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**The Evolution of Communication Technology:
Implications for Remote-site Training
in the Navy**

Henry Simpson

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13. ABSTRACT (Maximum 200 words) The overall objective of the project is to find more cost effective ways to train personnel who are geographically remote from instructional resources. Three surveys were conducted and, based on the findings, conceptual designs of Navy remote-site training systems were developed. By extrapolating from developments in communication technology, it is possible to envision a workstation of the future that integrates a computer, high-definition television display, facsimile machine, telephone, and other communication devices and that allows interactive two-way communication. The same developments in communication technology that make advanced multimedia workstations possible open up new possibilities for videoteletraining. Such classrooms will supplant a significant percentage of present day "live" classrooms and will be used by groups of people for the same purposes as live classrooms. The widespread use of videoteletraining has significant implications for the future mission and organization of the Navy training establishment.			
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FOREWORD

This technical note describes work conducted as part of the Navy Personnel Research and Development Center's Communication Networks in Training (CNIT) project in the general area of remote-site training. This work was performed under the sponsorship of the Office of Naval Technology. The CNIT project is one part of the Schoolhouse Training product line and falls under the Personnel and Training Technology (NP2A) Block of the 6.2 Mission Support Technology Program Element 0602233N (Work Unit RM 33T23.02).

The objective of this project is to find more cost-effective ways to train personnel who are geographically remote from training resources. This technical note surveys the technologies, research and development efforts, and Navy training environments in which the technologies might be used to export training. Conceptual designs of future Navy remote-site training systems are described.

The recommendations in this technical note are intended for use by the Chief of Naval Education and Training and OP-11 in developing policy for the application of advanced communication technology in the Navy.

W. H. WULFECK II
Director, Training Technology Department

SUMMARY

Background and Problem

A requirement currently exists to train Navy personnel who are geographically remote from instructional resources. Evolving communication technologies have the potential to reduce the impact of geography on training. For example, developments in compressed digital television have made it increasingly cost-effective and promising for training applications. Satellite and wide-bandwidth land-line links enable users at different locations to share training experiences and resources and essentially shrink global geography. The solution to the Navy's remote-site training problem lies in understanding the future course of these technologies and harnessing them for use.

Objective

The overall objective of the project is to find more cost-effective ways to train personnel who are geographically remote from instructional resources. The objective of the work reported in this technical note was to assess the applicability of new communication technologies to the solution of Navy training problems.

Approach

Three surveys were conducted and, based on the findings, conceptual designs of Navy remote-site training systems were developed. The surveys covered communication technologies, remote-site research and development efforts, and Navy instructional/training environments. The findings were then consolidated to identify possible uses of new communication technologies to resolve present and potentially growing Navy training problems.

Findings

Survey of Communication Technologies

Computer networking technology is strongly established and growing, although relatively little research has examined its use for instruction. The ability of networking to overcome geographic and time barriers appears to hold promise for instructional support and for information sharing among professionals. Current electronic mail network systems are evolving to enable communication that combines video, audio, and graphics.

Key trends in evolving communication technologies are networking and integration of communication and computer technologies; together, these trends suggest that future systems will allow two-way interactive communication using machines that combine the features of computers, high-definition television systems, facsimile machines, telephones, and other communication devices.

The state of the art of artificial intelligence technology is not yet able to support natural language interaction or to provide robust intelligent computer-aided instruction.

Survey of Remote-site Training Research and Development Efforts

The current project can capitalize on what is being learned in several other ongoing projects in related areas: the Army Research Institute's asynchronous computer conferencing and networked computer-based instruction projects, the Army's SIMNET project, various educational networks, and various videoteleconferencing and videoteletraining systems.

Survey of Navy Instructional Environments

The most severe training problems exist in shipboard/pierside training and in the Naval Reserves. In both cases, training resources and instructional expertise are in short supply; lack of time for training is a serious additional problem in the reserves. Problems in the correspondence course program and the Naval Postgraduate School are relatively minor.

Discussion

Workstation of the Future

By extrapolating from developments in communication technology, it is possible to envision a workstation of the future that integrates a computer, high-definition television display, facsimile machine, telephone, and other communication devices and that allows interactive two-way communication. Such workstations are a logical evolution of present day electronic mail and may be used by individuals to (1) participate in formally structured, group-paced training, (2) participate in self-paced instruction, (3) participate in conferences on topics of interest to professional groups, and (4) access technical resources or subject matter experts not readily available locally. The use of such workstations has significant implications for the future mission and organization of the Navy training establishment. These workstations may be used effectively not only by individuals, but by two or three students to maximize their effectiveness.

Videoteletraining in the Future

The same developments in communication technology that make advanced multimedia workstations possible open up new possibilities for videoteletraining. It appears that, because of their relative costs, group training with videoteletraining will become cost-effective earlier than will individual training with workstations. The videoteletraining classroom of the future will use the same media as the multimedia workstation: computers, high-definition television displays, facsimile machines, telephones, and other communication devices. Such classrooms will supplant a significant percentage of present day "live" classrooms and will be used by groups of people for the same purposes as live classrooms.

While the technology will be able to provide effective instructional transmission, instructional design procedures must be developed to ensure quality materials.

Mission and Organizational Implications of Technological Changes

The widespread use of videoteletraining has significant implications for the future mission and organization of the Navy training establishment. These include:

1. More training could be delivered remotely and less in resident schools.
2. The number of classrooms devoted to resident training could decline.
3. Schools could employ fewer personnel for training delivery and concentrate on development of quality training.
4. Schools will assume new roles as managers and repositories of a new generation of instructional resources.
5. Schools will manage the use of the network's resources for training-related purposes.

Future Efforts

The following suggestions for future efforts are based on the findings of the project to date.

1. The Chief of Naval Education and Training and the Naval Education and Training Management Support Activity should continue efforts to refine the Naval Education and Training Command videoteletraining system.
2. Chief of Naval Operations (OP-11) and the Office of Naval Technology should support research into the integration and cost effectiveness of advanced communication technologies for remote-site instructional delivery. The goals of this research would be to design and develop advanced videoteletraining classrooms and multimedia workstations for use in remote-site instruction in the late 1990s.
3. The Navy Personnel Research and Development Center should develop a laboratory for carrying out research concerning the optimal mix of technologies in remote-site training, use of visuals/graphics in video learning, and the instructional protocols that will maximize learning in the remote site training environment.

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INTRODUCTION

Problem and Background

A requirement exists to train Navy personnel who are geographically remote from training resources. This requirement exists throughout the Navy, but is perhaps most obvious for personnel aboard ships at sea. Shipboard training is limited by available training resources and the skills of shipboard trainers. By necessity, personnel are periodically assigned to formal schools to receive training that they cannot receive aboard ship. Strategic Homeporting is dispersing Navy ships over numerous small, graphically isolated ports. The remote-site training requirement also exists in the Navy Reserves. Reservists typically belong to small, widely dispersed detachments with limited training resources, few qualified trainers, and little time for training. The requirement to deliver training to remote sites is widespread and exists in the civilian as well as the military world.

Evolving communication technologies have the potential to reduce the impact of geography on training. For example, developments in compressed, digital television have made it increasingly more cost-effective and promising for training applications. Satellite and wide-bandwidth land-line links enable users at different locations to share training experiences and resources and essentially shrink global geography.

The solution to the Navy's remote-site training problem lies in the proper selection and use of new communication technologies. In general, these technologies are costly and constantly changing; new technologies appear regularly. Proponents of one technology or another proclaim the virtues of their favorite. Many technologies are in regular use; others, in demonstration projects. Investigators are exploring strengths, limitations, cost effectiveness, and other dimensions governing suitability for different applications. Unfortunately, there is no road map to follow to determine which technology is "best" in a particular application today and which one will be best next week, next year, or 10 years from now. The Communication Networks in Training (CNIT) project at the Navy Personnel Research and Development Center (NPRDC) is exploring different technologies, research and development projects, and the Navy's training problems in order to gain a better understanding of which technologies hold the greatest potential for future use in the Navy.

Objective

The primary objective of the CNIT project is to find more cost-effective ways to train personnel who are geographically remote from training resources. This objective is being addressed along four different tracks:

1. Assess the applicability of new communication technologies to the solution of training problems caused by geographic dispersal of training.
2. Develop, test, and evaluate an experimental, instructional support network based on computers.
3. Develop, test, and evaluate an experimental, two-way videoteletraining system.

4. Investigate the impact of alternative equipment configurations and training delivery methods on training effectiveness in a videoteletraining laboratory.

This technical note describes the work performed on track 1. Other documents will describe work performed on tracks 2 and 3 (Simpson & Pugh, in press; Simpson, Pugh, & Parchman, in press). The work performed on track 4 is commencing during FY90.

The work on track 1 is concerned with developing conceptual designs of future Navy remote-site training systems. This technical note describes three field surveys and, from the findings, develops the conceptual designs of two future systems: advanced multimedia workstations for individual use; and videoteletraining classrooms for group training and conferencing.

APPROACH

Overview

The project conducted three surveys and, based on the results, developed conceptual designs of future Navy remote-site training systems. The surveys covered communication technologies, remote-site training research and development efforts, and Navy remote-site instructional environments. The survey development and administration procedures are described in greater detail below.

Survey Communication Technologies

A literature review was conducted using the Manpower and Training Research Information System (MATRIS) and computer data bases for ERIC, the National Technical Information System (NTIS), and PsychInfo. Key topics and subtopics were remote-site training, evolving training and communication technologies (e.g., video, CD ROM, Hypertext), computer networking (e.g., networks in training/instruction, computer conferencing, new networking technologies), and artificial intelligence (e.g., intelligent computer-aided instructional systems, natural language processing, expert systems). Approximately 900 citations were located via the formal search. Promising articles were obtained and reviewed and a project bibliography was established. In addition, the most current information was obtained on some subtopics by attending conferences, and reviewing articles published electronically and in trade magazines.

Survey Remote-site Training Research and Development Efforts

To avoid duplication with other efforts and to determine how new communication technologies were being used elsewhere, we made a strong effort to identify projects using technologies that might be used for remote-site instruction. Contact was made with researchers in the Navy, Army, and Air Force training communities to discuss research agendas and projects.

Survey Remote-site Instructional Environments

Remote-site instruction is applicable in many possible instructional environments. The differences among the environments may be described along dimensions such as instructional content, group size, group-versus-individualized instruction, and instructional method used. A

small-scale survey was conducted of the following environments to identify training problems and their potential for solution with evolving communication technologies: Navy technical schools, Naval Reserve training, Navy correspondence course program, college- and graduate-level officer training, and shipboard and pierside training.

The survey was conducted by visiting representative sites, conducting telephone interviews, and reviewing documents relating to the particular environments.

FINDINGS

Survey of Communication Technologies

This survey focused on technologies that are candidates for incorporation into Navy remote-site training systems: computer networking, evolving communication technologies, and training and communication-related applications of artificial intelligence. The objective of the survey was to determine the current maturity of the technologies and potential for application in Navy remote-site training systems in the near term; that is, the next 10 to 20 years.

Computer Networking

Computer networking is defined, for purposes of this discussion, as linking separate computer nodes (e.g., terminals, workstations) such that files may be transferred among them under user control, stored locally, and accessed at will. The user's perception of what a network is depends upon its particular form, the system of rules built into the network governing who communicates with whom and under what conditions. Common forms of computer networks are electronic mail, computer bulletin boards, and computer conferences. An electronic mail system is typically used to provide one-to-one communication; a bulletin board, one to many; a conference, many to many. These forms may operate synchronously (in real time) or asynchronously (non-real time). Most networks do not transfer video, sound, or communication modalities other than text but this constraint is eroding rapidly with the advent of plug-in cards that enable computers to transfer facsimiles and still- or slow-frame video using fairly narrow bandwidth telephone lines; e.g., 64 kbps (kilobits per second).

Networks enable their users to communicate across both distance and time. Users do not have to be at the same location or working in the same timeframe; a message dropped into an electronic mailbox will be read where received when its recipient reads the computer mail. Networking links computers via local, regional, national, or worldwide networks which give their users access to the human and computer-based resources of the network.

Computer networks are a relatively recent phenomenon. They began in the early 1970s but have grown steadily so that presently they are accessible on most university campuses, government laboratories, and private firms involved in high technology and/or government contracting. Their primary use is for communication and information sharing and their primary users are technical professionals and managers.

To date, networks have seen limited use in education and training, although their use is growing. Relatively few studies deal with the application of networking technology to instruction.

Those that do are generally informal reports of case studies or loosely controlled studies with limited generalizability. For example, Barnes, Swehosky, and Laguna-Castillo (1988) report on a classroom experiment involving the use of a local area network to support a statistics course; students expressed a liking for the new method of instruction and their performance was on a par with classroom instruction. Levin and colleagues have experimented with the use of networks in elementary school classrooms. In one study, students in classrooms in the U.S., Mexico, Japan, and Israel were linked by network and participated in group problem-solving tasks (Levin, 1985; Levin, Riel, Miyake, & Cohen, 1986). The authors reported that the instructional environment with networks helped students understand problems more fully than they did in a conventional classroom.

In a related study, analysis of electronic mail traffic in a networked instructional environment found that instructor-student discourse had more strands and the discourse persisted longer than in the classroom (Quinn, Mehan, Levin, & Black, 1983). The Army Research Institute with its Asynchronous Computer Conferencing project (Richards & Phelps, 1987), which is described in detail later in this report, has recently conducted significant research in this area.

To date, most networks have been limited to the transmission of text data at fairly slow data rates (e.g., 64 kbps). As the technology matures and wide bandwidth links become more available, these networks become increasingly capable of communicating using other digital media such as video or facsimile.

Evolving Communication Technologies

Within the last few years, several technological trends have become apparent. Among the most important of these trends is the integration of communication and computer technologies (Grantham, Landauer, Mackay, & McNinch, 1988; King, 1988). The integration of technologies has many faces; for example:

- Increased use of digital rather than analog recording media such as digital compact disks replacing analog vinyl records.
- Development of digital, high-definition television.
- Increased popularity of CD ROM as an information storage medium for storing encyclopedias, telephone directories, software documentation, etc.
- Development of computers with high-resolution displays capable of presenting both video and computer output in separate windows.
- Development of techniques to compress video signals to permit transmission using relatively narrow communication bandwidths.
- Proliferation of fiber optic links for telephone, video, and computer data communication in place of copper land line, satellite, and microwave transmission.

One of the fundamental changes in communication technology is its transition from analog to digital transmission and storage methods. As this change progresses, communication technology

increasingly resembles computer technology and the differences between them diminish. These trends can be extrapolated in several directions, but, to keep the discussion within bounds, it is reasonable to consider two possible and likely directions.

1. Consider how such trends might be incorporated in a multimedia computer network of the future designed for use by individual users. Industry observers now predict the integration of high-definition television and computer technology with related communication media, printers, facsimile machines, telephones, and other devices that will allow two-way interactive communication, which will permit the delivery of various services over wide-bandwidth fiber optic links (Iversen, 1989). Based on such trends, one can envision workstations that are able to present computer text in one window, full-motion video in another, videotelephone communication in another as well as a spreadsheet or a simulation game with another computer in other windows. The technology is available today; creating the workstations is largely a matter of putting together the pieces. This has already begun with machines such as the NeXT¹ and latest Sun computers.
2. Groups of people, working with the same media, could use these technologies in conferences and classrooms. An example is videoteletraining/conferencing using compressed, narrow-bandwidth video signals among two or more sites. The increased availability of powerful, relatively inexpensive minicomputers (e.g., 80386-based microprocessor) combined with the development of algorithms to digitize and compress video signals have led to the development and commercial availability of a device called a coder-decoder (CODEC). The CODEC permits video signals to be transmitted using a fraction of the bandwidth of commercial analog video. Much of the cost of using video signals is the price of the transmission medium (e.g., satellite bandwidth and time). The advent of CODEC technology is dramatically reducing this cost and increasing the feasibility of using video in education and training; moreover, the cost continues to decline steeply with each passing year. In the past five years, the cost per unit has declined roughly by a factor of 10; and the required bandwidth for acceptable video, by a similar factor.

A middle position is possible. Practical experience with Navy students (both officer and enlisted) has shown that the cooperative learning that occurs among two or three students using a single computer workstation simultaneously can be equal to or more effective than the learning of one student working alone. This also would reduce the number of workstations required.

The major barrier to the use of communication technology in training is the cost of the transmission medium. The wide bandwidth links needed to transmit the amount of data necessary to generate video signals require essentially the same communication media as commercial broadcasting (i.e., satellite, microwave, infrared, and fiber optic links). These media are expensive today, although there is reason to believe that fiber optic links will proliferate and cost less in the future. How rapidly this cost will decline is uncertain.

At the present time, potential users continue to debate the relative merits and costs of satellite versus terrestrial communication links. Each has certain advantages and disadvantages and both

¹Identification of the equipment and software is for documentation only and does not imply endorsement.

are expensive, though cost comparisons are not simple. A satellite cost about \$200 million installed, has a transmission rate of about 1.2 Gbps (gigabits per second), and a lifespan of about 10 years (Horn, 1988). Satellite users must share its available bandwidth; the number of users is limited by users' bandwidth requirements and usage time. Users must have satellite dishes and receivers/transmitters. The cost of satellite communication is high. A representative of the National Institute of Education estimated that using video to connect up to 30 locations may cost between \$150,000 and \$200,000 for several hours, depending upon number of locations (Parker, 1983). Thus, a very rough estimate of the costs for using the medium might be about \$100 per hour per location. This estimate assumes commercial wideband television transmission. The cost of using a satellite with narrower bandwidths such as standard T1 (1.54 Mbps--megabits per second) varies according to the hour of day and other factors, but is in this same price range. The advantage of satellite communication is that it covers large areas; for example, a single satellite can cover the entire continental United States. Clearly, the cost of using satellites is presently too high for linking individual instructional workstations.

Wide bandwidth land lines (e.g., fiber optics) can be used for much of what satellites are used for and are less expensive to use under certain circumstances. Fiber optic systems cost about \$5,000 per mile; each fiber can carry about 1.2 Gbps, and this translates, for a 500-mile link, to about \$2 million per Gbps versus about \$20 million for a satellite (Horn, 1988). Other factors favoring fiber-optic links over satellites are relatively long life (about 25 years for fiber optics) and the fact that fiber optics permit more efficient use of the electromagnetic spectrum; i.e., as transmission is through fibers instead of the air, many different users can employ the same frequencies without interference (Karn, 1988). Satellite links remain obligatory where fiber optic lines cannot be run such as to ships at sea or to very remote locations.

The Defense Commercial Telecommunications Network (DCTN), currently under development by American Telephone and Telegraph Corporation, will eventually provide the wide-bandwidth-network connectivity required to link many sites across the continental United States so that these capabilities will be technically feasible. The DCTN will rely mainly on fiber optic lines, the majority of which are not yet installed. The DCTN is growing with demands for its services, but at present covers limited geography and is expensive to use. For example, the monthly cost to link two sites within its existing matrix is \$12,000 per site or \$24,000 per month. Though this cost will undoubtedly drop as more users subscribe and the capital costs of the initial installation are amortized, the DCTN appears to be prohibitively expensive to use for training delivery for the foreseeable future.

Artificial Intelligence

The survey of literature in artificial intelligence (AI) was motivated by potential AI applications in training. One such application is to use AI to assume some of the functions of a human instructor such as to answer student questions, provide intelligent tutoring, or route questions to subject matter experts or instructors. The feasibility of such AI functions rests on the assumptions that AI-based systems can or eventually will be able to handle natural-language interaction with students and provide robust tutorials based on inferred student needs. The literature indicates that these assumptions are not presently satisfied. Moreover, it is not clear if they will ever be satisfied. The survey revealed that expert system technology is much more mature than that for natural language interaction and intelligent computer-aided instruction (ICAI).

Standard methods for developing expert systems are in widespread use and expert systems are generally acknowledged to be useful, practical tools when developed properly. However, the utility of expert systems in education/training is limited--they are decision-making tools--and, for this reason, the following discussion does not include them.

One of the most challenging AI problems is natural language interaction. Systems that can parse simple sentences using restricted vocabulary and syntax have been available for several years but these systems lack the ability to handle the subtleties and complexities of normal interpersonal communication. Closest to this ideal, perhaps, are natural language "front ends," which translate sentences composed of restricted vocabulary and syntax into the formal language of the computer (Charniak & McDermott, 1985). Natural language systems are evolving and may be expected to improve in the future. However, some AI experts believe that systems with full natural language understanding will only be possible in the remote future, if ever, and may require a fundamental improvement in available computing equipment and a better understanding of human language processing (Winograd & Flores, 1986).

Much research has been conducted in the field of ICAI, yet it is difficult to find robust, operational exemplars of the technology. The available programs are limited. Most are laboratory tools, which were developed at great expense, work within narrow domains, are fragile, and lack the flexibility of a human tutor. A recent review of 20 ICAI systems developed over the past 15 years concluded that most of the projects had purely scientific goals, that practical ICAI systems that are used routinely do not exist, and that the cost of producing instruction is on the order of one man-year per student-hour (Camstra, 1986). These conclusions are reinforced, in whole or part, by other critics of ICAI (e.g., Dede, 1986; O'Shea, 1982; Ross, 1987; Yazdani & Lawler, 1986). Even the strongest proponents of ICAI acknowledge its limitations. Kearsley, while contending that ICAI will shape the future direction of automated instruction, admits that the development of ICAI programs is "a very lengthy and laborious task" and that the wider availability of ICAI programs requires the growth of ICAI expertise (1985, 1987). ICAI programs differ from conventional CAI programs because they "understand what they teach" (Kearsley, 1987). This claim, like many others made for programs with AI, appears to be a wishful exaggeration of reality.

This literature-based pessimism was reinforced by some practical experiences. During the first quarter of FY88, NPRDC in-house training and project needs led to the informal trial of two key technologies--computer networking, ICAI--in an instructional setting. At the time, many staff members wanted to learn to program in LISP and so a voluntary, in-house LISP course was set up. All participants had access to center VAX computers, electronic mail (e-mail), the Kyoto Common LISP interpreter, and John Anderson's LISP tutor. The LISP class began in September 1987 and met approximately once per week for six months. During this time, participants worked through *Essential LISP* (Anderson, Corbett, & Reiser, 1987) and some began more advanced topics (e.g., Clos, Flavors). The volume of e-mail traffic in the class surged during month 4, as participants reacted to the introduction of the LISP tutor software. Many class members used the software but none completed more than a few early lessons. User reactions to the tutor were negative; the tutor was criticized for:

1. Slowness.
2. Pacing lessons in lockstep fashion; i.e., each lesson had to be completed before moving on to the next lesson.
3. Treating variations in programming style as errors; i.e., any solution not within the tutor's repertoire was declared incorrect even if correct.
4. Lacking a "UNIX-like character" in that it required users to perform certain housekeeping tasks normally performed by the UNIX operating system.
5. Its didactic approach--it did some things a programmer should do (such as closing parentheses) and prompting the user on the correct syntax.

Reactions of class participants were contrary to those expected based on Anderson and Reiser's success with the tutor as an instructional tool (Anderson & Reiser, 1987). The tutor may have been unfairly handicapped by its late arrival. By the time it became available, course participants were well into the textbook it supports and did not want to work through the tutorial material for earlier lessons, which would have been required (see objection 2 above). Other possible reasons for its lack of acceptance are that the LISP course was loosely structured and that participants were fairly computer sophisticated. Whatever the explanation, the bottom line is that the tutor failed to deliver on expectations.

The use of e-mail in the LISP class was a powerful adjunct to conventional methods of instruction. On the other hand, the experience of using the LISP tutor was disappointing.

Survey of Remote-site Training Research and Development Efforts

The following projects using technologies that might be used for remote-site instruction in the Navy were identified:

1. Asynchronous computer conferencing project (Army Research Institute).
2. Simulation network (U.S. Army).
3. Networked computer-based instruction (Army Research Institute).
4. Educational computer networks (various organizations).
5. Videoteleconferencing and videoteletraining (various organizations).

Asynchronous Computer Conferencing

The asynchronous computer conferencing project is being conducted by the U.S. Army Research Institute (ARI) with contractor support. Work began in 1986 and is ongoing. Computer conferencing over the Army Forum Network is used to link geographically remote students to an instructor and to each other for discussion in an "electronic" classroom and with smaller working groups. During the first two years, the subject matter was the U.S. Army Engineer Officer Advance course; the instructor was an honors graduate of the course and Army Reserve Officer who was

hired under contract; and the students were Reserve officers (Hagman, 1988). Training materials were developed from those used in the corresponding resident course (Hahn, 1988). Primary instructional delivery was with correspondence-type training materials, supported by computer conferencing for discussion. Students were paced through materials at a group rate. Students were also provided with text-editing software for use in preparing written assignments.

Hahn (1988) reported that the students quickly became bored when a single medium of presentation was used and opted for variety in presentations to sustain interest. Project participants have reported their experiences and several "lessons learned" (Phelps & Richards, 1987; Richards, 1988; Richards & Phelps, 1987). Among the problem areas were hardware breakdowns, student difficulties in setting up PC-XT computer equipment, lesson pacing problems, and the need for training both instructors and students in the rules of computer conferencing. The project has solved these and many other practical problems of the electronic classroom and offers useful lessons to educators and trainers working in this area. Two additional significant contributions are the design of a metaphorical user interface for students' computers (Halbert, 1988) and considerable well-documented experience in the training of instructors (Kaplan & Jones, 1988).

Simulation Network

Simulation network (SIMNET) is a computer-based battlefield simulation used in training U.S. Army officers. It allows for fully interactive force-on-force engagements in a combined arms environment using ground troops, artillery, armor, attack helicopters, close air support, aircraft, air defense, and other elements. Networking technology is used to tie together different computer workstations so that several players can participate simultaneously (Lubaczek, 1988; Madden, 1988). SIMNET allows its users to play roles in a simulated battle, to determine the effects of decisions, and to play back moves afterward. It is not a training delivery system, but a vehicle for learning battlefield command by practice in a simulation environment. Unlike most simulators, which allow a single user to interact with the system, SIMNET allows units to conduct collective training by networking several workstations together. The degree to which simulators such as SIMNET provide a cost-effective alternative to field practice is a research question currently being addressed by ARI (Hiller, 1988).

Networked Computer-based Instruction

ARI is conducting a research project involving a networked computer-based instructional (CBI) system at the Quartermaster School, Ft. Lee, VA. The system consists of 15 workstations, which are networked to a server that can present CBI lessons and videodisc presentations. The network is used as a vehicle for distributing instruction but not for communication between student and instructor or among students. The system includes both instructional delivery and authoring modules. It is being used as a research testbed of the networked CBI technology. Primary emphasis of the project currently is to develop a good research strategy for investigating this technology and evaluating the effectiveness of the authoring system in the hands of Army trainers (Mirabella, 1988). The use of networks for delivery of computer-aided instruction (CAI) has its origin in computer systems such as PLATO and TICCIT (Kearsley, 1987). Such systems are used for both training delivery and authoring. The ARI project uses a less-expensive, smaller-scale approach than earlier systems.

Educational Computer Networks

Educational networks are widely used in colleges and universities. We did not conduct a comprehensive survey to determine their full penetration into education but are aware of several cases which are probably typical. The U.S. Air Force Academy uses a local-area network (LAN) to link students and faculty. All students have access to Zenith 248 computers; the system provides e-mail and there are plans to use it for delivery of computer-aided instructional programs (Regian, 1988).

The U.S. Naval Postgraduate school employs a similar network. Use of the network depends upon the academic major and the particular instructor; there is no standard way to use the network in instruction (Buoni, 1988). Some instructors do not use it. Others--particularly in more technical majors--use it, for example, to transmit homework assignments and solutions to exercises, and to communicate with individual students. These uses are informal in the sense that they are natural outgrowths of the e-mail system and supplant other means of communication such as dropping notes in mailboxes, providing handouts in class, meeting during office hours. These informal uses do not include delivery of instruction or computer conferencing.

Many colleges and universities--particularly those with working students--now permit students to take some classes by computer; i.e., the class is essentially a computer conference. The Western Behavioral Sciences Institute, La Jolla, CA, has for several years used computer conferencing to link high-level managers at remote sites to study and discuss strategic planning in a course combining classroom meetings and electronic meetings (Richards & Phelps, 1987). These educational applications are more formal than those discussed above and employ wide-area networks. However, such applications are within the capability of any institution processing a LAN even if they are not present policy. While the use of LANs appears to be growing in institutions of higher learning, we have found no evidence that this is happening in primary or secondary schools, technical/trade schools, or within the military schoolhouse training environment.

NPRDC, as part of its Communication Networks in Training project, designed, developed, and recently field tested the Instructional Support Network, which linked remotely-located continuing education students of the Naval Postgraduate School with a resident tutor (Simpson, 1989; Simpson & Pugh, in press). This system was designed to be extremely easy to learn and use, and its field test indicated the benefits of careful human factoring to system success.

Videoteleconferencing and Videoteletraining

Videoteletraining is the use of television to conduct training. It encompasses both conventional one-way, standard bandwidth, analog video and two-way, narrow bandwidth, digital video. Depending upon the particular system, video may be one- or two-way and audio may be one- or two-way. Conventional systems are less likely than narrow-bandwidth systems to employ two-way video or audio. Videoteleconferencing uses the same technology as videoteletraining but its objective is to link its participants in a two-way conference rather than to deliver training.

Conventional video has been used in educational institutions for more than 30 years, primarily as a way of extending instruction to a larger audience. More recently, it has linked different institutions via satellite, land line, or microwave relay.

The Army Satellite Education Network (SEN), based at the Army Logistics Management College, Ft. Lee, VA, is a fairly typical example to videoteletraining using conventional technology such as unencrypted, analog, one-way video, and two-way audio. The SEN has been in operation since 1985 and is steadily growing. By mid-1990, it included 1 uplink and 58 downlinks. It is used primarily to deliver training in the logistics area such as courses in acquisition, contracting, work statement preparation, and integrated logistics support. The Army intends to expand course coverage to other courses; e.g., the Army's Management Engineering College will use the network to deliver courses during 1990 (Brockwell, 1989).

Several firms currently offer videoteleconferencing services and will, for a fee, install video equipment, establish satellite links, and set up studios at the customer's site. The facility, once established, may be used to communicate between sites in real time with video, audio, and other media. As in present-day commercial broadcasting, the primary communication link is by satellite. Typically, these facilities are used to support televised two-way meetings or conferences. Small-scale videoteleconferences usually involve business executives who meet electronically rather than travel cross-country to meet physically (Cushman & Derounian, 1988). On a larger scale, videoteleconferencing has come into widespread use for special interest conferences, many of which involve a significant educational component. In the usual arrangement, conference speakers meet at a central site, their presentations are transmitted by satellite relay to ground stations with receiving antennas, and the signal is presented by large-screen television to the on-site audience. A two-way audio link enables the audience to direct questions to speakers and to participate in discussions. This arrangement is common and is used, for example, by the PROFNET network via a node at San Diego State University. The same configuration is used to conduct electronic classes. For example, within the San Diego area, PROFNET currently offers 15 electronic courses at the graduate level. Television is widely used for remote-site education and training. We are presently conducting a survey of 12 systems in public education, private industry, and the military. These systems vary in design, size, and other dimensions but share the objective of delivering instruction to personnel who are located at a distance from instructional resources. The results of this survey will be reported in the future.

The Naval Education and Training Command's videoteletraining demonstration project, based at Fleet Combat Training Center, Atlantic (FCTCLANT), uses encrypted, digital, two-way video and audio and is a good example of the use of newer videoteletraining technology. Because the system links five sites, each capable of originating and receiving video and audio signals, its system design is more ambitious than most conventional instructional television systems. Videoteletraining was used to reduce the significant travel and per diem costs FCTCLANT expends each year delivering training to the fleet. FCTCLANT used videoteletraining to deliver 12 courses to several hundred students. Analyses conducted by the Center for Naval Analyses indicate that performance and attitudes of students at remote sites are comparable to those at the originating site and that training costs can be reduced by using teletraining. The project has received funding for FY90 and is expected to continue, with further development, in the future (Mahnke, 1989; Snowdon, 1989).

In support of the FCTCLANT videoteletraining project, a small scale videoteletraining facility was established at the Fleet Combat Training Center, Pacific (FCTCPAC) in a cooperative research effort involving Commander, Training Command, Pacific Fleet (COMTRAPAC), NPRDC, and

Fleet Training Center, San Diego (FTC). NPRDC oversaw and provided technical support to this effort as part of its Communication Networks in Training project. The West Coast effort used technology very similar to what was used on the East Coast, but connected two sites (San Diego and Treasure Island) using a T1 land line instead of satellite. A field test of this system was conducted during the fall of 1989 and obtained results similar to those of the East Coast effort (Simpson, Pugh, & Parchman, in press).

Survey of Remote-site Instructional Environments

The following instructional environments were surveyed to identify training problems and their potential for solution with evolving training and communication technologies:

1. Navy technical schools.
2. Naval Reserve training.
3. Navy correspondence course program.
4. College- and graduate-level officer training.
5. Shipboard and pierside training.

Navy Technical Schools

On an ongoing basis, the Navy delivers 7,800 courses to 73,000 enlisted and officer students (CEP, 1988). Most of these courses are conducted in classrooms and laboratories and many are Navy technical schools such as "A" schools, "C" schools. Academic attrition in "A" schools average 24 percent for technical ratings and 9 percent of nontechnical ratings. The cost of student attendance at these schools includes travel, per diem, and the work time lost to the student's command. Costs could be averted to the extent that technical training could be delivered remotely to students in their workplace. In addition, the ability of students to receive training remotely would increase training opportunities for both skill enhancement and refresher training. Training would be conducted that would otherwise not occur, thereby improving force readiness.

Naval Reserve Training

There are 235 Naval Reserve training sites in the continental United States. These units vary in size, resources, mission, training requirements, and training expertise. Their training requirements may be met in many different ways; e.g., by conducting classes, sending personnel to other units or resident schools, bringing in instructors, using various training resources. Based on the evidence, training in the reserves is minimally effective. A recent GAO report concluded that 23 percent of selected reservists lack the required individual skills for their position (General Accounting Office, 1988). The most severe constraint on reserve training generally, and individual skill training in particular, is the limited time to train (38 days per year). Simms (1986) observes that reservists have much less time to train than their active duty counterparts, that many reserve units do not have a peacetime mission that enables them to practice wartime jobs, and that reserve units are often located far from training facilities and the active duty units they will join in wartime.

Visits were made to Naval Reserve training headquarters and to the central Naval Reserve training center to gather information on reserve training management and delivery. The San Diego area readiness command (REDCOM 19) supports 10,000 reservists in 73 units at 12 drill sites. Units range in size from 350 to 3,000. Every unit is required to have a reserve billet training plan, which defines what individuals in the unit must be trained to do in different training areas such as mobilization, professional training, directed training, and professional education. Training managers at both sites indicated that they found it difficult to meet training requirements within time constraints, but that new technologies might reduce these problems in the future.

Reservists are prime candidates for remote-site training.

Navy Correspondence Course Program

Contact was made with personnel in the Navy correspondence course program to obtain information about the program and assess its suitability for remote-site training. Approximately 60,000 students are enrolled in the Navy's 580 correspondence courses. Students include active duty military personnel, reservists, and civilians. The courses enable Navy personnel to learn about professional Navy subjects on a self-study basis. The courses are important both for advancement and for broadening general knowledge of the Navy (NETC, 1986). The completion rate for correspondence courses overall is 56 percent; however, in courses required for advancement in rating, the completion rate approaches 100 percent (King, 1988). The program has no instructors, as such, and no resident experts on the courses it offers. Thus, students are on their own if they have problems with a course.

The correspondence course program is a conventional form of remote education/training and seems to be working reasonably well.

College- and Graduate-level Officer Training

Contact was made with the staff at the Naval Postgraduate School (NPGS) Monterey, CA, to explore possible distance education applications. The NPGS is a Navy-sponsored institution of higher learning which enables active-duty military officers and DoD civilians to earn graduate degrees in the engineering and naval sciences. It has 1,800 resident students on an ongoing basis. The NPGS is highly selective, students are motivated, and the majority successfully complete their graduate degree. The NPGS has many computers on campus and an operational electronic mail system that is accessible by students, faculty, and staff. Until mid-1989, the NPGS also supported a continuing education (CE) program that enabled nonresident students to take certain courses by correspondence. This program was terminated due to its cost and the low completion rate of its students (less than 20%). The NPGS does not face the serious problems of other Navy instructional environments surveyed.

Shipboard and Pierside Training

Much Navy training must occur outside of the formal schoolroom. This training is required by personnel aboard ships and in shore assignments in order to maintain their skills, advance in rating, train with their shipmates as a team, cover mandated subjects, and learn whatever else is necessary to perform effectively on the job and advance professionally. Such shipboard training is not

adequately conducted. Two common strategies for attacking this training problem are to send students to resident schools or to send schools to the students. Both of these strategies are expensive and require locational moves. The Navy training community currently lacks the capability to bridge geographic barriers in training delivery. This fact impacts on training in many ways. Perhaps the most common impact is that training solely dependent on local resources often does not occur. If the prospective student is at sea, and cannot be spared to attend a resident school, then that sailor does not receive training. There are costs even if the student can be sent to school such as the monetary costs of travel and per diem, and the physical loss from the job of the person attending training. Moreover, because temporary training assignments may end with the newly-trained sailor going to another duty station, there are practical disincentives to release personnel for school. In many cases, attendance at a resident school is not feasible; e.g., if many people need training, the required training is of short duration, or costs are prohibitive. When this is true, an effort may be made to train personnel by using local training resources or bringing in resources. For example, training may be delivered locally by a visiting training team, local subject matter experts may act as instructors, on-the-job training programs may be established, or individuals needing training may be encouraged to attend local trade schools or to enroll in Navy correspondence courses.

Strategic Homeporting may result in the dispersal of Navy ships over a greater number of smaller, more geographically isolated ports than at present. As training resources are typically concentrated near larger ports, homeporting can be expected to accentuate the problem of isolated students. What is needed is a way to make schoolhouse training resources available to students when and where they can best fulfill local training needs.

Shipboard and pierside training are prime candidates for remote training.

DISCUSSION

This section consolidates the survey findings and suggests directions that Navy remote-site training efforts should pursue in the future. The survey of Navy instructional environments indicates that the most severe problems exist in shipboard/pierside training and in the reserves. Less severe problems also exist in Navy technical schools. The survey of training and communication technologies revealed that these technologies are evolving in directions that will eventually permit the development of very powerful, networked, multimedia workstations. Communication and computer technologies are becoming one; we can foresee future systems which allow two-way interactive communication with machines that integrate computers, high-definition television displays, facsimile machines, telephones, and other communication devices. It has been predicted that by the turn of the century, such machines will probably be in our homes. Their obvious uses are for communication and entertainment. Their less obvious use is for individual education and training. The design and potential application of such a system is described in the next section, "Workstation of the Future."

The same technological trends that make advanced workstations possible for individual use open new possibilities for group instruction using narrow bandwidth television and other supporting media. Current and future directions of this technology are discussed in the section,

"Videoteletraining in the Future." The utility of these workstations may be increased by having two or three students use them simultaneously.

Workstation of the Future

By extrapolating from developments in communication technology, it is possible to envision a workstation of the future. This workstation integrates a computer, high-definition television display, facsimile machine, telephone, and other communication devices and allows interactive two-way communication. As compelling as this vision of an exciting machine of the future is, the workstation is nothing by itself. To be of significance, this workstation must be a part of a network that links resources that are valuable to its users. This workstation concept is more powerful (or at least has more features) than any existing system, although the technologies it uses are within the present state of the art and all exist in stand-alone form; the workstation, as thus envisioned, integrates these technologies and networks them over large geographic distances using satellite and fiber-optic links.

How might such a workstation look? It is quite possible that, by the time the network required to support such workstations is in place, video displays will be flat, hang on walls, and will present three-dimensional pictures or project holographic images; that users will interact with them by using voice, data gloves, or other exotic input devices; and that paper will no longer be used. The workstation would have a high quality audio system for presenting computer-generated sounds, playing digital recordings, or presenting the human voice. Even stranger hardware is possible. If the workstation were designed today, it would probably look very much like an office workstation--with a large color video display, keyboard, mouse, and printer. It would use a direct manipulation user interface (Shneiderman, 1987) with an operating system similar to that of the Apple Macintosh computer. It would have windowing capability and be able to display, in different windows, computer text, graphics, and moving television images. It would include a video camera and microphone to transmit its user's picture and voice over the network to other users. Its printer would be able to generate color images and reproduce facsimiles. The network would use wide-bandwidth communication links (probably fiber optic) to tie users together into a network.

How might the workstations be used for Navy education and training? It is reasonable to view such a workstation as a logical evolution of present day electronic mail. As such, the two media have important similarities:

1. They may be used by individuals or small groups of two or three students.
2. Communication costs are computed on a per capita basis.
3. Individuals or small groups are, in general, outside the social context of a larger group in using the system.
4. Individuals or small groups are responsible for operating the system (mastering the medium) and performing the content task (receiving or delivering the message).

These two media have some important differences. Present day electronic mail is overwhelmingly asynchronous and isolating; two users are seldom able to converse

simultaneously. Alternatively, given a mature communication network with adequate bandwidth, future workstations will enable their users to engage in synchronous video and audio communication and should draw their users together into a single network.

Given the foregoing, these workstations could be used in several ways:

1. To deliver formally structured, group-paced training. Terminal users could participate in electronic "classes" even though at physically different locations. An instructor at one site could deliver instruction to students at several different geographically dispersed locations.
2. To permit individuals to participate in self-paced instruction. An individual could use a workstation to access and use local or remote instructional resources (including instructors, subject matter experts, and tutors) to learn.
3. To hold conferences on topics of interest to professional groups. Individuals could tie their workstations together into subnets to hold conferences.
4. To permit individuals to assess technical resources (information or people) not readily available locally.

Videoteletraining in the Future

The same developments in communication technology that make advanced workstations possible open up new possibilities for videoteletraining. In fact, it appears that, because of their relative costs, group training with videoteletraining will become cost-effective earlier than will individual training with workstations. Connecting two multimedia workstations across distance would cost about the same as connecting two videoteletraining classrooms. The workstation may be used to train one person; the classroom, many. Hence, videoteletraining seems to be the more practical training medium in the near future.

Compressed, fully-duplexed video has only recently begun to be used for videoteletraining. The technology is new and those applying it are still learning how to use it. The videoteletraining classroom of today typically employs inexpensive video cameras and 25-inch color video monitors, has marginal audio capabilities, and may have a facsimile machine. Classroom designs--color, sound conditioning, camera and monitor placement--lack recognized standards. Despite these shortcomings, watching training being delivered in a videoteletraining delivered in classroom today is impressive--an instructor appears on a video display and teaches students hundreds or thousands of miles away, and the students and instructor talk back and forth as if no distance separated them. Despite equipment shortcomings, non-optimal designs, and lack of experience, videoteletraining systems work. Technological changes, equipment improvements, better classroom designs, and more experience will all contribute to making this medium even more powerful than it is today.

Just as we may envision a workstation of the future, we may envision a videoteletraining classroom of the future. The videoteletraining classroom is to group training what the multimedia workstation is to individual training. The classroom uses the same media: computer, high-definition television display, facsimile machine, telephone, and other communication devices. The

communication devices. The displays are much larger than at present; wall-size displays are conceivable. As teletraining penetrates the training world, it will begin to make sense to dedicate permanent spaces to "videoteletraining classrooms." Today, many Navy commands are setting aside spaces for dedicated videoteleconferencing facilities which are especially designed for videoteleconferencing. As videoteletraining becomes more common, it will make sense to provide facilities for this purpose as well.

How might such a classroom look? The videoteletraining classroom will look much like a conventional classroom but will also include some or all of the following features:

1. Carpeting, acoustic tiling, and other sound conditioning features.
2. Large, high-resolution video displays at the front of the room.
3. Microphones on desks.
4. Cameras for the class, instructor, easel, and other centers of interest.
5. Classroom workstation and/or control center from which equipment can be operated.

Just as the workstation is the logical evolution of present day electronic mail, the videoteletraining classroom is the logical evolution of the live classroom. As such, the live and videoteletraining classrooms have certain similarities:

1. They are used by groups of people (i.e., students and instructors).
2. Operating costs are computed on a group basis.
3. The individual operates within the social context of a larger group within the classroom.
4. The instructor manages the classroom and oversees instruction.

The same four factors were considered for the multimedia workstation--for individuals.

Organizational Implications of Technological Changes

Technological changes will make it possible to develop multimedia workstations and videoteletraining classrooms which can be linked with a network (in all likelihood, the same network) to deliver training remotely, permit users to access remote training resources, conduct conferences, and extend technical expertise. For such advanced applications to become reality, the network must be supported by an overarching management and training structure. The network and its workstations are merely communication channels. In order to deliver group- or self-paced training with the network, a training establishment must make the training resources available via the network and manage the training being delivered. Likewise, to perform other functions with the network--such as hold conferences, access remote resources--resources must be provided and managed. Thus, for the revolution in communication technology to impact on training will require a revolution in the way that Navy training is organized and managed.

Some of the implications of this revolution are:

1. More training will be delivered remotely and less in resident schools.
2. The number of classrooms devoted to resident training will decline.
3. Schools will employ fewer trained personnel who will have received different training and will be effective users of the new technology (e.g., conducting training using television).
4. Schools will assume new roles as managers and repositories of computer libraries and data bases, training media (e.g., CD-ROM, video), and computer-based instructional resources (e.g., CAI and ICAI programs, simulations, games, and course-management software).
5. Schools will manage the use of the network's resources for training-related purpose (e.g., discussion groups, bulletin boards, and computer conferences).

There is no guarantee that the new technologies will be used effectively in training. Much research is needed to examine both the technology itself and its application in different instructional settings. Some of the questions that need answering concern the strengths and weaknesses of the technology on the traditional assessment variables (knowledge and skill acquisition and retention, on-the-job performance), the types of instructional protocols needed, and the social impacts of the technology. The new technologies are promising but they are also expensive. Research about their training use is lacking. Further work is required to ensure that these technologies are employed in a cost-beneficial manner. The quality of the instructional materials determines training effectiveness. Part of the research mission that remains is to develop the technological tools for developing instruction in this mixed-media format and making these tools usable by the Navy instructors who will be charged with developing and revising instruction within their school.

FUTURE EFFORTS

The following suggestions for future efforts are based on the findings of the project to date.

1. The Chief of Naval Education and Training and the Naval Education and Training Management Support Activity should continue efforts to refine the Naval Education and Training Command videoteletraining system.
2. Chief of Naval Operations (OP-11) and the Office of Naval Technology should support research into the integration and cost effectiveness of advanced communication technologies for remote-site instructional delivery. The goals of this research would be to design and develop advanced videoteletraining classrooms and multimedia workstations for use in remote-site instruction in the late 1990s.
3. The Navy Personnel Research and Development Center should develop a laboratory for carrying out research concerning the optimal mix of technologies in remote-site training, use of visuals/graphics in video learning, and the instructional protocols that will maximize learning in the remote site training environment.

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