database for each student, records responses, supports the simulator's instructional features capabilities) and would provide a medium through which the instructor or MTS can present messages (instructions, error messages, etc.) to the student. For interactive video display simulators, no additional hardware would be required since the device includes a VDU and keyboard or other input device. Thus, the findings in this research suggest that the student station should be composed of two components: the training device and a keyboard/VDU station to support the trainer's instructional features capability. This latter component is addressed in the Design Guidelines (Appendix C) that were developed during this research and is referred to therein as the student station.

The instructor station supports the information management and instructional features of the MTS computer software. As such, the instructor station (as well as the student station) can be viewed as the interface between the user and the MTS information/ training management software. Thus, to design an MTS instructor station and student station is to design an MTS user-system interface (USI).

The Design Guidelines developed address the USI principles and requirements relevant to MTS design and operation. Issues of physical design, functional requirements, data access, format, and manipulation are addressed.

The results of the commonality analysis and the criticality assessment indicate that the information management and instructional features requirements are virtually the same for all types of MTS. This suggests that the Design Guidelines can promote the standardization of MTS instructor stations and student stations.

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APPENDIX A

ATTRIBUTE TAXONOMY

Attribute: Information/Training Management

Definition: A training device capability that provides the instructor with the capability to automate some of the training management functions via the trainer's computer system. Information/Training Management is comprised of trainer initialization, performance monitoring, performance measurement, system monitoring, report generation, student recordkeeping, student tutoring, and training scenario control.

Feature: Initialization

Definition: A set of procedures to be executed for the purpose of preparing the training device for operation.

Description: Trainer initialization refers to the procedures and functions performed by the instructor/operator to initialize, verify, and configure the maintenance trainer for training. Specific elements of initialization are: program loading, verification, and component activation.

Elements of Initialization:

Program Loading - Loading the necessary operational programs to present the student with the problem exercise of interest.

Verification - Verifying that the operational programs are loaded.

Component Activation - Connecting and/or activating peripheral components (e.g., turning on printers, monitors, slide projectors).

Feature: Performance Monitoring

Definition: A trainer computer system capability that automatically monitors (i.e., senses and records) student responses on a given training exercise.

Description: Performance monitoring is a training device capability that provides the instructors with the means to have the trainer's computer system monitor some, or all, of an exercise. These responses can be recorded and later used to review specific areas of difficulty that the student had encountered. Specific elements of performance monitoring are sensing and recording student performance.

Elements of Performance Monitoring:

Sensing - A training device feature that enables the instructor to turn on or off the devices or mechanisms which sense the student's response(s) or to select only those responses which are to be sensed for a given student exercise. A response that is sensed by the trainer is not necessarily recorded by the trainer.

Recording - A training device feature that enables the instructor to turn on or off the devices or mechanisms which record student response(s) or to select only those responses which are to be recorded for a given student exercise. A response that is recorded by the trainer is not necessarily scored by the trainer.

Feature: <u>Performance Measurement</u>

<u>Definition</u>: A training device capability that utilizes the trainer's computer system to compare each student response to a criterion measure, assign a score, and store the results.

<u>Description</u>: Performance measurement capability provides the instructor with a means of having the trainer compare and score student responses against a pre-programmed set of criteria which can be modified by the instructor. Specific elements of performance measurements are performance scoring and rating criteria control.

<u>Elements of Performance Measurement</u>:

Performance Scoring - A training device feature that enables the instructor to turn on or off the devices or mechanisms which score recorded student responses or to select only those recorded responses to be scored for a given trainer.

Rating Criteria Control - A training device feature which enables the instructor to adjust (change or modify) the value(s) student responses are compared to during scoring.

Feature: <u>System Monitoring</u>

<u>Definition</u>: A training device feature that enables the instructor to turn on or off the devices or mechanisms which monitor the status of the controls and/or displays of the systems and subsystems being simulated, or to select which controls and/or displays are to be monitored for a given exercise. All system controls and displays which are monitored by the trainer are sensed, recorded, and reported by the trainer.

<u>Description</u>: System monitoring capability provides the instructor with a status report of the control positions and display indications at a given time. This enables the instructor to examine student responses with respect to the system status in order to identify the nature of an erroneous response or poor performance on a given training exercise. Specific elements of system monitoring are control positions and display indications.

Elements of System Monitoring:

Control Position - The location/indication of a control at a given time during an exercise.

Display Indications - The reading/indication of a training display at a given time during an exercise.

Feature: Report Generation

Definition: A feature of the trainer which enables the instructor to turn on or off the devices or mechanisms which report student response(s) or score(s) or allows the instructor to select which response(s) or score(s) are to be reported.

Description: Report generation capability enables the instructor to generate, via the trainer's computer, a report of student/class performance or the performance of students over several classes. Using this trainer capability, an instructor can generate a report summarizing the results of statistical tasks/measures of a student's performance in order to provide feedback to the student. Reports could also be generated to show the performance of a group of students over time or compare the relative performance of two or more groups (e.g., classes) of students. Specific elements of report generation are summary reports and statistical profiles.

Elements of Report Generation:

Summary Reports - Reports providing summaries (typically in tabular form) of student performance measures.

Statistical Profile - Reports providing summaries, averages, and/or trends of training performance in order to compare the performance profiles of two or more training classes or groups of students.

Feature: Student Recordkeeping

Definition: A trainer computer system capability which provides a means for storage, retrieval, and review (hard copy or electronic media display) of student training performance as well as student biographical information.

Description: Student recordkeeping provides the instructor and student with a means for reviewing student and class performance, both in terms of strengths and weaknesses. Analysis of student records can pinpoint areas which may need remedial training/special assistance. The record-keeping function can also assist in determining student end-of-course grades and class standing. Specific elements of the student record-keeping feature are amount of time, dangerous actions, sequence errors, helps, malfunctions, and summary data.

<u>Elements of Student Recordkeeping</u>:

Amount of Time - Time taken for the student to complete various tasks (e.g., fault isolation, repair/replace, operational checks, etc.).

Dangerous Actions - The instances (number and location) where the student performed actions which jeopardized equipment/personnel safety.

Sequence Errors - The number of and locations where the student performed out-of-sequence errors (e.g., used the wrong procedure, pressed wrong button, etc.).

Helps - The number of and locations where the student required special assistance.

Malfunctions - The number and type of malfunctions the student was assigned in the training scenario including the ones correctly solved and incorrectly solved, as well as those not identified by the student.

Summary Data - Tabular performance summary which provides an overview of student total performance.

Feature: <u>Student Tutoring</u>

<u>Definition</u>: A computer-based instruction capability that provides pre-programmed student training exercises via the trainer's computer system.

<u>Description</u>: Student tutoring is a training device capability that enables the student to practice, usually at his/her own pace, pre-programmed exercises. This feature enables the student to select remedial training in areas of weaknesses, and delve deeper into areas of interest. Specific elements of student tutoring are lock step tutorials and self-paced tutorials.

<u>Elements of Student Tutoring</u>:

Lock Step - Tutorial presented at a pre-set rate.

Self-Paced - Tutorial in which the student can proceed at his/her own pace.

Feature: Training Exercise Control

Definition: A training device capability that enables the instructor to generate one or more of the following: generate training scenarios, select from a set of pre-programmed scenarios, or modify existing training scenarios.

Description: Training exercise control provides the instructor with a means of control and flexibility over the creation and modification of training scenarios. Specific elements of trainer scenario control are training scenario generation and training scenario modification. Modification enables the instructor to update training exercises in order to keep current with changes in the system(s) for which training is being provided.

Elements of Training Exercise Control:

Training Exercise Selection - An instructor station capability that enables the instructor to select any one of a number of pre-programmed training exercises for presentation to the student.

Training Scenario Generation - A software editing capability that enables the instructor to create training exercises.

Training Scenario Modification - A software editing capability that enables the instructor to modify all or selected sections of existing training scenarios.

Feature: Operating Procedures

Definition: The procedures to be executed for the purpose of controlling the instructor station or student station.

Description: Operating procedures refer to the procedures and functions performed to operate the instructor/student station. This includes controlling exercises from the instructor station and performing exercises on the student station. Specific elements of operating procedures are: instructor station operating procedures and student station operating procedures.

Elements of Operating Procedures:

Instructor Station Operating Procedures - The sequence of steps an instructor must follow and actions that he or she must execute to control the functioning of the instructor station.

Student Station Operating Procedures - The sequence of steps a student must follow and the actions that he or she must execute to control functioning of the student station.

Attribute: Instructional Features

Definition: Instructional features are devices or mechanisms on the trainer and their associated software programs, which enable the instructor to control critical aspects of the learning environment, such as presentation of stimuli, reporting and scoring of responses, presentation of augmented feedback messages, and selection of the next activity that the student is to be engaged in. The following are instructional features:

Feature: Student Sign-in Capability

Definition: A training device capability which enables the student to identify himself/herself (usually for recordkeeping purposes) by entering his/her name into a file in the trainer's student monitoring software program.

Description: Student sign-in is a training device capability which uses the student's sign-in code (e.g., name or ID number) to create a file, or open an existing file in the trainer's student monitoring software program. The student typically signs-in by entering his/her name, ID, and sometimes lesson or exercise number into the trainer's student monitoring program via a keyboard. Specific elements of sign-in are student identification and lesson identification. If a trainer is going to record, score, or report student responses, and if responses are going to be stored for future reference, then a sign-in capability is a necessary feature.

Elements of Student Sign-in:

Student Identification - Name, number, or other code identifying the student about to practice on the trainer.

Lesson Identification - Name or number of lesson(s) or exercise(s) to be practiced.

Feature: Malfunction Insertion/Selection

Definition: A training device capability which enables the instructor to create and/or select the malfunction(s) to be presented to the student at any given time during an exercise.

Description: This capability enables the instructor to create malfunctions or insert pre-programmed malfunctions from a keyboard, CRT screen menu (via touch sensitive screen, bit pad, joy stick, light pen, mouse), or other input device. Malfunction conditions can also be created by mechanical means (e.g., the instructor can set switches on the back of the trainer or replace an operational LRU with one that is defective). Specific elements of malfunction exercise selection are malfunction creation and malfunction selection.

Elements of Training Scenario:

Malfunction Creation - The setting of system parameters, either through software control or by setting switches, to create a malfunction condition within the training exercise.

Malfunction Selection - The selection of a malfunction condition for a given training exercise from a list or menu of pre-programmed malfunctions.

Feature: Freeze Capability

Definition: A training device feature which causes the trainer to freeze (i.e., displays and controls remain in their present position) in response to certain pre-specified erroneous student responses.

Description: This feature causes the controls and displays of the trainer to freeze in response to student responses which would on the actual system being trained cause severe equipment damage or personnel injury in the job or training environment. This gives the instructor an opportunity to explain to the student why the freeze occurred. In addition to pre-programmed freeze control, a trainer may have the capability to enable an instructor to manually freeze the trainer by activating a switch which causes all displays and controls to freeze when he/she observes a student making a hazardous response. Specific elements of freeze capability are pre-programmed freeze capability and manual freeze control.

Elements of Freeze Capability:

Pre-programmed Freeze Control - A trainer capability which automatically monitors student performance and freezes trainer operations in response to a set of pre-specified, hazardous student responses.

Manual Freeze Control - A trainer capability which enables the instructor to freeze trainer operation at his/her discretion.

Feature: Augmented Feedback Capability

Definition: A training device feature which provides the student with feedback messages (i.e., knowledge of results information) usually via a video display screen.

Description: Augmented feedback is information given to the student concerning the correctness of his response(s) to a particular stimulus. There are two kinds of feedback; feedback which the student receives from the simulated equipment itself (e.g., the reaction of a display as a control is manipulated) and augmented feedback. Augmented feedback is the feedback given to the student by the instructor or by the instructional features built into the trainer. Augmented feedback usually consists of a message which contains a summary of the student's response(s), the correctness of the student's response(s), the consequences of any incorrect response(s), and the reason why a particular response was incorrect.

Elements of Augmented Feedback Capability

On/Off Feedback Control - A trainer capability which enables the instructor to turn on or off the augmented feedback messages programmed into the trainer.

Select Feedback Control - A trainer capability which enables the instructor to select the time or schedule of the augmented feedback messages presented to the student during a given exercise.

Feedback Message Adjust - A trainer capability which enables the instructor to adjust (change or modify) the augmented feedback messages presented to the student during a given exercise.

Feature: Next Activity Control

Definition: A training device capability that enables the instructor to turn on or off the next activity pre-programmed for the student, or enables the instructor to select the next activity from a list of pre-programmed next activities.

Description: This feature enables the instructor to control the next activity that a student receives after an objective has been met or after a student error has been made. Specific elements of next activity control are next activity on/off control, next activity selection, next activity override, and next activity modification.

Elements of Next Activity:

Next Activity On/Off Control - A trainer capability that enables the instructor to turn on or off the trainer's pre-programmed next activity selection mode.

Next Activity Selection - A trainer capability that enables the instructor to select the next activity to be presented to the student from a list of next activities.

Next Activity Override - A trainer capability that enables the instructor to override the trainer's automatic pre-programmed next activity selection feature.

Next Activity Modification - A trainer capability that enables the instructor to modify the trainer's next activity selection feature (i.e., alter the branching that has been pre-programmed).

Feature: Cue Enhancement

Definition: A training device capability that enables the instructor to control the highlighting of stimuli or responses.

Description: This feature enables the instructor to highlight (i.e., magnify, intensify, or otherwise make more noticeable) specific stimuli cues for emphasis or response feedback cues to draw attention to trainer responses to student actions. This capability allows the instructor to set all cues on or off or to select which cues are to be functional. Specific elements of cue enhancement are stimuli cue enhancement and response cue enhancement.

Elements of Cue Enhancement:

Stimuli Cue Enhancement - Places emphasis on (i.e, highlights) a given stimulus (or stimuli) in a training lesson sequence.

Response Cue Enhancement - Places emphasis on (i.e., highlights) a given trainer response to a student input or action.

Feature: System Parameter Control

Definition: A training device feature which enables the instructor to set, prior to the exercise, a system parameter value(s) or enables the instructor to input system parameter values during an exercise.

Description: This feature enables the instructor to set or change the value of parameters of the simulated system such as pressure, temperature, voltage, force, etc. in order to test a student's trouble-shooting skills, for example. Specific elements of system parameter control are parameter setting capability and parameter input capability.

Elements of System Parameter Control

Parameter Setting Capability - Enables the instructor to set system parameter values before a lesson begins.

Parameter Input Capability - Enables the instructor to input parameter values during a lesson.

Feature: Training Mode Control

Definition: A training device capability that enables the instructor to select the training mode (lock step, self-paced, or demonstration) in which the student will go through the training lesson(s).

Description: This feature enables the instructor to set the training device to conduct exercises at a pre-set rate or to allow the student to proceed through the training exercises at his/her own pace. The demonstration mode presents the student with a pre-programmed lesson where the responses as well as the stimuli are under trainer control. Demonstrations are typically used to provide introduction to training material, and/or to provide an introduction to a demonstration of the trainer's operation and capabilities. Specific elements of training mode control are lock step mode, self-paced mode, and demonstration mode.

Elements of Training Mode Control

Lock Step Mode - The training exercises proceed at a pre-set pace allowing the student a given interval of time within which to respond before the exercise is automatically terminated and the next exercise is presented.

Self-Paced Mode - Enables the student to terminate the present exercise and select the next exercise at his/her own pace.

Demonstration Mode - Provides the student with a pre-programmed demonstration of trainer operation and functions or of familiarization training lesson.

Attribute: Human Factors Design and Layout

Definition: The design and layout of system components (hardware and software) in order to effect an optimal user-system (student/instructor trainer) interaction. Human factors design and layout addresses those user-system interactions (data handling transactions) which are under software control and mediated through the trainer's input and output hardware. Human factors design and layout features are: input/control devices, display devices, workstation design, and user-system (software) interface.

Feature: Input/Control Devices

Definition: Any device(s) used by the instructor or student to enter data/information into the trainer for processing and/or storage by the trainer's computer system.

Description: Input devices are the training equipment components through which instructor and student actions and responses are sensed by the trainer. An input device can be either a data entry device (e.g., keyboard, touch screen, or mouse) or a control device (e.g., dial, switch, or lever). Specific elements of input/control devices are: type, function, coding, resistance, feedback, control-display ratio.

Elements of Input Devices:

Type - There are two general types of input/control devices: linear (e.g., push button, joystick, toggle switch, light pen) and rotary (e.g., knobs and dials).

Function - The types of input/control functions are: activation (on/off); discrete setting quantitative setting (used to input status or signal indications and quantitative information); quantitative setting; continuous control (inputs are quantitative, qualitative, or representational); data entry (inputs are alphanumeric or symbolic characters).

Coding - The design of displays to make them readily identifiable as a result of their shape, size, color, texture, and labeling.

Resistance - The degree to which an input/control device opposes forces applied to operate the device. The types of resistance found in input/control devices include: static friction, sliding friction, elastic resistance (e.g., spring loading in pushbuttons), and viscous clamping.

Feedback - An indication that the input/control device has been activated. There is both intrinsic feedback (sound of a toggle switch being thrown, or audible click from a keyboard) and extrinsic feedback (e.g., signal lights or characters and symbols on a CRT screen).

Control Display Ratio - The ratio of the distance of movement of a control relative to that of a display indicator (cursor, pointer, etc.). This ratio applies to continuous, but not discrete, data entry/control devices.

Feature: Display Devices

Definition: A display device is a trainer component that conveys data (stimuli, feedback, etc.) to the student or instructor which he/she interprets for its information content.

Description: A display device is the medium through which the student/instructor receives data and assimilates information from the trainer. There are two primary types of display devices used in maintenance trainers: auditory displays (e.g., speech synthesizers, noise generators, warning horns, bells, and tones) and more common visual displays (e.g., electronic displays and optical projector displays). Another type of display used to a lesser extent on training devices is a hardcopy paper display (i.e., printer output). Specific elements of display devices are: function, intensity, contrast, resolution, and frequency.

Elements of Display Devices:

Function - Display devices perform five main functions: display of quantitative values such as temperature or length (quantitative data display); representation of approximate values such as high, medium, and low pressure (qualitative data display); representation of the condition or status of a system such as power on/off channel selected; representation of a hazardous or emergency condition such as fire or component failure; representation of pictorial or graphic information; representation of alphanumeric or symbolic information such as numeric data or synthesized speech; presentation of time-phased data such as Morse Code or sonar.

Intensity - The amount of energy emitted by the display (luminance for visual displays, amplitude for auditory displays).

Contrast - The luminance difference between the data depicted on a display and the display background.

Resolution - The clarity (i.e., distinction from background) of display images. Resolution is measured in Raster scan lines per screen for video images, pixel density per screen for graphic images, and can be interpreted as the signal-to-noise ratio for auditory displays.

Frequency - The rate at which stimuli are presented. Measured in frames per second for video motion displays and cycles per second for auditory displays.

Feature: Workstation Design and Layout

Definition: Workstation layout is the design and arrangement of the trainer hardware components with which the student/instructor interacts.

Description: Workstation design takes into account the information/-perceptual needs, control action requirements, and anthropometric restrictions of the user (student/instructor) as well as the efficacy of system (trainer) performance. Workstation layout and design attempts to integrate the user with the system in order to optimize total system performance. Specific elements of workstation layout are: visibility, clearance, procedural efficacy, physiological factors, psychological factors, and dimensional factors.

<u>Elements of Workstation Design and Layout</u>:

Visibility - Concern with visual efficacy which is enhanced by identifying primary and secondary visual displays, establishing the workstation location for primary displays, and integrating other displays to the primary displays.

Clearance - Concerned with restrictions to body movement which inhibit access, control manipulation, or proper body position.

Procedural Efficacy - The grouping and positioning of displays and controls in such a manner as to optimize the ease and time required to perform task sequences.

Physiological Factors - Concerned with design-imposed physiological stressors such as restricted postural control, poor distribution of body weight, cardiovascular restriction, and fatiguing activities.

Psychological Factors - Concerned with user motivation as effected by workstation design. Positive motivation is associated with the logical, orderly arrangements of, and relationships among system controls and displays as well as ease of access and freedom of movement.

Dimensional Factors - Concerned with the compatibility of workplace dimensions with the anthropometric characteristics of the population of intended users.

Feature: <u>User-System Software Interface</u>

<u>Definition</u>: Those aspects of a trainer's computer system software design that affect the student's/instructor's participation in trainer related information handling transactions.

<u>Description</u>: This feature addresses all aspects of the user-system (i.e., student/instructor - trainer) interactions (information handling transactions) in terms of the software programs controlling those transactions. Specific elements of user-system software interface are: data entry, data display, sequence control, user guidance, data transmission, and data protection.

<u>Elements of User-System Software Interface</u>:

Data Entry - Student/instructor actions involving the input of data to a trainer's computer system. The complexity of data entry actions varies from positioning a cursor on a computer-generated display to having to control the format of data inputs as well as their contents. Data entry addresses cursor control (direction an position designation), text tables, graphics entries, and data entry validation modifications (correction or update).

Data Display - Computer output of trainer data to a student/instructor. Data display software controls the type and amount of data displayed, organization of data, data coding data format (e.g., menu structure), data generation, data suppression, and modification.

Sequence Control - Student/instructor actions and/or computer logic that initiate, interrupt, or terminate transactions. Sequence control governs the transition from one transaction to the next.

User Guidance - Trainer error messages, alarms, prompts, labels, and more formal instructional material designed to facilitate the student/instructor interaction with the trainer.

Data Transmission - The message exchange among the users of a system and message exchange with other systems. Remote lesson generation, modification, and/or scoring provides data transmission capability among instructors and course administrations.

Data Protection - Concerns the security of computer-processed data from unauthorized access, from inadvertent destruction from users, and from computer failure.

Feature: Maintainability

Definition: The ease/difficulty of providing preventive and corrective maintenance in order to keep the trainer fully operational.

Description: The maintainability of a trainer is influenced to a large extent by its design (e.g., the ease with which frequently malfunctioning components are observed and accessed) as well as the availability of spare parts and the personnel with the necessary skills and knowledge. Specific elements of maintainability are: maintenance concept, ease-of-maintenance, reliability, and repair time.

Elements of Maintainability:

Maintenance Concept - A contract provision stating who is responsible for providing trainer hardware and software maintenance (i.e., the vendor/manufacturer or the Navy).

Ease-of-Maintenance - The ease/difficulty of maintenance as determined by the accessibility of frequently serviced components, plug-in vs. soldered components, component labeling, keying of electrical connectors to ensure proper connections, and the quality of maintenance documentation and schematics.

Reliability - The amount of time that a trainer is expected to be operational throughout its lifecycle - expressed as either a percentage or more often as the Mean Time Between Failures (i.e., the average number of operational hours between periods of maintenance downtime.

Repair Time - The time required to complete a maintenance task expressed as the Mean Time to Repair and effected by ease of maintenance as well as availability of skilled technicians and spare parts.

Attribute: Computer System Characteristics

Definition: This feature addresses the hardware and software characteristics (i.e., configuration and function) of a trainer's computer system and subsystems.

Feature: Instructional Systems Programs

Definition: Instructional systems programs are software programs which are interactive and enable the instructor to change the status of the system/subsystem being simulated, as well as controlling the trainer's instructional features.

Description: Instructional systems programs can be grouped into three categories:

- Those programs which allow the instructor to input specific system or subsystem parameters so that the status of the system can be varied on any given exercise. These are called training/simulation programs.
- Those programs which allow the instructor to input parameters which control the learning environment (e.g., allow the instructor to change the value that student performance is compared against to derive the students' scores). These programs are called instructional features programs.
- Those programs which allow the instructor to change or alter the messages or instructional text that appear on the graphic display (e.g., to alter the text that appears during computer-assisted remedial instruction). These programs are called instructional text programs.

Specific elements of Instructional Systems Programs are: training/simulation programs, instructional features programs, instructional text programs.

Elements of Instructional Systems Programs:

Training/Simulation Programs - Computer system programs which enable the instructor to change system parameters for training purposes.

Instructional Features Programs - Computer system programs that enable the instructor to operate the trainer's instructional features interactively.

Instructional Text Programs - Computer system programs that control the trainer's computer-assisted instruction program.

Feature: Computational Subsystem Hardware

Definition: Computational subsystem hardware addresses all of the hardware necessary to support all of the trainer's software programs.

Description: Computational subsystem hardware includes computer peripherals as well as the main system hardware. Specific elements of Computational Subsystem Hardware are: computational equipment performance characteristics, input/output hardware, interface hardware, peripheral equipment.

Elements of Computational Subsystem Hardware:

Equipment Performance Characteristics - Addresses the computational speed of the processing units to assure that they are capable of supporting system software requirements.

Input/Output Hardware - Any computer vendor standard I/O boards and chassis installed in the computational subsystem.

Interface Hardware - Specialized hardware used to connect I/O hardware to a device (e.g., analog-to-digital input converter).

Peripheral Equipment - Additional equipment used f-: data input or output (e.g., modem, printer, or plotter).

Spare Capacity/Growth Capability - The capat , of the system to be expanded to meet future computational . requirements (i.e., amount of spare memory, spare interface capacity, input/output capacity, etc.).

Feature: Computational Subsystem Programs

Definition: This feature addresses requirements unique to the computer operating system.

Description: Computational subsystem programs manage and distribute processing across all the computational system components. These programs enable the trainer to run all the other support programs. Specific elements of computational subsystem programs are: supervisor/executive program, input/output programs, maintenance and test programs.

Elements of Computational Subsystem Programs:

Executive Program - The operating system program that maintains and directs the data/information and establishes priority control over all trainer computational system programs.

Input/Output Programs - Computer programs that control inputs to and outputs from peripheral equipment and interface hardware.

Maintenance and Test Programs - Perform all computational subsystem tests and diagnostics such as, tests of peripheral equipment, calibration test programs, spare capacity verification, memory storage checks, etc.

Feature: Trainer Support Subsystem

Definition: Those trainer support programs which support updates or modifications to the trainer throughout its lifecycle.

Description: The trainer support subsystem includes all hardware, computer programs, and documentation necessary to support updates or modifications to the trainer which result from modifications to the simulated equipment. Specific elements of trainer support subsystems are: modification support hardware and modification support computer programs.

Elements of Trainer Support Subsystem:

Modification Support Hardware - Hardware, such as alignment tools and test equipment, required to modify the computational system.

Modification Support Programs - Computer programs that support modification of the computational system and major interface components.

APPENDIX B

SURVEY INSTRUMENT

PRIVACY ACT STATEMENT

A. This survey is part of an effort by the Naval Training Equipment Center to assess the utilization and effectiveness of the certain characteristics of maintenance simulators.

B. Your participation in this survey is voluntary. We encourage your honest and thoughtful feedback in this study. Your assistance will contribute to improving both the acquisition and training use of maintenance simulators. No adverse action of any kind will be taken against any individual who elects not to participate in this study. As Subject Matter Specialists in the field of maintenance training, your assistance will contribute to the future acquisition and training effectiveness of maintenance simulators.

C. Disclosure of this information is voluntary. Your participation in the survey will be strictly anonymous. Individual identities will not be revealed. All information gathered will be used for research purposes only. Failure to provide this information might impact the effectiveness of future maintenance training programs. Your cooperation in this effort is greatly appreciated.

YOUR RESPONSES TO THIS SURVEY ARE CONFIDENTIAL AND YOU WILL REMAIN ANONYMOUS. AT NO TIME WILL ANY ATTEMPT BE MADE TO DETERMINE HOW YOU, AS AN INDIVIDUAL, RESPONDED TO THESE QUESTIONS.

INSTRUCTOR/OPERATOR QUESTIONNAIRE

Instructor/Operator Name (optional): ______________________________

Rank/Rate: ________________________________

Length of Time Operating this Maintenance Simulator:
___ Years ___ Months

This questionnaire is an important part of a study to develop a design specification for Navy maintenance simulator instructor and student stations. Specifically it asks for information on the effectiveness and desirability of the simulator's instructor and student station design and instructional features.

For each question on the following pages, first answer by circling Y for Yes or N for No. Then use the scale provided to rate the feature asked about in the question.

1	2	3	4	5	6	7	NA
Strongly Disagree	Disagree	Slightly Disagree	Neither Agree Nor Disagree	Slightly Agree	Agree	Strongly Agree	Not Applicable

INSTRUCTOR STATION

FEATURE — RATING

1. Student Performance Monitoring - A simulator computer system capability that automatically monitors (i.e., senses and records) student performance on a training exercise.

   Does the simulator have this feature? (Circle one)
   YES NO

   If you answered YES to this question, please use the rating scale above to state your agreement/disagreement with the following statements:

   A. The student monitoring feature increases simulator effectiveness. A. ___

   B. I often use this feature on my simulator's instructor station. B. ___

   If you answered NO, please use the rating scale to state your agreement/disagreement with the following statements:

   C. If there were a student monitoring feature on this simulator, it would increase trainer effectiveness. C. ___

   D. If this feature were available on the simulator, I probably would use it often. D. ___

   Comments: ______________________________

1	2	3	4	5	6	7	NA
Strongly Disagree	Disagree	Slightly Disagree	Neither Agree Nor Disagree	Slightly Agree	Agree	Strongly Agree	Not Applicable

2. Initialization - Simulator initialization refers to the procedures and functions performed by the instructor/operator to initialize, verify, and configure the maintenance simulator for training. Specific elements of initialization are: program loading, verification, and component (e.g., printer, CRT, panel) activation.

Please use the rating scale above to state your agreement/disagreement with the following statements:

A. Simulator initialization is difficult to perform. A. ___

B. Simulator initialization is completed in a short period of time. B. ___

Comments: ____

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1	2	3	4	5	6	7	NA
Strongly Disagree	Disagree	Slightly Disagree	Neither Agree Nor Disagree	Slightly Agree	Agree	Strongly Agree	Not Applicable

3. Performance Measurement - A simulator capability that utilizes the simulator's computer system to test students and/or score student responses.

Does the simulator have this feature? (Circle one) YES NO

If you answered YES to this question, please use the rating scale above to state your agreement/disagreement with the following statements:

A. Performance monitoring increases simulator effectiveness. A. ___

B. I often use this feature on my simulator's instructor station. B. ___

If you answered NO, please use the rating scale to state your agreement/disagreement with the following statements:

C. If there were a performance monitoring feature on this simulator, it would increase simulator effectiveness. C. ___

D. If this feature were available on the simulator, I probably would use it often. D. ___

Comments: ______________________________

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1	2	3	4	5	6	7	NA
Strongly Disagree	Disagree	Slightly Disagree	Neither Agree Nor Disagree	Slightly Agree	Agree	Strongly Agree	Not Applicable

4. System Monitoring - System monitoring capability provides the instructor with information about the control positions and display indications if a student error occurs.

Does the simulator have this feature? (Circle one) YES NO

If you answered YES to this question, please use the rating scale above to state your agreement/disagreement with the following statements:

A. The system monitoring feature does not increase simulator effectiveness. A. ___

B. I seldom use the feature on my simulator's instructor station. B. ___

If you answered NO, please use the rating scale to state your agreement/disagreement with the following statements:

C. If there were a system monitoring feature on this simulator, it would increase trainer effectiveness. C. ___

D. If this feature were available on the simulator, I probably would use it often. D. ___

Comments: ____

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1	2	3	4	5	6	7	NA
Strongly Disagree	Disagree	Slightly Disagree	Neither Agree Nor Disagree	Slightly Agree	Agree	Strongly Agree	Not Applicable

5. Report Generation - A feature of the simulator that provides instructor with a report of student responses or scores.

Does the simulator have this feature? (Circle one) YES NO

If you answered YES to this question, please use the rating scale above to state your agreement/disagreement with the following statements

A. The report generation feature increases simulator effectiveness. A. ___

B. I often use this feature of my simulator's instructor station. B. ___

If you answered NO, please use the rating scale to state your agreement/disagreement with the following statements:

C. If there were a report generation feature on this simulator, it would increase simulator effectiveness. C. ___

D. If this feature were available on the simulator, I probably would use it often. D. ___

Comments: ______________________________

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1	2	3	4	5	6	7	NA
Strongly Disagree	Disagree	Slightly Disagree	Neither Agree Nor Disagree	Slightly Agree	Agree	Strongly Agree	Not Applicable

6. Student Recordkeeping - A simulator computer system capability that provides a means for storage, retrieval, and review of student training performance.

   Does the simulator have this feature? (Circle one) YES NO

   If you answered YES to this question, please use the rating scale above to state your agreement/disagreement with the following statements

   A. The student recordkeeping feature increases the simulator's effectiveness. A. ___

   B. I often use this feature on my simulator's instructor station. B. ___

   If you answered NO, please use the rating scale to state your agreement/disagreement with the following statements:

   C. If there were a recordkeeping feature on this simulator, it would increase simulator effectiveness. C. ___

   D. If this feature were available on the simulator, I probably would use it often. D. ___

   Comments: ______________________________

1	2	3	4	5	6	7	NA
Strongly Disagree	Disagree	Slightly Disagree	Neither Agree Nor Disagree	Slightly Agree	Agree	Strongly Agree	Not Applicable

7. Training Exercise Selection - A simulator capability that enables the instructor to select an exercise from a set of pre-programmed exercises.

Does the simulator have this feature? (Circle one) YES NO

If you answered YES to this question, please use the rating scale above to state your agreement/disagreement with the following statements:

A. Training exercise selection does not increase simulator effectiveness. A. ___

B. I seldom use this feature of the simulator's instructor station. B. ___

If you answered NO, please use the rating scale to state your agreement/disagreement with the following statements:

C. If there were a training exercise selection feature on this simulator, it would increase simulator effectiveness. C. ___

D. If this feature were available on the simulator, I probably would use it often. D. ___

Comments: ______________________________

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1	2	3	4	5	6	7	NA
Strongly Disagree	Disagree	Slightly Disagree	Neither Agree Nor Disagree	Slightly Agree	Agree	Strongly Agree	Not Applicable

8. Training Exercise Creation/Modification - A simulator capability that enables the instructor to create new training exercises or modify existing exercises.

Does the simulator have this feature? (Circle one) YES NO

If you answered YES to this question, please use the rating scale above to state your agreement/disagreement with the following statements:

A. Training exercise generation/modification increases simulator effectiveness. A. ___

B. I often use this feature of the simulator's instructor station. B. ___

If you answered NO to this question, please use the rating scale to state your agreement/disagreement with the following statements:

C. If there were a training exercise generation/modification feature on this simulator, it would increase simulator effectiveness. C. ___

D. If this feature were available on the simulator, I probably would use it often. D. ___

Comments: ____

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1	2	3	4	5	6	7	NA
Strongly Disagree	Disagree	Slightly Disagree	Neither Agree Nor Disagree	Slightly Agree	Agree	Strongly Agree	Not Applicable

9. Malfunction Insertion/Selection - A simulator capability which enables the instructor to select the malfunctions to be presented to the student during an exercise.

Does the simulator have this feature? (Circle one) YES NO

If you answered YES to this question, please use the rating scale above to state your agreement/disagreement with the following statements:

A. The malfunction insertion/selection feature does not increase simulator effectiveness. A. ___

B. I seldom use this feature of the simulator's computer system. B. ___

If you answered NO, please use the rating scale to state your agreement/disagreement with the following statements:

C. If there were a malfunction insertion/selection feature on this simulator, it would increase simulator effectiveness. C. ___

D. If this feature were available on the simulator, I probably would use it often. D. ___

Comments: ______________________________

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1	2	3	4	5	6	7	NA
Strongly Disagree	Disagree	Slightly Disagree	Neither Agree Nor Disagree	Slightly Agree	Agree	Strongly Agree	Not Applicable

10. Freeze Capability - A simulator feature that causes the simulator to freeze (i.e., displays and controls stop in their present position) in response to certain student errors.

Does the simulator have this feature? (Circle one) YES NO

If you answered YES to this question, please use the rating scale above to state your agreement/disagreement with the following statements:

A. The freeze capability does not increase the simulator's effectiveness. A. ___

B. I seldom use this feature on my simulator's instructor station. B. ___

If you answered NO, please use the rating scale to state your agreement/disagreement with the following statements:

C. If there were a freeze capability feature on this simulator, it would increase simulator effectiveness. C. ___

D. If this feature were available on the simulator, I probably would use it often. D. ___

Comments: ____________________

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1	2	3	4	5	6	7	NA
Strongly Disagree	Disagree	Slightly Disagree	Neither Agree Nor Disagree	Slightly Agree	Agree	Strongly Agree	Not Applicable

11. Next Activity Control - A simulator capability that enables the instructor to turn on or off the next activity pre-programmed for the student, or enables the instructor to select the next activity to be presented to the student.

Does the simulator have this feature? (Circle one) YES NO

If you answered YES to this question, please use the rating scale above to state your agreement/disagreement with the following statements:

A. Next activity control increases the simulator's effectiveness. A. ___

B. I often use this feature of the simulator's instructor station. B. ___

If you answered NO, please use the rating scale to state your agreement/disagreement with the following statements:

C. If there were a next activity control feature on this simulator, it would increase simulator effectiveness. C. ___

D. If this feature were available on the simulator, I probably would use it often. D. ___

Comments: ____

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1	2	3	4	5	6	7	NA
Strongly Disagree	Disagree	Slightly Disagree	Neither Agree Nor Disagree	Slightly Agree	Agree	Strongly Agree	Not Applicable

12. Cue Enhancement - This feature enables the instructor to highlight (i.e., magnify, intensify, or otherwise make more noticeable) specific cues such as trainer sounds or messages on a CRT screen.

Does the simulator have this feature? (Circle one) YES NO

If you answered YES to this question, please use the rating scale above to state your agreement/disagreement with the following statements:

A. The cue enhancement feature does not increase simulator effectiveness. A. ___

B. I seldom use this feature on the simulator's instructor station. B. ___

If you answered NO, please use the rating scale to state your agreement/disagreement with the following statements:

C. If there were a cue enhancement feature on this simulator it would increase simulator effectiveness. C. ___

D. If this feature were available on the simulator, I probably would use it often. D. ___

Comments: ____

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1	2	3	4	5	6	7	NA
Strongly Disagree	Disagree	Slightly Disagree	Neither Agree Nor Disagree	Slightly Agree	Agree	Strongly Agree	Not Applicable

13. System Parameter Control - This feature enables the instructor to set or change the value of parameters of the simulated system such as pressure, temperature, voltage, force, etc. to set up the simulator for specific exercises.

Does the simulator have this feature? (Circle one) YES NO

If you answered YES to this question, please use the rating scale above to state your agreement/disagreement with the following statements:

A. System parameter control does not increase simulator effectiveness. A. ___

B. I seldom use this feature on the simulator's instructor station. B. ___

If you answered NO, please use the rating scale to state your agreement/disagreement with the following statements:

C. If there were a system parameter control feature on this simulator, it would increase simulator effectiveness. C. ___

D. If this feature were available on the simulator, I probably would use it often. D. ___

Comments: ______________________________

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1	2	3	4	5	6	7	NA
Strongly Disagree	Disagree	Slightly Disagree	Neither Agree Nor Disagree	Slightly Agree	Agree	Strongly Agree	Not Applicable

14. Training Mode Control - A simulator capability that enables the instructor to select the training mode (lock step, self-paced, freeplay, or demonstration) in which the student will go through the training exercise.

Does the simulator have this feature? (Circle one) YES NO

If you answered YES to this question, please use the rating scale above to state your agreement/disagreement with the following statements:

A. Training mode control increases the simulator's effectiveness. A. ___

B. I often use this feature on the simulator's instructor station. B. ___

If you answered NO, please use the rating scale to state your agreement/disagreement with the following statements:

C. If there were a training mode control feature on this simulator, it would increase simulator effectiveness. C. ___

D. If this feature were available on the simulator, I probably would use it often. D. ___

Comments: ______________________________

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1	2	3	4	5	6	7	NA
Strongly Disagree	Disagree	Slightly Disagree	Neither Agree Nor Disagree	Slightly Agree	Agree	Strongly Agree	Not Applicable

15. Control-Display Layout and Operation - The arrangement and operation of controls (switches, knobs, keypads, etc.) and displays (CRTs, meters, signal lights, etc.).

Please use the rating scale above to state your agreement/disagreement with the following statements:

A. The layout and operation of controls and displays on the instructor station is logical and efficient. A. ___

B. It was easy to learn to use the instructor station's controls and displays. B. ___

Comments: ____________________

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1	2	3	4	5	6	7	NA
Strongly Disagree	Disagree	Slightly Disagree	Neither Agree Nor Disagree	Slightly Agree	Agree	Strongly Agree	Not Applicable

16. Instructor Station Operating Procedures - The procedures that an instructor has to follow to operate the simulator's instructor station.

Please use the rating scale above to state your agreement/disagreement with the following statements:

A. The instructor station procedures are easy to perform. A. ___

B. I closely follow the instructor station's operating procedures. B. ___

Comments: ____

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1	2	3	4	5	6	7	NA
Strongly Disagree	Disagree	Slightly Disagree	Neither Agree Nor Disagree	Slightly Agree	Agree	Strongly Agree	Not Applicable

17. Input Devices - The keypads, switches, touch screens, etc. on the simulator that enable the instructor to make inputs to the trainer.

Does the simulator have instructor-only input devices? (Circle one) YES NO

If you answered YES to this question, please use the rating scale above to state your agreement/disagreement with the following statements:

A. The instructor's input devices on this simulator are an effective way for the instructor to make inputs to the simulator. A. ___

Whether you answered YES or NO, indicate on the Comments lines below the type of input devices that would increase the simulator's effectiveness.

Comments: ______________________________

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1	2	3	4	5	6	7	NA
Strongly Disagree	Disagree	Slightly Disagree	Neither Agree Nor Disagree	Slightly Agree	Agree	Strongly Agree	Not Applicable

18. Display Devices - CRTs, meter indicators, signal lights, sound generators, etc., on the simulator that present information to the instructor.

Does the simulator have instructor-only display devices? (Circle one) YES NO

If you answered YES to this question, please use the rating scale above to state your agreement/disagreement with the following statements:

A. The instructor display devices on the simulator increase simulator effectiveness. A. ___

Please indicate the type(s) of display devices that would increase simulator effectiveness in the Comments lines below.

Comments: ____

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1	2	3	4	5	6	7	NA
Strongly Disagree	Disagree	Slightly Disagree	Neither Agree Nor Disagree	Slightly Agree	Agree	Strongly Agree	Not Applicable

STUDENT STATION

FEATURE | RATING

19. Student Tutoring - A computer-based instruction capability that provides pre-programmed remedial practice via the simulator's computer system.

Does the simulator have this feature? (Circle one) YES NO

If you answered YES to this question, please use the rating scale above to state your agreement/disagreement with the following statements:

A. The student tutoring feature does not increase simulator effectiveness. A. ___

B. Students seldom use this feature. B. ___

If you answered NO, please use the rating scale to state your agreement/disagreement with the following statements:

C. If there were a student tutoring feature on this simulator, it would increase simulator effectiveness. C. ___

D. If this feature were available on the students probably would use it often. D. ___

Comments: ____

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1	2	3	4	5	6	7	NA
Strongly Disagree	Disagree	Slightly Disagree	Neither Agree Nor Disagree	Slightly Agree	Agree	Strongly Agree	Not Applicable

20. Student Sign-in Capability - Student sign-in is a simulator capability which uses the student's sign-in code (e.g., name or ID number) to identify the student. The student typically signs-in by entering his/her name, ID, and sometimes lesson number into the trainer's student monitoring program via a keyboard.

Does the student station have this feature? (Circle one)
YES NO

If you answered YES to this question, please use the rating scale above to state your agreement/disagreement with the following statements:

A. The student sign-in procedure is easy for students to perform. A. ___

B. Student sign-in is completed in a short period of time. B. ___

If you answered NO, please use the rating scale to state your agreement/disagreement with the following statements:

C. If there were a student sign-in feature on this simulator, it would increase simulator effectiveness. C. ___

D. If this feature were available on the simulator, I probably would have students use it often. D. ___

Comments: ____

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1	2	3	4	5	6	7	NA
Strongly Disagree	Disagree	Slightly Disagree	Neither Agree Nor Disagree	Slightly Agree	Agree	Strongly Agree	Not Applicable

21. Augmented Feedback - Information (often a message on a CRT screen) given to the student, by the simulator, concerning the correctness of his/her responses on a particular exercise.

Does the simulator have this feature? (Circle one)
YES NO

If you answered YES to this question, please use the rating scale above to state your agreement/disagreement with the following statements:

A. The augmented feedback feature does not increase simulator effectiveness. A. ___

B. I seldom use this feature on the simulator. B. ___

If you answered NO, please use the rating scale to state your agreement/disagreement with the following statements:

C. If there were an augmented feedback feature on this simulator, it would increase simulator effectiveness. C. ___

D. If this feature were available on the simulator trainer, I probably would use it often. D. ___

Comments: ______________________________________
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1	2	3	4	5	6	7	NA
Strongly Disagree	Disagree	Slightly Disagree	Neither Agree Nor Disagree	Slightly Agree	Agree	Strongly Agree	Not Applicable

22. Input Devices - The keypads, switches, touch screens, etc. on the student station that enables the student to make inputs to the simulator.

Does the student station have input devices? (Circle one)
YES NO

If you answered YES to this question, please use the rating scale above to state your agreement/disagreement with the following statements:

A. The input devices on this simulator's student station are an effective way for the student to make inputs to the simulator. A. ___

Whether you answered YES or NO indicate on the Comments lines below the type of input devices that would increase the student station's effectiveness.

Comments: ____

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1	2	3	4	5	6	7	NA
Strongly Disagree	Disagree	Slightly Disagree	Neither Agree Nor Disagree	Slightly Agree	Agree	Strongly Agree	Not Applicable

23. Display Devices - CRTs, meter indicators, signal lights, sound generators, etc. on the student station that present information to the student.

Does the simulator's student station have display devices? (Circle one) YES NO

If you answered YES to this question, please use the rating scale above to state your agreement/disagreement with the following statements:

A. The display devices on the student station are an effective way to present information to the student. A. ___

Please indicate the type(s) of display devices that would increase student station effectiveness on the Comments lines below.

Comments: ______________________________

____

____

____

1	2	3	4	5	6	7	NA
Strongly Disagree	Disagree	Slightly Disagree	Neither Agree Nor Disagree	Slightly Agree	Agree	Strongly Agree	Not Applicable

24. Student Station Operating Procedures - The procedures that a student has to follow to use the simulator's student station.

A. The student station procedures are easy to follow. A. ___

B. The student station operating procedures do not interfere with learning. B. ___

Comments: ______________________________

____

____

____

1	2	3	4	5	6	7	NA
Strongly Disagree	Disagree	Slightly Disagree	Neither Agree Nor Disagree	Slightly Agree	Agree	Strongly Agree	Not Applicable

25. Student Station Control - Display Layout and Operation - The arrangement and operation of controls (switches, knobs, keypads, etc.) and displays (CRTs, meters, signal lights, etc.).

Please use the rating scale above to state your agreement/disagreement with the following statements:

A. The layout and operation of controls and displays on the student station is logical and efficient. A. ___

B. Students find it easy to learn the student station's controls and displays. B. ___

Comments: ______________________________

____

____

____

Ranking of Instructor Station and Student Station features.

Please rank importance of the following simulator features from 1 to 6 (1 = most important and 6 = least important).

_____ Student Performance Monitoring

_____ Performance Measurement

_____ System Monitoring

_____ Report Generation

_____ Student Recordkeeping

_____ Malfunction Insertion/Selection

Please rank the importance of the following features from 1 to 8 (1 = most important and 8 = least important).

_____ Training Exercise Selection

_____ Training Exercise Creation/Modification

_____ Malfunction Insertion/Selection

_____ Freeze Capability

_____ Next Activity Control

_____ Cue Enhancement

_____ System Parameter Control

_____ Training Mode Control

Please rank the importance of the following Student Station features from 1 to 6 (1 = most important and 6 = least important).

_____ Student Tutoring

_____ Student Sign-in Capability

_____ Augmented Feedback

_____ Input Devices

_____ Display Devices

_____ Control-Display Layout and Operation

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APPENDIX C

GUIDELINES FOR DEVELOPING INSTRUCTOR AND STUDENT STATION DESIGN SPECIFICATIONS

GUIDELINES FOR DEVELOPING INSTRUCTOR AND STUDENT STATION DESIGN SPECIFICATIONS

Introduction

The purpose of these guidelines is to assist the user in developing an instructor station and student station Prime Item Development Specification for Maintenance Training Simulators (MTS).

The results of the MTS study suggest that although the physical configuration of the four classes of trainers are very different, the requirements that must be addressed in instructor station and student station designs are quite similar. These guidelines, therefore, apply to all types of maintenance training simulators. The specific parameters of the instructional and information/training management features are to be determined by training device requirements specified in the MTS Prime Item Development Specification.

These guidelines describe instructor and student station features and provide recommendations for incorporating them into a design specification. The features are grouped into three major attributes:

1. Human Factors Design and Layout
2. Information/Training Management
3. Instructional Features

The features within each attribute are described, their relevance to instructor and/or student station design is noted, and recommendations are made as to their inclusion in the instructor station and/or student station design specification.

Human Factors Design and Layout

This refers to the design and layout of system components hardware and software to effect an optimal user-system (student/instructor-trainer) interaction. Human factors design and layout addresses those user-system interactions (data handling transactions) which are under software control and mediated through the trainer input and output hardware. The following are human factors design and layout features:

1. Input/Control Devices
2. Display Devices
3. Workstation Design and Layout
4. User-System Software Interface

Input/Control Devices

Application: Instructor station and student station design.

Definition: Any device(s) used by the instructor or student to enter data/information into the maintenance trainer for processing and/or storage by the trainer computer system.

Description: Input devices are the training equipment components through which instructor and student actions and responses are sensed by the trainer. An input device can be either a data entry device (e.g., keyboard, touch screen, or mouse) or a control device (e.g., dial, switch, lever). Specific elements of input/control devices are: type, function, coding, resistance, feedback, control-display ratio.

Elements of Input/Control Devices:

Type - There are two general types of input/control devices: linear (e.g., pushbutton, joystick, toggle switch, light pen) and rotary (knobs and dials).

Function - The types of input/control functions are: activation (on/off); discrete setting (used to input quantitative information); quantitative setting; continuous control (inputs are quantitative, qualitative, or representational); and data entry (inputs are alphanumeric or symbolic characters).

Resistance - The degree to which an input/control device opposes forces applied to operate the device. The types of resistance found in input/control devices are: static friction, sliding friction, elastic resistance (e.g., spring loading in pushbuttons), and viscous damping.

Coding - The design of controls and displays to make them readily identifiable as a result of their shape, size, color, texture, and labeling.

Feedback - An indication that the input/control has been activated. There is both intrinsic feedback (e.g., sound of a toggle switch being thrown, or audible click from a keyboard) and extrinsic feedback (e.g., signal lights or characters and symbols on a video screen responding to the activation of an input device).

Control Display Ratio - The ratio of the distance of movement of a control relative to the corresponding movement of a display indicator cursor, pointer, etc. This ratio applies to a continuous, but not discrete, data entry/control device.

Recommendation: Instructor station and student station designs must always incorporate relevant, established human factors input/control design principles as documented in MIL-STD-1472. Since the instructor station and student station designs developed in this study require only menu selection and some text/numerical entry, the input device recommended for both the instructor and student stations is an alphanumeric keyboard. The following are recommendations for the specification of keyboard functional and physical design requirements:

1. The keyboard should consist of alphanumeric keys arranged as specified in MIL-STD-1280, 10 function keys, 4 cursor control keys, and a number pad containing the digits 1 through 9 and 0; all keys should provide ASCII characters.

2. The keyboard should require a minimum resistance force of 0.9 oz and maximum force of 5.3 oz for alphanumeric, and a minimum resistance force of 3.5 oz and maximum force of 14.0 oz for numeric only or function keys.

3. The keyboard should provide both tactile and auditory feedback in response to key activation.

4. The keyboard should have an adjustable tilt from 0 to 25 degrees.

Display Devices

Application: Instructor station and student station design.

Definition: A display device is a trainer component that conveys data (stimuli, feedback, etc.) to the instructor or student which he/she interprets for its information content.

Description: A display device is the medium through which the student/instructor receives data and assimilates information on the trainer. There are two primary types of display devices used in maintenance trainers: auditory displays (e.g., speech synthesizers, noise generators, warning horns, bells, and tones) and, more commonly, visual displays (e.g., electronic displays and optical projector displays). Another type of display used to a lesser extent on training devices is a hardcopy paper display (e.g., printer output). Specific elements of display devices are: function, intensity, contrast, resolution, and frequency.

Elements of Display Devices:

Function - Display devices perform seven main functions: display of quantitative values such as temperature or length (quantitative data display), representation of approximate values such as high, medium, or low pressure (qualitative data display); representation of the condition or status of a system such as power on/off or channel selected; representation of a hazardous or emergency condition (e.g., fire or component failure); representation of pictorial or graphic information; representation of alphanumeric or symbolic information (e.g., numeric data or synthesized speech); and presentation of time-phased data such as Morse Code or sonar.

Intensity - The amount of energy emitted by the display (luminance for visual displays, and amplitude for auditory displays).

Contrast - The luminance difference between the data depicted on a display and the display background, on visual displays.

Resolution - The clarity (i.e., distinction from background of display images). Resolution is measured in Raster scan lines per screen for video images, pixel density per screen for graphic images and can be interpreted as the signal-to-noise ratio for auditory displays.

Frequency - The rate at which stimuli are presented. Measured in frames per second for video motion displays and cycles per second (Hz/sec) for auditory displays.

Recommendation: Instructor station and student station display designs must always incorporate relevant established human factors display design principles as documented in MIL-STD-1472. The following are recommendations for the specification of display functional and physical design requirements for both instructor station and student station designs:

1. Imaging - monochromatic capabilities will normally be sufficient.

2. Reverse Video.

3. Cursor.

4. Text Windows.

5. Data Display - 80 column by 25 row format is recommended.

6. Screen Resolution - a minimum of 320 (w) x 240 (h) pixels.

7. Refresh Rate - refresh rate for viewing under normal ambient light conditions should preferably be 50-60 Hz. Thirty Hz, interlaced, is acceptable if screen flicker is perceptually unnoticeable.

8. Phosphor Equivalence - a phosphor or equivalent display medium with a rating of medium persistence should be utilized; e.g., P-4.

9. Brightness - the display symbols should be at least 45 foot-lamberts.

10. Contrast Ratio - display contrast should be a 3:1 minimum, 8:1 to 10:1 optimum, with a background luminance between 15 and 20 cd per m.

11. Glare - no glare is permissible.

12. Viewing - the display should be easily viewable from distances up to three feet.

Workstation Design and Layout

Application: Instructor station and student station design.

Definition: Workstation layout is the design and arrangement of the instructor/student work area.

Description: Workstation design takes into account the anthropometric restrictions of the user (instructor/student) as it effects the efficacy of system (instructor/student-trainer) performance. Specific elements of workstation layout are: clearance, physiological factors, psychological factors, and dimensional factors.

Elements of Workstation Design and Layout:

Clearance - Addresses restrictions to body movement which inhibit access, control manipulation, or proper body position.

Physiological Factors - Addresses design imposed physiological stressors such as restricted postural control, poor distribution of body weight, cardiovascular restriction, and fatiguing activities.

Psychological Factors - Addresses user motivation as effected by workstation design. Positive motivation is associated with the logical, orderly arrangements of, and relationships among system controls and displays, as well as ease of access and freedom of movement.

Dimensional Factors - Addresses the compatibility of workplace dimensions with the anthropometric characteristics (i.e., physical features, including linear dimensions; weight and volume of the body; and reach and movement requirements of the population of intended users.

Recommendation: Instructor station and student station designs must always incorporate relevant, established human factors workstation design and layout principles as documented in MIL-STD-1472. For both the instructor and student stations the workstations support the user's interaction with the input and display devices. This requirement suggests a desk which would provide a supporting structure for the keyboard and display unit and provide a surface for writing or reviewing manuals on the instructor station, and a chair sufficient to provide adequate body support while the user carries out his/her functions at the instructor/student station. Since the student station, as conceptualized in this study, is only used briefly for sign-on and to receive messages from the instructor (i.e., the student spends most of his/her training time interacting with other components of a training device), the requirements vary from those of the instructor station where more time is spent controlling and monitoring exercises, reviewing scores, manuals, and other written material, as well as conversing with students. The following are recommendations for instructor and student station chair and desk design:

1. Instructor Station Desk Chair. The instructor station chair should be provided with a swivel mount and casters. Provision should be made for vertical seat adjustment from 380 to 535 mm (15 to 21 inches) in increments of no more than 25 mm (1 inch) each. A supporting backrest that allows the instructor to recline between 1745 and 2005 mrad (100 and 115 degrees) while conversing with students or other instructors should be provided. The backrest should engage the lumbar and thoracic regions of the back, and support the torso in such a position that the occupant's eyes can be brought to the "Eye Line" within no more than 75 mm (3 inches) of forward body movement. Arm rest should be provided. Armrest should be at least 50 mm (2 inches) wide and 200 mm (18 inches) long. The seat pan should be a maximum of 457 mm (18 inches) deep, and minimum of 483 mm (19 inches) wide. The backrest and seat should be cushioned with at least 25 mm (1 inch) of compressible heat dissipating material and provided with a smooth surface.

2. Instructor Station Desk. The instructor station desk should be 2134 mm (84 inches) wide, 914 mm (36 inches) deep, and 737 mm (29 inches) high. The desk should provide a minimum knee cavity height and width of 610 mm (24 inches) and 635 mm (25 inches), respectively. The desk should provide storage drawers. The upper surface of the desk structure should be covered with a smooth mar-free plastic laminate to facilitate writing.

3. Student Station Chair. The student station chair should meet the same requirements as given for the instructor station chair, with the exceptions that the student chair need not recline and have armrests, since it is only used for interaction with the keyboard and visual display unit.

4. Student Station Desk. The student station desk need not be as wide as the instructor station desk, and storage drawers are not necessary. The student station desk should be at least 760 mm (30 inches) wide, 914 mm (36 inches) deep, and 737 mm (29 inches) high. The desk should provide a minimum knee cavity height and width of 610 mm (24 inches) and 635

mm (25 inches), respectively. The upper surface of the desk structure should be covered with a smooth mar-free plastic laminate.

User-System Software Interface

Application: Instructor station and student station design.

Definition: Those aspects of a maintenance trainer computer system software design that support the student's/instructor's participation in trainer related information handling transactions.

Description: This feature addresses all aspects of user-system (i.e., instructor/student - trainer) interactions (information handling transactions) in terms of the software programs controlling those transactions. Specific elements of user-system software interface are: data entry, data display, sequence control, user guidance, data transmission, and data protection.

Elements of User-System Software Interface:

Data Entry - Student/instructor actions involving the input of data to a trainer's computer system. The complexity of data entry actions varies from positioning a cursor on a computer-generated display to having to control the format of data inputs as well as their contents. Data entry addresses cursor control (i.e., direction and position designation), text tables, data entry validation, modifications (correction or update), and graphics entries where applicable.

Data Display - Computer output of trainer data to a instructor/student. Data display software controls the type and amount of data displayed, organization of data, data coding, data format (e.g., menu structure, data generation, data suppression, and data modification).

Sequence Control - Instructor/student actions and/or computer logic that initiate, interrupt, or terminate transactions. Sequence control governs the transition from one transaction to the next.

User Guidance - Trainer error messages, alarms, prompts, labels, and more formal instructional material designed to facilitate the instructor/student interaction with the trainer.

Data Transmission - The exchange of information among system users with other systems. Remote lesson generation, modification, and/or scoring creates a data transmission requirement among instructors and course administrators.

Data Protection - Concerns the security of computer-processed data from unauthorized access, and from inadvertent destruction or modifications by users, and from computer failure.

Recommendation: Instructor station and student station user-system software interface designs must always incorporate relevant, established human factors display design principles as documented in MIL-STD-1472. The following are recommendations for the development of instructor station and student station software specifications:

1. Data Display. Both the instructor and student stations will have to support the display of data necessary for users to complete their respective tasks in the instructional situation. Both stations will also have to support certain display manipulations such as a moving cursor and reverse video.

2. Windows. The instructor and student stations will have to support the definition of text windows for the presentation of data. These windows should present data in a 80 column by 25 row format, with alphanumeric characters in upper and lower case, bolding, underlining, and vertically and horizontally defined lines, all available.

3. Text Displays. To be legible, text displays for both the student and the instructor station should adhere to the following constraints:

   a. Font Size - Text not presented as footer information should be readable from a distance of no less than three feet. Footers should be legible from at least 24 inches.

   b. Line Width - A text line should not be longer than 95 percent of the screen width, and preferably it should have margins of 5 character spaces on each side.

   c. Line Breaks - Text lines should not be broken with the hyphenation of a word. A screen display should not terminate with either a partial sentence or paragraph.

4. Data Formats for the Instructor Station. The instructor station should be able to support the following data formats:

   a. Menu - This presents the choices the user has at a particular point in his/her interaction with the system

b. Table - A table presents information elements to be compared with each other.

c. Parameter Value Change Form - This is a form which allows the instructor to change the values of the training device's manipulatable parameters.

d. Message Edit Form - This is a form which allows the instructor to compose and send a message to the student.

e. Title - A title supplies information as to the content of of the data displayed upon the visual display unit screen.

f. Prompt Form - A prompt supplies the user with information concerning how to access or manipulate data.

g. Footer - Footer information can supply the user with a listing of his/her function key options or be a location to present system messages.

h. System Messages (error and confirmatory) - This is information indicating the state of the system.

i. Sign-On Form - This is the form which a user initially accesses in order to supply the system with his/her access identification information.

5. Menus. The following format rules pertain to menus:

a. A menu should consist of user choices lined up vertically; if possible, each item should appear on a separate line.

b. If there is adequate space within the frame, a line should be skipped between each menu item and the next.

c. Items in a menu should be sequentially numbered.

d. Menu items should be left justified.

e. A menu should contain no more than eight choices at one time.

f. A frame containing a menu should also include a title for the menu; prompting information for the use of the menu; a bounded, reserved field for the display of the user's choice; and a cursor to indicate the space available for input.

6. Tables. Tables should be used to present the following data:

   a. Student Performance - This is a table that updates itself whenever the student performs a behavior that affects monitored performance parameters.

   b. Student Profile - This is table that presents a student's cumulative performance at the conclusion of a training session. This table should be accessible at a later date and therefore should include information identifying the student and the lesson.

   c. System Status - This is a table that presents, as minimum data, the current state of the trainer in regard to parameter values and existing malfunctions.

Tables should conform to the following rules:

   a. A table should consist of labeled rows and columns and numeric values or text as entries for said rows and columns.

   b. Values should be vertically aligned with their column labels and horizontally aligned with their row labels.

   c. All numerical values contained within a table should be expressed to the same number of decimal places.

   d. Numerical values placed within a column should be vertically aligned with each other according to their decimal point.

   e. A blank line should be skipped between each row of values or text presented in parallel.

   f. A table should be left justified.

   g. A frame containing a table should include the following: a title for the table, footer information if it is needed, and additional text as appropriate.

7. Parameter Value Change Form. The following rules pertain to the formatting of the parameter value change form:

   a. The form should consist of a table of parameter names and current values. The values should be contained in fields reserved for data input.

b. The table should conform to the specifications for tables as stated above.

8. Message Edit Form. The message edit form should conform to the following rule:

a. The message edit form should consist of a bounded area reserved for data input, a cursor indicating the next space for character input, a prompt explaining how to input the message, a menu for selection of message presentation options, a title, and any applicable footer information.

9. Titles. Titles should follow these rules:

a. All titles should be horizontally centered above the information to which they pertain.

b. A major title identifying the information type being presented in the frame should appear at the top of the frame. Secondary titles should appear directly above the information to which they pertain.

c. All letters in a title should be capitalized.

d. A title should identify the information to which it refers by information content and format (e.g., TRAINING EXERCISE CONTROL MENU).

10. Prompts. The following rules pertain to information presented in prompts.

a. Prompting information should be expressed as a sentence or series of sentences which indicate to the user the procedures for accessing or inputting data.

b. Prompting information should appear below all data types other than footer information.

c. The second person imperative should be used in prompts to direct the user to take the required actions.

d. When the action required of the user includes the input of alphanumeric information, a bounded reserved data input field should be placed on the line next to the sentence in which the input action is stated.

e. When the action required of the user includes the activation of a switch controlled by a function key, said key should be written in all capital letters within the context of the prompt.

11. <u>Footers</u>. If footers are included, then they should fulfill the following requirements:

    a. Footers should be placed on the bottom line of a frame.

    b. Footer contents should be evenly spaced between the left and right frame margins.

    c. Footer information should consist of a list of functions currently accessible through function key action, their associated function key, and their current status.

12. <u>System Messages</u>. The following requirements pertain to system messages, both error and confirmatory:

    a. If there is no prompting information, messages should appear directly above footer information, or directly above the prompting information.

    b. Messages should be in reverse video.

    c. Messages should be written so as to convey the information needed by the intended user.

    d. Messages should be accompanied by a one (1) second tone in the 500-3000 Hz range in order to draw the user's attention to the screen. Said tone should be compatible with the acoustical environment in which the trainer resides.

13. <u>Sign-On Form</u>. Sign-on forms for the system should:

    a. Include the title of the training system centered at the top of the screen.

    b. Include a prompt requesting the user to input his/her Identification (ID) code, and a data input area with cursor to allow for entry of the code. Identification codes should <u>not</u> be echoed to the display upon input, to prevent data access control and security compromise.

14. <u>Data Formats for the Student Station</u>. The student station will need to support the following data formats:

    a. Menu - Same as for instructor station.

    b. Table - Same as for instructor station.

    c. Text Message - This is the information that the instructor composed as feedback for the student.

d. Title - Same as for instructor station.

e. Prompt Form - Same as for instructor station.

f. Footer - Same as for instructor station.

g. System Messages (error and confirmatory) - Same as for instructor station.

h. Sign-On Form - Same as for instructor station.

i. Miscellaneous Data Entry Forms - These are formats specific to the trainer and the information that the student is required to input during the course of a training exercise.

j. Tutor (optional) - The format of a tutor will be dependent on the type of tutor selected.

15. Text Messages. Text messages that are displayed at the student station should conform to the following rules:

a. Each line of message should not require more than 95 percent of the screen.

b. A message should be presented in the upper half of the text window, unless the student is currently displaying his/her performance record. In this latter case, the message should appear below the performance record.

c. Words should not be broken across lines.

d. Messages containing more than one line should be single spaced.

16. Miscellaneous Data Entry Forms. The formats for requests for data input specific to any instantiation of a trainer will be determined by the Contract, the Statement of Work (SOW), or the purchase order.

17. Tutor. The format of the information presented by the student tutor will be determined by the type of tutor that is selected. The determination of tutor will be dependent on the nature of the tasks being taught.

18. Display Manipulation Functions. Both the instructor and student stations should support the following data manipulation functions:

a. Reverse Video - Reverse video causes the background and character shades to be reversed from their normal relationship in a rectangular area completely containing the particular character. The video image of any character, line, or string should be reversible.

b. Moving Cursor - A cursor symbol should be utilized for two situations.

1) A cursor symbol should be available to move incrementally in horizontal and vertical directions across the display to any allowable character position.

2) Within a data input field, a cursor should point to the next available character field. In this latter use of a cursor, when a user inputs a character, the cursor should move to the beginning of the next field. When the user wishes to delete a character, the cursor should return to the beginning of the first character field made available by deletion. Each time the cursor symbol is placed, it should be erased from its previous location.

c. Hard Copy - The system should have the capability to make hard copies of information displayed upon the screen via a peripheral printer.

d. Blink - All displays should be flicker free-except in the case in which blinking should be used as a method to cause any designated character, line, or string to be repeatedly displayed and erased so as to create a blinking effect.

Information/Training Management

Information/Training Management refers to training device capabilities that allow the instructor to automate some of the training management functions via the trainer's computer system. The following six features are characteristic of this attribute:

1. Student/System Performance Monitoring
2. Performance Measurement/Recording
3. Report Generation
4. Student Tutoring
5. Training Exercise Control
6. Operating Procedures

Student/System Performance Monitoring

Application: Instructor station design.

Definition: A trainer computer system capability that automatically monitors (i.e., senses and records) student responses on a given training exercise.

Description: Performance monitoring is a training device capability that provides the instructors with the means to have the trainer's computer system monitor some, or all, of an exercise. These responses can be recorded and later used to review specific areas of difficulty that the student may encounter. This feature is a necessary prerequisite for the next two features: Performance Measurement and Report Generation. Providing an enable/disable capability on the instructor station allows the instructor to reduce the trainer's computer processing requirements when the feature is not needed. Specific elements of performance monitoring are sensing and recording student performance.

Elements of Performance Monitoring:

Sensing - A training device feature that enables the instructor to turn on or off the mechanisms which sense student responses and system indicators, or to select only those responses/indicators which are to be sensed for a given student exercise.

Recording - A training device feature that enables the instructor to turn on or off the mechanisms which record student/system responses, or to select only those responses which are to be recorded for a given student exercise.

Recommendation: The instructor station should support maintenance trainer performance monitoring capability. This enables the instructor to monitor selected student actions and maintenance trainer status (i.e., control positions and display indications) during an exercise. The monitor/record option should be selected from a top-level menu (see Human Factors Layout and Design section for guidelines on menu design), a secondary menu should appear which provides the instructor with options to turn the performance monitoring feature on or off and to select the actions to be monitored. For example, the instructor may select an option to monitor all troubleshooting tests and remove and replace actions made by the student as well as the corresponding trainer display indications (voltmeter, temperature gauge, etc.). The specific student actions and system status indicators to be monitored and recorded should be obtained from the maintenance trainer Prime Item Development Specification or Front-End Analysis.

Performance Measurement/Recording

Application: Instructor station design.

Definition: A training device capability that utilizes the trainer's computer system to compare each student response to a criterion measure, assign a score, and store the results.

Description. Performance measurement capability provides the instructor with a means of having the trainer compare and score student responses against a defined set of criteria, which can be modified by the instructor. Specific elements of performance measurements are performance scoring and rating criteria control.

Elements of Performance Measurement:

Performance Scoring - A training device feature that enables the instructor to turn on or off the mechanisms which score recorded student responses, or to select only those recorded responses to be scored for a given exercise.

Rating Criteria Control - A training device feature which enables the instructor to adjust (change or modify) the values to which student responses are compared during scoring.

Recommendation: The instructor station should support the training device capability which compares each student response to a criterion measure, assigns a score, and stores the result. The instructor should be able to have the trainer automatically score student performance on relevant training dimensions such as: number of errors committed, number of tests made, number of component replacements, and time to completion for each task. The instructor station should allow the instructor to select the training dimension(s) which are measured. Further, the instructor station should provide the instructor with the capability to adjust (change or modify) the criteria (values student responses are compared to during scoring). By selecting the monitor/record option from the top-level menu, a secondary menu should be presented which provides the instructor with options to turn the performance measurement feature on or off and to select the actions to be monitored and scored. Examples of specific parameters to be included in the performance measurement are the total number of errors, time to completion, and accuracy of adjustments. Performance measurement may be a feature of the student station when the maintenance trainer includes a computer-based student tutoring capability. The specific scores to be recorded and the criteria against which scores will be measured are obtained from the maintenance trainer Prime Item Development Specification or Front-End Analysis.

Report Generation

Application: Instructor station design.

Definition: A feature of the trainer which enables the instructor to turn on or off the mechanisms which report student responses and/or scores, or allows the instructor to select which responses or scores are to be reported.

Description: Report generation capability enables the instructor to generate, via the trainer computer, a report of student or class performance, or the performance of students over several classes. Using this trainer capability, an instructor can generate a report summarizing the results of statistical tests/measures of a student's performance in order to provide feedback to the student. Reports could also be generated to show the performance of a group of students over time or compare the relative performance of two or more groups (e.g., classes of students). Specific elements of report generation are summary reports and statistical profiles.

Elements of Report Generation:

Summary Reports - Reports providing summaries (typically in tabular form) of student performance measures.

Statistical Profile - Reports providing summaries, averages, and/or trends of training performance in order to compare the performance profiles of two or more training classes or groups of students.

Recommendation: The instructor station should support the training device capability to generate, via the maintenance trainer computer, a report of student or class performance, or the performance of students over several classes. By invoking this maintenance trainer capability, an instructor should be able to generate a report summarizing the results of statistical tests/measures of a student's performance. Reports should also show the performance of a group of students over time or compare the relative performance of two or more groups (e.g., classes of students). Summary reports should provide summaries of student performance measures in tabular form. Statistical profiles should produce reports providing summaries, averages, and/or trends of training performance in tabular form. Student scores and class summary statistics should be presented via a printer or visual display unit at the instructor's discretion.

Student Tutoring

Application: Student station.

Definition: A computer-based instruction capability that provides pre-programmed student training exercises via the trainer's computer system.

Description: Student tutoring is a training device capability that enables the student to practice, usually at his/her own pace, pre-programmed exercises. This feature enables the student to select remedial training in areas of weakness, and delve deeper into areas of interest. Specific elements of student tutoring are lock step tutorials and self-paced tutorials.

Elements of Student Tutoring:

Lock Step - Tutorial presented at a pre-set rate.

Self-Paced - Tutorial in which the student can proceed at his/her own pace.

Recommendation: The instructor station should support the training device capability that enables the instructor to provide computer-based instruction/tutoring, only when this capability is present in the maintenance trainer. If the maintenance training has a tutoring capability, it should be initiated and controlled from the instructor station via the top-level menu. A secondary menu should appear which provides the instructor with choices available for the maintenance trainer student tutoring feature. For example, the instructor may be able to select either remedial training in areas of student weakness, or allow the student to select areas of interest to explore. Other options that could be selected from the student tutoring menu are lock step (tutorial presented at a pre-set rate) and self-paced (tutorials in which the student can proceed at his/her own pace). The maintenance trainer Prime Item Development Specification will specify the student tutoring options to be presented on the instructor station.

Training Exercise Control

Application: Instructor station design.

Definition: A training device capability that enables the instructor to perform one or more of the following: generate training exercises, select from a set of pre-programmed exercises, or modify existing training exercises.

Description: Training exercise control provides the instructor with a means of flexible control over the creation and modification of training exercises. Specific elements of training exercise selection are training exercise generation and training exercise modification. Modifications enable the instructor to update training exercises in order to keep current with changes in the system(s) for which training is being provided.

Elements of Training Exercise Control:

Training Exercise Selection - An instructor station capability that enables the instructor to select any of a number of pre-programmed training exercises for presentation to the student.

Recommendation: This feature should require a minimum of programming experience or training from the instructor. This feature should enable the instructor to select, modify, and/or generate training exercises by selecting the training exercise control option from the top-level menu. A secondary menu should present the instructor with the training exercise control options. This feature should allow the instructor to select an exercise from a set of pre-programmed exercises, generate new exercises, or modify existing exercises. The specific exercises to be included in the exercise selection menu would be obtained from the maintenance trainer Prime Item Development Specification or Front-End Analysis.

Operating Procedures

Application: Instructor station and student station design.

Definition: The procedures to be executed for the purpose of controlling the instructor station or student station.

Description: Operating procedures refer to the procedures and functions performed to operate the instructor/student station. This includes controlling exercises from the instructor station and performing exercises on the student station. Specific elements of operating procedures are: instructor station operating procedures and student station operating procedures.

Elements of Operating Procedures:

Instructor Station Operating Procedures - The sequence of steps an instructor must follow and actions that he or she must execute to control functioning of the instructor station.

Student Station Operating Procedures - The sequence of steps a student must follow and the actions that he or she must execute to control functioning of the student station.

Recommendation: Lengthy (i.e., time consuming and complicated) instructor/student station operating procedures make demands on valuable training time and could cause instructors and students to become frustrated with the trainer, thereby negatively effecting their acceptance and utilization of the device. Whenever possible, it should be specified that instructor station operating procedures shall require a minimum of instructor action to select a training management procedure or an instructional feature. Similarly inputs on the student station should require a minimal amount of data entry; e.g., inputting a number or letter to indicate a selection from a menu of optional inputs, rather than typing in words or sentences.

Instructional Features

Instructional features are trainer mechanisms and their associated software programs which enable the instructor to control critical aspects of the learning environment, such as presentation of stimuli, reporting and scoring of responses, presentation of augmented feedback messages, and selection of the next activity that the student is to be engaged in. The following are instructional features.

1. Student Sign-in Capability
2. Malfunction Insertion/Selection
3. Feedback Control
4. System Parameter Control
5. Training Mode Control

Student Sign-in Capability

Application: Student station design.

Definition: A training device capability which enables the student to identify himself/herself (usually for recordkeeping purposes) by entering his/her name or an identification number into a file in the trainer's student monitoring software program.

Description: Student sign-in is a training device capability which uses the student's sign-in code (e.g., name or ID number) to create a file, or open an existing file in the trainer's student monitoring software program. The student typically signs-in by entering his/her name, ID, and sometimes lesson or exercise number into the trainer's student monitoring program via a keyboard. Specific elements of sign-in are student identification and lesson identification. If a trainer is going to record, score, or report student responses, and if responses are going to be stored for future reference, then a sign-in capability is a necessary feature.

Elements of Student Sign-in:

Student Identification - Name, number, or other code identifying the student about to practice on the trainer.

Lesson Identification - Name or number of lessons or exercise(s) to be practiced.

Recommendation: Whenever it is determined that the maintenance trainer is to have performance measurement or report generation capability, a means of student identification shall be provided on the student station. This could be provided by means of a keypad to enter a numeric code (e.g., identification number) or alphanumeric keyboard to enter names, if required.

Malfunction Insertion/Selection

Application: Instructor station design.

Definition: A training device capability which enables the instructor to create and/or select the malfunctions to be presented to the student at any given time during an exercise.

Description: This capability enables the instructor to create malfunctions or insert pre-programmed malfunctions. Malfunction conditions can also be created by mechanical means on some maintenance trainers; e.g., the instructor can set switches on the back of the trainer or replace an operational LRU with one that is defective. Specific elements of malfunction exercise selection are malfunction creation and malfunction selection.

Elements of Malfunction Insertion:

Malfunction Creation - The setting of system parameters, either through software control, or by setting switches or replacing LRUs, to create a malfunction condition within the training exercise.

Malfunction Selection - The selection of a malfunction condition for a given training exercise from a list or menu of pre-programmed malfunctions.

Recommendation: For most maintenance trainers, malfunction insertion is a necessary instructional feature. The instructor station should allow the instructor to select the malfunction option from the top-level menu, which in turn would present a menu of malfunction options. Most instructors consider malfunction creation to be a very desirable feature. The instructor station should support this feature by including it as an option on the Malfunction menu. When included, this feature shall allow the instructor to create new malfunctions via the trainer computer software. The actual malfunction to be included and must be obtained from the maintenance trainer Prime Item Development Specification.

Feedback Control

Application: Instructor station design.

Definition: A training device feature which provides the student with feedback messages; i.e., knowledge of results information, usually via a video display screen.

Description: The instructor station should support the training device capability which enables the instructor to present messages (e.g., error messages), enhance stimuli (e.g., display bold text for critical message segments), enhance response feedback (e.g., provide auditory beeps or tones in response to incorrect student responses), and enable student performance results presentation to be displayed on the student station. Elements of Feedback Control are On/Off Feedback Control, Select Feedback Control, and Feedback Message Adjust.

Elements of Feedback Control:

On/Off Feedback Control - A trainer capability which enables the instructor to turn on or off the feedback messages option.

Select Feedback Control - A trainer capability which enables the instructor to select the type of feedback messages presented to the student during a given exercise.

Feedback Message Adjust - A trainer capability which enables the instructor to adjust (change or modify) feedback messages presented to the student during a given exercise.

Recommendation: Feedback control capability should be included in the instructor station. Feedback messages should provide the student with information on the correctness of his/her inputs to the trainer. The nature and the comprehensiveness of the feedback messages is determined during the training requirements analysis and can vary from a buzzer indicating an error, to a detailed explanation of the error and related information displayed on a video screen. The instructor should be able to select the feedback control option from the top-level menu which would result in the presentation of a secondary menu which would provide the instructor with the menu of feedback control options.

System Parameter Control

Application: Instructor station design.

Definition: A training device feature which enables the instructor to set system parameter values prior to the exercise, or to input system parameter values during an exercise.

Description: This feature enables the instructor to set or change the value of parameters of the simulated system such as pressure, temperature, voltage, force, etc., in order to test a student's troubleshooting skills, for example. Specific elements of system parameter control are parameter setting capability and parameter input capability.

Elements of System Parameter Control:

Parameter Setting Capability - Enables the instructor to set system parameter values before a lesson begins.

Parameter Input Capability - Enables the instructor to input parameter values during a lesson.

Recommendation: System parameter control capability should be an instructor station capability. This feature enables the instructor to set or alter the critical parameters of the equipment being simulated (temperature, frequency, voltage, etc.). The menu through which the instructor will access this feature can be combined with the Malfunction Insertion/Creation Control options to create a Malfunction/Parameter Modification menu as an option on the top-level menu. Selection of this menu would present a secondary menu on which all of the System Parameter Control and malfunction/parameter modifications would be presented.

Training Mode Control

Application: Instructor station.

Definition: A training device capability that enables the instructor to select the training mode--lock step, self-paced, free play, or demonstration--in which the student will go through the training lessons.

Description. This feature enables the instructor to set the training device to conduct exercises at a pre-set rate or to allow the student to proceed through the training exercises at his/her own pace. The demonstration mode presents the student with a pre-programmed lesson where the responses as well as the stimuli are under trainer control. Demonstrations are typically used to introduce the student to training material and/or to demonstrate trainer operation and capabilities. Specific elements of training mode control are lock step, self-paced, freeplay, and demonstration mode.

Elements of Training Mode Control:

Lock Step Mode - The training exercises proceed at a pre-set pace allowing the student a given interval of time within which to respond before the exercise is automatically terminated and the next exercise is presented.

Self-Paced Mode - Enables the student to conclude the present exercise and select the next exercise at his/her own pace.

Freeplay Mode - Allows the student to branch off in any direction during the exercise; e.g., the student can decide which of several paths to take when troubleshooting a fault.

Demonstration Mode - Provides the student with a pre-programmed demonstration of trainer operation and functions or familiarization with training lessons.

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