VIRTUAL ENVIRONMENT TRAINING:
AUXILIARY MACHINERY ROOM (AMR) WATCHSTATION TRAINER

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ABSTRACT

Virtual Environment Training offers a cost effective alternative to high-priced simulators and training devices. It uses the advantages of multimedia technology to provide quick access to motivating video sequences, audio warnings, realistic images and detailed text and drawings to interactively train critical tasks. This paper will highlight a recent project completed at Newport News Shipbuilding to use Virtual Environment Training to improve performance of submarine crewmen. It will detail critical considerations in the use of Digital Video Interactive (DVI®) in Virtual Environment Training. This paper will also identify a Virtual Environment Training development process and highlight a software application that was developed to aid in training design. Finally, significant performance improvements from a recent test/evaluation of this virtual environment part-task trainer will be discussed.

ABOUT THE AUTHORS

Dennis C. Hribar is a Training Programs Developer at Newport News Shipbuilding and was responsible for the training development for this project. He holds a Doctor of Educational Administration from Vanderbilt University and an M.S. in Industrial Management from George Washington University. Since 1986, he has worked to design videodisc training products and factory training courses for the U.S. Navy. He recently developed a computer- and videodisc-based expert diagnostic and equipment maintenance system.

David C. May is a Logistics Engineer at Newport News Shipbuilding and served as System Engineer for this project. He holds a B.S. in Computer Science from James Madison University and is currently completing an M.S. in Engineering Management from Old Dominion University. He has over 6 years experience as a programmer/analyst for several defense related companies, and has developed computer programs for the U.S. Navy, Air Force, Army Reserve and NASA. Since 1987, he has worked for Newport News Shipbuilding to design and implement multiuser applications.

James A. Probsdorfer is a Training Programs Developer at Newport News Shipbuilding and served as Project Leader for this project. He has over 22 years experience as a military trainer and project manager. He has planned, designed, and implemented various training programs, including training devices, gaming techniques, and simulations. He holds an M.S. in Educational Research from Bucknell University.

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INTRODUCTION

This project was a Newport News Shipbuilding (NNS) research effort to develop a computer-based realistic shipboard training device for use by U.S. Navy submarine crews who are awaiting delivery of their newly constructed submarine. The Auxiliary Machinery Room (AMR) Watchstation Trainer uses Digital Video Interactive (DVI®) technology to create an AMR-like environment for the sailors.

The Watchstation Trainer permits the sailor to tour his AMR compartment, to become familiar with the location of equipment, and to allow him to advance to standing watch in the AMR. The sailor can follow his lineup and drill procedures to throw a switch, turn a valve, and take a log reading from a gauge. Furthermore, the sailor has available technical manuals, engineering drawings, and training aid book (TAB) information, as required, to assist him in his duties in the AMR. All of this happens before the sailor ever sets foot on his new submarine.

This paper highlights the methodology used to develop this project, the essential features of the training application developed for the Pre-Commissioning Unit (PCU) at NNS, and some results of the initial test and evaluation of this trainer. This paper also discusses some unique considerations in the use of DVI® technology.

OBJECTIVE

The objective of this effort was twofold: (1) to provide the PCU a useful training device to assist in the mission of readying a newly assigned crew to take a new construction submarine out on its first sea trial, and (2) to become familiar with the emerging DVI® technology and determine its application at Newport News Shipbuilding.

This objective was a technological challenge to the project team. It demanded a solid focus on the end product while maintaining freedom to explore ways to make DVI® more useful for subsequent applications.

THE PROBLEM

Newly assigned crews awaiting the completion of submarine construction are confronted with the problem of how to conduct training on a system or subsystem which, in many cases, is not yet completed (see Fig.1). PCU crews undergo NNS familiarization training prior to ship launch. Additionally, the crew receives intensive onboard training prior to the initial sea trial.

The problem has always been to schedule the training to take advantage of construction cycles and to ensure that sailors get to see and touch the equipment as soon as possible. In many cases, construction materials and processes hinder access to the ship.

The approach used in this project was to bring the ship to the sailor and let him see his compartment and touch the equipment before it became possible to schedule him for essential onboard training.

Successful completion of this project would also determine if DVI® technology: (1) could provide a realistic computer-based training environment for the sailor, (2) could improve sailor performance, and (3) could be developed in a cost effective manner.

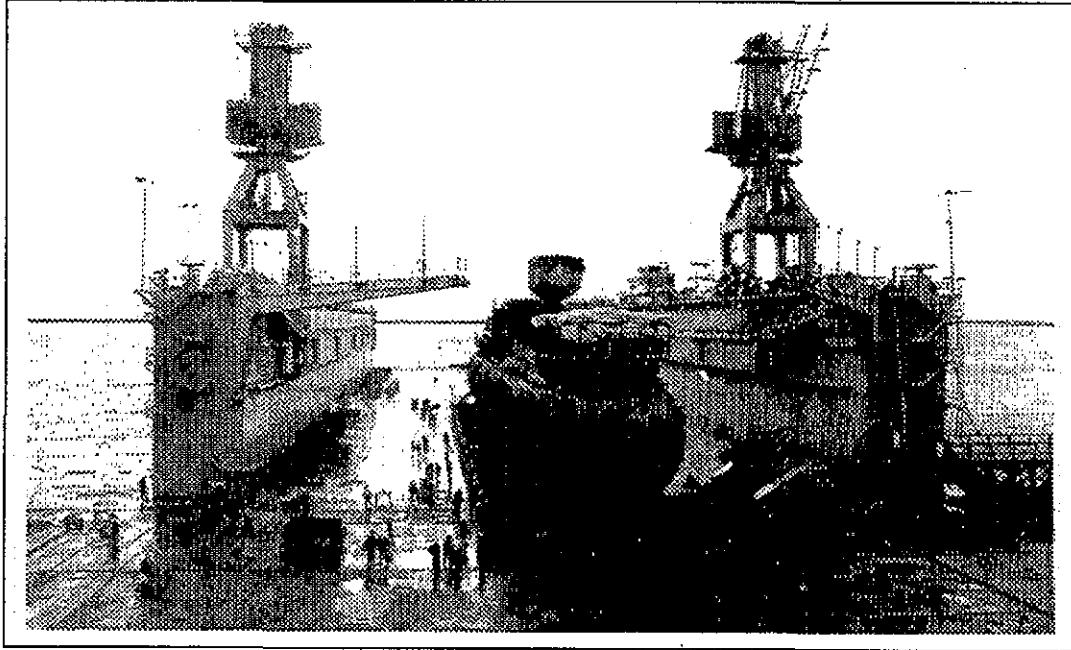® DVI is a registered trademark of the Intel Corporation.

Figure 1   Submarine Under Construction

THE METHODOLOGY

Emerging Technology

DVI® technology makes possible the first system to truly merge personal computers and video. Video (with realistic but passive pictures and sound) and personal computers (with calculating, formatting, and drawing capability) make this multimedia environment a rich, active experience under full user control.

Simply stated, this technology captures an analog signal and digitizes it. Once digitized, the media becomes the ultimate creative medium with virtually endless possibilities. With DVI® technology, digitized video and audio are compressed to require less storage space and decompressed for actual real-time presentation. Special computer chips process and display video and graphics. The delivery system uses a custom PC board to handle video, audio, and CD-ROM interface (see Fig. 2). Authoring packages can also be added.
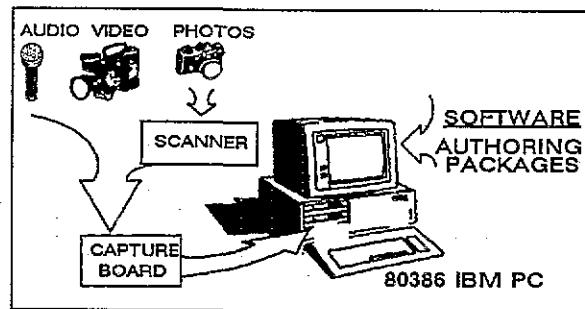

Figure 2   Digital Video Interactive Technology

Multimedia Team

Shortly after the analysis phase of the project was completed by a Training Programs Developer, a multimedia team was formed to focus the varied disciplines required to complete a project of this nature (see Fig. 3).

Each member of the team had a critical specialty. Team members brought a wide variety of experience and creative abilities to the project. With the exception of the Training Programs
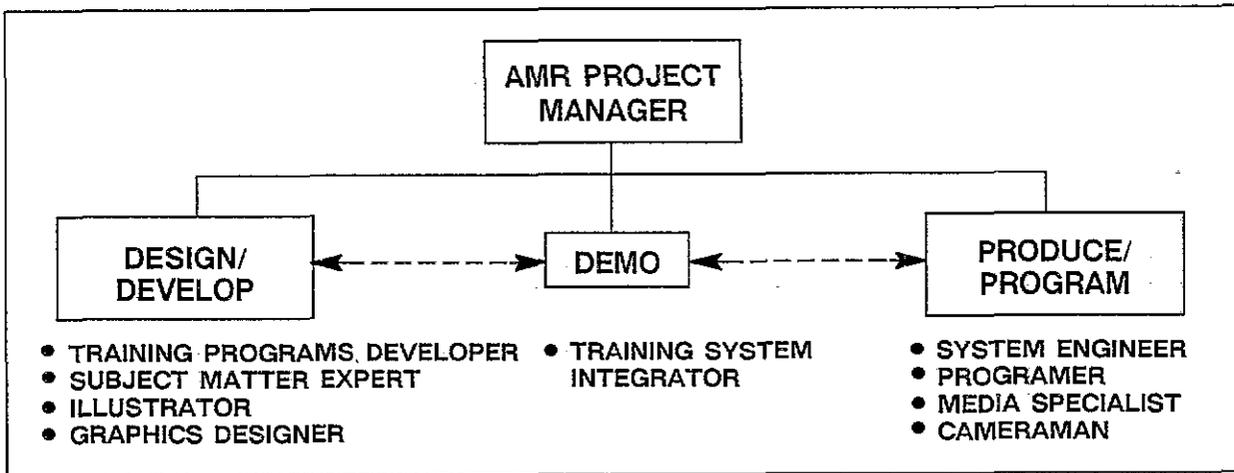
Figure 3   Multimedia Team

Developer and the System Engineer, the rest of the team performed part-time duties on the project. The team was located in an enclosed separate area and initially developed a work plan. Training was conducted for the System Integrator and System Engineer on DVI® operation at Intel Corporation in June 1990; for the Project Manager on DVI® application development at Avtex Research Corporation in July 1990; and for the Illustrator on Lumena® paint package user training at Intel Corporation in August 1990.

Training Development

This project started with a project plan to initially focus the efforts of the Instructional design and then moved into the analysis phase. Several meetings with subject matter experts from NNS

departments and PCU crews detailed the subject audience and training tasks related to the AMR.

A content analysis outlined AMR watchstation qualification, standards, and procedures. Watch qualifications and ship systems manuals provided most of the task analysis information. This process culminated in the development of Terminal Learning Objectives (TLOs). Finally, a front-end analysis (FEA) was completed and reviewed by subject matter experts.

AMR flowcharting and database development followed and was based on the content analysis. It provided a training sequence and program flow for the project (see Fig. 4).

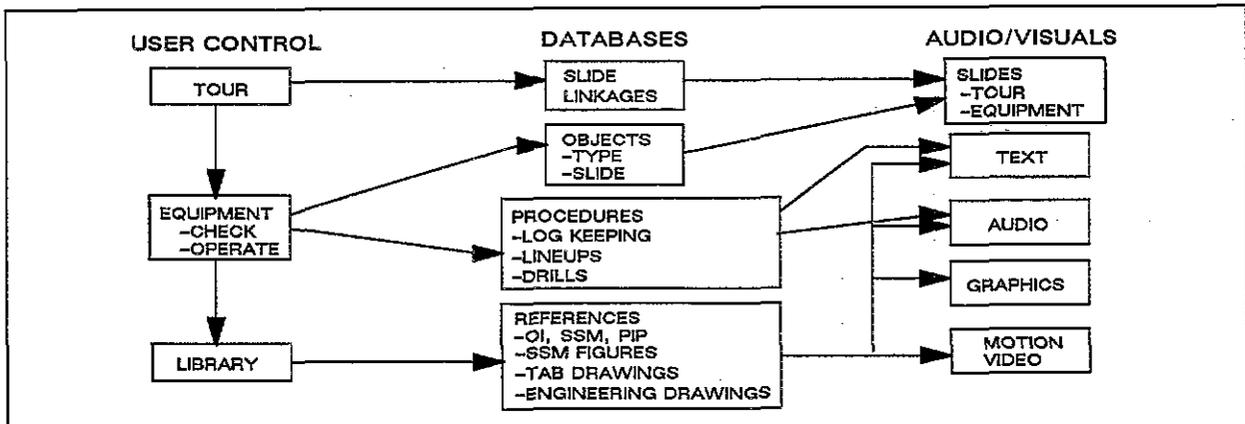® Lumena is a registered trademark of TIME ARTS, INC.

Figure 4   Program Flowpath

Engineering drawings, training aid books (TABs), VIVID® 3-D model information, along with the qualification cards, ship systems manuals and technical manuals for systems (e.g., CO_2 Scrubber, Ventilation, Demineralized Water, etc.), and drills (e.g., Fire, Flooding, General Emergency, etc.) were consulted.

THE AMR WATCHSTATION TRAINER

Top Level Design

This application addressed ship watchstation training, including touring the space, selecting items of equipment to read or operate, and accessing related technical and training information. The AMR Watchstation Trainer offers three user modes (basic, advanced, and test) to provide a path for each trainee to achieve proficiency for ship and watchstation qualification

and review. It uses an electronic environment to practice equipment log keeping and operation, and compartment lineups and drills.

The top level design lays out the training strategy. The sailor can select the user mode he wants to achieve and proceed through basic and advanced watchstanding to lineups and drills. All the while, the sailor can learn his compartment by touring, locating equipment, browsing technical information or following specific procedures. Once familiar with the space, he can practice by first electing to be guided step-by-step through the AMR and then going through the procedures without help. Should the sailor become confused, technical information would be readily available in the database to help out. Finally, the sailor can be tested using a timed scenario. The results of training are displayed in terms of time, error rate, and areas for improvement (see Fig. 5).

AMR WATCHSTATION TRAINER TOP LEVEL DESIGN

USER LEVELS	USER OPTIONS			
	BASIC WATCHSTANDING	ADVANCED WATCHSTANDING	AMR LINEUPS	AMR DRILLS
• STEP-BY-STEP WALK THROUGH DRAWINGS PROCEDURES EXPLANATIONS • PRACTICE WITH ON-LINE HELP AVAILABLE • PROFICIENCY TESTING 　NO HELP 　TIMED	• DUTIES AND RESPONSIBILITIES • LOCATIONS: 　EQUIPMENT 　GAUGES 　VALVES • LOG KEEPING • ROUTINE WATCH ACTIONS	• INTERPRET LOG READINGS & TAKE REQUIRED ACTIONS • STARTUP & SHUTDOWN OF EQUIPMENT • RESPOND TO EXTERNAL STIMULI 　DRILLS 　LINEUPS • ALL OF BASIC WATCHSTANDING	• DIVE • SURFACE • GENERAL EMERGENCY • FIRE • FLOODING • COLLISION • TOXIC GAS • REDUCED ELECTRICAL • WEAPONS EMERGENCY • VENTILATION / SNORKEL • SILENT RUNNING • DEPTH CHARGE • DEEP SUBMERGENCE	• FIRE • FLOODING • COLLISION • WEAPONS EMERGENCY • TOXIC GAS • EMERGENCY DEEP • REDUCED ELECTRICAL • POWER PLANT EMERGENCY

Figure 5 Top Level Design

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Screen Layout

The AMR Watchstation Trainer uses a main screen layout that is user friendly and designed to take advantage of user control features and image workspace. The right side of the screen contains a user control interface that allows the trainee to conduct a tour of his space using a mouse to control forward, left, right, backward, and U-turn movements. Additionally, the user can select help information from the available engineering drawings and technical manuals. He can elect to move from object to object rather than touring the space. Finally, he can query the system to learn in what condition the boat is operating (i.e., General Emergency). Visual images appear on the left/center part of the screen and clearly show the user where he is located or which piece of equipment he is operating. The bottom of the screen displays text information that outlines procedures to follow to complete the watch (see Fig. 6).
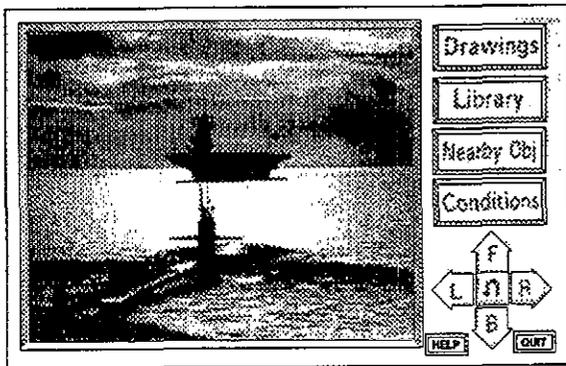

Figure 6   Main Screen Layout

Tour Package

It is important to remember that the tour of the AMR is the method used to get to the right piece of equipment in the right order at the right time. The tour, in itself, is not the sole focus of the training. It adds randomness and flexibility to the environment and makes the space more realistic. The AMR watchstander may be taking a log reading in front of the burner when a Fire Drill is suddenly called, and he must quickly relocate to the scrubber for action. The tour package enables him to get there.

A custom program was designed to set up or build the surrogate tour. It uses the relational database of the AMR slides to keep track of the views available to the user who might elect to go forward, left, right, backup, or do a U-turn.

Additionally, an added feature of the tour package is the ability of the program to follow the users location in the AMR space and, in the event of disorientation, the user can call up a help screen to locate his position. When executed, this feature will show the user where he is currently located on an AMR floor plan (see Fig. 7).
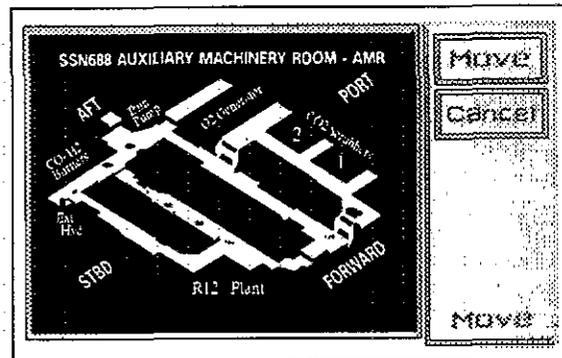

Figure 7   Floor Plan of the AMR

Watchstation

The focus of the AMR Watchstation Trainer is to help prepare the user to qualify as an AMR watchstander. Actions requiring the watchstander to read a gauge, throw a switch, and shut a valve are critical. The trainer addresses these functions realistically using a computer environment. Also, with the creation of audio to simulate a ship's alarm or a video sequence of a critical testing procedure, the user has a multimedia training experience – one that requires him to use more of his senses to respond (see Fig. 8).
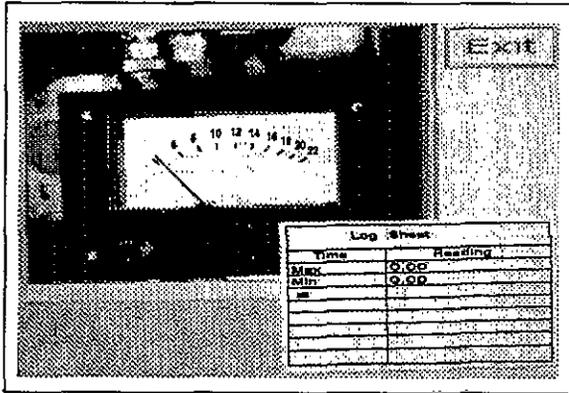
Figure 8 Log Reading with a Gauge

For example, the watchstander can be directed to go to the CO_2 Scrubber (the user must first locate his position in the AMR to know if he must move left or right); he can turn a switch to position No. 3; and then locate a gauge and take a log reading at 0300 hours. If the gauge reading is above normal, then the watchstander may have to locate a valve and open it. At any point, the watchstander may want to call for additional technical manual information, or an exploded view of the equipment, or a drawing, or a 3-D model to help him locate and understand the system operation (see Fig. 9).

Figure 9 3-D Model

User Module

The AMR Watchstation Trainer has a user module that provides a log on/off procedure, an introduction to the training experience, a computer familiarization segment, a mechanism to know if correct responses are being executed, and a training sequence that can be customized for the user.

TEST AND EVALUATION

Test and Design

The test design consisted of an initial background questionnaire, a pre-test, a phased evaluation period, and a series of post-tests, surveys, and interviews (see Fig. 10).
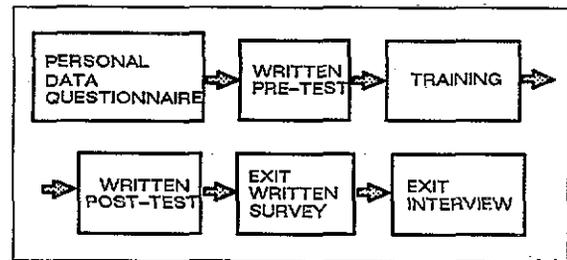

Figure 10 Test Design

Test Sample

In May and June 1991, 20 sailors from 3 Pre-Commissioning Units (PCU) at Newport News Shipbuilding evaluated the AMR Watchstation Trainer. In September and October, 12 additional sailors from a submarine in Post-Shakedown Availability (PSA) used the trainer. In January 1992, six sailors from operational boats took part in the test. The enlisted sailors were of various rates and experience levels. They were organized into two groups: Trainer Group and Control Group (see Fig. 11).

	Control	Trainer
Watchstation Qualified	3	4
Ship Qualified	6	9
Non-Qualified	5	11
Total	14	24

Number of Sailors in Test (N=38)

Figure 11 Test Sample

525

Test Procedure

Sailors used the same 100-point written test for pre-test and post-test. The relative gain score was computed by subtracting the pre-test from the post-test results. The test is valid based on review by experts from the PCUs and is reliable based on test performance.

Training Procedure

The training period was six hours. The control group studied by reading manuals, talking to crew members, and visiting a submarine. The trainer group individually used only the trainer for two hours at a time.

Data Analysis

Given the short period for self-study or use of the trainer, the learning achieved by the sailors was sufficient to show a trend. The relative gain score on a 100-point test is 31.6 for the trainer group, which is three times greater than that of the control group at 10.6 (see Fig. 12).
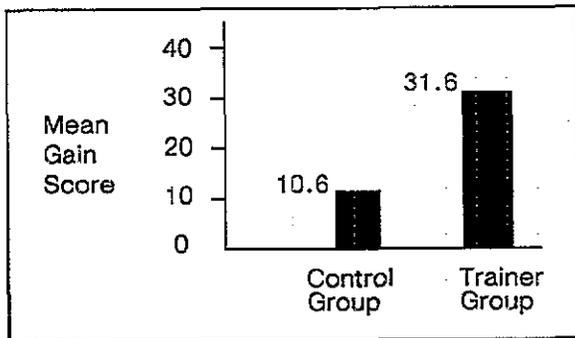

Figure 12 Relative Gain Score

An Analysis of Variance test of the scores shows the trainer and control groups to be significantly different at a greater than 99 percent confidence level. A comparison of subgroup performance showed the non-qualified trainer group to be the most significantly different, followed by the ship-qualified group. An important finding was that the least significant difference was between the post-test scores of the non-qualified trainer group and those of the ship-qualified control group. This showed that the trainer could quickly bring a novice up to the level of an experienced sailor.

Another indication that the trainer can quickly bring the novice to a higher skill level was the time required to complete tasks on the trainer. Although the non-qualified sailor could not perform as fast as the ship-qualified sailor the first or second time, by the third time both groups performed the tasks in half the time of their first performance (see Fig. 13).

GROUP PERFORMANCE			
	TN	TQ	MEAN
SECOND	.77	.53	.64
THIRD	.47	.44	.46

Figure 13 Percentage of Original Time Required for Subsequent Task Performance

The average post-test gain per group increases with less experienced sailors in the trainer group and decreases with less experienced sailors in the Control Group. With inexperienced sailors, the trainer produced a gain 4.3 times that of the similar sailors in the control group (see Fig. 14).

	Control	Trainer	Gain Ratio
Watchstation Qualified	13.3	18.5	1.4
Ship Qualified	11.0	30.6	2.8
Non-Qualified	8.6	37.2	4.3

Figure 14 Mean Gain Score By Group

User Reactions

"Awesome!" "It's like being there." "It's easy to use." "I went to a submarine for the first time and was already familiar with the equipment." Sailors rated the AMR Watchstation Trainer 9.2 on a 10-point scale.

Summary Results

● Computer-based audio and visual procedural training significantly increases job

task knowledge and skills within a short time. **trainer group improved three times better than the self-study group.**

- Dramatic improvement in task knowledge and skills occurs with individuals who have little previous submarine experience. **Non-qualified sailors derived the most benefit.**

- Individuals from a variety of skill backgrounds can use the trainer to obtain training appropriate for their level. **All levels showed improvement, but especially those with little and no previous experience.**

- Skills learned through the computer medium are easily transferable to real equipment operation. **Sailors who used the trainer and then visited a submarine were surprised at how familiar they were with the floor plan and equipment.**

DVI® CONSIDERATIONS

One of the most important elements of any project is a keen understanding of the technology. For a multimedia team well-founded in computer-based training, it meant breaking new ground with DVI®. As expected, there was a learning curve to overcome, as the team stretched the limits of the technology to find out what worked and what did not work. Several decisions at the start of the project were critical to subsequent success. These decisions concerned still images, image source, authoring language, and video.

Still Images

Believe it or not, the hardest media to deal with is the still image. Still images form the basis for training and are the essential visuals that training information supports. In DVI®, three basic relationships must be considered. The first is the relationship between resolution and size. Generally, the lower the resolution of the still image, the smaller the size of the still image. The decision was made to develop the watchstation trainer in a 512 X 480 screeb abd tgeb iverkat a 320 X 300 image in a window. This resolution provided a screen that was well utilized, a good quality image, and good load times from a hard drive.

A second relationship exists between format and size. DVI® provides several basic still image formats: 8-bit, 9-bit, and 16-bit. The fewer bits there are per pixel, the less clear the photographic image. An 8-bit image required little space in the hard drive but left much to be desired for photographic clarity. Conversely, a 16-bit image required a significant amount of space but provided excellent photographic clarity. The decision to develop the Watchstation Trainer in 9-bit format was a compromise of space and quality and provided an added advantage of being compatible with motion video.

Finally, the size of the still image determined how many images can be loaded into video memory at one time. The ActionMedia® delivery boards had two megabytes of video memory. This allows two 512 X 480 9-bit bitmaps and seven 320 X 300 bitmaps to be loaded at one time. In general, the more bitmaps that are available, the more images that can be loaded at one time. Space consideration made it possible to store over 500 good quality still images in the Watchstation Trainer (see Fig. 15).

Resolution 512 X 480			
Format	Size	Theoretical Load Times	Max Bitmap Loaded in VRAM at Once
8	240K	2.4 sec	8
9	272K	2.6 sec	7
16	491K	4.1 sec	4

Figure 15   Still Image Information

Image Source

Another consideration in DVI® development is the original image source. Early decisions on how to capture images will save time, money, and quality. The easiest way to capture images is with a good quality video camera. Still image capture tended to be fuzzy with average quality cameras. Additionally, the image environment was a photographic challenge. The auxiliary machinery room of an SSN688 Class attack submarine is a dark and confining space and provides little

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opportunity for quality shots and proper angles. The multimedia team decided to use a quality 35-mm camera and added background lighting to get adequate training material. The trade-off with 35-mm slides was in scanning time. It took over 5 minutes per slide to scan an image into the platform. As a note, photographs would have been an excellent compromise because they can be scanned easily with Lumena®. They provide an excellent quality image and they can be readily altered to fit the application.

Authoring Language

The authoring language was a big issue in the Watchstation Trainer. As might be expected with any emerging technology, authoring tools which offer all of the features needed to develop the applications are not available. Since the multimedia team felt a virtual environment was critical in making the user feel that he was actually in the Auxiliary Machinery Room, a custom program had to be developed. No authoring package on the market provided a surrogate tour capability. Additionally, the multimedia team wanted to be able to walk around, start up/shut down equipment and react to ship emergencies. These requirements led to a programming design document written in "C" language. The approach was generic. It could have been any space in the submarine, any piece of equipment and any procedural drill. The decision to develop the application using "C" was the most important decision made. It led to a more robust application with features that accurately simulated the actual environment. Since the virtual environment was defined by databases rather than by a program, this approach provided a standard methodology that could be quickly adapted to meet other training requirements.

Video

Finally, the use of video affected development time and image quality. There are two varieties of video: Real Time Video (RTV) and Presentation-Level Video (PLV). RTV can be easily captured using the ActionMedia® boards

and is great for rapid prototyping. RTV gives the advantage of using video to ensure proper content and length early in the development cycle. The multimedia team and, particularly, the trainees in our evaluation, found the quality adequate for training purposes. For best quality of the RTV, a quarter screen image appears quite sharp. Unfortunately, the production process requires that video be converted to PLV in order to press a CD-ROM. The cost per minute of video footage is significant from a training standpoint.

WHAT'S DIFFERENT ABOUT DEVELOPMENT

For training developers who were baptized in the Instructional Systems Development (ISD) process, DVI® technology presented some interesting development issues. One issue was the realization that early accumulation of images provided a opportunity for rapid prototyping of the Watchstation Trainer.

Rapid Prototyping

Shortly after the decision was made to create a surrogate tour, a camera crew was dispatched to shoot enough tour shots to get a good idea of what the environment was like. With these visuals in hand, the training development process was greatly aided. Storyboarding and scripting became much easier to develop with visual images to describe task activity and sequencing. With visual images available early on in the application, it was easier to develop a prototype and refine it. Programming was easier too, because the training developer could point out precisely what he wanted to occur on the image.

Since development time can be saved with early acquisition of images, the authoring and testing process can be streamlined. In the Watchstation Trainer, two databases were critical: the surrogate tour and the equipment objects. With pictures scanned into the platform according to a relational database, linkages between tour slides and object slides were easy to establish. Internal testing was also easier to accomplish. When the subject matter expert reviewed each task, it was easy to correct any discrepancies.

Interactivity

The multimedia team had to rethink its concept of using video to support training. People have been conditioned through decades of television viewing that video is learning. On the contrary, video is a passive media that limits trainee interactivity. Video is very linear and unless it can be broken into short vignettes and interspersed with trainee responses, it fails to motivate and cause learning. The multimedia team concluded that still images with interactive hot spots that required frequent trainee response would be a better training technique. Video was confined to a short training introduction and a four-part vignette on employing the Emergency Breathing Apparatus.

Generic Development

The development process was also greatly aided by the desire to go "generic." The multimedia team looked on this project as a starting point in designing DVI® part task trainers. As operational equipment and training tasks were analyzed, commonality was the key and, where possible, generic designing and programming was employed. Several different gauges and switches were modelled in an identical manner. The needles of all gauges were removed through Lumena® and were computer-generated for the particular task. Generic development and programming added flexibility. Every log reading in the current application is within specification. If the customer wanted, it would not be difficult with a computer-generated needle to make the next reading be outside the specification. The trainee would then be called upon to diagnose the problem and take remedial action.

VIRTUAL ENVIRONMENT SOFTWARE

As an outgrowth of this project, the multimedia team developed a low-cost personal computer application development tool called MediaMagic*. This Virtual Environment Training (VET) tool was designed to aid in developing subsequent training and touring applications.

MediaMagic* makes possible the creation of an environment where the user can take a familiarization tour and manipulate objects. MediaMagic* software accelerated the organization of training material into the Watchstation Trainer. A VET development procedure was adapted by the multimedia team to streamline production (see Fig. 16).
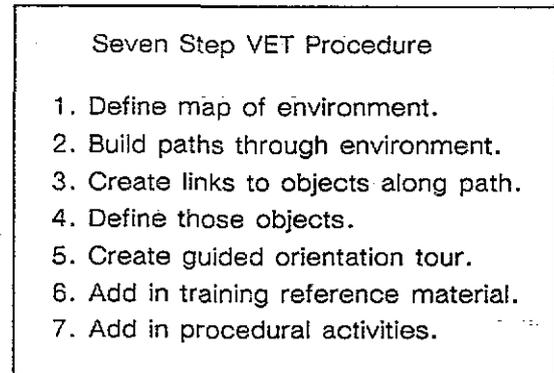
Seven Step VET Procedure

1. Define map of environment.
2. Build paths through environment.
3. Create links to objects along path.
4. Define those objects.
5. Create guided orientation tour.
6. Add in training reference material.
7. Add in procedural activities.

Figure 16 VET Procedure

PERFORMANCE ADVANTAGE

The AMR Watchstation Trainer demonstrated that DVI® was an emerging technology that offered some clear advantages for training. Through evaluation using any criteria for success, this training media cannot be ignored (see Fig. 17).
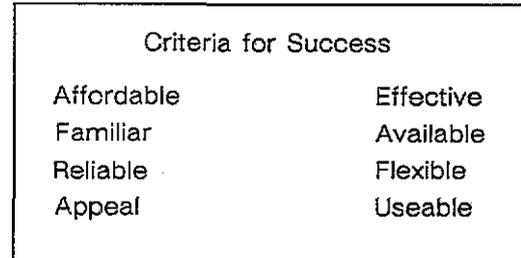
Criteria for Success

Affordable	Effective
Familiar	Available
Reliable	Flexible
Appeal	Useable

Figure 17 Criteria for Success

DVI® was particularly effective in motivating trainees through clear images and high interactivity. The technology proved to be reliable and flexible. Images and text could be updated easily. Today's trainee had no problem understanding how to operate the personal computer or to use the application features. The AMR Watchstation Trainer appealed to the test sample. They rated it 9.2 on a 10-point scale. The technology could be useable ashore or at sea and the price of the ActionMedia® boards is within reach of any serious developer or trainer.

MediaMagic* is a proprietary product developed by Newport News Shipbuilding

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