COMPUTER SIMULATION FOR A COMMAND AND CONTROL TRAINING SYSTEM

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The Navy is currently utilizing a greater number of tactical command and control systems comprised largely of digital computers and digitally-driven CRT displays. Examples in the area of Submarine Fire Control Systems include: MK 113 Mods 9, 10, the MK 117, and the Commanding Officer's Tactical Display (COTD), and the Standard Information Display (SID). The training on these and other similar command and control systems has developed along the somewhat limited lines of each hardware system. Thus, a need for optimizing the employment of these systems exists.

The most frequent assumption with regard to training equipment has been to suggest duplicating the original MIL Spec hardware. A number of reasons offered in support of this approach include:

1) Control of the training program by the respective technical code.
2) Additional buys of hardware units for training to reduce per/unit cost.
3) Ease of accommodating software adaptions in the engineering change cycle.
4) Common application of the MIL Spec hardware for spares logistics and knowledgeable maintenance personnel.
5) Greater potential acceptance of actual hardware by the military user personnel.

Several arguments which we submit in rebuttal of this position are more powerful and overriding. These are:

1) The cost of the actual MIL Spec systems is from 5 to 20 times as expensive as commercial off-the-shelf hardware which can be used to simulate the actual systems.
2) Many of the training requirements can be met with part-task simulators which do not require the complete military system to be erected at one time.
3) The military system's computer core is usually allocated to the main program, not allowing room for an efficient integration of the main program, the training exec, and the performance measurement and diagnostic routines.
4) The similarities in the hardware design of existing military systems enhances the ability to generalize across these systems with one training system.
5) Often the implementation of a military system in a training mode results from the assumption that training technology is not available in the form of curricula, strategies, performance measurement, and models of Weapon System Effectiveness. This situation is complicated further by placing the burden of training on operational Navy personnel. These personnel range widely in experience, in their awareness of training technology, and in the potential alternate implementation of these technologies.

The real need in the implementation of training is to provide training systems which are designed to instruct in the various subject matter, not the "knobology" of the military hardware.

This problem directly addresses one aspect of the theme of this conference.

Namely, the issue of training economy through simulation as opposed to actual hardware stimulation or stand-alone military hardware with built-in training and test modes.

Several studies directly support this thesis, specifically those of Hammell, Allen and Sroka (1971) and Hammell, Gasteyer and Pesch (1973), where it was recommended that the Navy develop a generalized individual training device. Several of the generalized applications of "instructional cores" for the device include: individual operator training, advanced training in the area of decision-making, conceptual training in basic TMA/tactics, weapon deployment, and environmental physics.

Somewhat independent of the generalized training concept, the Navy has had reason to concern itself with the quality of command and control decision-making. It has become apparent that increasing the number of individuals involved in the decision-making process and the availability of information per se does not necessarily improve the quality of the decisions nor the tactical performance of Navy commanders. Accompanying this observation, there has been the realization that reduced opportunity for tactical experience and individual differences in decision-making capabilities are contributing to less than optimal decision-making behavior on the part of Navy tacticians. Therefore, the requirement exists for a decision-making training program which will enhance the development of the tactical decision-making capabilities of Navy personnel.

OBJECTIVE

This paper describes a research program initiated to develop a prototype system for conducting an evaluation of various techniques for training tactical decision-making and to verify the concept of the generalized individual training device. The ultimate objective is to define the training technology and design criteria for the training systems to support the development of skills required by the command and control functions associated with threat evaluation, weapon selection, and weapons employment in a Navy tactical environment. A requirement of this effort is to define a training system which can satisfy actual instructional needs of decision-making using the MK 81 Analyzer of the MK 113 Mod 10 FCS as an applied working context.

MAJOR FEATURES OF THE PROGRAM

Research findings have generally indicated that a structured approach, with training curricula and objectives defined in behavioral terms, is needed to develop an effective system for training in dynamic decision-making processes. Investigations of tactical training (Hammell, Allen and Sroka (1970), and Hammell, Gasteyer and Pesch, (1973) have recommended the development of a generalized and individualized approach. Also suggested was the potential application of this approach for operator training and advanced training in the decision-making functions associated with submarine fire control systems. These findings and recommendations served as a basis for the developmental efforts pursued in the design of a prototype system for conducting research in the training of decision-making processes.

In dealing with real world tactical problems, Navy decision makers must frequently respond to data of varied reliabilities and values from a dynamic environment. In an attempt to attain relevancy to the operational environment, and thus, develop a potential for high positive transfer from the training simulation to the operational environment, the major design features of the prototype system are based on real world material.

The structure of the training system is based on submarine task analysis and tactical decision-making training data derived from training objectives and tactical scenario descriptions. The requirements of decision-making training for the submarine officer from the junior level through the senior level are addressed in the structure. The training objectives are based on the compilation of the findings reported in the decision-making training research literature and on the task analysis data of the submarine officer's tactical functions. The MK 113 Mods 7 through 10, Fire Control System and the MK 81 Analyzer served as the principal hardware sources for implementation of the data.

Several alternate approaches exist for the development of a training structure. A combination of two alternate approaches, described by Kanarick, Alden and Daniels (1972), in which a distinction is made between the "component behavior" approach and the "process task" approach to training decision making, was used in developing a four-level structure for the prototype system. Table 1 presents an outline of the four levels of the generalized training structure with headings for the major sub-topics. Series of training topics and supporting scenarios which represent the core of the curriculum are not shown in the table.

Level I provides an indoctrination into the fundamentals of various decision-making techniques and an understanding of the potential value and application of these in the decision-making process. The basic skills and

Table 1 Generalized Training Structure

LEVEL I

BASIC INTRODUCTION TO MILITARY DECISION-MAKING

HISTORY OF DECISION-MAKING RESEARCH	DECISION-MAKING APPLICATIONS IN MILITARY COMMAND AND CONTROL	QUANTIFYING DECISIONS WITH BASIC TOOLS	ELEMENTS OF TRAINING IN THE DECISION-MAKING PROCESS	BEHAVIORAL VS FORMAL ANALYSIS	EXAMPLES OF DECISION ANALYSIS APPLICATION

LEVEL II

SKILLS AND KNOWLEDGES IN THE DECISION-MAKING PROCESS

PERCEIVE THE EXISTENCE OF A DECISION PROBLEM	DEFINE THE PROBLEM	ACQUIRE AND PROCESS INFORMATION	ANALYZE AND STRUCTURE THE PROBLEM	SCALE THE PARAMETERS OF THE PROBLEM	IMPLEMENT THE DECISION	MONITOR/STORE FEEDBACK RELATED TO THE PROBLEM

LEVEL III

BEHAVIORAL DEFICIENCIES IN DECISION-MAKING

STEREOTYPY	PERSEVERATION	INCOMPLETENESS	UNTIMELINESS	SERIES INCONSISTENCY

BEHAVIORAL DECISION-MAKING PROFICIENCIES

PROBABILITY GENERATION	PROBLEM VISUALIZATION	ADAPTABILITY	INDIVIDUAL AUTONOMY

LEVEL IV

TEAM DECISION-MAKING

GROUP DYNAMICS (LEADERSHIP)	GOAL DIRECTION	COMMUNICATION	KNOWLEDGE OF OPPONENT	KNOWLEDGE OF OWNSHIP CAPABILITIES

knowledges required in the decision-making process are presented by Level II. The training at Level III addresses the deficiencies and proficiencies identified in the decision-making research of Sidorsky (1964). The goal of this training level is to place the trainee in specific structured situations which will provide familiarity with and an understanding of the known deficiencies and proficiencies involved in decision-making processes. The fourth level of the structure is directed toward the application of decision-making processes in a team context. The objectives of this training level follow to a great extent the recommendations of Hammell and Mara (1970) and represent an integration of the training objectives of Levels I, II, and III in the team structure.

The principal strategy for implementing the training material in a specific context was to follow an individualized approach to training. Selection of the individualized approach was guided by the following factors.

1. Decision skills are largely individual.
2. Trainees are more receptive to critique when provided in an individual context which allows the application of self-evaluation techniques.
3. An individualized instructional approach permits some adaptation of the curriculum to the individual variations of the trainees.
4. Performance measurement techniques using tactical effectiveness models are readily implemented in an individualized approach.
5. Individualized instruction is more compatible with the scheduling constraints of the Navy.

The training strategy includes several alternate formats, applicable at the various levels, for presenting the training. The formats cover a range from the traditional classroom presentation to tactical exercises in existing team training devices. Most of the training will take place at Levels II and III with carefully controlled training scenarios being determined as the best format for presentation of the material appropriate to these levels. The scenarios being developed for this program differ from those used in existing team trainers since specific training objectives and instructional guidelines are included. Also, the scenarios are derived from fleet exercise data and include specific performance measures and feedbacks to the trainee which are integrated with an ASW Weapon System Effectiveness (WSE) computer model.

A number of qualitative and quantitative approaches exist for the measurement of performance in the tactical situation. The use of intra-exercise operational criteria and Weapon System Effectiveness Models (Hammell, Gasteyer and Pesch, 1973) is considered to be one of the most plausible approaches for providing measurement information concerning decision-making performance. The WSE models are currently in use by the Navy for performing tactical evaluations and to extrapolate sea trial data for purposes of the projections of future interactions. There are two categories of tactical analysis models, one is probabilistic and the second is deterministic. Probabilistic models utilize system effectiveness curves and provide results in terms of unique outcomes; therefore, multiple exercises are required to provide an adequate set of probability data for a particular training event. Information regarding performance during the exercise is not available to the trainee. While this process is consistent with the real world situation, this lack of feedback concerning performance is not contributive to the learning of correct decision-making processes. Deterministic models utilize system effectiveness curves, but a profile of the performance throughout an exercise can be provided. However, use of these models may result in the development of stereotyped responses.

Therefore, a model has been developed for this training program which has the capability to provide feedback concerning the outcome as a function of a specific response. In this model, the trainee is given feedback in tactical terms at key-event stages of the scenario. This feedback is correlated with the training objectives and, therefore, the trainee is able to relate the objectives to the tactical events and data.

The training strategy also permits the implementation of alternate training techniques such as positive guidance through the decision-making process and self-evaluation. In the positive guidance technique the trainee is led through an optimal decision-making process in order to imprint the optimal decision-making processes rather than allowing free play and possible development of less-than-optimal processes. The self-evaluation technique allows the trainee to evaluate performance on both an interim and final event basis. The self-evaluation approach requires a focusing of insight into complex problem situations by enabling a selection and evalution of alternative processes and solutions.

TACTICAL TRAINING MODEL DESCRIPTION

The block diagram in Figure 1 shows the first level of a computer simulation model. The major functions of this model are summarized below.

The Target Motion Analysis routines are employed to develop own ship and target position information, and the system solution for the target. These routines are responsible for generating display information during the training exercise on a time dependent basis, interactively responding to instructor and trainee commands, and for calculation of feedback related information. The Target Motion Analysis portions of this model are highly accurate and generalized across multiple surface, sub-surface, and air scenarios.

The Opponent routines possess the capability for rational action in response to own ship action and situation developments. The current model is capable of canned, console-directed, or model-derived actions. The model capability includes deviation and selection of maneuver times and course changes based on counterdetection probabilities and known enemy response patterns.

The ship characteristics routine includes own ship and target noise characteristics, and maneuver rates. These data are relevant to performance measurement, detection/counterdetection, and the Target Motion Analysis routines.

The set of Sonar routines relate to performance measurement, diagnostic feedback, and tracking ability. The calculation of Figure of Merit, Figure of Demerit, and Signal to Noise Ratio are necessary for performance measurement and diagnostic feedback. Contact acquisition and loss of contact models are necessary to determine the time detection, counterdetection, and loss of contact for certain scenarios; they may be used for both own ship and target.

The specific Performance Measurement routines include a monitor/record. Five major measures are currently used while other measures are under development. The monitor/record routine operates in conjunction with particular training techniques or instructor designated procedures to indicate when performance has a pre-defined threshold. It also acts to designate which observations should be recorded.

The diagnostic routines act to organize and calculate information for presentation as feedback or cues. Performance measurement data (e.g. probability of counterdetection), own ship parameters (e.g. course, signal-to-noise ratio), and other relevant data (e.g. propagation loss to the target) can be arranged in a graphical format as functions of time to provide trainee feedback. One, two or three curves can be displayed simultaneously. The performance measures can also be summed to provide an aggregate value across the exercise. The diagnostic information be displayed, printed, or punched on tape.

The training technique routines assemble the appropriate sequences for providing training in accordance with the specific techniques — self-evaluation, positive guidance, and individual paths. They operate in conjunction with other sets of routines, such as performance measurement.

The Environment routine is designed to calculate propagation loss between own ship and the target. This value, which is used by other routines, is updated periodically.

The Display Format routines fetch the information that is to be transmitted to the display or to the paper tape punch/printer. They organize this information into the appropriate output format prior to transmission, and set the control commands that are used by the terminal. These operations are conducted in the host computer's code, and are translated into the terminals code immediately prior to transmission by the output routines. The display format routines organize the MK 81 Analyzer displays and the diagnostic outputs, including the diagnostic displays and the hard copy summary of the information record.

The remaining functions are somewhat standard to any program of this type.

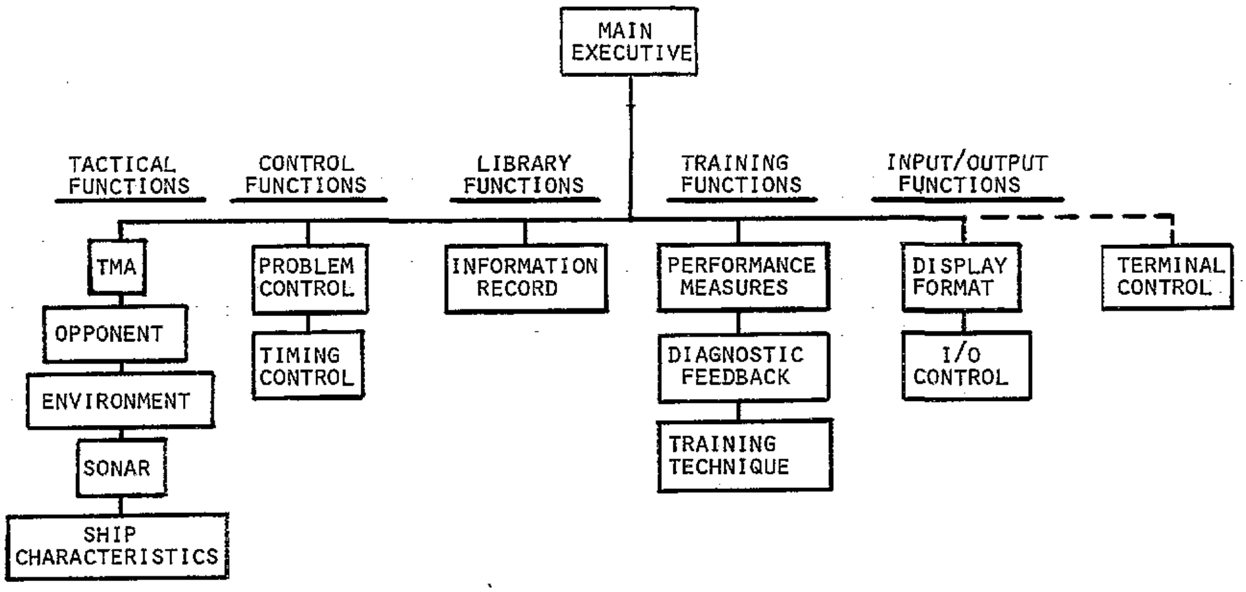

Figure 1 Computer Simulation Model

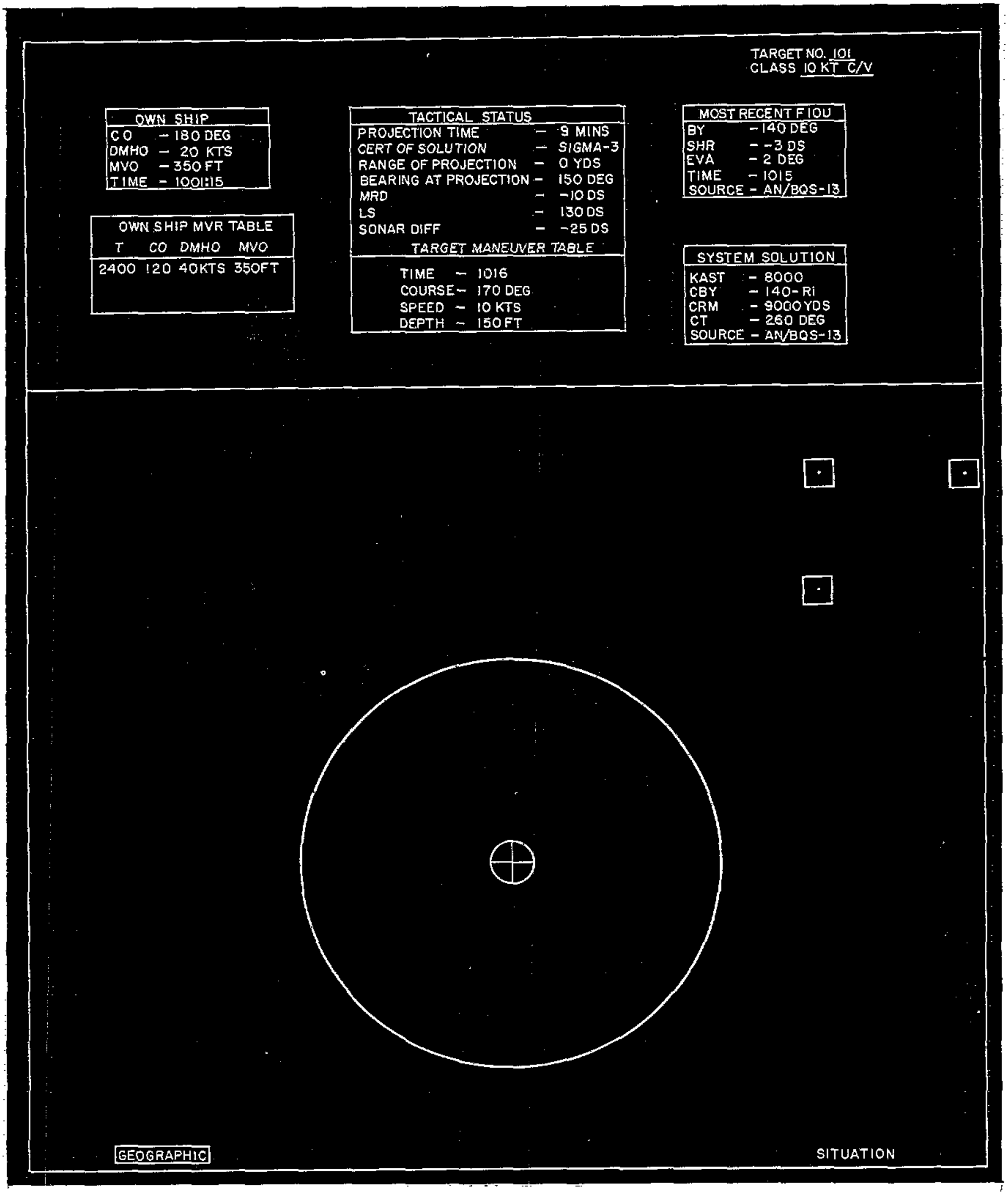

Figure 2 Training System Simulation of a MK 81 Analyzer Display

While complex in nature and requiring extensive programming, their discussion is of little value in terms of the intent of this paper.

PROTOTYPE SYSTEM

The prototype system has been designed along the lines of the eventual generalized individual training device in that it is comprised of the application of "intelligent terminals" for individual trainees driven from a major host computer. The terminals are capable of complete MK 81 Analyzer simulation presentation and availability at approximately 10% of the cost of the military version. The major computer is currently represented in two different configurations of the system by medium size commercial machines used to process a FORTRAN compiler which is being optimized into a training simulation language. The eventual system would logically apply AN/UYK-7 machines.

The MK 113 Mod 10 Fire Control System was chosen as a typical application area for purposes of evaluating the prototype training system in terms of research through the utilization of an applied weapon system. A typical display generated by the training system is shown in Figure 2. This display represents the GEOSIT submode of the TACTICS mode of the MK 81 Analyzer. This particular display enables the trainee to conduct alternate evaluations of various own ship and probable enemy ship courses and speeds.

The trainee's evalutions are oriented toward situation-specific tactical objectives, while the exercise scenario is oriented toward both the tactical and decision-making training objectives. In this particular example, the decision-making training objective is to plan and implement an action/expected reaction sequence. The tactical objective is to maneuver own ship into a firing position as soon as possible, consistent with minimizing the probability of counterdetection and maximizing the probability of kill. The upper portion of the display provides status information, including own-ship, environment, and Target Motion Analysis-derived target information. The lower portion presents a graphical plot of own ship and target positions, including their track histories. Own ship is represented by a **O**. The large circle around the own ship symbol denotes the range at which a 50% probability of counterdetection occurs. The target is represented by a □. The estimated target track is shown by the series of target symbols. In this particular example, each target symbol is plotted at a 15 minute interval, hence the target has been tracked for a 30 minute period during which it maneuvered once.

The trainee achieves his tactical objectives by assuming probable target maneuver actions, projecting them on the display, projecting appropriate own ship maneuvers, and evaluating the alternatives. Thus, the trainee must estimate future target actions based on the accumulation of information over time (e.g. is the target on 15 minute legs, or is he on 30 minute legs, or did he make an isolated maneuver 15 minutes ago?), and select the optimum own ship actions accordingly.

Performance measurement, relevant to both tactical and decision-making training objectives, occurs throughout the exercise. This enables the empirical evaluation of various decision-making training techniques. A diagnostic feedback display provides performance measurement information and other relevant parameters, in a variety of formats, to the trainee. An example of this type of display for the performance measure of probability of counterdetection is shown in Figure 3. This feedback display corresponds to the example problem discussed in reference to Figure 2. It represents one of an infinite variety of situation occurrences — i.e. the target made 90° zigs at 15 minute intervals around a base course of 210°; own ship waited until time 0922, then maneuvered to course 278° until time 0948, then maneuvered to course 340° until time 1010, when the attack began. The instantaneous probability of counterdetection, as shown in Figure 3 as a function of time, is below the 50% level throughout the duration of the exercise for this particular action sequence. Note that the trainee waited excessively long prior to initiating the first maneuver at time 0922; the probability of counterdetection was rising at a rapid rate and closely approaching the unacceptable value of 50%. Other available performance measures in terms of the decision-making training objective would further document the existence of a perseveration deficiency. The trainee acted at time 0922 to an acceptable firing point. His tactical performance was acceptable; however, a more aggressive action series would be preferable. For example, the probability of counterdetection summed across the exercise duration is relatively high. Other performance measures, such as a measure of tactical aggressiveness, together with various other parameters, would normally supplement this display.

The foregoing material has been presented to provide the reader with a background and overview of the training research program. The familiarity gained by the reader will facilitate his understanding of an in-depth visual presentation of the training system in operation.

SUMMARY

This program has resulted in the following accomplishments:

1. Prototype development of one "instructional core" of a generalized individual training system for command and control training. Verification and subsequent development of this program will result in significant cost savings to the Navy via simulation and generalized training development.
2. Formulation of a training structure for the training of decision making.
3. Definition and implementation of alternate training strategies to implement research in decision-making training for Navy command and control systems.
4. Definition and development of a computer program which implements a command and control training model. This system will be operable at two sites early in 1975.
5. Definition and design of a training system based on documented instructional needs and requirements.
6. Detailed development of Weapon System Effectiveness models developed explicitly for training and diagnostic feedback.

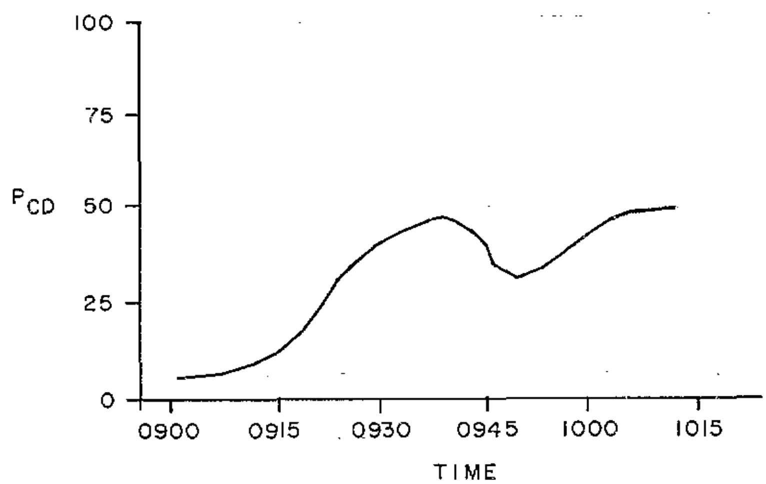

Figure 3 Example of Performance Measurement Display

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