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Computer-Based Training Technology: Overview and System Selection Criteria

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Selection of computer-based training (CBT) technology is dependent primarily on the intended application. CBT system applications fall into six categories: informational, drill-and-practice, tutorial, simulation, inquiry, and intelligent. The types of hardware and software used for each of these applications are different, and selection criteria include such items as cost, training location requirements, required video quality, ease of operation, and numerous other factors. The most important point in system selection is to identify the training application first and then select the appropriate technology to meet the training need.

This document addresses the technologies that can be used in CBT applications. It gives an overview of the types of hardware and software that make up a CBT system, and discusses selection criteria for the various types of CBT systems.

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PREFACE

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J.R. Short
Head, Combat Control Systems Department

COMPUTER-BASED TRAINING TECHNOLOGY:
OVERVIEW AND SYSTEM SELECTION CRITERIA

1. INTRODUCTION

This document addresses the technologies that can be used in computer-based training (CBT) applications. It also discusses what the important considerations are when choosing between technologies for a particular application. The overall intent of the document is to provide the reader with an understanding of the major considerations in the CBT hardware and software selection process.

Section 2 describes the technologies available for CBT. It gives an overview of the types of hardware and software that make up a CBT system and discusses some of the alternatives a person doing system selection must consider when choosing between the available technologies available.

Sections 3 through 8 give guidance for hardware and software selection for the various types of CBT systems. The six types of CBT systems covered are:

- Informational CBT systems
- Drill-and-practice CBT systems
- Tutorial CBT systems
- Simulation CBT systems
- Inquiry CBT systems
- Intelligent CBT systems.

These sections describe each of these six CBT categories and discuss the considerations for choosing between them. The information presented assumes that the reader already has a specific CBT application in mind. This approach is taken because it is felt that the particular training problem should govern the entire selection process, from the primary decision that CBT is the best solution for the training problem to even minor details of system hardware selection. Each step in the selection process should dictate the next.

While this document is not intended to be comprehensive,* specific product examples are cited in many areas that are representative of the products or services being discussed. These citations are, by no means, endorsements of particular products or companies, but merely acknowledgements of popularity in the industry.

*See references 1 and 2 for more comprehensive works in this field.

2. CBT TECHNOLOGY

2.1 HARDWARE OVERVIEW

The hardware currently used for CBT applications is as almost as diverse as the applications themselves. The advances in technology of the entire computer industry are quickly adapted to specific CBT applications. These advances include computers, mass storage devices, peripherals, and particularly man-machine interfaces (MMIs). In this section, each of these categories is addressed, with particular emphasis on MMIs.

2.1.1 Computers

The word "computer" has become very generic in the industry. In this document, "computer" refers to the device that actually processes the data and generates output, and that most often consists of one or more central processing units (CPUs).

Computers used to be broken down into categories that described their size (e.g., micro, mini, mainframe, etc.). These terms also described the computer's power, at least in broad categories. With present advances in technology, these terms have all but completely lost their meaning in terms of computing power. Some modern computers, no bigger than a desktop computer (or microcomputer), can outperform slightly older computers in the minicomputer or even mainframe categories, particularly in the area of processing speed. For this reason, it is more accurate to describe computers in terms of capabilities, of which size is no longer an accurate indicator.

2.1.2 System Configurations

CBT systems can primarily be broken down into three categories; multi-user, single-user, and networked. A multi-user system (figure 1) consists of a central computer running two or more "dumb" stations ("dumb" indicates that the station has no independent processing power). The single-user system (figure 2) is a self-contained workstation or system with its own dedicated processor and peripherals, intended to train one student at a time. The networked system (figure 3) is a hybrid of the other two systems. In the networked system, two or more stations with individual processors and resources share those resources, and/or access a central resource facility that can contain both processing power and other peripherals.

2.1.3 Monitors

In most CBT applications, the selection of a monitor is a secondary consideration because monitors have become very much standardized into four categories. These categories are monochrome and color, in either interlaced or non-interlaced formats. It should be noted here that the computer itself must be capable of supporting the monitor chosen. Some computers require

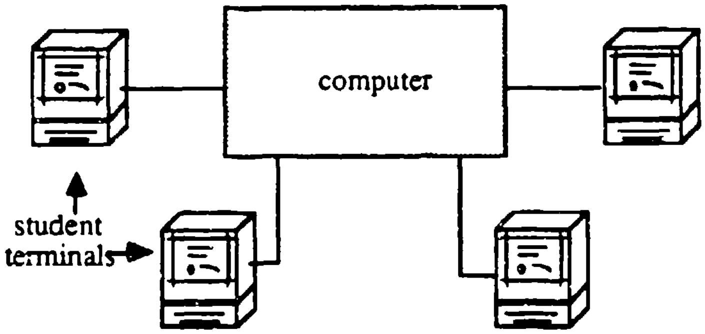

Figure 1. Multi-User CBT System

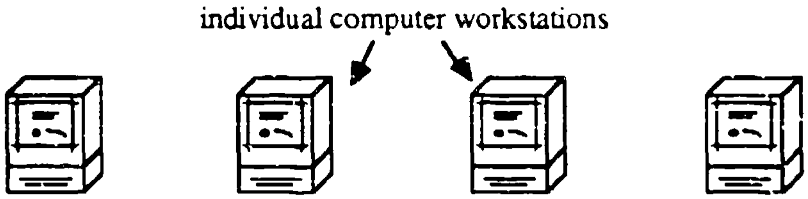

Figure 2. Single-User CBT System

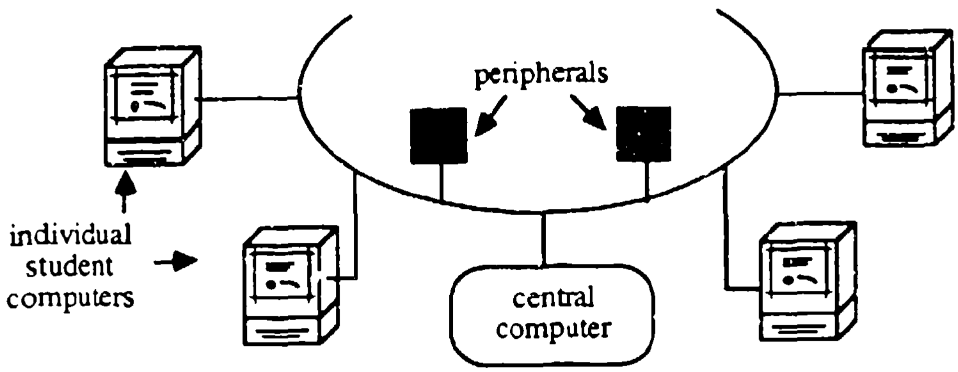

Figure 3. Networked CBT System

special options to support various types of monitors, while others cannot support certain types of monitors at all (this rule particularly applies to personal or small computers).

The most common monitors in present CBT systems are medium-resolution, interlaced color monitors. Such monitors have a resolution superior to that of a home television set (the standard IBM color resolution is 320 x 200 pixels) and a screen refresh rate of 30 Hz -- enough to give flicker-free performance. These monitors are adequate for most training applications. For applications where very high resolution color graphics are to be used, higher resolution equipment is available. In situations where high resolution is required but color is not, a monochrome non-interlaced monitor can give acceptable performance. This type of monitor (as found on the Apple Macintosh™) offers high resolution, high quality, and a 60-Hz refresh rate for flicker-free performance at a price comparable to or less than that of color displays.

The other two categories of monitors, monochrome interlaced and color non-interlaced, are both normally unacceptable for use in CBT systems, although for opposite reasons. The interlaced monochrome monitor is very inexpensive. However, in a CBT application, a person who lives in a world of color television can quickly become bored if presented with a crude black and white image. On the opposite side of the spectrum, the non-interlaced color display is an expensive alternative that is used only in applications where the 60-Hz refresh rate is considered an important factor.

2.1.4 Mass Storage Devices

The application of mass storage devices to digital information storage for CBT uses is, in most cases, no different from their application to any other computing task. Available storage media include magnetic tape, magnetic floppy disk, Winchester disk, optical disk, and, now becoming available, laser card. The choice between these media is primarily governed by storage needs and cost, with flexibility also a consideration. Table 1 lists some characteristics of these mass storage media.

CBT also often requires a source of video storage. This storage may take the form of either frame-by-frame or full-motion video, and must be randomly accessible by computer. Media that meet these requirements include 35-mm slides or microfiche (for frame-by-frame access only), videotape (which provides very slow access to full-motion sequences, with major limitations on still-frame capabilities), and video disk (which meets all the requirements but is relatively expensive, costing about $1000-$1500 to produce the master copy).

In certain cases, these two types of storage can be merged into a single format. The only storage medium capable of this task at present is the hybrid optical/video disk. While the technology has limitations right now, it is possible to put a complete course, both video and software, on a hybrid disk. This technology has a lot of potential for training applications and will surely become more widely used as the technology matures. This type of courseware is particularly useful when large quantities of the course will be distributed, since it necessitates the distribution of only one item. It is also conducive to quantity production because production costs of this type of media drop sharply as quantity goes up.

Another area in which CBT has great potential to expand is in the use of optical storage of digital information systems, such as optical read-only

Table 1. Digital Storage Media

Storage Medium	Size (inches)	Capacity (megabytes)	Cost (dollars/kbyte)	Access Speed
Floppy Disk	3 - 8	0.15 - 1.2	0.20 - 0.80	High
Winchester Disk	3 - 8	5 - 150	0.02 - 0.20	Very High
Hard Disk Pack	8 - 16	100 - 300	0.02 - 0.20	Very High
Tape	Varies	up to 200	0.02 - 0.05	Very Low
Optical ROM Disk	5 - 12	up to 2000	0.003 - 0.01	High
Laser Card	1.5 x 2	2 - 4	0.10 - 0.25	Low

memory (ROM, which is now available), write once-read many times memory (WORM, which also is now available), and an erasable/writable memory (still under development). As these very high density storage and retrieval technologies become perfected, technologies such as digital television and audio will become feasible for CBT applications.

2.1.5 Man-Machine Interfaces

The man-machine interface (MMI) is one of the most important single factors in CBT effectiveness. A good man-machine interface can act as a transparent interface between the student and the information being presented by the CBT system. On the other hand, a poor MMI will interfere with the information flow between the student and the CBT system, substantially reducing its training effectiveness.

While the monitor is the primary way for the computer to convey information to the student, there are other ways, usually in addition to the monitor, currently used with CBT. The most common of these are mockups of equipment panels and voice synthesis by the computer. Both of these are systems for computer output, and their technologies are straightforward. Even voice synthesis, in a reasonable quality, is available today for almost any computer. It is primarily application-dependent as to when the additional expense, and potential noise problem in a multi-student environment, are a worthwhile tradeoff for the advantages of voice synthesis.

The student input aspect of the MMI is at present the more complex issue as it relates to CBT. Table 2 lists input devices, all of which are used in currently operational CBT systems. Table 2 also gives an approximate price range for each type of device, which ranges from a standard keyboard (usually provided with the computer at no additional charge) to a voice recognition system, the most basic of which costs slightly under $1000, but which can have virtually unlimited development costs if a natural language interface is being implemented. When choosing between these devices for a CBT application, many factors must be considered. Factors such as application, screen design, operating environment, etc., must all be taken into account.

Table 2. Interface Devices

Interface Device	Cost
Joystick	Low
Light Pen	Low
Mouse	Low
Standard Keyboard	Low
Track Ball	Low
Custom Keyboard	Medium-High
3-D Equipment Mockup	Medium-High
Touchscreen	High
Voice Recognition	High

2.1.6 Hard-Copy Devices

Almost all CBT systems require some sort of hard-copy device to output student information, for both the instructor's and student's use. It is also a requirement on any system used for development work to be able to print out source code as it is being developed. In a multi-user or networked system, a single printer may be sufficient. In a single-user setup, one or more of the student stations must have a printer.

In choosing a printer for CBT applications, one must consider factors including printout quality, printout speed, printer reliability, and, of course, cost. Table 3 gives a comparison of the features and costs of the various types of hard-copy devices, all of which are commonly available.

Table 3. Hard-Copy Devices

Type	Cost	Speed	Resolution	Graphics	Color
Dot Matrix	Low-Medium	High	Low-Medium	Yes	Optional
Thermal	Low	High	Medium-High	Yes	No
Ink Jet	Low-Medium	High	Low-Medium	Yes	No
Daisy Wheel	Medium	Low	High	No	No
Laser	High	Medium-High	Very High	Yes	No
Pen Plotter	Medium	Low	Medium	Yes	Yes

2.1.7 Other Peripheral Devices

If a source of video images is going to be used with a CBT system, then a decision must be made as to whether separate screens will be used for the video and computer outputs, or whether all displays will be shown on a single monitor. If the latter is the case, the system will require a keying system, a device that overlays one video signal on another. These systems are available off-the-shelf for most computers, and have various features depending on price. Keyers for microcomputers are generally in the $500-$1500 price range and often fit inside the host computer. They enable the system to place computer-generated text and graphics on top of a standard video signal coming from a videotape or videodisk machine, and permit the combined signal to be shown on a standard monitor.

2.2 SOFTWARE OVERVIEW

Software designed for CBT applications can be broken down into three major categories: authoring languages, authoring systems, and training management systems. Software in each of these major categories has been designed to run on any size system, and is available off-the-shelf for many systems.

The primary limiting factor for features and capabilities in CBT software is not hardware capability but software cost. This is a generalization and, like most generalizations, has some important exceptions. The major determinant of software cost is the marketing strategy of the company that produces the software. Some software producers place a very high value on their products, expecting to sell licenses in small numbers; others price their software for volume selling.

Another important consideration in the procurement of software for CBT is how the software is sold. There are three ways in which producers usually market their software: leasing of licenses, sale of compiled code, and sale of source code. If the software is leased, yearly payments are usually made to the software company, and the lessee cannot modify the program. The sale of compiled code involves a one-time payment, but also does not allow for modifications by buyers, leaving them locked in to the exact format the software gives. Finally, the most desirable option for the consumer is the sale of source code. Not only do buyers own this software, but they can modify it to suit any particular CBT application.

2.2.1 Authoring Languages

A programming language is software that allows the programmer to direct the computer to execute a series of specific commands, entered into a computer in a specific format. An authoring language is a programming language designed specifically for CBT courseware development. Authoring languages have a special set of commands that are optimized for CBT and that allow for maximum capabilities and flexibility when CBT is being developed. A list of examples of common CBT software including languages is given in table 4.

Table 4. Common CBT Software

Name*	Type	Hardware	CBT Management
Authority™	Authoring System	Microcomputer	Included
TenCORE™	Authoring Language	Microcomputer	Capable
MicroTICCIT™	Authoring System	Micro & Mini	Included
PLATO™	Authoring System	Microcomputer	Included
SuperPilot™	Authoring Language	Microcomputer	Capable
WISE™	Language and System	Microcomputer	Included
AIS-II™	Authoring System	Main Frame	Included

*Authority™ is a trademark of Interactive Training Systems Inc.; TenCORE™ is a trademark of Computer Teaching Corp.; MicroTICCIT™ is a trademark of Hazeltine Corp.; PLATO™ is a tradema k of Control Data Corp.; SuperPILOT™ is a trademark of Apple Computer Inc.; WISE™ is a trademark of Wicat Corp.; AIS-II™ is a trademark of McDonnell Douglas Corp.

2.2.2 Authoring Systems

An authoring system is software designed to allow a non-programmer to develop CBT courseware, or to allow for the quick development of courseware. An authoring system is easier to use than an authoring language but may trade off either features or flexibility or both to achieve this ease of use. Authoring systems are often menu driven and do not require any special knowledge to operate. Often, an authoring system will lead the user through the development process, presenting the developer with a "fill in the blank" style of course design.

2.2.3 Management Systems

A CBT management system is software designed to do tracking and other helpful management functions during and after the execution of courseware. A management system performs such functions as student grading, maintaining student progress files, and keeping track of the time a student spends on the system. Most often, CBT management systems are built into authoring systems and can be implemented with authoring languages.

2.3 HOW CBT IS USED

2.3.1 Shore-Based Training

Many of the military applications of CBT are in the area of tactical operator training. This type of training usually is delivered in either a textual style of questioning by the computer with student-entered responses, or by a CBT system simulation of the actual piece of equipment the student is being trained for. In the world of military training applications, the more common of these techniques is the latter.

With CBT equipment simulation, relevant gages, switches, etc., or relevant CRTs are mocked up through the use of either computer-generated graphics or videodisk-recorded images, which are shown on the system's monitor. An example of this type of training is the Navy's Portable Aircrew Trainer (PAT), based on a Regency single-user CBT system.

The PAT is a good example of the military use of CBT. This device is designed to train the tactical coordinator (TACCO) for the P-3 ASW aircraft. It has a modified keyboard to reproduce the functions of the keyboard on the actual TACCO console and shows a display similar to that found on the actual console. The system operates in real time and allows the trainee to perform most of the operations for which he is responsible onboard. The emphasis of this trainer is on tactics and correct search and prosecution of a submarine target. The system allows the trainee to launch sonobuoys, give the aircraft pilot a new course or pattern to fly, and fire weapons. The system then evaluates the performance of the trainee, including whether or not he hit the target.

Another very common military application of CBT is in the area of maintenance training. Maintenance training lends itself to CBT because of the expenses involved in training on actual military hardware. CBT is used as a practice medium so that when a trainee sees the actual equipment he will already have a good knowledge of the equipment, including having done simulated repair procedures on it. This arrangement creates far less wear and tear on the actual equipment; it also allows schools to speed up the training process, since the trainees require less time on the heavily scheduled actual hardware. Most computer-based maintenance trainers being developed today use videodisk-generated images, along with computer-generated graphics. Examples of this type of system include the Cubic maintenance trainer currently used by the Navy, and the Army's Electronic Information Delivery System (EIDS), which is still under development but is expected to be distributed in large numbers.

2.3.2 Onboard Training

The trainers described above are examples of stand-alone classroom trainers. CBT is also used by the military for onboard or field training. The technology in the area of onboard CBT has not yet been developed to the same extent as shore-based CBT; however, this is an area that holds great potential. Some onboard CBT systems are already in use, and many others are sure to follow as the technology becomes more established in the classroom.

One example of onboard CBT is a maintenance training system aboard the USS CARL VINSON (CVN-70), a nuclear-powered aircraft carrier. The system aboard the VINSON uses a microcomputer and videodisk system to train new personnel on the maintenance of the elevator system aboard the ship. The technology used in the implementation of this system is quite old, but it proves that such training can be done onboard.

2.3.3 Potential for CBT

The potential for onboard CBT extends beyond sit-down training. Other areas in which the types of systems currently being considered could be applied include maintenance and troubleshooting assistance, and even tactical aid and advice. Many of these systems will use expert-system-type knowledge bases to act as an "expert" trainer. It is a short step from an expert CBT system in a subject to one that can use the training ability and expert knowledge base in actual situations.

2.4 WHAT CBT CAN DO

As discussed earlier, CBT has applications in almost all areas of military training. This includes both onboard and land-based training in areas such as maintenance training, tactical operator training, and various required skills training. However, in selecting an application area for CBT, care must be taken not to expect too much from a CBT system.

In the areas of tactical operator and maintenance training, CBT is best used as a training aid to support actual equipment. Students can spend time becoming familiar with actual equipment, without having to actually study or operate the tactical hardware, time on which can be very expensive. In its present state of technology, CBT can come very close to actual equipment training; however, it cannot replace it. A CRT showing a piece of equipment cannot fully prepare a trainee to do complex repairs or procedures on a tactical console the first time he sees it.

The previous statement is not meant to imply that CBT does not have advantages over actual equipment training. In addition to cost savings, CBT can provide the beginning student with a much more forgiving environment in which to become familiar with the equipment. This might mean that if a student learning maintenance forgets to disconnect a line cord, instead of receiving a shock, he receives a computer-generated warning to that effect. In the tactical sense, CBT can concentrate a beginning student's attention on a single detail of the display or console, a luxury not afforded him when he is sitting at a fully functional piece of tactical equipment.

In the onboard situation, a CBT system can aid training in the maintenance and tactical areas in many ways. As stated previously, expert system technology will allow a training system to act as an advisory system in many situations. Such a training system could also train people to handle new jobs, as well as prepare them for a return to a shore-based school. An onboard CBT system could also aid experienced people by giving them refresher training or update them on new procedures or equipment.

Finally, an onboard CBT system could also act as an information delivery and storage system, maintaining documents and manuals for easy reference in a digital storage format. This type of system could instantly call up any page of any manual desired, and produce a hard copy of the manual if necessary. The system might even include "help" features to explain manuals or repair procedures, integrated as part of its CBT capabilities. Such a system would greatly reduce the load of paper carried aboard a modern ship, and make that paper into an accessible data base.

3. INFORMATIONAL CBT SYSTEMS

According to the Air Force CAI [computer-aided instruction] Decision Handbook (reference 2), informational CBT/CAI systems serve the following purpose:

> Information can act as part of the instructional process without being specifically instructional. For example, during a group-paced lecture it may be important to demonstrate or elaborate on an instructional point. The instructor can use a microcomputer and large screen monitor as a kind of electronic blackboard or dynamic slide to show a graphical representation of a process or a set of procedures. Factual information can be available as an addition or adjunct to the instruction either under lesson control as a prompt to the student or under learner control as an optional help. In the course of a practice or problem solving session, the student may require factual information in order to work towards a problem's solution, e.g., the problem may require that the student refer to manufacturers specifications.

In this section, the types of technology and hardware/software that can be considered applicable to this type of instruction are discussed, with particular attention paid to the considerations for their selection for a specific CBT application.

3.1 INFORMATIONAL CBT SYSTEM HARDWARE

The informational system described above is a rudimentary form of CBT, requiring very little computer capability to be achieved. Almost any computer system on the market today could be utilized for this simple type of training, as long as it meets a few basic requirements. These requirements in terms of capabilities include:

- Central processing unit (CPU),
- Internal memory -- both permanent (usually ROM) and volatile (RAM)
- Operating system
- Capability to generate either video or printer output
- Mass storage system.

The minimum capabilities available on a standard, off-the-shelf computer usually include at least the following:

- 8-bit CPU (minimum industry standard)
- 64K bytes of RAM (can be less than 64K for strictly electronic blackboard applications)
- ROM as required for system operation
- Video generation or printer output capability or both.

Additionally, a mass storage system, often consisting of a floppy disk drive is added to the system.

These capabilities are all that are required for the computer in an electronic-blackboard-type training system. However, in other applications at this level of CBT, these may be insufficient to meet the needs of the training problem. A situation where these requirements may not be sufficient is the case of an informational-type system where a student might be required to look up a set of specifications using a computerized data base or information delivery system. In this case, 64K bytes of RAM may be insufficient to allow for rapid search through large quantities of information. Another possibility in this type of application is that the capacity of a floppy disk will be insufficient to provide all the necessary information. In this case, a Winchester-type hard disk is often used. The capacity of the Winchester drive is many times greater than that of a floppy disk (see table 1) and allows the computer to retrieve information faster than with a floppy disk.

When selecting a monitor for this type of application, one must first consider if the system will be used as an electronic blackboard. If the system will be used in this fashion, it is likely that a large-screen display will be required. In selecting a large-screen display, the primary considerations are bandwidth and light output. A projection television set must have a bandwidth sufficient to reproduce clearly an 80-column computer-generated screen of text. This requirement, which many home projection televisions cannot meet, is essential for this application. Light output, the second requirement, must be sufficient to make the projected image visible at the chosen level of room lighting from any possible student location.

In the case of normal size monitors, almost any will meet these kinds of system requirements. Decisions must be made as to whether color is desired and whether a videodisk is to be used. If the decision is made to use color graphics or a color videodisk, then a color monitor with the correct inputs must be chosen. If it is determined that color is not required, then a monochrome monitor should be selected. (For more information on the monitors available, refer to section 2.1.3.)

Other hardware capabilities might also be required depending on the exact capability required by the user. For instance, if the student must refer to a schematic or other image that might be best stored as an image rather than as digital information, an analog image source is required. In most modern applications, this source would be provided through the use of a videodisk player. If a videodisk player is used, an additional monitor is required to show its images, or a switcher or keyer must be provided so that it may share the same screen with the computer's own output (see section 2.1.7). A videodisk player connected to an electronic blackboard system could allow the instructor to show recorded video or, with the appropriate hardware, to draw directly on top of a videodisk player image with computer-generated graphics.

3.2 INFORMATIONAL CBT SYSTEM SOFTWARE

A system as simple as an informational CBT system requires only a rudimentary level of software for most applications. Any one of the examples of common CBT software listed earlier in table 4 could easily be adapted for this type of use. All of the products listed in table 4 are designed to be capable of developing CBT systems at a much higher level of complexity than the informational-type system requires. Almost any language at all, and many software packages, could be used to develop such a system.

A particularly good example of software that would be well suited to application in an informational-type CBT system is the authoring language of SuperPilot™. SuperPilot™ is a simple to learn and use authoring language that has been designed for elementary CBT applications. It has provisions for lessons and graphics and has a built-in set of commands for running a videodisk player. Another feature of SuperPilot™ that makes it suited for application to a CBT system at this level is its price; a complete SuperPilot™ software package costs less than $100 for many microcomputers.

4. DRILL-AND-PRACTICE CBT SYSTEMS

According to reference 2, drill-and-practice-type CBT systems serve the following purposes:

> The rather stereotyped view of computer-assisted drill and practice is exemplified by problem sets of simple math facts problems or sets of multiple choice questions that quiz the learner about factual information. However, drill-and-practice can be a good deal more sophisticated. For example, even with facts, the computer can keep track of the facts that are most difficult for each student and adapt the questions to reflect the need for additional practice in particular areas. The drill-and-practice technique is commonly used to quiz students on nomenclature (e.g., parts of anatomy, parts of a vehicle, etc.) It is also used to drill students on parts of a process, e.g., what do you do after you have installed the condenser or what do you do after you have secured the patient on the stretcher, etc. Often, instruction may be delivered by instructors or another medium while the computer will be used for the drill and practice. Thus, drill-and-practice is often provided at the subtask level.

This section discusses the types of technology and hardware/software that are applicable to the drill-and-practice-type of instruction, with particular attention to the considerations for their selection for a specific CBT application.

4.1 DRILL-AND-PRACTICE CBT SYSTEM HARDWARE

A typical drill-and-practice CBT system has a higher level of hardware requirements than an informational CBT system. This difference is due to the greater amount of interaction with the student, the increased informational and record-keeping requirements, and the greater programming complexity involved.

The computer for the typical stand-alone drill-and-practice application is an 8-bit or 16-bit microcomputer, with 64K bytes or more of RAM, and a floppy or hard disk drive for mass storage. The microcomputer selection is governed primarily by the type of software being used and, for this reason, is a secondary consideration. The differences between the various computers are not significant at this level, making software selection a much more important factor.

Because most applications at this level will make use of color, a color monitor must be selected. However, it is still well within the application to use a good monochrome display, particularly if there will be little or no graphics or if a separate video source will be used and displayed on a separate monitor. (For a more detailed discussion of the considerations for selecting a monitor, refer to section 2.1.3.)

Another feature of this type of instruction is the use of video. In some applications (e.g., parts of a vehicle), an actual video image of the vehicle (rather than a computer-generated graphics image) might be desired. In this case, a source of video -- usually a videodisk player -- must be provided. If a videodisk player is used, it must be decided if individual screens will be used for the videodisk and computer outputs, or if a keyer or switcher (see section 2.1.7) will be used.

At this level of application, mass storage takes on increasing importance. The most commonly used mass storage device is the floppy disk drive, which is well suited to this type of CBT. The floppy disk has enough memory capacity to hold the software for a fair number of course hours for most courseware of this type. Floppy disks are also inexpensive, so that students can keep their own personal copies of the courseware, and their performance and records can be recorded on the same disk. In a networked system, a networked hard disk might provide courseware and have individual student records on it.

Another piece of hardware almost universally required as part of at least one system in a drill-and-practice CBT application is a printer. A printer is required so that, at the least, an instructor can make a printout of student performance records. Other potential uses include making a printout of an often used reference table or of a lesson for additional study. These printer uses do not require very high quality print; rather, speed and cost are the important factors. As can be seen by referring to table 3, a dot-matrix printer meets these requirements and, because of its low maintenance and supplies cost, is most often chosen for this kind of application.

4.2 DRILL-AND-PRACTICE CBT SYSTEM SOFTWARE

As is the case with informational CBT systems, it is possible to use almost any language to develop a drill-and-practice CBT system. However, a drill-and-practice-type system has various complexities that make a CBT software package more desirable than a non-CBT language. Either an authoring system or an authoring language should be used and, for many applications, a management system should be included as part of the software. The use of dedicated CBT software will usually provide for quicker and more simple system development, as well as allow for record-keeping functions without additional development.

The complexities that govern this choice are the CBT management tasks that are added to the software functions. As described in section 2.2.3, management systems allow the student's progress to be tracked by the computer for feedback to the student and the instructor when necessary. In a drill and-practice CBT system, these functions begin to become important, as there is an actual structure of CBT lessons. Because testing is an integral part of most CBT lessons, performance evaluation based on the testing is important in determining student progress. A management system that automatically aids in record-keeping can reduce the instructor's workload, as well as potentially increase the CBT's effectiveness. This increase in effectiveness comes as the CBT system can consult its records and evaluate (based on the student's performance) exactly which lesson segment the student should be studying.

Another reason for preferring CBT-dedicated software is the ease of lesson development that this type of software usually provides. When working with an evolving or frequently updated curriculum, or when instructors are doing their own software development, it is important that the courseware development process be simple and quick. Many of the authoring systems available are menu-driven to provide the non-programmer with a very easy-to-use system; for this reason, they are particularly useful in applications where instructors are expected to do courseware development.

5. TUTORIAL CBT SYSTEMS

Regarding the purpose of tutorial CBT (CAI) systems, reference 2 has this to say:

> In tutorial CAI, the computer presents instruction. Frames of text and graphics are typically interspersed with embedded questions such as constructed answer, true/false, multiple choice, or matching questions. Immediate feedback messages and schemes (including branching to remediation or elaboration segments) are, in good measure, what makes the lesson a tutoring experience.

5.1 TUTORIAL CBT SYSTEM HARDWARE

Hardware selection for a tutorial CBT system shares many of the same considerations as hardware selection for a drill-and-practice-type system. As with almost all hardware selection criteria, the considerations are very much application-specific. In general, however, the factors discussed below, in addition to those specified in section 4.1, are particularly important.

In a tutorial application, particular attention must be given to the quality of video. This requirement derives from the fact that, with this type of CBT, the student is expected to spend more time in front of the monitor. For this reason, if the learning is to be as effective as possible, the student must be comfortable watching the CPT -- a consideration very much dependent on monitor quality.

The other factors of particular consideration in this type of instruction are computer speed and capacity. It is very important to the training that computer speed be adequate so as not to keep the student waiting in between inputs. It is extremely distracting and frustrating to have to wait after each screen of material while the computer grinds away at setting up the next one. Computer systems should be selected, and courseware should be designed, so that there is no more than a few seconds between any two screens.

5.2 TUTORIAL CBT SYSTEM SOFTWARE

As with hardware, tutorial CBT system software selection criteria are very similar to those for a drill-and-practice CBT system. However, in addition to the considerations called out in section 4.2, particular attention must be paid to selection of a language or authoring system that can deliver lessons in the format necessary to meet the application-specific training goals. Some applications are very flexible and may be taught in any number of lesson styles, while others have effectiveness that is dependent on the delivery style. It is up to the system designer to ensure that the hardware and software chosen can optimally deliver courseware to meet the training goals.

6. SIMULATION CBT SYSTEMS

Simulation CBT systems are designed to mock up a particular piece of expensive, scarce, or potentially hazardous equipment. They can also be used to place a trainee in a simulated hazardous situation or in one that is not convenient to duplicate in a training environment. Simulation-type CBT is very useful because it not only allows the trainee to practice required actions, operations, or decisions, but often holds the trainee's attention better than ordinary class presentations or even lesson-type CBT.

6.1 SIMULATION CBT SYSTEM HARDWARE

Hardware selection for simulation systems is more critical than for the other types of CBT. This is so because simulation applications generally impose heavy processing requirements on computing equipment, as well as because of the important role the hardware plays in the delivery of the training. The following areas are the most important in the hardware selection process.

6.1.1 Computer Requirements

The primary requirements for the computer used in simulation-type CBT are in the same areas as most computer requirements: processing speed and memory capacity. Once again, these requirements are very much application-dependent; however, depending on the complexity of the simulation and the complexity of the displays, a computer ranging from a small microcomputer up to a large mainframe computer might be required.

6.1.2 Storage Requirements

Many simulations deal with large quantities of data that are required both to maintain the simulation and to act as a historic data base. These circumstances usually require real-time storage and retrieval of information from a mass storage device. In most applications, a hard disk pack or Winchester drive must be used to meet these speed and capacity requirements. With simple simulations and a large computer, it might not be necessary to have the capacity and speed provided by a hard disk; but this is the relatively rare exception. If it is determined that historic data need not be maintained, and if other record-keeping functions can be minimized, a floppy disk might be an acceptable storage medium.

The large data base associated with simulation CBT systems is often required to store initial conditions for a number of scenarios to be run by the simulator. The initial conditions for a simulation can often require many kilobytes of data, leaving little room on a floppy disk for historic data storage. A hard disk with its high storage capacity is usually sufficient to maintain all necessary information. One alternative approach is a combined floppy/hard disk system, having at least one of each type of drive. On this type of system, the scenarios and operating data are kept on a hard disk, permanently connected to the computer, while specific student records are kept on a personalized floppy disk that the student brings to the training session.

6.1.3 Monitor Requirements

A primary consideration when choosing a monitor or monitors for a simulation system is the level of detail to be shown on each monitor. If a simulation will be displaying detailed computer-generated graphics, then a flicker-free, high-resolution monitor will be required. If all the simulator will show is text and composite video (from videodisk or tape machine), a low- or medium-resolution monitor will be sufficient. (A more detailed discussion of the various types of monitors available is given in section 2.1.3.)

The other major consideration in monitor selection for simulation CBT is monitor size. Again, this is very much application-dependent. The main concern is that the simulation be realistic. If the simulation is a mockup of a piece of tactical equipment, the monitor should not be smaller than the one in the actual piece of equipment, so as not to cause negative training (e.g., trainees learn to look for something in the wrong location in a simulation and must relearn to look for it when they try to use the actual equipment). The monitor screen should be a different size from the actual equipment's screen only when less information will be displayed on it or when the information will be displayed in a different fashion.

6.1.4 Man-Machine Interface Requirements

Another very important consideration for simulation CBT is selection of the optimal man-machine interface. Section 2.1.5 describes the interfaces available and their basic capabilities and requirements.

When selecting a man-machine interface, the system designer must keep in mind the training task and the student's environment. If a simulator is being designed to train the operators of a piece of hardware that uses a light pen input, it is likely that the most desirable interface for the trainer would also be a light pen. This rule is not necessarily a universal one, but it often holds true. One case where it might not apply is where the simulator is designed to teach only a simplified version of a task. In such a case, a more simple man-machine interface (e.g., a touchscreen) might replace a keyboard. Again, however, the designer should be alert to negative training problems.

6.2 SIMULATION CBT SYSTEM SOFTWARE

Simulation CBT system software is quite different from the software for the types of CBT discussed previously. This difference is due to the fact that a simulation application involves software that is, for the most part, application-unique. For this reason, most simulation systems must be written in a more conventional computer language. The choice of language is primarily dependent on the nature of the simulation and the experience of the developers.

The software for a simulation system must include the simulation portion of the software, a scenario to run on the simulation, an interface with the trainee, and whatever record-keeping functions are deemed necessary. The development of all these modules is almost never a trivial task and should not be underestimated.

7. INQUIRY CBT SYSTEMS

Reference 2 addresses inquiry CBT (CAI) systems as follows:

> The unique quality of inquiry CAI is in who defines the objectives of the instructional event: the student or the course developer (from the specialty training standards). In the case of inquiry, the student controls the interaction or dialogue; in tutorials, objectives have been defined by the author or developer (although the means for reaching the objectives may be as flexible as in intelligent CAI or as relatively inflexible as in very linear tutorial CAI). Inquiry CAI as opposed to information CAI is an interactive instructional experience in which information, concepts, and/or rules may be supported with examples, after which practice may be available at the user's, i.e., the learner's, discretion.

7.1 INQUIRY CBT SYSTEM HARDWARE

The hardware required for an inquiry CBT system does not substantially differ from that required for a tutorial CBT system as described in section 5.1. The only effective differences are in the areas of computing power and man-machine interfaces. Slightly more computing power and memory are often required for an inquiry CBT application, since the inquiry portion of the system makes additional demands on the computer. The man-machine interface also is more critical in an inquiry application, as it handles a bigger task in the training process, allowing for more interaction between the machine and the trainee.

7.2 INQUIRY CBT SYSTEM SOFTWARE

As in the case of hardware, software requirements for an inquiry system are very similar to those for a tutorial system as described in section 5.2. Once again, though, there are added complexities in the software involved in an inquiry system. The inquiry mechanism that allows the system to respond to student inputs cannot be implemented with all CBT software packages. If an authoring system is used, care must be taken to select one that is capable of inquiry type training. If an authoring language is used, additional development time must be allotted for the implementation of the inquiry mechanism.

8. INTELLIGENT CBT SYSTEMS

Intelligent CBT systems are decribed in reference 2 as follows:

> ...it is not easy to create courseware that emulates the one-on-one interaction of an instructional dialogue. Over the years, techniques have been developed that help approach this ideal. Taken collectively, these techniques are known as ICAI [intelligent computer-aided instruction].
>
> Specifically, it has been learned that in order to provide Socratic dialogues or meaningful coaching, three types of knowledge must be brought together and coordinated in the lesson. The first type of knowledge that is required is subject matter expertise. The computer itself must know how to solve what it is trying to teach just as a human teacher would. Second, an accurate model of the student's current state of knowledge is required. What does the student know, what does he or she not know, what misconceptions does he or she have? Finally, using the first two types of knowledge, the third component is invoked: the rules of how to conduct an instructional experience (the means to master the instructional objective). This knowledge includes when to ask questions, when to tell or illustrate, when to review, etc.

8.1 INTELLIGENT CBT SYSTEM HARDWARE

Hardware selection for an ICBT (intelligent computer-based training) system is governed primarily by the "intelligent" aspect of the system. As discussed previously, many different systems and configurations may be used for a tutorial or inquiry CBT system. The intelligent portion of an ICBT system has very specific requirements, particularly pertaining to computing speed and RAM. However, the ICBT system does not substantially differ from a tutorial or inquiry CBT system in its hardware requirements in other areas.

In the area of computing power, an ICBT system is very intensive. Intelligent systems use many iterations and take a lot of processing time to be effective. These factors force the requirement for a relatively powerful computer to be the basis for the system, particularly when the application is a real-time simulation in which there are very strict constraints on the amount of time the intelligent system can take to reach a conclusion.

RAM rqeuirements should be sufficient to hold in memory a good portion of the subject matter expertise (also called the "rule base"), in addition to the rest of the training software. This is necessary so as not to force frequent accesses to the mass storage system, a factor that usually substantially slows the speed of the system.

8.2 INTELLIGENT CBT SYSTEM SOFTWARE

The software requirements for intelligent CBT are split into two parts. One part of the software is not dissimilar from the software normally used for any particular type of CBT and is governed by the application, as described in the preceding sections. The other part of the software, or the "intelligent system," must be dealt with separately from the courseware or simulation portion of the CBT system.

Intelligent system software can be developed in two forms. One uses off the shelf software called a shell, into which the developer inserts the subject matter expertise in a form called a "rule base." This shell with a rule base residing within it comprises the intelligent system. If such a shell can be found that will interface with the training system, then this is a time-saving and efficient way to develop the system.

If no off-the-shelf shell that meets the requirements of the training system is available, then the developer must build his own. This process is a time consuming one that can add very large development times to a CBT project. The developer must start with a programming language and build a software "engine" to sort through the rule base in a logical fashion.

An intelligent system, as explained in the hardware section, is very much processor-intensive. For this reason, when selecting software one must choose a programming language or shell that is designed to run quickly. When dealing with languages, this usually means one that runs in compiled code and is good at doing iterative processes. The languages used at present for a very large portion of intelligent system development are Lisp, Prolog, and, to a lesser extent, "C". These languages meet the above requirements and can provide the developer with a fast enough system to run real-time applications.

If the entire training system must be developed in one language, tradeoffs will have to be made. While languages like Lisp and Prolog are optimized for intelligent system applications, they are not particularly well suited to general CBT tasks. For this reason, the developer may have to trade off intelligent system capability, speed, and ease of development for trainer capability, speed, and development time. Once again, the decision is dictated largely by the specific CBT application under development.

9. SUMMARY

The technology available to the developer of computer-based training systems is very diverse. It is difficult to know which of the many different types of products on the market is best for an application, or even which brand among equivalent products should be selected. Throughout the selection process, the system developer is faced with this kind of choice, which very often must be made solely on the basis of his particular set of requirements. This document has given an idea of the considerations involved in making these choices.

The most important factor in the technology selection process, as has been stated many times throughout this document, is the particular application for which CBT will be used. A developer of CBT cannot select a system and then look for potential applications of that system. If CBT is applied in this way, it will never achieve its potential gains in training effectiveness. The only way to maximize the benefits of CBT is to let the application dictate the development, and to make all decisions based on the training and financial requirements of the project.

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