ADVANCED INSTRUCTOR'S WORKSTATION
for
MILITARY TACTICS TRAINERS

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ABSTRACT

As military tactical systems have become more complex, the costs of the operational hardware and the consequences of having inadequately trained personnel manning the equipment have both risen dramatically. The increased complexity of the operational equipment is reflected in the training devices and simulators built to train the operators. The additional burdens placed on the training device instructors and operators by this increased complexity can be mitigated through the use of modern display system hardware and software systems which can provide improved man-machine interface techniques and trainee performance monitoring and evaluation facilities at costs comparable to those of older, less effective systems.

INTRODUCTION

For a number of years, the United States Military Services have been aware of the many advantages which simulators and training devices offer in training. They are cheaper to produce and to practice on than the operational equipment, and they are often easier to understand than the actual equipment because they can depict normally invisible functions and events, such as the shape of a sonar beam pattern. Based on observed student performance, the simulator personnel can determine how much practice the student needs and can isolate and repeat the difficult segment of a task. Since training scenarios can be made to occur at speeds that are much faster than real time, the effect of manipulations can be seen quickly and additional practice accomplished quickly. Perhaps of greatest importance is the fact that simulators can incorporate important training variables such as detailed student performance evaluation and feedback.

However, in order to provide these capabilities on increasingly complex operational systems, simulator design and associated operating procedures are themselves becoming more and more complex. This results in increased instructor workload, and the primary task of monitoring and evaluating trainee performance becomes increasingly difficult.

Realizing that instructors are a very expensive resource, *new efforts in instructor/operator station (IOS) design* must focus on reducing the instructor's workload (and hopefully the instructor to student manpower ratio) by providing a powerful and easy to use man-machine *interface and trainee performance monitoring solutions* utilizing workstation-based color graphic display technology.

Man-Machine Interface Principles

Man-Machine Interface PrinciplesMany IOS features are not fully exercised because their functional designs and operating procedures are too complicated. Many of today's IOS systems require too much thinking about how to operate or gain access to trainer control and monitoring features rather than allowing the instructor to concentrate on the principal task of student instruction and evaluation. For these reasons, ease of use becomes a primary consideration in the man-machine interface design.

One principle which must be adhered to is that of maintaining a consistent screen layout. There may be dozens of different displays on a given IOS, and it is important that a common format be carried throughout, so that control functions and status information are where the instructor would "expect" to see them on each screen. As an example, the screen format is divided into three separate regions, which occupy the same screen location on every display. The Master Index Display shown in Figure 1 illustrates these screen layout conventions.

Along the top edge of the screen is the Status Region. This contains important simulator status information such as problem time, trainer mode, current scenarios, etc. It also contains a field for presentation of alert messages.

At the bottom of the screen is the Control Region, which provides direct access to all main displays (e.g., Master Index, Tactical Summary, etc.) and primary simulator control functions (e.g., freeze/run, reset, etc.). Included in the Control Region is a dialogue area which accepts and echoes all keyboard input.

The Data Region is located in the center of the screen and occupies the majority of the viewing area. The Data Region contains display-specific information and its content will be different for each display, but screen location, color conventions, and function selection/activation methods will not vary.

A second principle is to maintain ease of use by minimizing the number of steps or keystrokes required to interact with the displays and trainer functions. There are times when keyboard input is appropriate (e.g., when numeric input is called for), but position entry devices such as mouse, touch screen, digitizing tablet or trackball can be much faster and easier to use when implemented in the proper environment. Position entry device input manipulating a screen-resident locator (arrow, balltab, cross hair, etc.) is used wherever possible to activate control functions and initiate display requests.

Screen targets (areas of the screen which respond to locator selection) are color coded to provide visual feedback to the operator. Normally, a screen target for a selectable function is medium blue in color. When the locator device is positioned within the screen target and the button is pressed, the screen target will "highlight" to light blue indicating that it is currently selected. No action is initiated however, until the button is released. This allows the operator to change his mind, move the locator out of the screen target area before releasing the button and initiate no action. If the cursor remains within the screen target and the button is released, the selected function will be initiated. This philosophy of using a position entry device to position a locator symbol on the screen target not only provides effective feedback

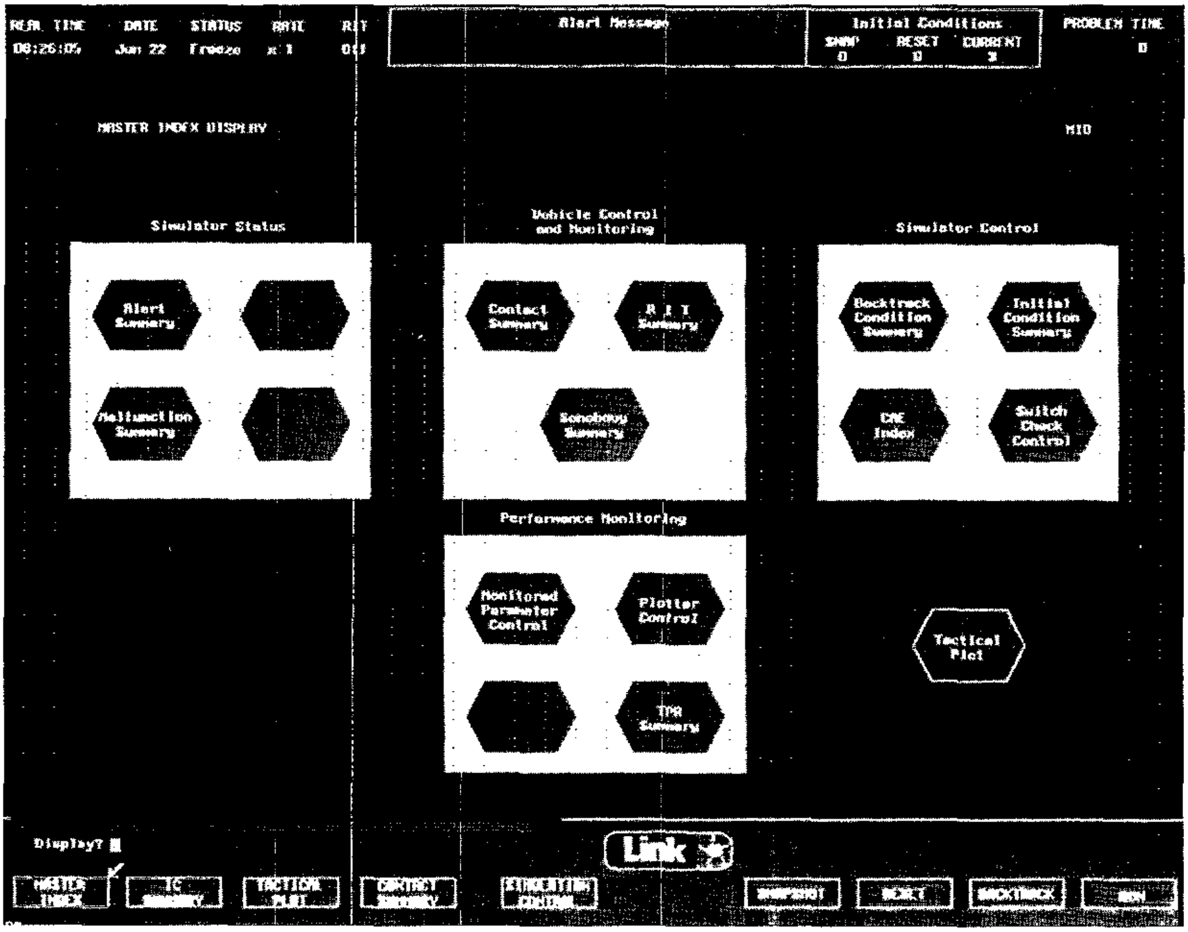

Figure 1. Typical Display Page Organization

to the user, but also eliminates any problems associated with parallax, which is especially important when the position entry device/locator is a touch screen. The color change from medium blue to light blue provides a fool-proof visual feedback that allows the operator to accurately position the locator device before activation of any function.

The third principle for promoting ease of use is a philosophy of "information at a glance." Consistent screen layout contributes to this goal (the user will know where to glance because related information will be in the same location on different displays) but advantage is also taken of spatial arrangement and color cues to facilitate rapid information assimilation. Referring again to the Master Index display in Figure 1, note that the displays are arranged in functional groups which are delineated graphically, rather than in an alphabetically ordered list of titles. The adherence to this principle is further promoted by the extensive use of graphical representation of information rather than alphanumeric representation of data. A prime example of this philosophy is the performance monitoring Detectability Display which is discussed later in this paper.

Use of Color

The judicious and consistent use of color in the man-machine interface design is another powerful mechanism for providing information at a glance. Due to the complexities of the physiological, perceptual, and cognitive issues involved, the use and selection of specific color schemes cannot always be supported by references to precise scientific evaluation; however, guidelines can be formulated. As with the physical screen layout, color coding is used consistently on each display. Color coding for the screen targets is universal (medium blue = selectable, light blue = selected, orange = activated, black = non-selectable) as is the color coding for contacts on the Tactical plot displays (white = friendly, yellow = unknown, red = hostile).

A viewer can sense the relationship of various screen elements by color over space (different areas of the screen) and time (in sequences of displays). Similar background colors for related areas can subtly orient the viewer to recognize the conceptual linking of two separate areas without other, more explicit cues. An example of this is shown in the Tactical Summary Display in Figure 2, where the same shade of gray is

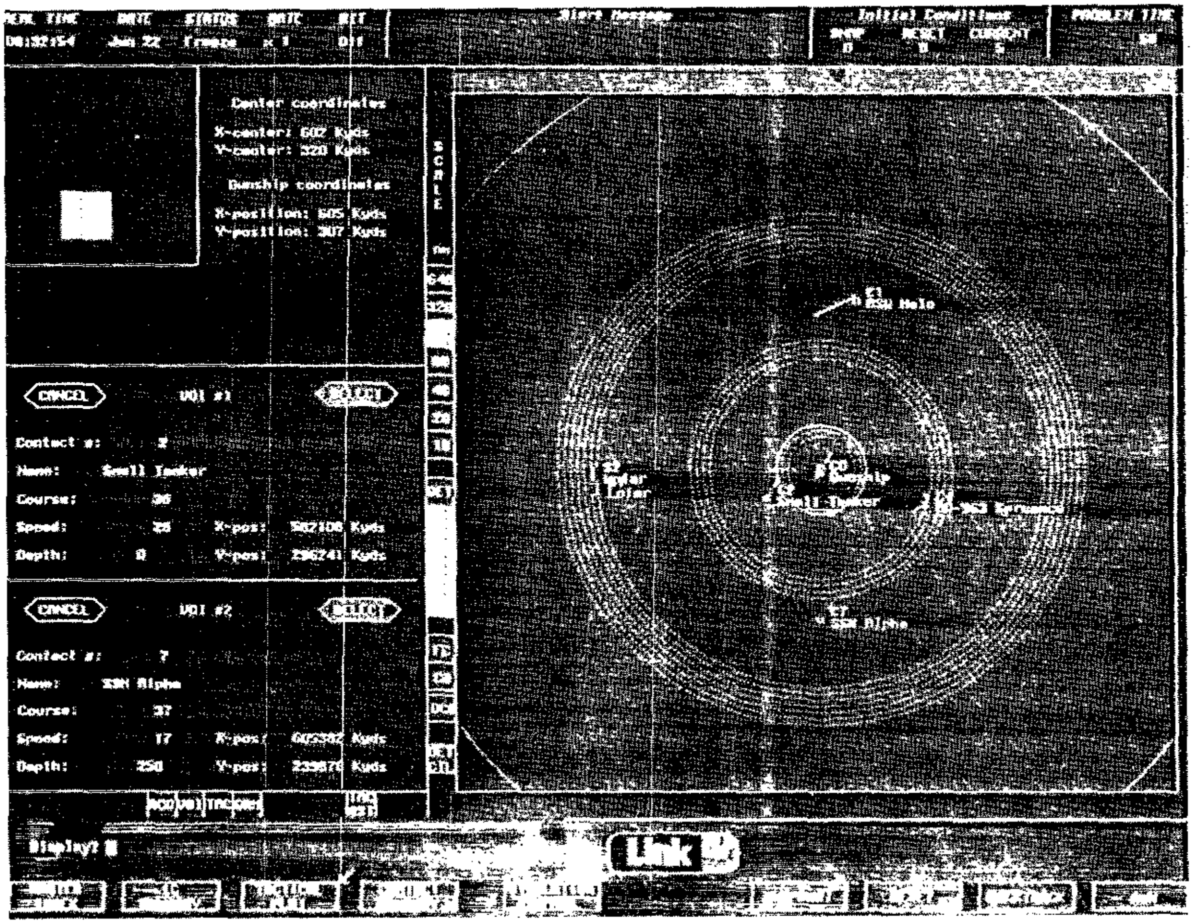

Figure 2. Tactical Summary Display Page

used in the overview window and the main Tactical plot elevator bars to represent the currently visible portion of the gaming area.

Screen background and window background colors were selected to provide adequate contrast and reduce visual fatigue. Low saturated blue (dark grayish blue) and cool gray colors were chosen for those reasons. The number of colors used in the man-machine interface was also chosen with deliberation. A subdued color scheme with a small number of color values and saturated accent colors was selected. The use of many colors, especially saturated colors, dilute the communicative effect of the display, as well as the impact of emphasis.

<u>Windows and Popups</u>

When designing a man-machine interface for a complex system with many different displays it is important to:

- Organize the displays in a functionally logical fashion so it will not be difficult for the user to find his way from one display to another.
- Employ detail masking techniques to prevent the user from being inundated with a flood of data. The most important information is presented in response to the initial request, and then further detail is provided as the user requests it.

Both of these problems are addressed by organizing the displays and the information they present in a hierarchical structure. This structure is in the Master Index Display page (Figure 1). This display provides direct access to the four main summary displays that have been implemented thus far (Initial Condition/Scenario Summary, Contact Summary, Sonobuoy Summary and Reactive Intelligent Target Summary). These displays show high level summary information as their titles indicate. Additional detail and control functions are provided at the user's request via popup windows. It is important to point out that most of these popups are context sensitive and all of them display dynamic information.

Figure 3 shows the Contact Control Popup as an example. Although the format of the popup is fixed, its display content is context sensitive in that it displays the information for the specific contact (in this example, contact which is an Alpha class submarine) that was specified when the popup was requested. Parameters such as x and y position, range and bearing from ownship, ordered and actual course, speed, and depth are

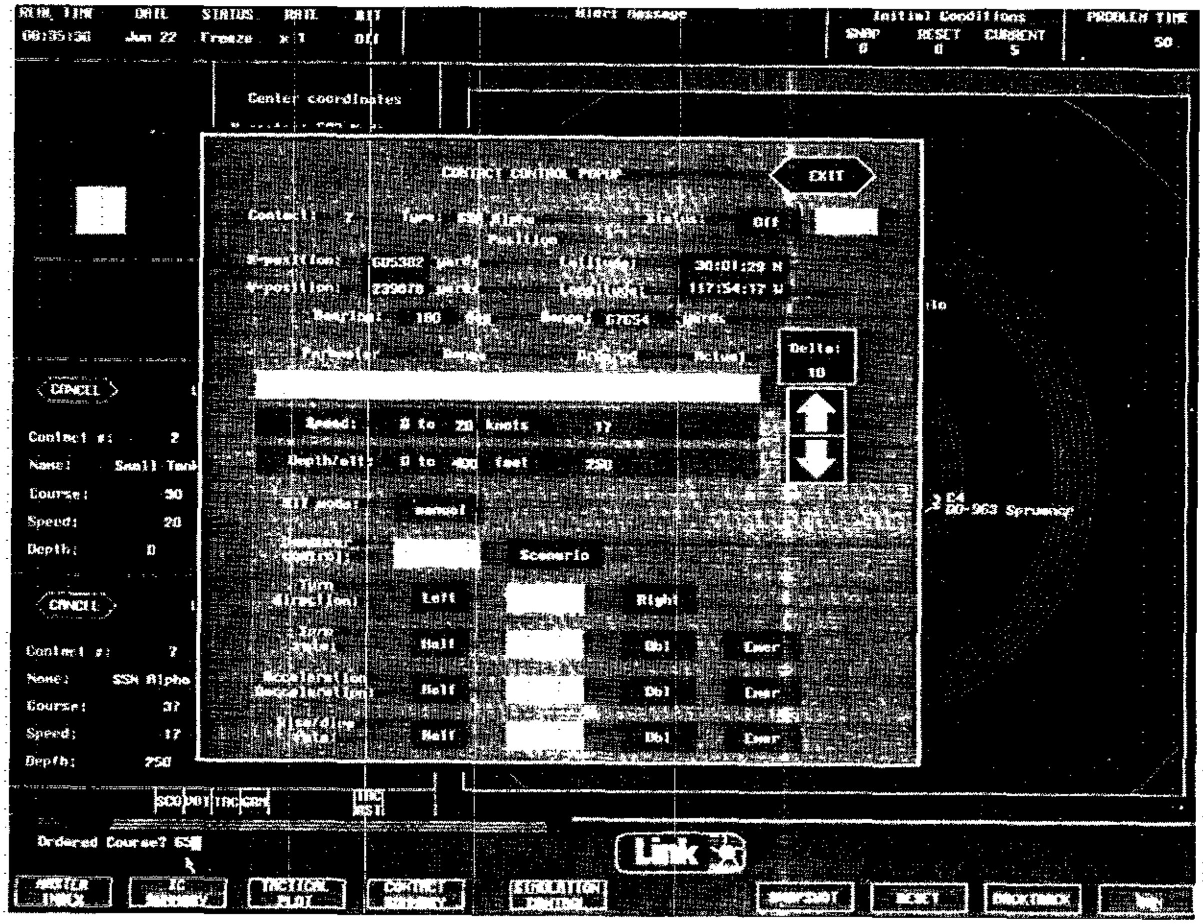

Figure 3. Tactical Summary Display with Overlay Popup

all displayed for this particular contact and are updated periodically. Control functions are also provided via the screen target/locator device mechanism described earlier. The currently active engine orders are shown in orange so that status can be determined at a glance.

The major disadvantages of using popup windows is that part of the underlying screen must be occluded. In a real time tactical training situation that is undesirable, especially when viewing the Tactical Summary display. To alleviate the problem one may be tempted to reduce the size of the popup, or allow the user to interactively select its location on the screen. The first approach reduces the amount of information that the popup can contain and also impacts readability. The second approach requires the user to take the time to distract himself from the training problem (which is his primary task) and deal with the task of arbitrarily determining where to position the popup on the screen. Both of these "solutions" miss the point of the utility of the popup feature. The reason the popup is being displayed is because the user requested access to additional information or control functions. Regardless of where the popup is placed on the screen, the instructor will have to focus his attention there for as long as it takes to assimilate the requested information and/or perform the desired control functions. Thus, it is necessary to make that time period as short as possible so the instructor can deal with it and return to what he was doing. This imposes two important requirements on the system:

- The information and control functions within the popup must adhere to the design principles of information at a glance and ease of use.
- The display system hardware must be powerful enough to present, update, and close the popup with a minimum of delay time.

The first requirement has been addressed in the man-machine interface design itself, and the second requirement must be addressed during the equipment phase of hardware design.

In addition to the available popup windows shown in Figure 3, the Tactical Summary Display (TSD) is also provided with fixed windows (or "tiles") whose content can be customized by the instructor to provide information which he feels is important.

Tactical Summary Display

The Tactical Summary Display (Figure 2) is the most important part of the IOS man-machine interface because it provides the instructor with a graphic overview of the simulated training problem. For that reason, particular attention has been focused on its design and it contains several features and capabilities which are discussed here.

The TSD comprises three fixed windows within the Data Region of the screen. The main tactical plot occupies approximately two-thirds of the region and is bordered by elevator bars and feature selection screen targets to control tactical plot scaling, center and the presentation of range rings, track history, and heading vectors.

The scaling and function selection screen targets follow the color conventions described earlier. The center of the viewing area may be translated in several ways:

- By using the horizontal and vertical elevator bars to independently change the x and y locations of the center point. Note that the gray portion of the elevator bar represents the viewable area with respect to the entire gaming area and thus provides a visual cue for the current scale factor.
- By selecting the Fixed Center (FC) function and then picking a new center within the tactical plot area with the locator device.
- By selecting the Center On Ownship (CO) function to recenter the display at the current coordinates of ownship.
- By selecting the Dynamic Center on Ownship (DCO) function which recenters the tactical plot on the ownship and maintains it there as the ownship moves (relative motion display).

These methods are provided to facilitate manipulation of the plot area without the need to type in specific coordinates (although numeric input could be provided if desired). Note that the entire tactical plot window is also a screen target. When one of the contacts or sonobuoys is selected with the locator device, the corresponding context-sensitive contact or sonobuoy control popup is displayed. This provides the instructor with "one touch access" to additional information and control functions for every contact and sonobuoy displayed in the tactical plot area.

To the upper left of the TSD is a tactical overview window. It contains a color encoded location marker for every contact and sonobuoy in the gaming area and also shows a gray square which represents the area currently visible in the main tactical plot window. The user can then see the relative location of all contacts, whether or not they are currently displayed in the main tactical plot area.

The third window, at the lower left of the TSD may be configured in one of three different modes:

- Vehicle of Interest
- Auxiliary Tactical Summary
- Gram Plot Display.

The screen targets below this auxiliary window are used to select the desired mode. Vehicle of Interest mode can display tactical parameters (course, speed, depth, position, etc.) for one or two selected contacts. The Auxiliary Tactical Summary mode can be set to view a certain area of interest within the gaming area with selected features (detectability, track history, etc.) enabled. This auxiliary display will maintain the initial scale, translation, and feature settings until reset by the instructor (independent of the corresponding selections in the main tactical plot window). This affords the instructor with a "split-screen" tactical plot so two separate regions of the gaming area may be monitored at once.

The key design consideration for the TSD is flexibility. By providing the features discussed above, the instructor has the capability to easily "customize" his view of the tactical situation to focus on what he feels is important at any point in the training scenario. Since the area of interest and the relative importance of various parameters change dynamically, it is important for the instructor to have this flexibility at his disposal.

A second design consideration is display system performance. The TSD is a critical display which summarizes the training problem for the instructor and the information represented on this display must be updated in a timely fashion. Experience with both workstations based and graphic processor board-based instructor station designs shows that display update intervals of one second and display page change intervals of two seconds can easily be achieved with off-the-shelf general purpose equipment.

TRAINEE PERFORMANCE MONITORING

Automated Trainee Performance Monitoring

The primary task for the instructor is monitoring and evaluating the performance of the trainees. Any improvements in the man-machine interface must address the issue of providing the instructor with easy access to trainee performance indicators that are both readily interpreted and easily assimilated. Initial IOS development efforts investigated the feasibility of automating trainee performance monitoring (TPM), in an attempt to allow the IOS computer system to reduce the instructor workload. There are several salient problems associated with TPM in general, and automated TPM in particular:

- Much of the critical input for trainee performance evaluation must be extracted from verbal communication between the trainee and the instructor and/or between trainees at different stations. At present, the technology does not exist (i.e., real-time speech recognition systems and natural language assimilation) to cost effectively automate this information extraction process.
- Aside from checks on the accuracy of calculations and plots and whether or not the trainee has placed the hardware in the proper operating modes (knobology monitoring), there is very little objective measurement available to the instructor. Most performance assessment methodology involves the qualitative evaluation of decisions and tactics, which does not lend itself to automated measurement.
- There is a great reluctance for instructors to fully embrace the concept of computer-generated scoring because they tend to form their own opinions about how a particular student is performing and would not trust the "judgement" of a computer program over their own judgement.

With respect to the first of these problems, discussions with customer personnel have indicated that attempts to use such devices as event-marked tape recordings of voice communication during a training event have been of minimal or no use, even for debrief purposes. This is due primarily to the necessity for each member of the training staff to relate his critique of the voice communications which he overheard. Since there does not seem to be a practical way to remove the man-in-the-loop at the present time, the development efforts for the IR&D must focus on providing an easy to use mechanism at the IOS to allow the instructor to monitor and manually annotate significant voice communication events.

Upon analysis of the second problem, which addresses the issue of expert system technology as applied to trainee performance monitoring, research and discussions with experts in the field indicate that successful application of this technology to date has been in the area of "smart targets". This is probably due to the fact that expert systems are (at least at present) practically limited to "fixed" tactics.

Ideally, an automated TPM system would be capable of running a trainee through a given exercise or multiple exercises, automatically evaluate the trainee's performance, and compute a pass/fail score. The computer would also perform adaptive problem selection, recommending specific training scenarios based upon an analysis of the trainee's past performance, and could even update the student's training record. But even if this "ideal" system did exist, it may take some time for the instructors to develop trust in its output.

Due to these complexities which are inherent in developing the "machine intelligence" necessary to automate the trainee performance monitoring process, attention was instead focused on designing a system which would make it easier for the instructor to evaluate students by providing him with intuitively obvious graphic displays which would summarize the training situation. However, this system would be designed so that an expert system could easily be integrated at a later date. To accomplish this, the "scorecard approach" to TPM was developed.

A scorecard is a manual checklist that most instructors use as a guide to evaluate student performance. In order to provide a familiar point of reference within the performance monitoring system of the IOS, a scorecard display was developed. The initial implementation is a copy of the paper score card which is displayed on the screen. The intention is to provide increasing capability as time and technological advances will allow:

- Prompt the instructor to manually enter scores at the appropriate times during the exercise.
- Add an expert system to provide "recommended"scores which the instructor can query back to their origin and/or override with his own scores.
- Provide additional graphic display formats to support the "recommended" scores.
- Allow the capability to easily modify the scorecard and its associated expert system rule base.

A sample scorecard display format is shown in Figure 4.

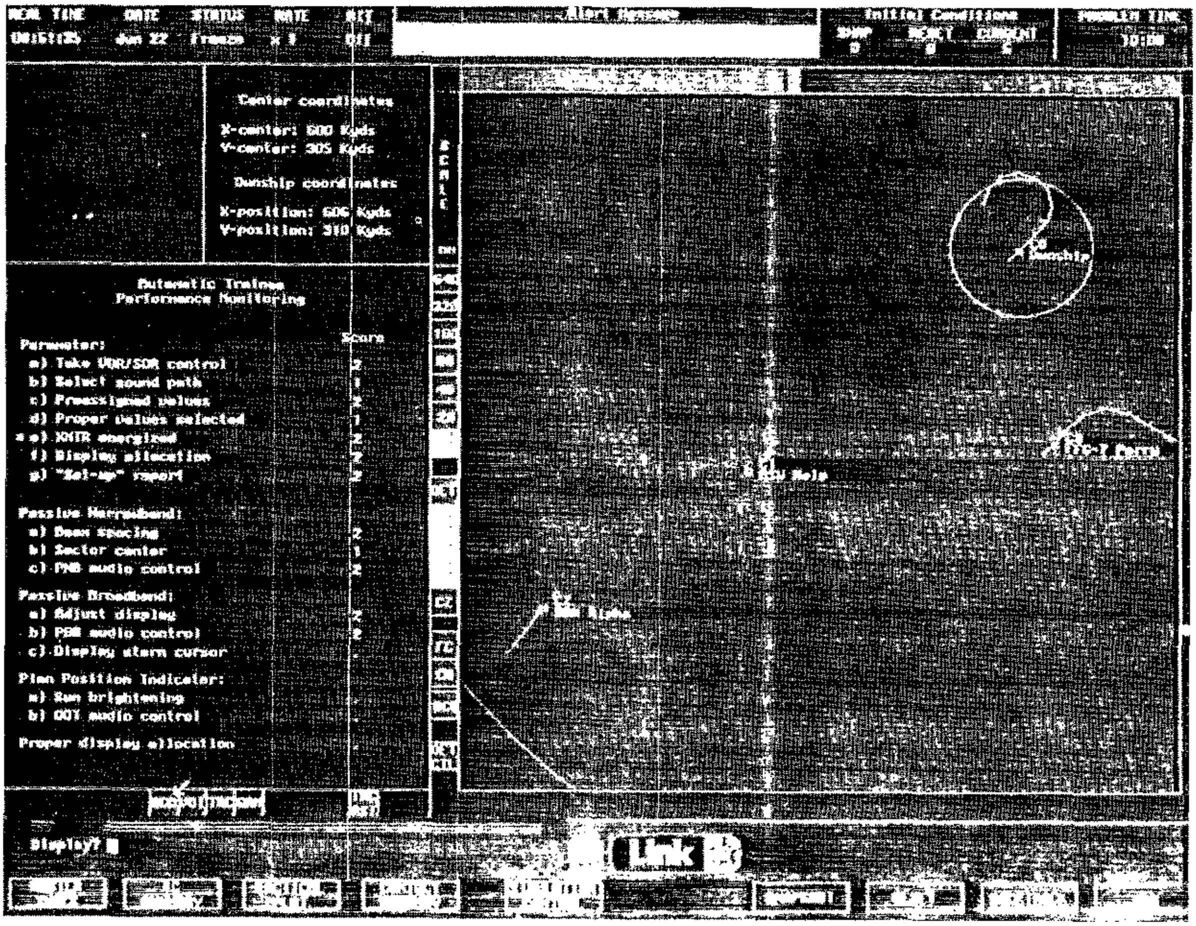

Figure 4. Tactical Summary Display with Scorecard Popup

Detectability Plot

The detectability display is one of the graphic display formats which is designed to reduce instructor workload by providing a graphic representation of one of the most critical student performance parameters. During the "detection phase" of a training exercise, it is important for the instructor to know when it becomes possible for the trainee to acquire a given contact. The detectability display presentation provides a means for the instructor to determine if a student should be able to detect a contact with a given sensor system. Typically, a scenario is established by the instructor. During that scenario, the instructor needs to be able to quickly determine whether or not a contact is detectable by a sensor at any point in time. This is not a trivial matter since all targets can be moving and sensors can move also. Even though the instructor established the problem, (and theoretically has "perfect" knowledge of the problem) there is such a large number of target/sensor pairs, that it is not obvious who can detect whom and with what sensor. The detectability display presentation gives the instructor an interactive display from which he can find the target/sensor pair of interest.

The detectability control popup is shown in Figure 5. This display allows the instructor to "filter" the information that is displayed on the tactical summary display when it is in detectability mode. The control popup allows the instructor to select in any combination any of five sensor systems (radar, sonar, ESM, MAD, infrared) and to enable or disable detecting and detected platforms. As the instructor enables sensors, detecting platforms, and detected platforms of interest, the detectability matrix within the popup is updated with yes/no (Y/N) values to indicate who is detectable by whom. At the same time, the TSD is updated with lines between the platforms of interest to represent the detectability situation graphically.

In addition to this yes/no detectability display, additional TSD display elements (convergence zone and propagation loss displays) will be provided to facilitate the instructor's understanding of how and why the detectability determination was made. The data base which supports these display elements will be derived from simulation data alone, without any need for expert system inputs.

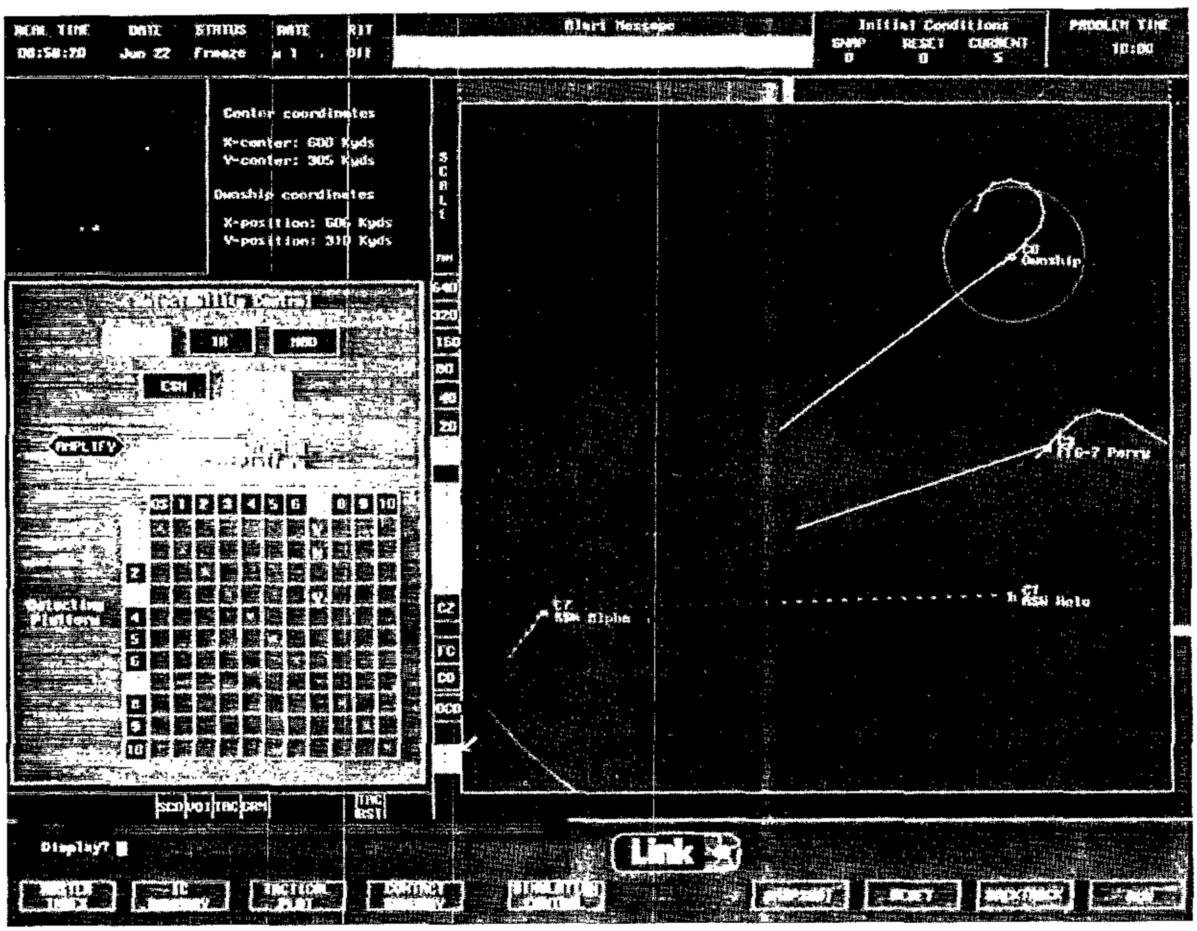

Figure 5. Tactical Summary Display with Detectability Matrix Popup

Additional TPM Displays

Recent developments in the field of video processing and format conversion, coupled with the increasing use of high resolution video displays in operational tactical equipment now provide the opportunity to reproduce at the IOS the tactical display images seen by the trainee on his sensor displays. These repeat images can either be shown on separate display monitors at the IOS, or can be inset into a window on the instructor's color monitor. This will permit the instructor to effectively "look over the shoulder" of the trainee without having to leave the IOS and the other monitoring and control functions it provides.

CONCLUSIONS

Instructor workload can be effectively reduced by:

- Providing an easy to use man-machine interface using context sensitive popup windows
- Providing trainee performance monitoring aids such as interactive graphic displays of critical student *performance parameters*

A powerful and easy to use graphic software development environment has been designed and implemented on a commercially available UNIX workstation. Within this environment, a window-managed man-machine interface and several graphic displays have been developed to facilitate the instructor's task of trainee performance monitoring. The *man-machine interface and the TPM displays have* been demonstrated to numerous customers and potential users with favorable comment. Feedback from these demonstrations indicates that the concepts are sound and the work done thus far has potential for training device application.

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JOHN GAUGHAN is a Staff Scientist with the Link Tactical Simulation Division of the CAE-Link Corporation. He reports to the Director of Military Systems and is responsible for new business support and front-end analysis and design for instructor station and display systems. He also provides oversight during the design and integration of these systems. He has been the lead instructor station and display system engineer on several military and commercial trainers including the Trident tactical team trainers, the U.S. Army Training Battle Simulation System (ARTBASS), the Saudi Arabian Air Force F-5E flight simulator and several Action Speed Tactics Trainers (ASTT). Mr. Gaughan holds a Batchelor of Science degree in Electrical Engineering from Rose-Hulman Institute of Technology and is the co-owner of a patent for a high-performance special purpose graphic processor.