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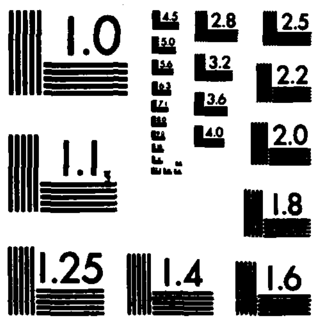

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TECHNICAL REPORT

SIMULATORS FOR MARINER TRAINING AND LICENSING: GUIDELINES FOR DECK OFFICER TRAINING SYSTEMS

PREPARED FOR

U. S. DEPARTMENT OF TRANSPORTATION

MARITIME ADMINISTRATION
OFFICE OF RESEARCH AND DEVELOPMENT
WASHINGTON, D. C. 20590

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16. Abstracts

This report addresses the proper use of the shiphandling/ship bridge simulator in effectively conducting simulator training for senior commercial ship deck officers. Information regarding the three major elements of the training system – the simulator design, the training program structure, and the instructor qualifications – is compiled into a set of guidelines. These guidelines provide the potential user of simulator-based training at the senior mariner level with the information regarding considerations to be made during development and use of an appropriate simulator-based training system. Specifically, the purpose of this report is to establish criteria to guide U. S. Coast Guard personnel in the approval or disapproval of simulator training courses for partial credit toward licenses or license endorsements. A secondary objective is to assist ship operations personnel, as prospective customers, in the evaluation of simulator training courses for their personnel.

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INTRODUCTION

1.1 TRAINING AND LICENSING PROJECT

The Training and Licensing Project, jointly sponsored by the U.S. Coast Guard and the Maritime Administration was initiated primarily in response to a recognized need for improvements in vessel safety. The purpose of the multi-phase project was to thoroughly investigate the proper use of simulators as part of the mariner training and licensing process. The overall objective of this project was to compile technical information regarding the design and use of the simulator-based training system for deck officer training leading to:

- The development of criteria for evaluating the training system
- The development of a simulator functional specification for cadet level training
- Operational guidelines for both master and cadet level training

Recommendations as to specific license requirements are beyond the scope of this effort. However, it is anticipated that the U.S. Coast Guard will utilize the information which has been developed concerning simulator-based training and the evaluation of simulator-based training, when considering alterations to the maritime licensing structure.

These objectives were achieved through a process which involved three distinct phases: (a) exploratory research, (b) empirical research/experimentation, and (c) major product development. The exploratory research phase assisted in directing and defining the scope of the effort. The empirical research phase, which involved the design, conduct, and evaluation of several simulator-based training programs at the Computer Aided Operations Research Facility (CAORF), Kings Point, New York, generated valuable information on a number of critical issues. Finally, the major product development phase applied the insight gained during the project to assist the U.S. Coast Guard, U.S. Maritime Administration, and other potential users of simulator-based training with the design and evaluation of appropriate training systems to meet their particular needs.

1.1.1 EXPLORATORY RESEARCH PHASE

The purpose of the exploratory phase of the project was threefold: (1) to develop an investigative methodology applicable to the maritime community, (2) to compile an extensive information base regarding the use of simulators for deck officer training, and (3) to identify critical research issues for empirical investigation in later phases.

The methodology developed for the investigation drew heavily on the previous experience of other industries. This included the armed forces which had extensive research, development and operational experience with simulators; the Federal Aeronautics Administration which has set up standards for the design and use of simulators and extensively employed simulators for the training and testing/certification of pilots; and the maritime industry which also has some experience in using simulators (e.g., radar endorsement).

During this phase of the project the senior level deck officer positions of chief mate and master were examined with respect to the skills and knowledge necessary to adequately perform required tasks. The resultant report provides a behavioral data base including a task analysis, training objectives, and a sample modular training program structure from which research regarding deck officer simulator-based training could progress. Also identified were critical research issues concerning the use of simulators for maritime training for subsequent empirical investigation (Hammell, Williams, Grasso, and Evans, 1980).

1.1.2 EMPIRICAL RESEARCH/EXPERIMENTATION PHASE

During this phase of the project several experimental training programs were conducted both at the senior mariner level and the cadet level. The first experimental program involved chief mates who were in the process of upgrading to master. It investigated a number of high cost alternative shiphandling/ship bridge simulator design characteristics which could impact the effectiveness of simulator-based training. The variables investigated during this phase of the research were color/black and white visual scene, day/night simulation, horizontal field of view, target controllability, feedback methodology, and instructor differences. The results of this investigation led to a number of interesting findings. The most important finding was that, of the variables investigated, the instructor had the greatest impact on the effectiveness of training, thus implying that the instructor, not the simulator elements, is the most important element of the training program. That is, the level of sophistication of the simulator (i.e., fidelity level) is not as important as the instructor's ability to present the material in an effective manner.

It is the instructor's teaching ability, the techniques used, the type of feedback provided, and the instructor's overall attitude that will be the program's major asset or its major limitation. This finding underscores the importance of the non-simulator elements of the training system including training objectives, instructor's guide, classroom visual aids, and simulator exercises, thereby indicating that simulator-based training must take into account both simulator and non-simulator elements to be effective.

This investigation provided data relating to the specific alternative shiphandling/ship bridge simulator design characteristics described above, from which tradeoffs can be made to arrive at an acceptable, cost effective design to achieve effective deck officer training. For a more in-depth review of the findings, one should refer to the technical report describing this empirical investigation (Hammell, Gynther, Gaffney, and Grasso, 1981).

Subsequent to the investigation at the master level, training at the cadet level was investigated. Two cadet training experiments were involved. The first experiment was conducted in 1979 at CAORF. Three groups of cadets from two different maritime academies (U.S. Merchant Marine Academy and The New York State Maritime College) participated in the training program that addressed Rules-of-the-Road related skills and Port Approach Planning. The objectives of the program were to:

- Determine the effectiveness of a shiphandling/ship bridge simulator for the training of graduating cadets
- Investigate one simulator variable: day only versus night only visual scene
- Investigate one training methodology variable: distributed training over a six week period versus concentrated training over a one week period
- A secondary objective was to delineate the current level of first class cadet shiphandling proficiency

The findings reveal that the training program was effective in improving the shiphandling skills of the first class cadets. Perhaps of greater importance is the fact that this prototype experimental investigation established the positive potential for employing simulator-based training at the cadet level in addition to the more advanced level training of chief mates and masters. Further information concerning this experimental project can be found in the project's final report (Hammell, Gynther, Grasso, and Lentz, 1981).

Research of cadet-level training requirements was furthered in a second experiment using two groups of cadets from the U.S. Merchant Marine Academy as subjects. The experiment was similar to the previous one in which Rules of the Road and Port Approach Planning skills were trained. The difference was in the simulator design characteristic investigated, horizontal field of view (120 degree/240 degree) in place of the day/night visual scene. This second cadet experiment provided substantially more information with regard to the first class cadets shiphandling proficiency level. It was found that the second iteration of the cadet training program was more effective than the first, primarily because more was known as a result of the information generated from the first training program regarding areas that could be potentially improved via simulator-based training. Based upon this insight, the second program was designed such that it addressed those specific need areas. The result of this more specifically tailored training program was greater training effectiveness. Details of this second cadet experiment are provided in the experiment report (Hammell, Gynther, Grasso, and Lentz, 1981).

A second master level experiment focused on the investigation and development of sample test criteria for the evaluation of a training system's effectiveness, including the establishment of minimum performance standards. The evaluation criteria for assessment of training system effectiveness can be based on (1) design criteria which establish necessary training system characteristics (i.e., pertaining to the simulator, training program, and instructor), and/or (2) test criteria which are not concerned with the particular design characteristics of the training system, but rather the evaluation of a sample of the training system's graduates to determine if the training system is producing deck officers that meet minimum proficiency standards. Either of these criteria would be appropriate; the combination of both criteria would ensure greater validity and reliability of the evaluation. The investigation of test criteria established a method for determining performance standards to be used to assess the effectiveness of shiphandling training, and demonstrated and validated several performance measures for testing shiphandling proficiency. The investigation focused on the development of a simulator test that would discriminate between relatively inexperienced shiphandlers (i.e., containership chief mates who are placed in the position of handling a large tanker in restricted waters) and highly proficient shiphandlers (i.e., experienced pilots). The minimum standard of proficiency for investigative purposes was linked to the pilot groups' performance. Five situations were investigated: (a) approaching a harbor; (b) responding to a rudder failure in confined waters; (c) negotiating a 51-degree turn with passing ship effects; (d) negotiating a 129-degree turn around a shoal with oncoming traffic; and (e) responding to a propulsion failure in the vicinity of a bridge and shoal. Of the large number of performance measures investigated with regard to these situations, several were found to discriminate between the different levels of shiphandling expertise. For example, the amount of time to reduce ownship's speed over the ground was found to be a significant indicator of performance in an emergency situation with a rudder failure. The situations investigated and the resulting significant performance measures provide a base of information to draw upon for the development of methods to evaluate shiphandling expertise on a simulator. The final report of this effort should be referenced for details of the test design, methodology employed, and the specific results obtained (Williams, D'Amico, Goldberg, DiNapoli, Kaufman, and Multer, 1982).

1.1.3 MAJOR PRODUCT DEVELOPMENT PHASE

The purpose of this phase of the project was to apply the insight gained during the exploratory and empirical research phases through the development of specific products which could be employed by the maritime community. This report represents the accomplishment of one of the major objectives of the Training and Licensing Project. It provides criteria to guide U.S. Coast Guard personnel and ship operations personnel in the evaluation of simulator training courses.

The development of other products of the Training and Licensing Project, namely a functional specification for a maritime cadet simulator and associated training program guidelines, will be contained in a subsequent report.

1.2 REPORT OBJECTIVES

During the early phases of the project the focus was toward determining the role of the shiphandling/ship bridge simulators for training deck officers. Once it was recognized that the simulator was going to play an important role in deck officer training, the question remained of how to best utilize such simulator-based training to effectively promote maritime safety.

The U.S. Coast Guard is presently considering the allowance of some form of license credit for successful completion of approved simulator-based training programs. The specific amount and type of license credit to be allowed for such training, along with the specific procedures for CG approval of simulator-based training facilities, remain to be developed. Persumably, these will be established by the U.S. Coast Guard, as appropriate, based on the information contained in this report. As a result of these factors, the specific objectives of this report are twofold:

- Provide the potential user of simulator-based training at the senior mariner level with guidelines regarding the considerations to be made during the development and use of an appropriate training system
- Provide the U.S. Coast Guard with information on simulator-based training at the senior mariner level to be used as the basis for the development of appropriate U.S. Coast Guard approval procedures

The reader is reminded that the emphasis on simulator-based training within this report is not intended to overlook the contribution of more traditional methods of mariner training, such as at-sea training. Simulators should be viewed as a potentially valuable complement to existing training programs and not as a comprehensive substitute for existing training programs.

1.3 REPORT ORGANIZATION

Chapter 2 of this report identifies the specific types of simulator-based training that should be promoted at the senior mariner level. These areas for potential training were determined through a review of a number of comprehensive accident analyses, which have been conducted and publsihed by a wide variety of groups interested in improving the safety of maritime operations.

Chapter 3 of this report contains guidance with regard to the three major elements of a simulator-based training system: the simulator, the training program, and the instructor. For each of these major elements, a number of critical characteristics (e.g., horizontal field of view for simulators) are defined and discussed for training senior mariners. In addition, where appropriate, alternative levels of these characteristics (e.g., 60, 120, and 240 degrees) are also identified and discussed.

Chapter 4 of the report contains sets of recommended and minimum training system characteristics for each of the six critical training/skills categories identified in Chapter 2. The set of recommended characteristics is provided for the potential designer/operator of senior mariner simulator-based training system, while the set of minimum characteristics is provided to assist the U.S. Coast Guard in the approval of training facilities and their programs. It should be noted that these standards are based on the authors' interpretation of the guidance set forth in Chapter 3. They have been reviewed by both simulation and training experts to ensure their validity.

Finally, Chapter 5 of this report contains guidance with regard to evaluating the effectiveness of simulator-based training through the utilization of post-training test scenarios. *Evaluation of these scenarios* could be either quantitative or qualitative depending on the level of objectivity required. Performance testing could be employed either by the U.S. Coast Guard during simulator-based training facility accreditation or by maritime interests concerned with the quality of training being provided to their personnel.

1.4 INDUSTRY REVIEW

A vital element in the Training and Licensing Project has been the involvement of the maritime industry throughout the various stages of the project. A working group comprised of representatives from various maritime interests has reviewed the work of the project team and provided appropriate comments. This report has undergone this review process. All comments, both insights and criticisms, were considered by the project team and necessary changes incorporated.

However, it should be noted that this final version of the report represents the project team's findings and recommendations, which are not necessarily the same as all members of the working group, although their critique was invaluable in its development.

The organizations listed below participated in the working group review of this report. The project team wishes to extend their gratitude to these organizations and to the specific individuals within these organizations who contributed to the success of this project.

American Institute of Merchant Shipping

American Pilots Association

Exxon U.S.A.

Maritime Institute of Technology and Graduate Studies

U.S. Coast Guard

- Office of Merchant Marine Safety
- Office of Research and Development

U.S. Maritime Administration

- Office of Advanced Ship Operations
- Office of Maritime Manpower

U.S. Merchant Marine Academy

CHAPTER 2

THE IDENTIFICATION OF SENIOR MARINER SHIPHANDLING SKILLS FOR SIMULATOR TRAINING

2.1 GENERAL

The potential of shiphandling/ship bridge simulators as a training device to upgrade and ensure high mariner standards, has become increasingly recognized. The earlier phases of this joint U.S. Coast Guard/Maritime Administration Training and Licensing Project has provided considerable analyses and documentation of this potential.

The Port and Tanker Safety Act of 1978 requires the U.S. Coast Guard to develop "... standards relating to -(D) qualification for licenses by use of simulators for the practice or demonstration of marine-related skills." Subsequently, the Coast Guard has indicated a desire to provide an individual with some form of license credit for successfully completing specific CG-approved simulator-based training programs. Prior to the development of the criteria for Coast Guard approval of these simulator-based training programs, it is necessary to identify the specific type of training that the Coast Guard should be promoting through such a license credit.

Both shipping companies and maritime unions are becoming increasingly aware of the simulator's potential for training their personnel. In recent years, there has been increased interest not only in the procurement of simulator-based training as a service but also the procurement of simulator-based training systems. In order for these potential customers to evaluate the benefits of a given simulator training program or simulator training system, it is advantageous and desirable to have additional insight into the specific senior mariner skills that should be trained via the shiphandling/ship bridge simulator.

The purpose of this section of the report is to provide additional information concerning the identification of the specific types of senior mariner skills that are appropriate for development via simulator. This has been accomplished through the identification of high criticality shiphandling skills based primarily on a review of a number of comprehensive accident analyses, which have been conducted and published by a wide variety of groups interested in improving the safety of maritime operations.

2.2 APPROACH

In the initial exploratory phase of the Training and Licensing Project, a comprehensive list of specific functional objectives (SFOs) were developed for master level mariners and their potential for simulator-based training analyzed. SFOs represent, in detail, the desired skills of the mariner, or the goals of the simulator-based training system. This listing of SFOs appeared to be an appropriate basis for commencing our analysis. It assisted in limiting the problem to those training areas where simulator-based training may be a cost-effective alternative.

The specific approach taken to identify master level shiphandling skills appropriate for simulator training was to review a number of accident analyses for the purpose of identifying training-related issues which would seem to require additional attention during deck officer training based on their correlation with vessel accidents. No attempt was made to transform each accident report's training-related issues into the categories of SFOs established during the exploratory phase of this project. Training deficiencies as cited by accident analyses generally were not written in terms similar to the SFOs and it was feared that tailoring them to those terms might mask otherwise overall common tendencies. It was thereby determined to identify the broader category of desired skills. These skill categories were then reviewed as regards the availability of appropriate simulator-based training. Finally, a list of desired skills was developed for the most advantageous skill categories as recommended candidates for simulator training.

2.3 ACCIDENT ANALYSES

The principal accident analyses reviewed in the process of identifying the critical shiphandling skills for senior mariners included the following:

- ORI Analysis – During the late 1970s Operations Research, Incorporated (ORI) conducted several analyses for the U.S. Coast Guard relating to the causal factors of collisions, rammings, and groundings. For purposes of this analysis, the report entitled "Study of Task Performance Problems in Reports of Collisions, Rammings, and Groundings in Harbors and Entrances" (Paramore et al., 1979) was utilized. In this report the available accident data (i.e., U.S. waters FY 1972-FY 1976) were analyzed in three primary categories: (1) collisions, (2) groundings, and (3) rammings.

- TAEG Analysis – In 1976, the Chief of the U.S. Naval Education and Training (CNET) asked the Training Analysis and Evaluation Group (TAEG) to analyze and propose a shiphandling training strategy. Their report, entitled **Shiphandling and Shiphandling Training** (TAEG-41) (Cordell and Nutter, 1976) included an analysis of both Navy and Merchant Marine accidents.

- NTSB Analysis – The National Transportation Safety Board (NTSB) annually reviews marine accidents occurring during the previous year and publishes appropriate recommendations in its annual report. As part of this analysis for the identification of high criticality training issues at the master level the NTSB annual reports for 1977, 1978, 1979, and 1980 were reviewed.

- Shipping Company Analysis – In recent years, a number of major oil companies have independently conducted their own evaluation of vessel accidents. Several papers presented in Washington, D.C. at the 1978 Safe Navigation Symposium, which was sponsored by the Oil Companies International Marine Forum provide insight into the results of these various analyses. Specifically, insight was gained from a review of papers presented by Mr. J. A. Butt (Shell), Captain B. B. Leland (Chevron), Captain R. Maybourn (BP Tankers), and Mr. W. O. Gray (Exxon).

- T&L Working Group Analysis – As part of the review process of the Training and Licensing Project Phase I report, the maritime community working group, which was made up of industry, labor, and training facility representatives, ranked the training modules identified therein, based on their perceived need. Their responses were analyzed and considered during this phase of the project.

- Det Norske Veritas Analysis – The Norwegian society Det Norske Veritas conducted research into the causes of collisions and groundings of Norwegian registered vessels for the period 1970 to 1978. While this report does not involve U.S. flag vessels, it was included as a means of interjecting the findings and experience of foreign researchers in this area (Karlsen and Kristiansen, 1980).

- MTRB Analysis – In 1976 the National Academy of Sciences published its Maritime Transportation Research Board's report entitled "Human Error in Merchant Marine Safety." This report identifies 14 factors as either major or potentially major causes of casualties and prioritizes a number of recommendations.

2.4 MASTER LEVEL TRAINING NEEDS

Combining the results of the preceding analyses of shiphandling requirements at the master level is difficult, due primarily to the different categories utilized by each analysis. However, after a comprehensive analysis, Figure 1 was developed which attempts to summarize and present the results in an organized manner.

Based on this summarization of shiphandling requirements at the master level, it appears that additional training in the following desired skill categories would be advantageous:

1. Navigation Management Training
2. Ship-to-ship Communications Training
3. Shiphandling Training
4. Emergency Shiphandling Training
5. Rules-of-the-Road Training
6. Restricted Waters Navigation (Piloting) Training

A brief description of the training within each area is presented below:

2.4.1 NAVIGATION MANAGEMENT TRAINING

The accident analyses indicate few dominant problem areas where additional training would be desirable. They do, however, indicate a number of areas where additional training in proper bridge procedures and proper bridge organization normally associated with the prudent mariner would be helpful to improve the inherent safety of the navigation process. Of concern is the lack of coordination between those individuals on the bridge during a transit of restricted waters, primarily the master, mate, and pilot. The majority of individual mariners appear to have proficient navigation and shiphandling skills (e.g., position-fixing). However, they may be unaware of their responsibilities

RESTRICTED WATERS NAVIGATION MANAGEMENT

	ORI	TAEG	NTSB	SHIPPING COMPANY ANALYSIS	T & L WORKING GROUP	DET NORSKE VERITAS	MTRB
VESSEL TO VESSEL COMMS	●	◒	●	○	○	○	◒
SHIPHANDLING					●	◒	
– SAFE SPEED	◒		●				
– MAINTAINING POSITION	●						
– COMPENSATING FOR EXTERNAL FORCES		◒					
PILOT/MASTER RELATIONSHIP	◒	◒	●	●	●		●
BRIDGE PROCEDURES			●	●	○	◒	●
– LATE DETECTION	●						
– FAILURE TO MONITOR OTHER VESSEL	◒						
– FAILURE TO ESTABLISH NAVIGATION POSITION	◒						
– FAILURE TO TAKE ADEQUATE FIXES		◒					
BRIDGE ORGANIZATION			◒	●			○
– VESSEL MANNING						●	
RULES-OF-THE-ROAD		○	●		●	◒	○
EMERGENCY SHIPHANDLING					●		
NAVIGATION				◒		◒	○
– FAILURE TO ESTABLISH NAVIGATION POSITION	◒						
– FAILURE TO TAKE ADEQUATE FIXES	◒						

● DENOTES HIGH CRITICALITY STRESSED

◒ DENOTES MEDIUM CRITICALITY NOTED

○ DENOTES IMPLIED CRITICALITY INTERPRETED

Figure 1. Summary of Critical Shiphandling Requirements Identified by Referenced Analyses

during a particular transit in a specific geographic area. If they are aware of their responsibilities, they should not be viewed as infallible and their performance should be verified by other members of the bridge team. One area that is viewed as critical by nearly all the studies and warrants consideration during this type of training is the relationship between the pilot and the ship's officers, particularly the master. For example, the NTSB recommends:

- "... that masters and pilots discuss beforehand and agree to the essential features and relevant checkpoints of planned ship maneuvers (NTSB Annual Report, 1977)"
- that masters and mates "... exercise their responsibility to assure that the vessels were navigated safely, rather than indiscriminately relying on the pilots of the vessels (NTSB Annual Report, 1980)"

Bridge team training, which appears to address many of these areas, is presently being emphasized in Europe by a number of oil companies. There was a tendency here in the U.S. to view this occurrence from the perspective that the Europeans were doing a good job maximizing the training benefit for the level of simulator technology available in their simulators. This analysis indicates that the Europeans are apparently moving in the right direction and there may be greater benefit in such training than was first perceived. For our purposes, however, we should refrain from calling it "bridge team training" since in the U.S. we will probably be involved in training only one member of the team (e.g., master), not the bridge team from a particular vessel as a unit.

It should be noted that navigation management training should provide training not only in bridge procedures and bridge organization, but also refresher training in a myriad of individual skills including rules-of-the-road, restricted waters navigation (piloting), shiphandling, and ship-to-ship communications. The type of scenarios utilized for this training should occur in restricted waters with traffic, preferably port approaches or port departures.

2.4.2 COMMUNICATIONS TRAINING

The high number of communication problems indicated, primarily in the ORI analyses, point to a requirement for additional training in ship-to-ship communications.[1] Since the majority of cases reviewed indicated no attempt to communicate by either one or both vessels, shipboard personnel could be hesitant about utilizing communications due to: (1) unfamiliarity with proper procedures or (2) high workload for the pilot or master prior to the collision. The latter may reflect a bridge team organizational problem, which should be emphasized during training. Many of the skills in this communications category may be covered as secondary skills within the navigation management category. However, it is probably important that they be separately identified based primarily on the results of the ORI accident analysis.

It should also be noted that such communications training should be more comprehensive than simply training proper communications procedures. It should strive to prepare the trainee to handle the range and complexity of real world problems that hinder effective vessel to vessel communications. Such problems include but are not limited to chatter, identification problems, language/accent variations, delays, failure of others to respond, and problems of understanding the meaning of some messages even when the words/signals are clear.

2.4.3 SHIPHANDLING TRAINING

A review of the analyses summarized in this paper indicate that additional training should be provided to masters in shiphandling skills. For example, the ORI report indicates that the dominant factor involved in over 60 percent of the vessel groundings within the harbor and entrance area was the failure to maintain position resulting from (1) an incorrect assessment of current or wind effects, (2) an incorrect assessment of vessel response characteristics, or (3) a combination of both factors.[2] Although no data was available, one might reasonably expect that this may be a greater problem with vessels of "unusual handling characteristics" rather than with the more standard vessel types.

[1] The high criticality of ship-to-ship communications is supported by the interpretation of Gardenier and Jones in their paper entitled "Clear Communications Could Curtail Collisions (1981)."

[2] In another ORI report "Analysis of Bridge Collision Incidents" (R. B. Dayson, 1976) failure to maintain position was found to be the primary cause of towboat collisions with bridges in 93 percent of the cases studied.

The desired skills covered by such simulator-based training should address such topics as advance and transfer characteristics, stopping, effect of wind and current, shallow water effect, bank effect, etc. It may not be desirable to cover all of these skills in a particular course, unless that course were emphasizing piloting. One type of course in which all the skills would probably be desirable would be a course directed towards a specific type and size of vessel, with "unusual handling characteristics."

2.4.4 EMERGENCY SHIPHANDLING IN TRAINING

Although the accident data do not specifically indicate a requirement for emergency shiphandling training, it could be implied under the requirement for additional shiphandling training. Emergency shiphandling is identified here as a separate desired skills category because of the relatively wide-spread agreement that (1) this area is not receiving adequate training due to the high cost and high risk involved in utilizing actual vessels and (2) this area appears particularly suited for simulator-based training. It should be noted that in addition to the standard response to ownship casualties (i.e., loss of power), this training should address handling the vessel under unusual operational conditions. For example, another vessel that you are about to meet in a narrow channel has just transmitted an urgency message that he has lost steering, or another vessel unexpectedly backs out of a slip directly ahead of you as ownship is passing a group of piers. It should be emphasized to the students to take precautions to avoid situations that might endanger their vessel. However, this is not always possible. Therefore, the students should be provided with some training in extracting their vessels from these unusual operational conditions.

2.4.5 RULES-OF-THE-ROAD TRAINING

The application of the Rules-of-the-Road is another area in which master level training appears appropriate. As previously discussed, the ship operators apparently feel that masters should be given additional training in the application of the Rules-of-the-Road. Although the ORI analysis did not identify Rules-of-the-Road as a potential problem area, the TAEG, NTSB, and Det Norske Veritas analyses indicated that it does contribute to maritime accidents. Some facilities may find it appropriate to combine training in the communications and Rules-of-the-Road categories. However, care should be exercised such that the importance of the communications training is not diminished.

2.4.6 RESTRICTED WATERS NAVIGATION (PILOTING) TRAINING[3]

The application of piloting techniques, such as visual position-fixing, radar navigation, and use of soundings, also appears to be a candidate for simulator-based training at the master level. The ORI analysis cited the "failure to properly establish own navigational position" while the TAEG analysis noted the "failure to make adequate fixes." This category of desired skills should not be confused with the number one priority category of navigation management, which assumes that the deck officer already possesses proficient skills in position-fixing techniques.

2.5 MASTER LEVEL SHIPHANDLING SKILLS FOR SIMULATOR TRAINING

The following are specific desired skills that should be considered for inclusion as part of any simulator-based training program at the master level. It should be noted that a particular training facility might not train all the skills in a particular category. Rather, the training facilities would develop their own list of skills for a training program according to guidelines set forth by the Coast Guard.

2.5.1 NAVIGATION MANAGEMENT TRAINING

1. The trainee should understand the necessity for a port approach plan and should demonstrate high proficiency in the proper development of a comprehensive port approach plan.[4]

[3] It should be noted that the term "piloting" is utilized here since this terminology is contained in the CFR when defining deck officer examination requirements. Bowditch and Dutton also refer to "piloting" in the same context: "... directing of the movements of a vessel by reference to landmarks, relatively short range aids to navigation or by soundings (Dutton, 1978)." Under no circumstances is the requirement for improved deck officer training in this area intended to reduce the necessity for contracting the services of a duly licensed pilot when navigating in restricted waters.

[4] It should be noted that the term "port approach" is utilized here in its broadest sense, from landfall to arrival at the desired berth or mooring. Scenarios include maneuvers/evolutions prior to arrival at the pilot station (i.e., no pilot aboard) and after arrival at the pilot station (i.e., pilot aboard).

2. The trainee should demonstrate high proficiency in organizing a bridge team for port approach navigation and effectively instructing the other members of the bridge team in their duties and responsibilities.

3. The trainee should demonstrate high proficiency in the conduct of pre-transit discussions with the pilot in order to agree upon the essential features and relevant checkpoints of planned ship maneuvers.

4. The trainee should demonstrate high proficiency in the direction of the other members of the bridge team to properly establish and effectively monitor ownship's position during the transit.

5. The trainee should demonstrate high proficiency in the direction of the other members of the bridge team in the early detection and effective monitoring of vessel traffic and other navigation hazards.

6. The trainee should demonstrate high proficiency in effectively communicating with the pilot during the transit.

7. The trainee should demonstrate proficiency in the procedures for handling the following shipboard casualties:

- Loss or degradation of propulsion power
- Loss or degradation of steering
- Collision
- Fire
- Man overboard
- Loss or degradation of radar
- Loss or degradation of gyro
- Loss or degradation of rudder angle indicator
- Loss or degradation of pilothouse control of main engine

2.5.2 VESSEL TO VESSEL COMMUNICATIONS

1. The trainee should demonstrate high proficiency in the use of the ship whistle for maneuvering and warning signals under a variety of operational situations.

2. The trainee should have a basic understanding of the function, operation, and maintenance of the shipboard VHF radiotelephone.

3. The trainee should demonstrate high proficiency in the use of proper radiotelephone procedures for transmitting and receiving the following types of messages:

- Distress
- Urgency
- Safety

4. The trainee should demonstrate high proficiency in the proper monitoring of the required VHF communications frequencies under a variety of operational watch situations.

5. The trainee should demonstrate high proficiency in the proper use of VHF communications for collision avoidance in a variety of operational situations.

6. The trainee should demonstrate high proficiency in the proper use of VHF communications for vessel traffic services in several different geographic areas.

7. The trainee should demonstrate proficiency in transmission/reception of flashing light communications under a variety of operational situations.

8. The trainee should demonstrate proficiency in the proper use of flag hoist communications under a variety of operational situations.

2.5.3 SHIPHANDLING

1. The trainee should demonstrate high proficiency in determining safe vessel speed when handling a specific type and size of vessel under a variety of operational conditions.

2. The trainee should demonstrate proficiency in handling a specific type and size of vessel, holding course and heading, in order to maintain a DR track under various conditions of wind, current, and water depth.

3. The trainee should demonstrate proficiency in handling a specific type and size of vessel to avoid collision and pass at a safe distance with other traffic under various conditions of wind, current, and water depth.

4. The trainee should demonstrate proficiency in handling a specific type and size of vessel to safely maneuver in various left and right turns within confined channels under various conditions of wind, current, and water depth.

5. The trainee should demonstrate proficiency in handling a specific type and size of vessel to stop or slow the vessel effectively under various conditions of wind, current, and water depth when:

- Approaching a single point mooring buoy
- Approaching a dock/pier
- Maneuvering to bring up a pilot
- Maneuvering to bring up tugs
- Anchoring

6. The trainee should demonstrate proficiency in handling a specific type and size of vessel utilizing tugs under various conditions of wind, current, and water depth. The type of tug and tug use strategy should be appropriate for the type of operational situation envisioned.

7. The trainee should demonstrate proficiency in handling a specific type and size of vessel when compensating for bank effects under various conditions of wind, current, and water depth.

8. The trainee should demonstrate proficiency in handling a specific type and size of vessel when compensating for passing ship effects under various conditions of wind, current, and water depth.

9. The trainee should demonstrate proficiency in handling a specific type and size of vessel utilizing tugs under a variety of operational conditions.

2.5.4 EMERGENCY SHIPHANDLING

1. The trainee should demonstrate high proficiency in handling a specific type and size of vessel when executing a maneuver to pick up a man overboard in reduced visibility.

2. The trainee should demonstrate high proficiency in handling a specific type and size of vessel during a crash stop within confined channels under various conditions of wind, current, and water depth.

3. The trainee should demonstrate high proficiency in handling a specific type and size of vessel after a loss or degradation of propulsion power within confined channels under various conditions of wind, current, and water depth.

4. The trainee should demonstrate high proficiency in handling a specific type and size of vessel after a loss or degradation of steering within confined channels under various conditions of wind, current, and water depth.

5. The trainee should demonstrate proficiency in handling a specific type and size of vessel when placed in a variety of unusual operational conditions.

2.5.5 RULES OF THE ROAD

1. The trainee should demonstrate high proficiency in the application of the appropriate Rules-of-the-Road when in a meeting situation under a variety of operational conditions.

2. The trainee should demonstrate high proficiency in the application of the appropriate Rules-of-the-Road when in a crossing situation under a variety of operational conditions.

3. The trainee should demonstrate high proficiency in the application of the appropriate Rules-of-the-Road when in an overtaking situation under a variety of operational conditions.

4. The trainee should demonstrate high proficiency in the application of the appropriate Rules-of-the-Road when in "special circumstances" under a variety of operational conditions.

2.5.6 RESTRICTED WATERS NAVIGATION (PILOTING)

1. The trainee should demonstrate high proficiency in the use of proper dead-reckoning techniques under a variety of operational conditions.

2. The trainee should demonstrate high proficiency in the use of proper visual position-fixing techniques under a variety of operational conditions.

3. The trainee should demonstrate high proficiency in the use of proper radar navigation techniques under a variety of operational conditions.

4. The trainee should demonstrate high proficiency in the proper use of soundings under a variety of operational conditions.

5. The trainee should demonstrate high proficiency in the proper use of electronic navigation system (e.g., LORAN-C) under a variety of operational conditions.

CHAPTER 3

CRITICAL TRAINING SYSTEM CHARACTERISTICS

3.1 DESCRIPTION OF THE TRAINING SYSTEM

A simulator, such as the radar simulator or the shiphandling/ship bridge simulator, is a device that duplicates limited aspects of the real world. The radar and shiphandling simulators duplicate different subsets of the real world; each is also limited in those aspects that it can reproduce faithfully. The radar simulator is a part-task device that duplicates the hardware/control aspects of the radar system as well as the visual imagery of the radar display. This device permits, to a large extent, duplication of the radar-related tasks of a deck officer. Its duplication of other aspects of the bridge and deck officer tasks is particularly limited. The shiphandling/ship bridge simulator, on the other hand, is a whole-task simulator that duplicates many more aspects of the bridge environment, bridge hardware, and deck officer tasks; nevertheless, this simulator is also limited with regard to that which it can duplicate.

From a training standpoint, the simulator enables the practice of tasks, which may lead to the improvement of skills. Practice is one important element of the training process. However, other important elements of the training process also exist, such as providing feedback to the trainee regarding the outcome of his actions. The training system is more than just a simulator; it does more than provide a setting for the practice of tasks. It should be designed specifically to enhance the training process. The complex simulator-based training system should be viewed as being comprised of three major elements: (1) the simulator design, (2) the training program structure, and (3) the instructor qualifications.

Traditionally, the emphasis has been on the design of the simulator, that is, the real world fidelity characteristics of the training device. Recent research has indicated that the techniques employed by the instructor and the structure of the training program are more critical to an effective simulator-based training program than the fidelity of the simulator. It is important that the designers, operators, and users of simulator-based training become aware of the substantial impact that the non-simulator elements of the training system have on the effectiveness of the training process.

The critical characteristics associated with each of the major elements of a simulator-based training system are listed in Table 1. This section of the report discusses the appropriate guidelines for each of these critical characteristics, which should be considered when designing or evaluating a simulator-based training system for senior mariners. For each critical characteristic several levels of sophistication or quality are identified. Appropriate information is then provided to assist the designer or evaluator in establishing the most desirable features of the training system.

3.2 SIMULATOR DESIGN (CRITICAL CHARACTERISTICS)

3.2.1 VISUAL SCENE

This is the characteristic of a simulator that provides the trainee with the visual conditions of a scenario external to ownship's pilothouse (e.g., buoys, other ships, etc.). It is usually the most expensive element of a shiphandling simulator. Numerous optical and engineering techniques are available to generate a visual scene. These include projection of spotlight sources, model boards, filmstrips, and computer-generated graphics. The complexity and accuracy contained in a visual scene relate very closely with total simulator cost. Mariners tend to want high fidelity visual scenes for realism. Research has indicated that a very high level of fidelity is usually not required in the visual scene to effectively train the development of many shiphandling/navigation skills, although in some cases a high level of fidelity may be required. A careful analysis of the objectives to be accomplsihed and the associated requirements for visual cues will provide valuable insight into the identification of a satisfactory visual scene for minimum cost. The following discussion outlines several important considerations in the design or evaluation of a shiphandling simulator's visual scene.

TABLE 1. CRITICAL SIMULATOR-BASED TRAINING SYSTEM CHARACTERISTICS

Simulator Design (Critical Characteristics)

Visual Scene
- Geographic Area
- Horizontal Field of View
- Vertical Field of View
- Time of Day
- Color Visual Scene
- Visual Scene Quality

Radar Presentation
Bridge Configuration
Ownship Characteristics and Dynamics
Exercise Control
Traffic Vessel Control
Training Assistance Technology
Availability

Training Program Structure (Critical Characteristics)

Skill Levels After Training
Skill Levels Prior to Training
Training Objectives
Training Techniques
- Knowledge of requirements
- Positive guidance
- Adaptive training
- Post problem critique

Instructor's Guide
Classroom Support Material
Simulator/Classroom Mix
Training Program Duration
Class Size
Scenario Design
Number of Scenarios
Stress
Overlearning

Instructor Qualifications (Critical Characteristics)

Mariner Credentials
Instructor Credentials
Subject Knowledge
Instructor Skills
Instructor Attitude
Student Rapport
Instructor Evaluation

Geographic Area

The type of geographic area selected should depend on the types of scenarios needed to train the specific skills required to achieve the program training objectives. The proximity to land of the scenario gaming areas heavily impacts the design of the simulator's visual scene. Generally speaking, the closer the scenarios are to land the greater the investment required to provide a quality visual scene. This appears to be true with all the present visual scene generating technologies, from spotlight projectors to computer-generated graphics. Three alternative geographic areas are specified below.

Level I: Open Sea. These data bases employ scenarios in which land is not visible in the visual scene. Traffic vessels and buoys may be utilized as appropriate for specific training objectives in the following categories:

- Rules of the Road
- Communications
- Shiphandling
- Emergency Shiphandling

Level II: Coastal. These data bases employ scenarios in which only distant land, which may include prominent geographic features such as lighthouses, and a limited number of traffic ships are visible in the visual scene. A corresponding radar presentation and water depth data base may also be utilized as required by the specific training objectives. This level of geographic area would normally be the minimum level for many of the training objectives in the Navigation Management and Restricted Waters Navigation (piloting) skill categories previously discussed. Many of the skills in these categories require the use of visual information for determining or assisting in the determination of the geographic position of ownship.

Level III: Restricted Waters. These data bases employ scenarios in which landmass and numerous traffic ships are present close aboard. A complex environmental data base utilizing water depth, wind, and current may also be utilized as required for specific training objectives. This level of geographic area would normally be employed for the more sophisticated Shiphandling and Emergency Shiphandling skills. The student should be trained in the prudent practice of avoiding complex shiphandling situations, particularly under poor visibility conditions. However, complex shiphandling situations, where proficiency in handling bank effects, passing ship effects, etc., is required, can not always be avoided during restricted water transits.

In such situations, land and traffic vessels are clearly visible passing close aboard, thus establishing the visual scene requirements for a simulator to train such shiphandling skills.

Horizontal Field of View

The horizontal field of view required for a shiphandling/navigation simulator should depend on the specific objectives of the training program. If the visual cues required to execute a particular shiphandling maneuver are within a relatively narrow field of view, such as when training the skill of utilizing range lights, a reduced field of view is satisfactory and may even be preferable since it artificially focuses the trainee's attention on the required visual cues. However, prudent training practice would indicate that the student should then be trained in utilizing this skill under conditions with operational noise and distractions; for example, identifying the range lights and concentrating on them among the background lights and distracting traffic vessel movement. This type of training could then imply a requirement for greater horizontal field of view than that identified for the development of the basic skill. Consideration should also be given to the utilization of a variable horizontal field of view in order to gain the training leverage discussed above.

The cost of a shiphandling/ship bridge simulator increases as the horizontal field of view increases. This increase in cost results not only from increased projection equipment costs but also from increased processing hardware and software costs. This is particularly true for computer-generated graphic systems.

Level I: Greater Than 90°, Less Than 120°. Use of this horizontal field of view may be satisfactory for training a limited number of specific shiphandling skills (e.g., range lights, buoyed channels). It may also be satisfactory for training the application of the rules of the road in meeting and fine crossing situations. However, if it is employed in broader crossing situations or overtaking situations where visual contact is lost with the traffic vessel, there may be a danger that the trainees will have a tendency to neglect visual bearings and rely heavily on radar in these types of scenarios. A horizontal field of view of less than 120 degrees is generally unacceptable for training skills that involve visual position fixing since adequate horizontal angular separation of suitable geographic points suitable for a visual fix can not be obtained except for possibly a few unique cases. In this same light, such a limited horizontal field of view also precludes the development of skills in the use of turn bearings. There may, however, be some training value for a horizontal field of view of less than 120 degrees in the development of skills involving the integration of visual lines of position with radar information or other electronic navigation information, although the trainee may be inadvertently trained to neglect the more advantageous objects abeam for visual bearings.

Level II: Greater Than 120°, Less Than 240°. Use of this horizontal field of view appears appropriate for the majority of the desired skills categories identified in Chapter 2. It may, however, be limited if visual bearings abaft ± 120 degrees relative are important for navigation in a particular port. In addition, the application of the rules of the road in an overtaking situation is also constrained, although only for the situation when ownship is being overtaken and not when ownship is doing the overtaking. This situation, however, is somewhat unique and not particularly difficult (i.e., requiring specific training) since it usually involves a relatively slow closing rate which allows substantial time for analysis and action.

Level III: Greater Than 240°. Use of a horizontal field of view of this magnitude may be appropriate if the development of skills involving the following factors are deemed to be important:

- Vessel with pilothouse forward (i.e., ore carriers)
- Use of rear ranges
- Use of visual bearings abaft ± 120 degrees relative (e.g., specific port requirement)

It should be noted that many of the visual scene generating technologies have the capability, particularly if considered during the initial design, of optically/electronically rotating the fixed visual scene to provide visual cues in areas not normally considered possible with that design. For example, Figure 2 illustrates a 240° horizontal field of view providing a visual scene from 30 degrees left of ownship's heading to 30 degrees beyond dead astern. This may be particularly desirable during coastwise navigation exercises to facilitate the use of visual bearings, or when approaching and picking up a tow. This flexibility with the simulated visual scene should be used cautiously since it alters the bridge environment's proper orientation with the visual scene (i.e., front of pilothouse faces side of vessel). The impact of this effect on the training provided is unknown.

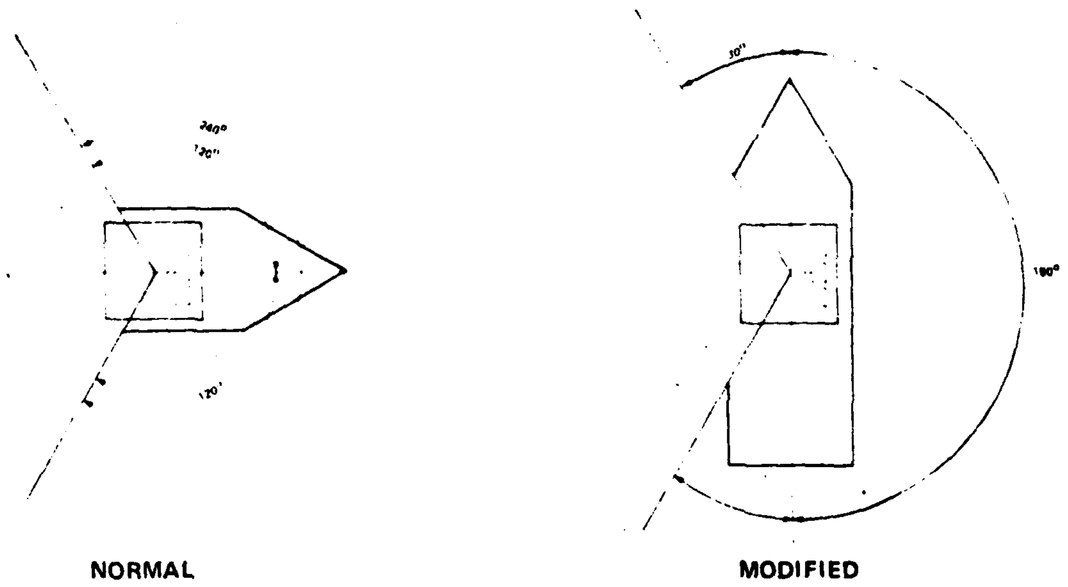

Figure 2. Rotation of Visual Scene

Vertical Field of View

The vertical field of view required for a shiphandling/navigation simulator should depend on the specific objectives of the training program. If the visual scene requirements for the training objectives are at or near the horizon (i.e., distant landmass or traffic vessels), then a relatively narrow vertical field of view would probably suffice. If the visual scene requirements are contained over a larger angular sector (i.e., landmass or traffic vessels close aboard), then a larger vertical field of view is required. Normally, docking exercises when ownship is being brought into a berth require the maximum capability of vertical field of view. Generally speaking, the greater the vertical field of view the greater the cost. Since relatively small increments of vertical field of view can substantially improve a simulator's capability, this is not a high cost characteristic as compared to a horizontal field of view.

Level I: ± 5° to ± 10°. This vertical field of view may be acceptable for distant land and traffic vessels. Caution should be exercised in utilizing a narrow vertical field of view, particularly under daytime conditions because the fidelity of the simulation is reduced considerably when a daytime scene is bounded top and bottom with large dark bands. Consideration should also be given to the amount of ownship bow required in the visual scene when attempting *reductions in vertical field of view.*

Level II: ± 10° to ± 15°. This vertical field of view would be acceptable for distant land and traffic vessels. It would also be acceptable for land relatively close aboard, and it may be acceptable for traffic vessels close aboard depending on several factors, including the height of eye of ownship.

Level III: Greater Than ± 15°. This vertical field of view would generally be acceptable for land and traffic vessels both at a distance and close aboard. This type of vertical field of view would probably be required for docking exercises. The vertical field of view requirements for docking exercises are usually driven by the height of eye on ownship.

With regard to vertical field of view, two additional points should be noted. First, it is not possible to realistically present objects in the visual scene which are closer than the distance from the preferred viewing point (*i.e.*, focal point) to the screen. This is usually not a problem when simulating large vessels with beams in excess of 100 feet. However, when simulating smaller vessels (e.g., tugboats), the reader is reminded it is not possible to accurately simulate a buoy which passes 20 feet abeam if the visual scene screen on which it is to be projected is 30 feet away.

Second, the vertical field of view can be optically manipulated to a certain degree to better view objects which are low in the visual scene such as docks, etc. It is accomplished by elevating the horizon on the visual scene. This allows a greater percentage of the visual scene below the horizon to be projected. Once again caution should be utilized since the impact of this modification on the effectiveness of training is unknown.

Time of Day

The ambient lighting conditions under which simulator-based training is accomplished is another critical simulator design characteristic. Some members of the maritime community have advanced the theory that only nighttime simulator-based training is required since it is the more difficult operational situation. Research from earlier experiments in this project, however, have indicated that simulator-based training should be conducted under the same ambient lighting conditions as the operational tasks. Nighttime shiphandling may be more difficult than daytime shiphandling, but training under daytime conditions prepares the shiphandler for daytime operations better than training under nighttime conditions. One would naturally expect the complement to be true; that nighttime training prepares one for nighttime operations best. Since it would appear to be prudent to train shiphandlers for most operations under both day and night conditions, a training facility that offers a comprehensive simulator-based training program should have a simulator with a day/night capability. However, economic or logistic constraints may allow training only the most critical skills under both day and night conditions. If this is the case, it would then appear desirable to train the remaining skills under the more difficult lighting condition, which would usually be the nighttime condition.

Level I: Night Only. Beneficial training in a number of training categories, such as Navigation Management, Communications, Rules of the Road, may be accomplished using a night only visual scene. However, caution should be exercised as regards the effect of such training during daytime operations. For example, experience has indicated that mariners have a tendency to neglect visual bearings and VHF communications more during daylight operations (when they have good visual contact) than under nighttime conditions. Training under nighttime conditions only, would not detect or correct such tendencies, and could give a false sense of trainee proficiency.

Very little information is available on the benefits associated with various levels of the night visual scene (i.e., spotlight sources versus silhouettes with lights). The only guideline presented here is that silhouettes do provide visual cue information and should be utilized in those scenarios where they are deemed important for training. As a result, simulators with a nighttime visual scene that is generated by spotlights may not be satisfactory for some specific training objectives.

Level II: Day Only. Beneficial training in nearly all of the training categories may be accomplished using a day only visual scene. As previously discussed, and intuitively realized by most people, such daytime training does not prepare the trainee for nighttime operations. However, it may be satisfactory to utilize a day only visual scene without nighttime limitations for specific shiphandling and emergency shiphandling training objectives, in which the shiphandler would not expect to operate his vessel at night. For example, a particular company or a particular port may restrict the arrival or departure of a certain size or type of vessel (e.g., LNG) to daylight hours.

Level III: Day/Night. This level of the time of day visual scene characteristic appears to be the most desirable for a simulator-based training facility which offers or plans to offer a comprehensive training program. With such flexibility designed into the simulator, scenarios under both day and night conditions can be provided within the training program as appropriate. A note of caution, however, is warranted. Since the visual scene generating hardware (and software, if appropriate) must have the capability for both daytime and nighttime presentation, the quality of either or both presentations may suffer as a result of tradeoffs made in the design process. The quality of the visual scene should be evaluated in accordance with the guidelines set forth under "Visual Scene Quality."

Color Visual Scene

The requirement for color in the visual scene of a shiphandling/navigation simulator is also related to the training objectives to be accomplished via the simulator-based training. Research appears to indicate that a color visual scene may not be required for some training objectives. Guidelines for scenarios in which a black and white visual scene will provide acceptable training are provided below. However, it does appear desirable for a simulator-based training facility which offers or plans to offer a comprehensive training program to have a visual scene capable of simulating color for at least vessel sidelights and aids to navigation —these being the principal color cues historically used by the maritime community.

Level I: Black and White. A black and white visual scene may be acceptable for training specific shiphandling training objectives under both day and night conditions. In daytime operations, the black and white presentation downgrades, but may not eliminate any important visual cues. In nighttime operations, all lights become white and the information transmitted by their color characteristic may be provided via an associated flash code. This is not viewed as a problem with aids to navigation since it is possible to encounter, in the at-sea environment, geographic areas marked by only white lights with distinctive flash rates. Hence, deck officers have experience in interpreting and using flash patterns during the navigation process, (although this may limit the application of such a simulator for training in specific ports where color is a key visual cue).

It is generally recognized that the sidelights of traffic vessels must be colored to be realistic. However, it has been shown that mariners can be successfully trained under conditions where they must process the flash rate of a light over time in lieu of instantaneously obtaining the red color of a port sidelight, if a relatively light amount of traffic is encountered in the scenarios. It is expected that the trainee's ability to keep track of traffic movement under such conditions will be taxed in scenarios with high contact workload.

Level II: Multi-color. The utilization of multiple color in the visual scene can provide acceptable simulator-based training for all the senior mariner desired skills identified. Experience has indicated that effective simulator-based training can be conducted without extensive use of color and shading. Caution should be exercised in the use of color and shading in order to add to the realism of the environment and not to introduce color cued distractions. See the following section on "Visual Scene Quality."

Visual Scene Quality

The simulated visual scene should have sufficient quality such that effective training can be conducted for the desired training objectives. Factors such as resolution, luminance, contrast ratio, update rate, etc., should be effectively manipulated during the visual scene design such that the following considerations are satisfied.

- When viewed from or near the design focal point, objects normally viewed from a ship's bridge appear clear and readily recognizable in the proper size and perspective.
- The sensitivity of the visual scene to distortion as the deck officer moves away from the focal point should not significantly impact his normal positions and movement within the pilothouse during the scenarios envisioned. For example, many pilots have conning positions other than at the center of the pilothouse. In addition, when bridge teams are involved, it is not uncommon to have several individuals evaluating the situations from different locations in the pilothouse. The sensitivity of the visual scene to distortion, as a function of location within the pilothouse, should accommodate such conditions if appropriate.
- The size and perspective of such objects should change as appropriate when motion is introduced into the simulation.
- The motion of objects in the visual scene appears in a relatively smooth sequence.
- The visual scene should be free from any distracting flicker.
- The visual scene should be free of any visible raster lines.
- The intensity of lights should appear to vary with range.
- Discontinuities between projected images/screens in the visual scene should be minimal.
- Color match between projected images/screens in visual scene should be minimal.
- The intensity and hues of critical color cues (e.g., traffic vessel sidelights) should be acceptable to the experienced mariner.
- The use of color and shading should be such that it adds to the realism of the environment and does not introduce color cued distractions.
- The visual scene should be free from substantial distortion or brightness variations as the trainee moves from the preferred viewing point (i.e., focal point) within the confines of the pilothouse.
- The resolution of the visual scene should be such that the required visual cues, at a particular range from own-ship, which have the minimum width in the visual scene are projected. For example, if it is (a) important and (b) normally possible to view traffic vessel masts at 5 nautical miles, then the resolution of the projected image should be such that they are contained in the visual scene when the traffic vessel is at that range.

- Auxiliary views of a particular segment of the projected (or unprojected) visual scene should not substantially detract from the realism of the simulated environment or become an operational crutch which would not be available in similar scenarios at sea. Examples of auxiliary views may include a single CRT display used to provide the mariner with (a) a view aft to assist in periodically checking a vessel being towed or (b) a "binocular effect" on simulators in which the resolution of the visual scene does not permit magnification by binoculars.[5]

3.2.2 RADAR PRESENTATION

The type of radar equipment required on a shiphandling/navigation simulator is related to the objectives of the training program to be accomplished. A sophisticated radar/CAS is generally not required for the majority of the identified training objectives. A full mission shiphandling/navigation simulator should not be utilized to develop radar plotting and evaluation skills. This may be more cost effectively accomplished on a part-task radar simulator.

The presence of noise (e.g., sea clutter and false echoes) on the simulator radar presentation may be employed if appropriate for the training objectives. As previously discussed for "Horizontal Field of View," it may be desirable to train basic skills, such as combining radar and visual information to establish risk of collision or to establish ownship's geographic position, without distracting noise. The ability to accomplish such tasks under noise conditions may then be assumed, if the trainee has already developed the skill of discriminating traffic vessels, aids to navigation, etc., from other noise on the screen through previous at-sea or radar simulator-based training. It would, however, be desirable to evaluate performance of the desired tasks under noise conditions during the final stages of training.

The simulation of line of sight considerations should be accomplished as required by the specific training objectives. For example, if masking of traffic vessels by a higher building or hill is important when training the approach to a particular port, it should be adequately included in the simulation. Such line of sight considerations, as well as the previously mentioned noise considerations, may be added to either Level II or Level III as outlined below.

Finally, it should be noted that appropriate procedures should be employed to ensure that the ranges and bearings obtained from the simulated radar presentation correlate satisfactorily with the simulated visual scene presentation, etc. In addition, it should be verified that the accuracy of this correlation between the radar and visual scene information does not vary as a function of scenario time.

Level I: No Radar. There are a number of senior mariner level training objectives, particularly in the shiphandling and emergency shiphandling areas, for which effective training may be accomplished without a radar presentation.

Level II: Low Fidelity Radar. The majority of senior mariner training objectives may be accomplished using a computer-generated synthetic radar presentation on an appropriate CRT display as long as the required radar or CAS functions are available. Care should be exercised that the necessary radar information and the tasks associated with obtaining that information during a simulator exercise are compatible with the information available and the tasks performed at sea.

Level III: High Fidelity Radar. This level of radar presentation would include the use of actual radar or collision avoidance hardware that are appropriately interfaced with the remaining simulation systems. Although desirable, such high fidelity is generally not required for the training objectives normally taught at the senior mariner level. However, there may be times when it would be necessary to have such radar systems. For example, when providing vessel specific training it may be desirable to have the specific radar/CAS on the simulator that the actual vessel has on its bridge.

[5] The resolution on many simulators is designed to provide the deck officer with an acceptable visual scene when viewed with the naked eye. If a set of binoculars were to be used by a watch officer to look at a traffic ship in order to determine its aspect, the ship would look larger through the binoculars but may not be resolved any better. In other words, if the traffic ship consisted of four units of resolution initially, it would still contain four units of resolution through the binoculars although each unit would appear larger to the eye. Therefore, no additional information is obtained by viewing in this manner. An auxiliary view is one technique for providing the deck officer with the additional information normally available through binoculars.

3.2.3 BRIDGE CONFIGURATION

The physical characteristics of the simulated bridge and the hardware located on same may be related to the specific training objectives to be accomplished. However, experience has indicated that this may not be critical as long as some minimum level of fidelity in the bridge environment is maintained. The size of the pilothouse, the type of equipment available, and the arrangement of this equipment should have a high degree of compatibility with that found on similar vessels at sea in order to minimize the introduction of any extraneous factors into the training process. The replication of the pilothouse of a particular vessel generally is not warranted except possibly when providing shiphandling/navigation training for a specific vessel type. The design of any shiphandling/navigation simulator should consider the inclusion of a high degree of fidelity since the bridge configuration is a relatively small proportion of the total simulator cost, it is cheap insurance to protect against any irregular behavior that may be associated with the simulated pilothouse environment. In addition, the student's confidence in the simulator as a training device and hence his motivation during the training program may be detrimentally affected if the simulated pilothouse environment does not meet his minimum expectations.

Level I: Reduced Bridge. A pilothouse that is substantially reduced in size and contains only the essential equipment necessary for the specific training to be accomplished. This bridge configuration may be of value in training a limited number of skills. Caution, however, should be exercised that any spatial or equipment alterations do not significantly impact the shiphandling/navigation tasks to be accomplished.

Level II: Full Bridge. A pilothouse that is full size, or nearly full size and contains all or the majority of bridge hardware normally found on similar vessels at sea. This bridge configuration is recommended for simulators that are involved with training senior mariners for the majority of the identified desired skills categories.

Level III: Replication Bridge. A pilothouse that is an exact copy of the pilothouse of a specific vessel as regards both equipment and layout. It may be desirable to provide such a high level of fidelity when training mariners to handle a specific vessel type. This may be particularly desirable for some training objectives if they are dependent on the specific bridge equipment and/or layout.

3.2.4 OWNSHIP CHARACTERISTICS AND DYNAMICS

The maneuvering response of ownship under various environmental conditions is another critical characteristic of a shiphandling/navigation simulator for training senior mariners. The sophistication of the required maneuvering response is related to the specific skills to be developed within the training program. If skills relating to the application of International Rules of the Road are desired, then a simulation model with only deep water hydrodynamic coefficients will probably suffice. If skills relating to compensating for bank effects while negotiating the turn of a narrow channel are desired, then the simulation model employed should have such capabilities. The identification and discussion of three levels of ownship characteristics and dynamics are discussed below.

Level I: Deep Water. This level of hydrodynamic model involves only deep water coefficients and may include constant or variable wind and current. The capability of reversing engines to decelerate more rapidly (but no astern motion) should also be included. This level would be used primarily for International Rules of the Road training and some limited Shiphandling/Emergency Shiphandling training.

Level II: Shallow Water. This level of the hydrodynamic model involves the capabilities indicated above for Level I, plus appropriate shallow water modifications and corresponding water depth data base of the particular geographic areas involved during the training. A spatial dependent current data base may also be employed particularly when modeling a specific port area in order to simulate the fact that current magnitude and direction vary with geographic position of ownship. Low speed hydrodynamic modifications may also be appropriate in order to accurately simulate forward velocities of less than two (2) knots. This level of ownship characteristics and dynamics would be recommended for the majority of senior mariner desired skills categories. It would not be sufficient for the more advanced Shiphandling training (e.g., bank effects) or docking/anchoring evolutions.

Level III: Special Effects. This level of the hydrodynamic model involves the capabilities indicated above for Level II, plus appropriate bank effects, passing ship effects, tugs forces, reverse motion capability, kick effect, bow thrusters and anchor forces. This level of ownship characteristics and dynamics would be recommended for the more advanced Shiphandling training (e.g., bank effects) or docking/anchoring evolutions.

There are several different versions of the hydrodynamic simulation model and a number of well-known hydrodynamicists and hydrodynamic research firms who develop appropriate coefficients for these models using various techniques. Commercial simulator-based training facilities should develop prudent procedures to ensure the accuracy of their hydrodynamic simulation models and coefficients. Such procedures should include both analytical evaluations (i.e., turning circles, advance and transfer trajectories) and experienced mariner evaluations for all load/ballast conditions over the range of the wind, current, water depth, etc., anticipated. The interested reader should contact the Computer Aided Operations Research Facility (CAORF) or the Society of Naval Architect and Marine Engineers (SNAME) for their latest publications on this subject.

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National Maritime Research Center
Kings Point, New York 11024

The Society of Naval Architects and Marine Engineers
(SNAME)
One World Trade Center, Suite 1369
New York, New York 10048

Similar precautions should also be taken to ensure the accuracy of the geographic/environmental data bases when modeling a specific port.

It should also be noted that different engine response models are available for various steam, diesel, and gas turbine propulsion plants. Generally, such modelling sophistication is not required for training the majority of senior mariner shiphandling skills. However, if it is important for the skills being taught, the appropriate engine response model should be employed.

3.2.5 EXERCISE CONTROL

This simulator characteristic refers to the amount of control that the instructor has over the exercises; their selection, their modification, etc. Although it is appropriate to design such flexibility into a shiphandling/navigation simulator to assist the instructor in maximizing the training benefit to be received, caution should be exercised in that too much instructor latitude, particularly by marginal instructors, may reduce, not increase, the training benefits associated with such design capabilities. This may result in negating the resources expended in the development of a well-structured training program with carefully conceived scenarios. Three levels of exercise control that may be appropriate for a shiphandling/navigation simulator at the senior mariner level are identified and described below.

Level I: Exercise Selection. At this level the instructor's console is limited to the intial exercise selection. The geometry, complexity, and duration of the exercise is fixed by the pre-set program of the particular scenario selected. Wind, current, water depth, traffic motion, etc., are constrained by the program. If the instructor wishes to change the scenario, the scenario must be stopped and an alternative scenario selected. This constrains the instructor to use only those particular scenarios within the training program, and may limit his adaptation of the training program to the specific needs of the trainees. This may not be a problem if the training program is well-designed and the scenarios are well-conceived to assist in the development of deficient trainee skills. In fact, a well-designed training program should consider the inclusion of additional scenarios to allow for such flexibility during implementation. This level of exericse control may be particularly appropriate for refresher courses where the trainees already possess the desired skills, but require the opportunity to practice same under the direction of a qualified instructor.

Level II: Instructor Pre-Programmed Exercise Control. This level of exercise control contains all the capabilities described above under Level I, plus the capability for the instructor to modify scenarios during initial set-up. Depending on student performance on the previous exercise, the instructor may want to alter the next scheduled scenario by modifying wind or current. He may also want to change traffic vessel positioning, course, speed, or maneuver point. This level of exercise control appears to be appropriate for a majority of the senior mariner training objectives. The danger associated with marginal instructors tinkering with a well-designed training program as previously mentioned should be noted.

Level III: Instructor Exercise Control. This level of exercise control contains all the capabilities described above under Level II, plus the capability for the instructor to modify the scenario while it is running. This allows the instructor maximum flexibility in adapting the scenario to the students training needs. However, it also provides him with maximum capability of bypassing the predetermined training program and to commence "shooting from the hip."

The capability of altering scenario time, such as freezing the scenario or advancing the scenario in fast time warrants discussion under this simulation characteristic. Generally speaking, the alteration of scenario time is not recommended as part of the training process. A "scenario freeze" capability may be beneficial if used judiciously. A "fast-time" capability is usually not desirable even for demonstration purposes since a danger exists that the trainee's sense of time may be distorted as a result of observing the visual scene in an accelerated mode. Graphic classroom feedback displays, however, which utilize fast time models can be an effective means of critiquing a scenario (See Training Assistance Technology). While alteration of scenario time on the simulator is not recommended as part of the training process, it may be a desirable feature for scenario or data base development in order to minimize the time required to checkout the simulator exercises prior to training.

Some training facilities have found that a play-back capability may be advantageous to return the simulated ownship to a critical time/geographic point within the previous scenario in order to demonstrate the effect of an alternate control action. If this capability is utilized with a fast-time option as a means of quickly returning to the desired time/geographic point, the cautions cited above, concerning alterations in scenario time, should be considered.

3.2.6 TRAFFIC VESSEL CONTROL

This characteristic refers to the amount of control that the instructor has over the selection (i.e., vessel type and size), position, courses, and speeds of traffic vessels in a given scenario. This characteristic may be considered by some to be a subset of the "Exercise Control" characteristic. However, due to its importance with regard to traffic vessel simulation, it is discussed separately here. Four alternative levels of traffic vessel control that may be appropriate for a shiphandling/navigation simulator at the senior mariner level are identified and described below.

Level I: Canned Traffic. This level refers to vessel traffic control in which the traffic vessel has a limited number of tracks that it can follow and cannot, at any time during the scenario, deviate from the track that the instructor selects no matter what course and speed changes ownship makes. The use of canned traffic may result in the development of somewhat unrealistic scenario situations in that the traffic vessels do not respond to ownship maneuvers as does traffic in the real world. This type of traffic control may be best suited for training skills that involve scenarios in which ownship does not interact with traffic vessels. In other words, the traffic vessels are used primarily as distractions (i.e., noise). For example, some navigation management and position fixing/dead reckoning training objectives may be effectively accomplished using this level of traffic vessel control.

Level II: Pre-Programmed Traffic. This level refers to vessel traffic control in which the instructor can alter to any track the traffic vessel motions during initial set-up to compensate for the tendency of the students in the earlier scenarios. This level of control allows greater flexibility to the instructor than the canned traffic capability. The majority of the senior mariner desired skills categories identified may be effectively trained using this level of control. The research to date appears to indicate that there may be a danger that the use of canned traffic vessels during training for situations in which ownship interacts with traffic vessels, may provide the mariner with a false sense of confidence in predicting the behavior of the other vessel. As a result, the training program and the instructor use of this capability should be such as to instill in the students an appreciation of the irregular traffic vessel behavior that is sometimes encountered at sea.

Level III: Independently Maneuverable Traffic. This level of vessel traffic control provides the instructor with complete control over the actions of the traffic vessels regarding changes in course and speed at any time during the scenario as well as alterations to initial position, course, and speed. The instructor is not limited to a few tracks or a limited number of pre-programmed scenarios. Independently maneuverable traffic allows the instructor to modify scenario complexity and difficulty based on the events as they unfold within the scenario. Although the majority, if not all, the senior mariner desired skills categories could be effectively trained through the proper use of Level II: Pre-Programmed Traffic, this more sophisticated level of vessel traffic control is desirable, particularly for many of the vessel-to-vessel communications training objectives and some of the advanced shiphandling training objectives (e.g., passing ship effects). As previously discussed, caution should be exercised in providing marginal instructors with the capability of bypassing a structured training program. The results may be more confusing than helpful.

Level IV: Interactive Bridges. The use of two (or more) simulated ownships each controlled from its own pilothouse, interacting in the same gaming area, is another technique for controlling traffic vessels during a training exercise. The principal advantages of this technique include

(a) a high level of realism to the situation involving the interaction between vessels since a wide range of behavior may be expected from those individuals conning each of the vessels and (b) the additional platforms for hands-on training. The principal disadvantages appear to be the high cost of the additional simulators and a reduction of training control in particular training exercises unless the instructor is conning or closely supervising the maneuvers of one vessel. Each training exercise should have a specific objective and should not be viewed as simply allowing the trainee to attain additional experience, except possibly during the latter stages of training.

3.2.7 TRAINING ASSISTANCE TECHNOLOGY

Training Assistance Technology refers to the use of computer processing and display capabilities to enhance the training process by assisting the instructor and trainees to comprehensively analyze the simulator training exercises. Research has indicated that this additional capability to more comprehensively analyze trainee performance, if done properly, may promote more rapid understanding of the desired shiphandling/navigation concepts. As a result, the training facility may (1) reduce the training time required to attain the desired proficiency levels, (2) increase the throughput of students, or (3) reduce the instructional staff requirements. However, caution should be exercised in the use of training assistance technology because improper design or use of this capability may detract from the training process, not enhance it. Training assistance technology should be designed by individuals knowledgeable in the use of this potentially powerful capability. Instructors should also be provided with adequate training in the use of training assistance technology for training shiphandling/navigation skills. Four levels of increasingly sophisticated training assistance technology are identified and discussed below.

Level I: Remote Monitoring. The capability for students not training on the simulator to view the simulator exercises remotely (i.e., from classroom) has some distinct advantages for training: (1) it allows the instructor and observing students to discuss the scenario as it unfolds without disturbing those students participating directly in the exercise, (2) it allows the instructor and observing students access to additional information on key parameters not normally available on the bridge (i.e., distance from channel centerline, current magnitude and direction), (3) it allows the instructor and observing students to better simulate vessel-to-vessel communications, etc., and (4) it allows class size to be increased without causing crowding in the pilothouse. Remote monitoring has the disadvantage for some training objectives of removing the student from the simulated environment where he has the opportunity to develop potentially important perceptual skills (i.e., estimating the distance from channel centerline or side-slip velocity of ownship using a pair of range lights). In some cases, the benefits of remote monitoring can be coupled with the benefits of pilothouse experience by videotaping the remote monitoring displays and replaying them during the feedback session.

Level II: Feedback Display. The use of computer-generated graphic displays, primarily in the classroom, to evaluate the history of key scenario variables (i.e., distance to turn, rudder angle, yaw rate) using appropriate plots, graphs, and listings can also be extremely valuable for training. Trackplots of ownship's center of gravity or swept path in relationship to other vessels or geographic hazards usually provide invaluable immediate feedback on the performance of the trainees above/beyond simple knowledge of CPA. Such feedback displays assist the instructor in explaining not only **what** happened but **why** it happened. This type of feedback appears to be of the greatest benefit when it is supplied immediately after each scenario. The feedback display equipment should have the capability of providing the appropriate displays immediately after each scenario. Computer processing limitations, however, may prevent this response. Although feedback displays can be added to a simulator after its construction, it is best to consider the flexibility for such an addition during the initial design of the training system. Finally, the use of color in such feedback displays is an extremely desirable technique to highlight key points within the display. It should be considered by every training facility employing or considering such feedback displays. These feedback displays may be either a CRT display or a large screen display. The CRT display would probably be utilized in the pilothouse while the large screen display would be employed in the classroom. If a feedback display is utilized in the pilothouse, appropriate cautions should be exercised to see that such a display does not become a "crutch" to the shiphandler during the scenario.

Level III: Instructor Alerts/Prompts. The capability of the simulator to provide the instructor with visual or audio cues at key points within a scenario may also be beneficial to effective training. Such cues may include appropriate direction to the instructor on a special instructor display terminal/console. Such direction may take a form similar to the information normally found in a detailed instructor's guide. This capability may reduce the instructor's burden during training and may result in more standardized instruction whenever multiple instructor's are utilized. There may, however, be a danger that the use of Instructor Alerts/ Prompts may restrict or distract a well-qualified instructor in the implementation of his normal effective teaching methods, resulting in reduced efficiency for this individual.

Level IV: Training Management Technology. This level involves the computer's capability to store and analyze trainee performance at key points within a training program over a long period of time. Such information may be valuable when evaluating or restructuring a training program. It may assist in identifying the strengths and weaknesses of the trainee population and form a basis for re-designing scenarios or modifying the sequence of scenarios. It may also assist in the refinement of more meaningful performance measures for the scenarios involved. Training Management Technology also has the capability of providing diagnostic information on the performance and reliability of a training facility's instructional staff, which can be useful in assisting instructors to upgrade their training techniques. Caution, however, should be exercised as regards this level of Training Assistance Technology since it is highly dependent on quantitative performance measures which must be evaluated from the proper perspective. Due to the vast amount of data available over time, there may be a tendency to conduct and accept the results of statistical tests on face value and forego more indepth analysis. It should also be noted that while these techniques have definite benefits associated with them, they also involve additional costs which should be carefully considered prior to making the required investment.

3.2.8 AVAILABILITY

Historically, radar simulator-based training facilities have had few problems with their equipment which impact their training schedule or the quality of the training provided. However, due to the greater complexity of the shiphandling/navigation simulator, particularly in the visual scene, experience to date indicates that the reliability of hardware and the time to repair may be more of a potential problem. Reasonable precautions should be taken to ensure that adequate preventative maintenance is provided, sufficient spare parts are on-hand, and properly trained repair personnel are available in order to minimize unprogrammed simulator downtime. Standards should be set forth defining acceptable versus unacceptable simulator performance for training. Such standards should be monitored by training facility personnel to ensure a quality simulation environment for training. Appropriate documentation should be maintained for U.S. Coast Guard approval processes. If possible, contingency lesson plans and training program schedule flexibility should be available in order to maximize the benefit of the training time should such simulator malfunctions/degradation occur. Guidelines for alternative levels of availability considerations are discussed below. These levels should be considered as broad guidelines only. The specific availability considerations will be determined by the type of hardware employed; particularly in generating the visual scene. Any simulator-based training facility should have a sufficiently high level of availability such that the quality and quantity of training is not substantially affected.

Level I: Moderate Availability

- Simulator should be designed using hardware of best commercial construction/manufacture.
- Moderate spare parts inventory for high usage or critical components, in view of experience, or an appropriate reliability analysis should be maintained.
- Simulator operational staff should have sufficient training to perform routine maintenance and an appropriate level of diagnostic troubleshooting and repair.
- No specially trained repairmen are onsite to maintain or repair critical hardware.
- Few, if any, service contracts are maintained.
- This level of training system availability may be acceptable for an undergraduate program (i.e., cadets) when a simulator course is only a small part of a curriculum and some flexibility is contained in the trainee's schedule.

Level II: High Availability

- Simulator should be designed using hardware of best commercial construction/manufacture with appropriate built-in diagnostic capability.
- Extensive spare parts inventory for high usage or critical components, in view of experience, or an appropriate reliability analysis should be maintained.
- Simulator operational staff should have sufficient training to perform routine maintenance and an appropriate level of diagnostic troubleshooting and repair.

- No specially trained repairmen are onsite to maintain or repair critical hardware.

- Service contracts should be maintained on many critical components.

- This level of training system availability may be acceptable for training senior mariners when the training workload is such that some simulator slack time is available for rescheduling.

Level III: Very High Availability

- Simulator should be designed using hardware of best commercial construction/manufacture with appropriate built-in diagnostic capability.

- Extensive spare parts inventory for high usage or critical components, in view of experience, or an appropriate reliability analysis should be maintained.

- Simulator operational staff should have sufficient training to perform routine maintenance and an appropriate level of diagnostic troubleshooting and repair.

- Specially trained repairmen are onsite to maintain or repair critical hardware.

- Service contracts should be maintained on all critical components.

- This level of training system availability may be desirable for training senior mariners when the training workload is such that little or no simulator slack time is available for rescheduling.

3.3 TRAINING PROGRAM STRUCTURE (CRITICAL CHARACTERISTICS)

3.3.1 SKILL LEVELS AFTER TRAINING

The first step in the design or evaluation of a simulator-based training program is a clear and concise identification of the goals of the training process. The goals of a particular simulator-based training program usually can best be stated in terms of skill levels after training or output behavioral objectives. Chapter 2 identifies, discusses, and prioritizes a number of critical/deficient skills for senior commercial ship deck officers, for which simulator-based training appears advantageous. It is recommended that the skill levels to be achieved as a result of a particular training program be developed or translated in these terms since these guidelines were developed on this basis. Three levels of training program goals are envisioned.

Level I: General Professional Training. These training programs result in the improvement or refinement of a number of skills already possessed by the trainees. The trainees are generally proficient mariners who desire an opportunity to refresh or practice their skills. No single skill area is emphasized in the training program. If during the program a mariner is observed to be deficient in a particular skill area, he should be directed to the appropriate Level II training program.

Level II: Direct Skill Improvement. These training programs strive towards the development of specific skills such as vessel-to-vessel communications or Rules of the Road. The goal of the training program and the structure of the training program is directed towards improvement in the specified skills only.

Level III: Specific Operational Training. These training programs are developed such that the trainee improves his skills in specific operational applications. These specific operational applications may include handling large vessels, vessels with unusual handling characteristics, or specific vessels within specific ports.

3.3.2 SKILL LEVELS BEFORE TRAINING

In designing or evaluating a simulator-based training program, it is important to identify the skills of the trainee prior to training in order to establish the basis upon which the training program will build. A secondary reason for identifying the trainee's skill levels before training is that it will assist in eliminating any unnecessary simulator-based training, thereby minimizing the training cost for the individual student. Skill levels before training may be stated in terms of license or experience levels (i.e., a masters license with at least two years experience on tankers of 30,000 DWT or larger), although it would be preferable to identify them in terms similar to those utilized in describing the desired skill levels.

Ideally, all students who have approximately the same level of expertise should be grouped together as a class. This would hopefully allow each trainee to proceed through the program at the same rate. Use of license level, vessel type experience, etc., may be discriminatory in this regard when accepting applications. From a logistical perspective once the deck officers arrive at the training facility, it is usually difficult to shift them to another class grouping that may be more appropriate based on their skill levels. It then becomes a matter of adapting the training program as appropriate to the strengths and weaknesses of the class as a whole.

Techniques of varying levels of sophistication can be utilized by a simulator-based training facility to identify skill before training once the deck officer arrives at the training facility.

Level I: No Diagnostic Evaluation. The skills already possessed by the deck officers prior to their participation in the training program are not evaluated. A standard training program is provided, addressing a fixed set of training objectives, independent of trainee entry skill proficiency.

Level II: Evaluation via Discussion. Each deck officer completes a questionnaire or participates in an interview/discussion with the instructor allowing an assessment of the trainee's individual skills. The instructor, upon completion of all trainee interviews, makes an evaluation of group proficiencies and deficiencies. The training program is then tailored as appropriate to meet the needs of each group.

Level III: Simulator Diagnostic Evaluation. A pretest simulation scenario is administered individually to each trainee prior to his participation in the training program. Each trainee's performance is evaluated against a set of minimal acceptable standards. The strengths and weaknesses of the group as a whole are determined based on the results of the diagnostic evaluation and the training program is tailored as appropriate to meet the needs of the group.

3.3.3 TRAINING OBJECTIVES

Training objectives are the progressive goals of the individual training modules which build on the trainee's skill levels prior to training and culminate with the trainee's attainment of the desired skill levels. The magnitude of the improvement goal for each progressive training objective will depend on many factors including the skill and knowledge of the trainee, the difficulty of the skill being taught, the trainee's motivation, the ability of the instructor, etc. Training objectives should be written in terms of (1) the desired skills or knowledge to be attained, (2) the conditions under which the student should be able to perform the new skill, and (3) the performance measures and standards to be employed to measure the attainment of this goal. For example, upon completion of this training session, the trainee shall be able to apply the International Rules of the Road under unrestricted visibility conditions in a variety of crossing situations in which ownship is the give-way vessel, such that a CPA of greater than two nautical miles is attained. However, the detail of a program's training objectives may vary as indicated below.

Level I: Very Flexible. The training objectives are written in general terms relating to the program goals or training module goals. They are not tied specifically to any particular topic areas or simulator exercises. Example: "Upon completion of this training, the trainee shall be able to apply the International Rules of the Road under a variety of operational conditions . . ."

Level II: Moderately Structured. The training objectives are written for each topic area to be covered within the training program or training module. These training objectives have more detail than the Level I training objectives discussed above. Example: "Upon completion of this training, the trainee shall be able to apply the International Rules of the Road in crossing situations under a variety of operational conditions . . ."

Level III: Highly Structured. The training objectives are written for each simulator exercise within the training program. Example: "Upon completion of this training, the trainee shall be able to apply the International Rules of the Road in crossing situations in which ownship is the give-way vessel when the visibility is 12 nautical miles . . ."

3.3.4 TRAINING TECHNIQUES

Training techniques are structured or unstructured methods of instruction used to teach the trainee how to perform various tasks so as to satisfactorily achieve the program's training objectives.

When conducting simulator-based training programs, no single training technique will suffice. Various techniques should be used to provide adaptation for individual differences. This will ideally allow the attainment of a high level of performance from all trainees. As exercises are developed, selection of training techniques should be based upon:

- Skills prior to training
- Desired skills after training
- The training objectives

- The time available for training
- Training aid (i.e., simulator) capability and availability
- Overall training cost

There are a number of training techniques that may be utilized during shiphandling/navigation simulator-based training programs. Four of the most relevant techniques that have been successfully employed for such simulator-based training are described below.

3.3.4.1 KNOWLEDGE OF REQUIREMENTS. Knowledge of requirements involves the presentation to the student of specific aspects of the pending training exercise prior to its conduct on the simulator (i.e., definition of problem). The purpose of this training technique is to eliminate the element of surprise from the training process until the student acquires the basic skills to perform the task when there is sufficient time to anticipate proper action. For example, if emergency shiphandling skills involving the reaction to a loss of power in a restricted channel are being taught, it would probably be desirable to train the students to handle the casualty without the element of surprise initially. After they have been adequately trained in the proper procedures and control actions to respond to the casualty, it would be then appropriate to add the element of surprise by initiating the casualty unannounced during later scenarios in the training program.

The methods for disseminating knowledge of requirements can vary as follows:

Level I: No Prior Knowledge of Requirements. As indicated above, in specific cases it may be appropriate not to provide advanced deck officers with the knowledge of the exercise requirements when attempting to develop specific decision-making and judgmental skills. The deck officer normally does not find scenarios at-sea that involve particular skills which were discussed just prior to their encounter. As a result, he should be able to recognize that a problem exists, properly define it, then take appropriate action.

Level II: General Knowledge of Requirements. The instructor, prior to the trainee's participation in the exercise, explains the general goals of the exercise and the criteria upon which his performance will be evaluated.

Level III: Specific Knowledge of Requirements. The instructor, prior to the trainee's participation in the exercise, explains the specific type of problem to be encountered, factors affecting the solution, and all criteria upon which performance will be evaluated. This level of knowledge of results is recommended for training when new concepts are being introduced or new skills are being developed.

3.3.4.2 POSITIVE GUIDANCE. Positive guidance is a technique whereby relevant information concerning the appropriate procedures or behavior is provided to the students prior to or during the training exercise on the simulator. That is, the instructor positively guides the students by explaining, demonstrating, or providing evaluative commentary during the exercise as regards the proper considerations and actions to be taken. This technique will assist the trainee in making the link between critical information (i.e., range/closing rate) with appropriate deck officer action (i.e., range at which maneuver is initiated).

Positive guidance should be employed early in the training process to ensure that the essential behaviors are learned. Positive guidance should then be removed and feedback on student performance is then provided solely by the post-problem critique. Caution should be exercised that positive guidance by the instructor does not become a necessary crutch for successful deck officer performance, since in the at-sea environment the instructor will not be available to provide such assistance. Various levels of positive guidance can exist.

Level I: No Positive Guidance. No postive guidance/relevant information is given to the trainees prior to or during the training exercise on the simulator regarding the appropriate procedures to be followed or the behaviors to be exhibited (i.e., post problem critique only). There is a danger that inappropriate behavior may be reinforced by this technique and may become difficult to overcome during the remainder of the training program. Desirable behavior should be emphasized, demonstrated, and practiced at every opportunity. Therefore, some amount of positive guidance should be employed particularly during the early stages of training.

Level II: Verbal Explanation. The instructor verbally explains to the trainees the appropriate procedures to be followed and behaviors to be exhibited prior to and possibly during the training exercises on the simulator. If positive guidance is provided during the exercise, care should be exercised that it does not become an operational crutch as indicated above.

Level III: Demonstration. The instructor verbally explains the appropriate procedures to be followed and the behaviors to be exhibited and then demonstrates on the simulator how the exercise should be performed, prior to the trainees participating in the simulator exericse.

Level IV: Detailed Analytic Introduction. The instructor verbally and through use of audio visuals or other training assistance technology, explains the appropriate procedures to be followed and behaviors to be exhibited. (See discussion of Training Assistance Technology, Level II: Feedback Displays.)

3.3.4.3 ADAPTIVE TRAINING. Adaptive training is a technique that varies the difficulty of tasks as a result of how well the trainee operates or performs on specific previously conducted tasks. As the trainee gains in skill, the trainee's tasks are made more difficult. This type of training represents a progressive training approach; it starts with basic tasks, goes to intermediate tasks, and finally to advanced level tasks. A key point is that the trainee progresses at his own rate through the program, based on his exhibited skill at each step. For example, adaptive training in shiphandling may have the trainee navigating an 80,000 DWT tanker around a 30 degree turn in a narrow channel with no wind, no current, and no traffic as a basic level task. An intermediate level task may be the navigation of the 80,000 DWT tanker around the 30 degree turn with 25 knots of wind and 1.5 knots of flood current. The most advanced level of training may require the trainee to navigate the same vessel through the same turn under 25 knots of wind and 1.5 knots of flood current, while avoiding two traffic vessels.

Adaptive training should be considered in the development of the scenario sequence as presented within the training program. Two major constraints in the implementation of this technique are (1) the availability of adequate performance measures to assess individual student proficiency and (2) a workable training program structure to accommodate varying rates of advancement for individual students. The latter constraint may not be a particular problem with small classes (i.e., less than three students), since adequate flexibility may be available.

Level I: No Adaptive Training. A standard training program is provided addressing a specific sequence of tasks of a predetermined difficulty level. No attempt is made to follow a progressive training approach based on the rate of advancement of the particular students.

Level II: Group Adaptive Training. The difficulty level of training is tailored to meet the needs of a group of trainees, not each individual trainee. The level of difficulty will progress from basic through intermediate to advanced, based on the group's performance.

Level III: Individual Adaptive Training. The difficulty level of tasks is varied as a result of how well the trainee performed on previously conducted tasks. The trainee progresses at his own rate through the program, first performing basic tasks then intermediate and finally advanced level tasks.

3.3.4.4 POST PROBLEM CRITIQUE. Post problem critique is a method of providing feedback regarding actions performed by the trainee in each simulator exercise. This technique should be employed immediately after each simulator exercise in order to maximize the benefit of the simulator training. It is recommended that the training program not be structured such that a post problem critique is employed only after several scenarios have been conducted on the simulator. This recommendation is made so as to minimize any confusion that may result in the trainee's mind between his behavior or control action on one scenario with the resulting vessel performance on another scenario. During the post problem critique, the instructor should:

- Emphasize and reinforce correct procedures and desirable behavior
- Point out specific errors in procedures/behaviors and explain their relationship to vessel performance (i.e., resulting CPA)
- Provide specific instructions on alterations to procedures/behavior in order to improve performance on future exercises
- Provide a discussion and, if appropriate, a demonstration of the benefits of correct procedures/behavior. This discussion/demonstration may be facilitated by the training assistance technology features previously discussed.

During the post problem critique the instructor should encourage student participation in the analysis of the previous exercise. This is particularly true when training senior mariners who usually have a wealth of experience upon which to draw.

The timing and completeness of post problem critique may vary as follows:

Level I: Delayed Feedback. The instructor reviews the material only after several simulator exercises have been completed. There may be a danger that this type of feedback may result in confusion in the trainee's mind between his behavior on one scenario with the resulting vessel performance on another scenario.

Level II: Immediate Feedback. A solely verbal critique of each simulator session is given by the instructor immediately upon its completion. This level of feedback may be given in the classroom or on the simulator between scenarios.

Level III: Complete and Immediate Feedback. The instructor uses verbal critique, classroom discussions and some form of training assistance technology to critique each simulator exercise immediately upon its completion.

3.3.5 INSTRUCTOR'S GUIDE

An instructor's guide should be developed and provided to all instructors who are to conduct the training program. The guide should set forth (1) the structure—the overall plan of training, (2) the strategy—detailed methodology and timetable for each hour of training, and (3) the materials used to enhance the training process. Such a guide is needed for two purposes: (1) to provide detailed guidance to the instructor to ensure that relevant issues are covered in an appropriate manner, and (2) to somewhat standardize the content of the training program should multiple instructors be used.

An outline of what should be contained in an instructor's guide is listed below.

I. Program Introduction

   A. Purpose of the training program
   B. Description of the training program
   C. Schedule
   D. Bridge Team Assignments—(if applicable) on and off watch bridge team locations (e.g., on-watch team is on the bridge; off-watch team remotely observing)

II. Simulator Familiarization

   A. Description of simulator capabilities and limitations
   B. Demonstration of bridge equipment
   C. Demonstration of ownship handling characteristics
   D. Standing orders

III. Training Category (e.g., shiphandling)

   A. Specific training objectives to be achieved at the completion of the program. Objectives should describe:

      1. Overt behavior
      2. The conditions under which the behavior is to be performed
      3. Performance measures and standards (e.g., the trainee should demonstrate proficiency in handling a specific type and size of vessel to avoid collision and pass at a safe distance with other traffic under various conditions of wind, current, and water depth)

   B. Detailed lesson guides for each hour of classroom instruction, each simulator session, and each feedback session.
      1. Each hour of classroom instruction should have detailed:
         a. The specific topic to be covered (e.g., safe vessel speed for a particular size and type of vessel under a variety of operational conditions)
         b. The training methodology to be used—detailing sample questions to be asked and points to be stressed
         c. All training materials/media to be used during this classroom segment
         d. The number code of the scenarios associated with the particular topic addressed
      2. Each scenario should have detailed:
         a. The specific training objectives to be achieved, including the appropriate performance measures and standards
         b. The methodology to be followed (i.e., demonstration of trainee hands-on)
         c. The coded scenarios to be run (specific scenario descriptions must be supplied in an appendix)
      3. Feedback session should have detailed:
         a. Training displays to be used, a description of acceptable performance to which the trainees' performance can be compared and evaluated

C. Course Evaluation/Student Debriefing

1. Upon completion of the entire training program the trainees should be given the opportunity to verbally evaluate the program. They should also be required to complete a debriefing questionnaire regarding the various aspects of training. It is recommended that the debriefing questionnaire request the following information:
   a. Simulator comments (e.g., realism of *visual scene, radar)*
   b. Training program comments (e.g., program organization, length, instructor effectiveness)
   c. General comments (e.g., improvements in course)

D. Appendices

1. The following more detailed information should be contained in the appendices to the instructor's guide as appropriate:
   a. Student handouts including a description of the training program, training program schedule, standing orders, ownship handling characteristics, description of the bridge configuration, and the debriefing questionnaire to be administered upon completion of the training program
   b. Any written tests and homework assignments
   c. Appropriate description of test and training scenarios
   d. Lis of reference texts used or case studies employed

The following levels represent types of instructor guides that may be used in various training programs.

Level I: No Documented Instructor's Guide. Each instructor teaches the course using his own structure, strategy, and materials. Little detailed coordination or consistency in what is taught exists between instructors.

Level II: Undocumented Instructor's Guide. No documented guide exists, however all elements of training are periodically discussed and agreed upon by all instructors teaching the course. This is apparent from observed similarity among instructors' materials, manners, and methods.

Level III: Documented Instructor's Guide. A written document is supplied to all instructors teaching the course. It details the overall plan of training, the topics to be covered, the training techniques to be employed and the support materials to be used.

3.3.6 CLASSROOM SUPPORT MATERIAL

The types of material/media available for the instructor to utilize during the classroom sessions is another key element of an effective simulator-based training program. Several types of material/media that have been successfully employed in the past and should be considered for use at various points throughout the training program include:

- Traditional classroom chalkboard
- Appropriate scale charts of the geographic gaming area
- Overhead projector transparencies
- Sound-slide presentations (i.e., an audio cassette type synchronized with a series of 35mm slides)
- Computer-generated graphic feedback displays*
- Remote monitoring of pilothouse personnel and key navigation parameters*
- Videotape monitoring of pilothouse personnel and key navigation parameters*

The selection of proper classroom support material/media should take into consideration a number of factors including (1) the subject matter content of each training objective, (2) the skill levels of the students prior to training, and (3) the strengths and weaknesses of the instructional staff. As with the selection of training techniques, no single type of classroom material/media will suffice when conducting a simulator-based training program. A repertoire of different materials should be available for the instructor to assist in adapting for individual instructor and trainee differences.

Classroom support material can range from traditional materials to advanced technological materials.

Level I: Basic Support Material. The instructor relys heavily on the use of the chalkboard and predeveloped handout materials to illustrate the concepts of the subject matter being taught.

*Note: See discussion of "Training Assistance Technology" under Simulator Characteristics.

Level II: Support Media. The instructor uses media such as the overhead projector and sound slide presentations in addition to the chalkboard and predeveloped handout materials to illustrate the concepts being taught.

Level III: Advanced Support Media. The instructor uses state of the art media such as computer-generated graphics, remote monitoring, and videotaping as classroom support material in addition to the traditional support media/materials.

3.3.7 SIMULATOR/CLASSROOM MIX

The proper combination of simulator and classroom time is important for effective simulator-based training. There appears to be a tendency among many senior mariners to want to spend the entire training program conducting exercises on the simulator. Such an approach may result in the trainees gaining "experience" by primarily a trial and error basis. This, however, usually is not the most effective or most economical means of developing the desired ship-handling/navigation skills. Adequate classroom time (i.e., prebriefing and postbriefing) should be included in the training program in order to:

- Provide the trainees with the necessary background knowledge required to adequately complete the simulator exercise (prebriefing).

- Provide appropriate guidance to the trainees regarding the correct action to be performed in a specific situation. For example, the instructor might discuss the effect of alternative rudder magnitudes and initiation points for navigating ownship through a 30 degree turn in a buoyed channel, and also make an appropriate recommendation prior to the simulator exercise (prebriefing).

- Provide the opportunity for seminar-type discussion in order to increase student involvement and draw on the experience of the trainees themselves.

- Evaluate and critique trainee performance on the simulator exercises in a thorough and professional manner.

Sometimes logistical and economical considerations significantly reduce the amount of simulator time available for training (See Training Program Duration). Each trainee, however, should have an adequate simulator familiarization period in order to eliminate any confusion with bridge hardware that may hinder the learning process. This familiarization period should also be sufficient to develop an appreciation/acceptance for the simulator's capability as a device for training the identified skills. Each trainee should have the opportunity to have hands-on experience at least once (preferably more) for each major topic area addressed. For example, when training students to handle a VLCC under Rules of the Road situations each student should handle the vessel in a crossing situation, although the geometry, complexity, and status of ownship (i.e., give-way/stand-on) may vary between students. In fact, these parameters should vary in order to ensure the development of generalizable skills with a high probability of transfer to at-sea situations.

Experience has indicated that in the absence of other guidance a 50/50 mixture of simulator/classroom time is an effective mix for training a majority of the skills normally considered for simulator-based training at the senior mariner level.

Several mixtures of classroom/simulator time are feasible. Various levels include the following.

Level I: Predominant Simulator Time. The simulator sessions encompass the majority of the training program (i.e., 85 to 100 percent). Prebriefing is generally not provided. Limited postbriefing feedback is given to the student, possibly on the simulator while resetting scenarios. The instructor may provide appropriate guidance and critique during the actual exercise. This level may be appropriate for training programs, or portions of training programs, involved in the development of skills such as compensating for bank effects that may require substantial repetition/practice by the individual deck officer.

Level II: Simulator/Postbriefing Mix. Simulator and postbriefing sessions are utilized. The postbriefing session is conducted not on the simulator but in an appropriate classroom. The ratios between simulator and classroom time may vary. However, the postbriefing classroom time should account for at least 15 percent of the total training time available. This level of simulator/classroom mix may be appropriate in an advanced training program, or during the latter stages of a training program, when it may be desirable to minimize/eliminate the preexercise guidance.

Level III: Prebriefing/Simulator/Postbriefing Mix. Prebriefing, simulator, and postbriefing sessions are provided in the training program. Both the prebriefing and postbriefing sessions are conducted in the classroom and when combined should account for at least 25 percent of the total training time available. This is the level of simulator/classroom mix that is recommended for the majority of senior mariner training.

3.3.8 TRAINING PROGRAM DURATION

When determining the appropriate length of a simulator-based training program, a number of issues should be considered. First of all, program duration may differ based on the nature of the skills to be trained, with the more complex skills and situations requiring task integration which needs a longer program to ensure mastery of both the basic and integration skills. Second, the program duration may vary based on the input characteristics of the trainees. If the proficiency of the entering student's prerequisite skills is lower than anticipated, additional training would be required, and hence a longer training program. Conversely, if the proficiency of the entering student is higher than anticipated, then a shorter training program would be sufficient. Third, economics may impose a restraint on the training program duration. Due to the relatively high cost of simulator time and limited resources available for training, it usually becomes imperative that only intensive, cost effective training programs be offered. Finally, the length of the program may also be constrained by the amount of time that prospective trainees have available for such training. Based on all the above considerations, training program durations from 1 day (8 hours) to 1 week (40 hours) may be appropriate. Additional information on three different program durations is provided below:

Level I: One Day (8 Hours). A simulator-based training program of this duration may be appropriate as a refresher course for training objectives involving basic skills or limited subject material (i.e., vessel-to-vessel communication procedures, restricted waters position fixing techniques). Caution should be exercised, however, when utilizing such a short course due to the following reasons: (1) if bad habits have already been engrained in the entering students (i.e., neglecting maneuvering and warning signals), sufficient training time may not be available to overcome such undesirable characteristics, (2) sufficient training time may not be available to ensure generalizable skills which are readily transferable to at-sea situations, and (3) sufficient training time may not be available to ensure high retention of skills particularly under stressful situations.

Level II: Three Day (24 Hours). A simulator-based training program of this duration may be appropriate as a refresher course for training objectives involving broader subject material or new skills, e.g., restricted waters navigation.

Level III: One Week (40 Hours). A simulator-based training program of this duration may be appropriate for training new skills and skills involving the integration of other more basic skills. At the senior mariner level, a training program of at least this duration would probably be desirable for training Navigation Management, which is both a new concept for U.S. Merchant Marine personnel and an integration skill. A training program of this duration may also be desirable for the more advanced shiphandling skills, such as compensating for bank effects, passing ship effects, etc.

Level IV: Two Weeks (80 Hours) or More. A simulator-based training program of this duration may be appropriate for the training of navigation management skills. Navigation management as a training area is a new concept for U.S. Merchant Marine personnel. A training program in this skill area would thus provide for the training of new skills and the integration of other skills.

Presently a two week training program is being recommended for navigation management only. However, it should be kept in mind that as the need develops to train senior mariners in others areas involving the integration of complex skills, or if several skill categories are addressed simultaneously in the same training program, a two week training program would be appropriate.

3.3.9 CLASS SIZE

The number of students in a simulator-based training program class is another important training program characteristic. Several factors should be taken into consideration. The principal factor is that all trainees should have adequate simulator hands-on training to acquire the desired skills, transfer them, and retain them within the operational environment (See Stress and Overlearning). Since only a finite amount of simulator time is available within the training program, the maximum class size is, therefore, usually established. The input characteristics of the trainees, the qualifications of the instructor, the availability of training assistance technology also can impact class size. Additional information on three different levels of class size is outlined below.

Level I: Three or Less Students. Classes of this size are recommended for the development of skills that require considerable individualized instruction and a relatively high number of individual simulator "hands-on" opportunities. An example of a training area, in which classes of 3 or less students would be appropriate, would be in the advanced shiphandling area for the development of skill in compensating for bank effect, passing ship effect, use of tugs, etc.

Level II: Six or Less Students. This class size is recommended for the majority of training objectives identified at the senior mariner level. It is small enough for an appropriate amount of individualized instruction and an adequate amount of simulator "hands-on" opportunities. For many of the training objectives, such as Navigation Management and Restricted Waters Navigation, it may be appropriate to divide the class for the simulator exercises into bridge teams consisting of two or three members each.

Level III: Greater Than Six Students. Class of this size may be effective in allowing the instructor or several students to demonstrate proper shiphandling/navigation techniques. Additional benefits may be gained through the use of the proper training assistance technology to observe and analyze performance (See Training Assistance Technology). However, generally speaking, class size of greater than 6 students is not recommended at the senior mariner level due to the substantial reduction in the amount of individual simulator "hands-on" training available. Students at this level generally have adequate knowledge. It is with regard to the skill in applying that knowledge where the training benefit lies. Typically, class sizes on the simulator should not exceed 10 under most circumstances; likewise, classroom class sizes should not exceed 25 students.

3.3.10 SCENARIO DESIGN

The scenarios to be utilized as training exercises within a simulator-based training program should be based on the identified training objectives. Considerable thought should be given to the design of these scenarios in order that each accomplishes its intended objective(s). Care should be exercised that too many training objectives are not attempted in any one scenario. If more than one training objective is covered during a scenario, they should be clearly prioritized as primary and secondary objectives.

Scenarios should be sufficiently long enough to allow the hands-on trainee to develop a mental awareness of the problem in the simulated environment, evaluate the situation, take his action and observe the result of his actions. Attempts to shorten scenarios by eliminating any of these elements may greatly reduce the effectiveness of the time on the simulator. Minimum time for a shiphandling/navigation scenario appears to be about 20-30 minutes.

Scenario complexity is another important consideration when designing a scenario for a simulator-based training program. It is recommended that the scenarios be designed within the training program such that the complexity level is progressively increased as the latter scenarios are presented. That is, the initial scenarios should be of low complexity, the middle scenarios should be of medium complexity, and the final scenarios should be of high complexity. This type of structure allows the trainees to initially focus on the tasks to be achieved without complicating the situation with a variety of extraneous conditions, thereby allowing the trainees to first become proficient in performing various skills. (See corresponding discussion under STRESS.)

Scenarios which are to be employed as exercises during a simulator-based training program should be thoroughly checked-out and the necessary modifications made prior to the commencement of the training. This check-out should involve several subjects with shiphandling expertise equivalent to that of the trainees expected for the program. Refinement of the scenarios after experience is gained with the training program should be encouraged in order to maximize the efficiency and effectiveness of the training.

Three levels of scenario design are discussed below.

Level I: Basic Skill Scenario. This type of scenario usually involves a single task or a single skill such as maneuvering a 30,000 DWT tanker around a 30 degree turn in a buoyed channel. These scenarios are usually relatively short in duration and allow the student to focus attention on the specific skill to be developed.

Level II: Intermediate Skill Scenario. This type of scenario usually involves multiple tasks or multiple skills, which the student may be required to perform simultaneously. For example, the student may handle a 30,000 DWT tanker around a 30 degree turn in a buoyed channel while encountering various traffic vessels. This type of scenario focuses the student's attention on the integration of skills that he has previously acquired.

Level III: Advanced Skill Scenario. This type of scenario is similar to that discussed above for Level II, except that it involves the addition of operational noise or distractions which complicate the scenario. For example, the student may handle the 30,000 DWT tanker in the 30 degree turn previously mentioned while encountering traffic vessels under restricted visibility conditions.

3.3.11 NUMBER OF SCENARIOS

The question of how many scenarios to employ within a simulator-based training program in order to allow sufficient practice on various sequences of tasks will depend upon the training objectives to be achieved. In general, for each training objective listed within the training program there should be at least two somewhat similar corresponding simulator exercises which would incorporate all the tasks required to achieve that objective. For example, if a training program had the following shiphandling training objective: "the trainee should demonstrate high proficiency in determining safe vessel speed (± 1 knot) when handling a 110,000 DWT tanker in a high traffic density, port approach scenario with visibility between 2 to 3 nautical miles" at least two scenarios should be incorporated for training this skill. Additional scenarios may be appropriate for training the same skill under different conditions (i.e., visibility 10-12 nautical miles, different levels of traffic density). In fact, sufficient scenarios with a wide variety of conditions should be employed in order to ensure that generalizable skills are being taught, which have a high probability of transfer to at-sea situations. If too few scenarios with too few conditions are utilized, a danger exists that the trainee will acquire only the specialized skill to handle a few specific scenarios, which he may never encounter at sea. In fact, with regard to restricted waters shiphandling training, if generalizable skills are desired, not only should multiple scenarios be employed but also multiple geographic and environmental data based (i.e., different ports). After sufficient scenarios are available for developing the basic skills, additional scenarios should then be incorporated into the training program for skill integration, stress, and overlearning considerations. (See discussions under corresponding Training Program Characteristics.)

Level I: Minimal Practice. Sufficient scenarios should be available for a particular training program objective such that at least one trainee completes the exercise successfully prior to advancing to the next training program objective.

Level II: Moderate Practice. Sufficient scenarios should be available for a particular training program objective such that at least two trainees complete the exercise successfully prior to advancing to the next training program objective.

Level III: Desired Practice. Sufficient scenarios should be available for a particular training program objective such that all trainees complete the exercise successfully prior to advancing to the next training program objective.

3.3.12 STRESS

This characteristic addresses the issue of stress induced by the scenario situations presented under training category. It should be noted that high stress is generally considered disruptive to training since it slows the learning process (Eysenck, 1976). Often, the instructor and his training strategy is the greatest source of stress (Krahenbuhl et al., 1980).

A positive approach by the instructor showing correct behavior is usually most effective, as opposed to a negative approach that emphasizes trainee problems. The trial and error learning approach followed by some ship bridge simulator facilities (i.e., the deck officer is placed in a difficult situation and allowed to figure the correct approach over several trials), therefore, would likely induce stress. A preferred approach is to show the correct action, or acceptable actions, prior to putting the trainee in the simulator. Stress should be minimized for those aspects of shiphandling training that deal with normal conditions. Attempts should be made to minimize stress for abnormal and emergency conditions also, to facilitate the training of skills and specific response patterns (e.g., Williamson turn). After the requisite shiphandling skills have been achieved to the criterion level of performance, stress should be introduced in training for the specific purpose of training the deck officer to satisfactorily perform under stressful conditions. Such methods of increasing stress would include increasing the traffic complexity, reducing the time available to react to the given situation, adding more noise on the radar, increasing the scenario complexity, having the deck officer perform more tasks, etc. New skills would not be trained at this time; rather, only the conditions would have been changed from low to high stress. Since the deck officer is likely to perform differently under stress, such training is desirable.

Level I: Low Stress

- Anticipated Shiphandling Tasks
- Maximum Time Allotment
- Low Scenario Complexity
- Minimum Noise/Distractions

Level II: High Stress

- Unanticipated Shiphandling Tasks
- Minimum Time Allotment
- High Scenario Complexity
- Substantial Noise/Distractions

Level III: Progressive Stress

- Initial Training Scenarios – Low Stress
- Final Training Scenarios – High Stress
- Stress Level Increased as Students Adapt

3.3.13 OVERLEARNING

Learning is the process by which the trainee acquires new skills at the level of proficiency set forth in the training objectives. Learning is said to be complete when mastery is achieved for a particular training objective. Overlearning occurs when the learning/training process is continued beyond the achievement of the performance standard by providing additional exposure to a variety of scenario situations that require the use of the newly acquired skills.

Overlearning is a desirable characteristic of the training process in that it improves the confidence of the trainee and thus results in a greater depth of skills, an assurance of skill generalizability to other situations, a greater retention of skill after training, and a higher probability of using the learned skills when necessary. Overlearning has been found to be a necessary condition to assure adequate performance during periods of emergency and stress (Fitts, 1965) and to assure that the trained and measured performance transfers to other situations and other aspects of the situation that were not measured. Hence, due to the complexity of the shiphandling problem, overlearning should often be accomplished by deck officers/trainees, particularly when the training objectives deal with performance during emergency periods and/or under stressful conditions such as those presented in (1) the Navigation Management training category regarding handling of shipboard casualties, (2) Shiphandling training category regarding compensation for restricted waters effects and wind and current effects, (3) Emergency Shiphandling training, and (4) Rules of the Road regarding potential collision situations.

Caution should be exercised that overlearning does not give the trainee a false sense of confidence, which results in his taking greater risks than necessary at-sea based on an inflated perception of his ability to handle the situation. This may be particularly dangerous if the scenario designs are too easy and do not tax the trainee's ability to perform or provide him with a proper sense of the gravity of the situation.

Two levels of this characteristic are described below.

Level I: No Overlearning. Training results in the achievement of the minimum acceptable performance standards specified for each training program objective.

Level II: Desired Overlearning. Training results in the achievement of the minimum acceptable performance standards specified for each training program objective if evaluated six months later under conditions of high stress.

3.4 INSTRUCTOR QUALIFICATIONS (CRITICAL CHARACTERISTICS)

3.4.1 MARINER CREDENTIALS

The license level and at-sea experience of the instructor is important to ensure the creditability of the training program with the students. While it is not necessary that a master-level instructor have a master's license, lack of such credentials could provide a handicap that the instructor would then have to overcome during the training program. From the other perspective, the fact that an instructor has the proper mariner credentials does not ensure that he is an effective instructor. Many other characteristics must be considered as outlined in this section.

Minimum mariner credentials for the instructor can also vary based on the material being covered within the training program. For example, an instructor with a second mate's license may be acceptable for providing senior mariners with refresher training in vessel-to-vessel communication skills. However, a pilot's license or endorsement would probably be desirable for training senior mariners in sophisticated shiphandling skills (e.g., bank effects, passing ship effects, etc.). Three levels of mariner credentials that appear appropriate for training senior mariners are listed below:

Level I: 2nd Mate/Chief Mate License (Minimum 2-5 Years At Sea). An instructor with this type of mariner credential would probably be acceptable in providing refresher training to senior mariners in skills that these individuals normally delegate to subordinates (i.e., communications, position fixing).

Level II: Master License (Minimum 5 Years At Sea). An instructor with this credential would probably be required for training skills in which most senior mariners normally consider themselves current and proficient (i.e., Navigation Management, Rules of the Road).

Level III: Pilot License/Endorsement (Minimum 2-5 Years At Sea). An instructor with this type of credential would probably be desirable when training advanced shiphandling/emergency shiphandling skills. Although a pilot's license or endorsement appears to be the best credential for this type of training, consideration should be given to the potential instructor's specific experience and the currency of this experience, since the type and amount of restricted waters shiphandling expertise may vary widely among individual pilots.

3.4.2 INSTRUCTOR CREDENTIALS

A fundamental background/experience in teaching or instructional techniques is an important characteristic for a simulator-based training instructor. The ability to organize a lesson, communicate concepts, and relate to people is as critical when training senior mariners as with other groups of comparable students. The potential instructor may have obtained his instructor credential through any of the following routes:

Level I: Educational Certificate. A graduate of a recognized institution which prepares individuals for careers as *teachers* within a given state school system. The individual's training should be concentrated preferably in the areas of secondary education or adult education.

Level II: Previous Instructor Experience. A potential simulator-based training instructor may have acquired his instructor credentials through experience in other non-simulator training programs involving students of equivalent backgrounds. This individual may or may not have appropriate educational certificates. However, it is very important that he recognize his role as an instructor and not simply the coordinator of simulator exercises.

Level III: Instructor Course. It would probably be appropriate for training facilities to provide their potential instructors with special training in the use of the simulator as an educational tool even if the individual has had previous teaching experience. The unique nature of the simulator as a training device, the high cost of simulator-based training, and the importance of the instructor in providing effective training, appear to make it prudent that the instructors be well-versed in the use of their expensive training device. It would not be necessary that such a course be tailored to the facility's specific simulator, although this would be desirable.

3.4.3 SUBJECT KNOWLEDGE

The knowledge and familiarity of the instructor with the subject material to be presented is another important characteristic. The instructor should have a high level of understanding in the particular subject area in order to effectively communicate the concepts involved and, in some cases, their subtle applications.

There appears to be a tendency in the maritime community to assume that if an individual has a master's license, he is satisfactorily versed in all areas except possibly with regard to the more sophisticated shiphandling techniques (e.g., bank effects, passing ship effects). This may very well be the case. However, when training the application of the Rules of the Road, for example, it would be advantageous to have an instructor who is a student of the Rules (or at least interested to become a student of the Rules) as compared to an individual who had passed the CG examination and as a result of a number of years of experience considers himself an expert on the subject. The experience gained during those years at sea is no doubt a valuable attribute. However, during that time, particularly if he sailed deep-sea, he may have had limited opportunities to apply the Rules, and as a result may not be as qualified as either he or the training facility would like to believe. Since it is rare to find individuals who possess such depth of knowledge in particular subject areas, it is perhaps more important to ensure that the potential instructor has the proper attitude towards seeking out a greater level of knowledge on the subjects to be taught in order to improve his base for instruction (see Instructor Attitude).

Level I: Satisfactory Knowledge

- Understands all appropriate shiphandling and navigation principles.
- Understands many advanced shiphandling and navigation principles.
- Understand the application of these principles for a variety of vessel types in a cross section of operational situations.

Level II: Exhaustive Knowledge

- Understands all appropriate shiphandling and navigation principles.
- Understands many advanced shiphandling and navigation principles.

- Understands the application of these principles for a variety of vessel types in a cross section of operational situations.

- Understands the historical development/evolution of present shipboard equipment, operational procedures, and regulations.

- Understands the impact of current regulations and technological changes on the inherent safety of the navigation process.

3.4.4 INSTRUCTOR SKILLS

The ability of the instructor to utilize the training techniques previously discussed in order to accomplish the objectives of the training program is another critical characteristic. Although a well-structured training program, as normally contained in a detailed instructor's guide, will greatly assist the instructor, he, and he alone, still has to accomplish the lesson plans. The instructor's ability to organize and conduct a pre-exercise briefing will prepare the trainees by directing their attention towards key concepts to be experienced/observed during the exercise. His ability to explain these concepts using language best understood by the students is also important. During the exercise, his ability to monitor and supervise the students in a constructive manner is critical. The proper amount of instructor interaction within, particularly the student conning the vessel, can impact student motivation during the training program. Some students tend to become discouraged if the instructor is constantly offering "suggestions." In the post-exercise feedback session, the ability of the instructor to focus on key problem areas in a constructive manner will assist in maximizing the benefits received by the student during the exercise. Well-designed computer-assisted feedback displays will assist the instructor in this area. However, he still must tailor discussion to the particular student's performance on the exercise.

The instructor should also possess the ability to identify students requiring special attention and provide same without diverting the entire class for long periods of time. In some cases, it may be more important that each trainee develop a basic understanding and necessary skills in a particular area, such as compensating for the effect of current on a particular vessel, then moving on to another area, such as passing ship effects, when only the advanced students have mastered the required skills. Care should be exercised when assigning students to classes so that they have approximately the same level of expertise (see discussion of Skills Before Training). However, since this is not always possible or effective the instructor should have the ability to compensate to a certain extent during the training program.

The instructor for senior mariners should be particularly adept at leading seminar type discussions with the students in order to draw on the experience of these trainees. This student involvement in the classroom sessions, if done properly, will not only add flavor to the training program, but also assist student motivation. A lecture presentation is much more appropriate at the cadet level when the students do not have the wealth of experience to question or appreciate many of the subtle issues involved.

Level I: Marginal

- Organizes classroom and simulator time in a manner which allows for improvement.

- Communicates concepts satisfactorily.

- Spends more time than is required in applying concepts to operational problems (e.g., too many sea stories).

- Uses basically one type of teaching method or training technique.

- Leads seminar discussions in an acceptable manner.

- Evaluates student performance in a manner which some students may consider abrasive.

- At least 80 percent of students perform satisfactorily after instruction.

Level II: Desirable

- Organizes classroom and simulator time effectively.

- Communicates concepts well.

- Applies concepts to operational problems in a professional manner.

- Uses several training techniques satisfactorily to adapt for individual differences.

- Leads seminar discussion well.

- Evaluates student performance in a positive manner which enhances *motivation*.
- At least 90 percent of students perform satisfactorily after instruction.

Level III: Outstanding

- Organizes classroom and simulator time very effectively.
- Communicates concepts extremely well, using language best understood by the trainees.
- Applies concepts to operational problems in a professional manner.
- Uses a variety of training techniques effectively to adapt for individual differences.
- Leads seminar discussions in an outstanding manner.
- Evaluates student performance in a positive manner which enhances motivation.
- One hundred percent of students perform satisfactorily after instruction.

3.4.5 INSTRUCTOR ATTITUDE

The enthusiasm of the instructor for the training program material and his conviction as to the importance of the program are generally recognized as desirable instructor attributes. Instructor enthusiasm is not only contagious, but it also is the vehicle by which discrepancies or obstacles in the training process are successfully overcome. This enthusiasm should be sincere; the result of deeply held convictions by the instructor. The instructor's attitude should also be professional in nature, treating the development of sea-going skills from the proper perspective, due to the serious business of navigating today's large and costly vessels, with their sometimes hazardous cargos.

The instructor, however, should not have an overbearing view of himself and his job. Not only could this reduce student motivation, but it could also limit student-instructor interaction as discussed below in Student Rapport.

Level I: Reserved

- Conveys subject matter with little emotion.
- Thoroughly answers but does not encourage questions.
- Neither motivates nor discourages students in attaining the proficiencies specified in the *course objectives*.

Level II: Positive

- Conveys subject matter in a positive, professional manner.
- Stimulates moderate student participation in seminar discussions.
- Motivates students to attain the proficiencies specified in the course objectives.

Level III: Enthusiastic

- Conveys subject matter in a contagious, professional manner.
- Stimulates active student participation in seminar discussions.
- Creates a sincere desire for attaining proficiencies over and above the specific course objectives.

3.4.6 STUDENT RAPPORT

The simulator-based training instructor should have the ability to develop personal relationships with the trainees which are conducive to the learning process. The students should feel free to ask *questions without fear of* ridicule. The instructor should be empathetic and constructive with his criticisms. He should provide appropriate support and encouragement during the training process. While it is not necessary that an instructor be well-liked by the students, it is important that they respect him as a professional.

Level I: Competent

- Instructor possesses the professional skills and knowledge of the material being trained within the training program.
- Thoroughly answers but does not encourage questions.

Level II: Respected

- Instructor possesses the professional skills and knowledge of the material being trained within each training program.
- Instructor viewed as an example of the proficiences to be attained as a result of the training program.
- Instructor easily approachable by students with questions concerning the concepts being taught.

Level III: Admired

- Instructor possesses professional skills and knowledge substantially beyond those being taught within the training program.

- Instructor viewed as an example of the proficiencies to be attained as a result of many years of professional experience.

- Instructor may or may not be easily approachable due to the student's awe of his professional abilities.

3.4.7 INSTRUCTOR EVALUATION

This characteristic refers to the evaluation of instructors conducted periodically by the training facility, to ensure consistently high quality of instruction. Each facility should develop and implement its own procedures regarding evaluation intervals and evaluation criteria. Two levels of instructor evaluation are discussed below.

Level I: Continuing. Instructor performance during each training program is monitored via student posttraining proficiency tests and student evaluation forms in order to ensure the maintenance of high standards at the training facility.

Level II: Diagnostic. At periodic intervals (e.g., every six months) or when the continuing evaluation indicates a problem, instructor performance should be reviewed via a more comprehensive evaluation. This evaluation should provide the instructor with constructive criticism of his proficiency for each of the applicable training categories discussed in Chapter 2.

The evaluation session should be one in which the evaluators observe at least two classroom segments and at least two simulator exercises in a particular training category.

The following items should be evaluated regarding the instructor:

- ability to organize a lesson

- ability to conduct a lesson

- ability to communicate concepts using language best understood by the students

- the instructor's level of understanding of the particular subject area

- ability to utilize various training techniques effectively

- ability to monitor and supervise the students in a constructive manner

- ability to provide constructive feedback regarding a particular student's performance on an exercise

- ability to identify students requiring special attention and providing it without diverting the entire class for long periods of time

- enthusiasm for teaching the material

- professionalism of the instructor's attitude

- ability to develop good student rapport

- improvement in student performance as a result of the training provided.

CHAPTER 4

RECOMMENDED TRAINING SYSTEM CHARACTERISTICS

The recommendation of specific characteristics for a senior mariner simulator-based training system is difficult primarily because the effectiveness of training is the result of the interaction of many complex factors. For example, as previously mentioned, a well-qualified instructor can compensate for certain deficiencies in simulator design (e.g., limited horizontal field of view). Likewise, a well-structured training program can assist a marginal instructor in organizing and implementing the course material.

Individuals involved in the design or evaluation of a simulator-based training system will have to make many judgemental trade-offs. Should capital resources be invested for a 240° horizontal field of view in lieu of a 180° field of view, or should these funds be invested in training assistance technology features? Should capital resources be invested for a night only capability in lieu of a day/night capability and the differential funds invested in built-in diagnostic features in order to improve system availability?

Although many of these decisions will be made during the initial design of a simulator-based training system, other decisions will have to be made concerning its operation. For example, should higher pay be offered to attract better instructors or should these funds be invested in service contracts to ensure high system availability? While this report does not answer these types of questions, it does provide background information to assist in the decision-making process.

Specifically, this section of the report recommends the appropriate level of the critical training system characteristics for each senior mariner desired skill category identified in Chapter 2. This is accomplished through the use of six sets of tables; one set of tables for each of the six training categories. It should be noted that each table contains both the recommended and minimum levels for these critical training system characteristics. The recommended level is the description of the specific characteristic which is identified and discussed in Chapter 3 that the authors deem most appropriate for training the particular senior mariner desired skill category. The minimum level of the characteristics is the description of the most inexpensive configuration of the particular critical training system characteristic that the authors judge to be effective for training the majority of the desired skills in a particular category. Through a comparison of the recommended and the minimum levels for each characteristic, a range of acceptability for the particular training system characteristic may be established.

It should also be noted that if a training facility meets all the minimum requirements for a particular skill category, it still may not be acceptable for training that particular category. The minimum levels of these training system characteristics are established on an item by item basis. It is assumed that other elements of the training system could realistically compensate in a properly designed training system for this minimum level of the characteristic. For example, in certain situations a black and white visual scene (i.e., minimum level) may be acceptable when color is recommended if the types of scenarios employed, the structure of the training program, and the procedures utilized by the instructor minimize the impact of this apparent simulator deficiency. The reader is reminded that the data contained in the following tables are the authors' interpretation of the guidelines set forth in Chapter 2 for each of the senior mariner desired skill categories. For more information concerning the relationship between the effectiveness of training and the particular training system characteristics, please refer to Chapter 3.

TABLE 2. SUMMARY OF RECOMMENDED TRAINING SYSTEM GUIDELINES FOR NAVIGATION MANAGEMENT

Critical Training System Characteristics	Recommended Level	Minimum Level
Simulator		
Visual Scene		
Geographic area	III: Restricted Waters	II: Coastal
Horizontal FOV	III: Greater than 240°	II: 120° to 240°
Vertical FOV	II: ±10° to ±15°	I: ±5° to ±10°
Time of day	III: Day/night	I: Night only
Color visual scene	II: Multi-color	I: Black and white
Radar Presentation	II: Low fidelity radar	II: Low fidelity radar
Bridge Configuration	II: Full bridge	II: Full bridge
Ownship Characteristics	II: Shallow water	I: Deep water
Exercise Control	III: Instructor exercise control	I: Exercise selection
Traffic Vessel Control	*III: Independently maneuverable*	I: Canned traffic
Training Assistance Technology	I: Remote monitoring	
	II: Feedback display	NONE
Availability	II: High availability	II: High availability
Training Program		
Skill Level After Training	II: Direct skill improvement	II: Direct skill improvement
Skill Level Before Training	III: Simulator diagnostic evaluation	I: No diagnostic evaluation
Training Objectives	III: Highly structured	II: Moderately structured
Training Techniques		
Knowledge of requirements	Various techniques	Various techniques
Positive guidance	Various techniques	Various techniques
Adaptive training	II: Group adaptive training	I: No adaptive training
Post problem critique	III: Complete and immediate feedback	II: Immediate feedback

TABLE 2. SUMMARY OF RECOMMENDED TRAINING SYSTEM GUIDELINES FOR NAVIGATION MANAGEMENT *(Continued)*

Critical Training System Characteristics	Recommended Level	Minimum Level
Training Program (Continued)		
Instructor's Guide	III: Documented instructor's guide	II: Undocumented instructor's guide
Classroom Support Material	III: Advanced support media	I: Basic support material
Simulator/Classroom Mix	III: Prebriefing/simulator/post-briefing mix	II: Simulator/Postbriefing mix
Training Program Duration	III: 2 Weeks (80 hours)	II: 1 Week (40 hours)
Class Size	II: 6 or less students	II: 6 or less students
Scenario Design	II: Intermediate skill scenarios	II: Intermediate skill scenarios
	III: Advanced skill scenarios	III: Advanced skill scenarios
Number of Scenarios	II: Moderate practice	I: Minimal practice
Stress	III: Progressive stress	III: Progressive stress
Overlearning	II: Desired overlearning	I: No overlearning
Instructor		
Mariner Credentials	II: Master license	II: Master license
Instructor Credentials	III: Instructor course	I: Educational certificate
Subject Knowledge	II: Exhaustive knowledge	I: Satisfactory knowledge
Instructor Skills	III: Outstanding	I: Marginal
Instructor Attitude	III: Enthusiastic	I: Reserved
Student Rapport	II: Respected	I: Competent
Instructor Evaluation	I: Continuing	I: Continuing
	II: Diagnostic	II: Diagnostic

TABLE 3. SUMMARY OF RECOMMENDED TRAINING SYSTEM GUIDELINES FOR VESSEL TO VESSEL COMMUNICATIONS

Critical Training System Characteristics	Recommended Level	Minimum Level
Simulator		
Visual Scene		
Geographic area	III: Restricted Waters	II: Coastal
Horizontal FOV	III: Greater than 240°	II: 120° to 240°
Vertical FOV	III: Greater than ±15°	II: ±10° to ±15°
Time of day	III: Day/night	I: Night only
Color visual scene	II: Multi-color	I: Black and white
Radar Presentation	II: Low fidelity radar	II: Low fidelity radar
Bridge Configuration	II: Full bridge	I: Reduced bridge
Ownship Characteristics	III: Special effects	I: Deep water
Exercise Control	III: Instructor exercise control	II: Instructor preprogrammed
Traffic Vessel Control	III: Independently maneuverable	II: Preprogrammed traffic
Training Assistance Technology	I: Remote monitoring	
	II: Feedback display	NONE
Availability	II: High availability	II: High availability
Training Program		
Skill Level After Training	II: Direct skill improvement	II: Direct skill improvement
Skill Level Before Training	III: Simulator diagnostic evaluation	I: No diagnostic evaluation
Training Objectives	III: Highly structured	II: Moderately structured
Training Techniques		
Knowledge of requirements	Various techniques	Various techniques
Positive guidance	Various techniques	Various techniques
Adaptive training	II: Group adaptive training	I: No adaptive training
Post problem critique	III: Complete and immediate feedback	II: Immediate feedback

TABLE 3. SUMMARY OF RECOMMENDED TRAINING SYSTEM GUIDELINES FOR VESSEL TO VESSEL COMMUNICATIONS (Continued)

Critical Training System Characteristics	Recommended Level	Minimum Level
Training Program (Continued)		
Instructor's Guide	III: Documented instructor's guide	II: Undocumented instructor's guide
Classroom Support Material	III: Advanced support media	I: Basic support material
Simulator/Classroom Mix	III: Prebriefing/simulator/post-briefing mix	II: Simulator/Postbriefing mix
Training Program Duration	II: 3 Days (24 hours)	I: 1 Day (8 hours)
Class Size	II: 6 or less students	III: Greater than 6 students
Scenario Design	Various levels	Various levels
Number of Scenarios	II: Moderate practice	I: Minimal practice
Stress	III: Progressive stress	III: Progressive stress
Overlearning	II: Desired overlearning	I: No overlearning
Instructor		
Mariner Credentials	II: Master license	I: 2nd Mate/chief mate license
Instructor Credentials	III: Instructor course	I: Educational certificate
Subject Knowledge	II: Exhaustive knowledge	I: Satisfactory knowledge
Instructor Skills	III: Outstanding	I: Marginal
Instructor Attitude	III: Enthusiastic	I: Reserved
Student Rapport	II: Respected	I: Competent
Instructor Evaluation	I: Continuing	I: Continuing
	II: Diagnostic	II: Diagnostic

TABLE 4. SUMMARY OF RECOMMENDED TRAINING SYSTEM GUIDELINES FOR SHIPHANDLING

Critical Training System Characteristics	Recommended Level	Minimum Level
Simulator		
Visual Scene		
Geographic area	III: Restricted Waters	II: Coastal
Horizontal FOV	III: Greater than 240°	II: 120° to 240°
Vertical FOV	III: Greater than ±15°	II: ±10° to ±15°
Time of day	III: Day/night	I: Day only
Color visual scene	II: Multi-color	I: Black and white
Radar Presentation	II: Low fidelity radar	I: Reduced bridge
Bridge Configuration	II: Full bridge	I: No radar
Ownship Characteristics	III: Special effects	I: Shallow water
Exercise Control	III: Instructor exercise control	I: Exercise selection
Traffic Vessel Control	III: Independently maneuverable	I: Canned traffic
Training Assistance Technology	II: Feedback display	NONE
Availability	II: High availability	II: High availability
Training Program		
Skill Level After Training	II: Direct skill improvement	II: Direct skill improvement
Skill Level Before Training	III: Simulator diagnostic evaluation	I: No diagnostic evaluation
Training Objectives	III: Highly structured	II: Moderately structured
Training Techniques		
Knowledge of requirements	Various techniques	Various techniques
Positive guidance	Various techniques	Various techniques
Adaptive training	II: Group adaptive training	I: No adaptive training
Post problem critique	III: Complete and immediate feedback	II: Immediate feedback

TABLE 4. SUMMARY OF RECOMMENDED TRAINING SYSTEM GUIDELINES FOR SHIPHANDLING (Continued)

Critical Training System Characteristics	Recommended Level	Minimum Level
Training Program (Continued)		
Instructor's Guide	III: Documented instructor's guide	II: Undocumented instructor's guide
Classroom Support Material	III: Advanced support media	I: Basic support material
Simulator/Classroom Mix	III: Prebriefing/simulator/post-briefing mix	II: Simulator/Postbriefing mix
Training Program Duration	II: 3 Days (24 hours)	II: 3 Days (24 hours)
Class Size	I: 3 or less students	II: 6 or less students
Scenario Design	Various levels	Various levels
Number of Scenarios	III: Desired practice	II: Moderate practice
Stress	III: Progressive stress	III: Progressive stress
Overlearning	II: Desired overlearning	I: No overlearning
Instructor		
Mariner Credentials	III: Pilot license/endorsement	II: Master license
Instructor Credentials	III: Instructor course	I: Educational certificate
Subject Knowledge	II: Exhaustive knowledge	I: Satisfactory knowledge
Instructor Skills	III: Outstanding	I: Marginal
Instructor Attitude	III: Enthusiastic	I: Reserved
Student Rapport	II: Respected	I: Competent
Instructor Evaluation	I: Continuing	I: Continuing
	II: Diagnostic	II: Diagnostic

TABLE 5. SUMMARY OF RECOMMENDED TRAINING SYSTEM GUIDELINES FOR EMERGENCY SHIPHANDLING

Critical Training System Characteristics	Recommended Level	Minimum Level
Simulator		
Visual Scene		
Geographic area	III: Restricted Waters	II: Coastal
Horizontal FOV	III: Greater than 240°	II: 120° to 240°
Vertical FOV	III: Greater than ±15°	II: ±10° to ±15°
Time of day	III: Day/night	I: Day only
Color visual scene	II: Multi-color	I: Black and white
Radar Presentation	II: Low fidelity radar	I: No radar
Bridge Configuration	II: Full bridge	I: Reduced bridge
Ownship Characteristics	III: Special effects	I: Shallow water
Exercise Control	III: Instructor exercise control	I: Exercise selection
Traffic Vessel Control	III: Independently maneuverable	I: Canned traffic
Training Assistance Technology	II: Feedback display	NONE
Availability	II: High availability	II: High availability
Training Program		
Skill Level After Training	II: Direct skill improvement	II: Direct skill improvement
Skill Level Before Training	III: Simulator diagnostic evaluation	I: No diagnostic evaluation
Training Objectives	III: Highly structured	II: Moderately structured
Training Techniques		
Knowledge of requirements	Various techniques	Various techniques
Positive guidance	Various techniques	Various techniques
Adaptive training	II: Group adaptive training	I: No adaptive training
Post problem critique	III: Complete and immediate feedback	II: Immediate feedback

TABLE 5. SUMMARY OF RECOMMENDED TRAINING SYSTEM GUIDELINES FOR EMERGENCY SHIPHANDLING (Continued)

Critical Training System Characteristics	Recommended Level	Minimum Level
Training Program (Continued)		
Instructor's Guide	III: Documented instructor's guide	II: Undocumented instructor's guide
Classroom Support Material	III: Advanced support media	I: Basic support material
Simulator/Classroom Mix	III: Prebriefing/simulator/post-briefing mix	II: Simulator/Postbriefing mix
Training Program Duration	II: 1 Week (24 hours)	II: 3 Days (24 hours)
Class Size	I: 3 or less students	II: 6 or less students
Scenario Design	Various levels	Various levels
Number of Scenarios	III: Desired practice	II: Moderate practice
Stress	III: Progressive stress	III: Progressive stress
Overlearning	II: Desired overlearning	I: No overlearning
Instructor		
Mariner Credentials	III: Pilot license/endorsement	II: Master license
Instructor Credentials	III: Instructor course	I: Educational certificate
Subject Knowledge	II: Exhaustive knowledge	I: Satisfactory knowledge
Instructor Skills	III: Outstanding	I: Marginal
Instructor Attitude	III: Enthusiastic	I: Reserved
Student Rapport	II: Respected	I: Competent
Instructor Evaluation	I: Continuing	I: Continuing
	II: Diagnostic	II: Diagnostic

TABLE 6. SUMMARY OF RECOMMENDED TRAINING SYSTEM GUIDELINES FOR RULES OF THE ROAD

Critical Training System Characteristics	Recommended Level	Minimum Level
Simulator		
Visual Scene		
Geographic area	III: Restricted Waters	I: *Open sea*
Horizontal FOV	III: Greater than 240°	II: 120° to 240°
Vertical FOV	III: ±10° to ±15°	I: ±5° to ±10°
Time of day	III: Day/night	I: Night only
Color visual scene	II: Multi-color	I: Black and white
Radar Presentation	II: Low fidelity radar	II: Low fidelity radar
Bridge Configuration	II: Full bridge	I: Reduced bridge
Ownship Characteristics	III: Special effects	I: Deep water
Exercise Control	III: Instructor exercise control	II: Instructor preprogrammed
Traffic Vessel Control	III: Independently maneuverable	II: Preprogrammed traffic
Training Assistance Technology	I: Remote monitoring	
	II: Feedback displays	NONE
Availability	II: High availability	II: High availability
Training Program		
Skill Level After Training	II: Direct skill improvement	II: Direct skill improvement
Skill Level Before Training	III: Simulator diagnostic evaluation	I: No diagnostic evaluation
Training Objectives	III: Highly structured	II: Moderately structured
Training Techniques		
Knowledge of requirements	Various techniques	Various techniques
Positive guidance	Various techniques	Various techniques
Adaptive training	II: Group adaptive training	I: No adaptive training
Post problem critique	III: Complete and immediate feedback	II: Immediate feedback

TABLE 6. SUMMARY OF RECOMMENDED TRAINING SYSTEM GUIDELINES FOR RULES OF THE ROAD (Continued)

Critical Training System Characteristics	Recommended Level	Minimum Level
Training Program (Continued)		
Instructor's Guide	III: Documented instructor's guide	II: Undocumented instructor's guide
Classroom Support Material	III: Advanced support media	I: Basic support material
Simulator/Classroom Mix	III: Prebriefing/simulator/post-briefing mix	II: Simulator/Postbriefing mix
Training Program Duration	III: 3 Days (24 hours)	II: 1 Day (8 hours)
Class Size	II: 6 or less students	II: Greater than 6 students
Scenario Design	Various levels	Various levels
Number of Scenarios	II: Moderate practice	I: Minimal practice
Stress	III: Progressive stress	III: Progressive stress
Overlearning	II: Desired overlearning	I: No overlearning
Instructor		
Mariner Credentials	II: Master's license	II: Master license
Instructor Credentials	III: Instructor course	I: Educational certificate
Subject Knowledge	II: Exhaustive knowledge	I: Satisfactory knowledge
Instructor Skills	III: Outstanding	I: Marginal
Instructor Attitude	III: Enthusiastic	I: Reserved
Student Rapport	II: Respected	I: Competent
Instructor Evaluation	I: Continuing	I: Continuing
	II: Diagnostic	II: Diagnostic

TABLE 7. SUMMARY OF RECOMMENDED TRAINING SYSTEM GUIDELINES FOR RESTRICTED WATERS NAVIGATION (PILOTING)

Critical Training System Characteristics	Recommended Level	Minimum Level
Simulator		
Visual Scene		
Geographic area	III: Restricted Waters	II: Coastal
Horizontal FOV	III: Greater than 240°	II: 120° to 240°
Vertical FOV	III: ±10° to ±15°	I: ±5° to ±10°
Time of day	III: Day/night	I: Night only
Color visual scene	II: Multi-color	I: Black and white
Radar Presentation	II: Low fidelity radar	II: Low fidelity radar
Bridge Configuration	II: Full bridge	I: Reduced bridge
Ownship Characteristics	II: Shallow water effects	I: Deep water
Exercise Control	III: Instructor exercise control	I: Exercise selection
Traffic Vessel Control	II: Preprogrammed traffic	I: Canned traffic
Training Assistance Technology	I: Remote monitoring	
	II: Feedback displays	NONE
Availability	II: High availability	II: High availability
Training Program		
Skill Level After Training	II: Direct skill improvement	II: Direct skill improvement
Skill Level Before Training	III: Simulator diagnostic evaluation	I: No diagnostic evaluation
Training Objectives	III: Highly structured	II: Moderately structured
Training Techniques		
Knowledge of requirements	Various techniques	Various techniques
Positive guidance	Various techniques	Various techniques
Adaptive training	II: Group adaptive training	I: No adaptive training
Post problem critique	III: Complete and immediate feedback	II: Immediate feedback

TABLE 7. SUMMARY OF RECOMMENDED TRAINING SYSTEM GUIDELINES FOR RESTRICTED WATERS NAVIGATION (PILOTING) (Continued)

Critical Training System Characteristics	Recommended Level	Minimum Level
Training Program (Continued)		
Instructor's Guide	III: Documented instructor's guide	II: Undocumented instructor's guide
Classroom Support Material	III: Advanced support media	I: Basic support material
Simulator/Classroom Mix	III: Prebriefing/simulator/post-briefing mix	II: Simulator/Postbriefing mix
Training Program Duration	II: 1 Week (40 hours)	I: 3 Days (24 hours)
Class Size	II: 6 or less students	II: Greater than 6 students
Scenario Design	Various levels	Various levels
Number of Scenarios	II: Moderate practice	I: Minimal practice
Stress	III: Progressive stress	III: Progressive stress
Overlearning	II: Desired overlearning	I: No overlearning
Instructor		
Mariner Credentials	II: Master's license	I: 2nd Mate/chief mate license
Instructor Credentials	III: Instructor course	I: Educational certificate
Subject Knowledge	II: Exhaustive knowledge	I: Satisfactory knowledge
Instructor Skills	III: Outstanding	I: Marginal
Instructor Attitude	III: Enthusiastic	I: Reserved
Student Rapport	II: Respected	I: Competent
Instructor Evaluation	I: Continuing	I: Continuing
	II: Diagnostic	II: Diagnostic

CHAPTER 5

EVALUATION OF TRAINING SYSTEM EFFECTIVENESS

5.1 PERFORMANCE TESTING

Evaluation of the critical design characteristics of a simulator-based training system in accordance with the guidelines provided in Chapter 3 and Chapter 4, is one technique available today to assess the effectiveness of simulator training. It assumes that if the simulator-based training system is properly designed and the training properly conducted, the training will be effective. A second technique available today is to evaluate the performance of trainees upon completion of the training program. This technique ignores the design of the training system and focuses on the bottom-line results, the proficiency of the trainees after training. It would conceivably involve a sample of graduates from a specific training facility handling a simulated vessel within an appropriately-designed test scenario. The proficiency levels identified for the sample of graduates would then be inferred through statistical techniques to represent the proficiency levels of the majority of graduates from the training facility for that specific training program.

Ideally, such performance testing of simulator-based training graduates should be conducted at sea. However, due to the costs associated with such testing in the at-sea environment, it is recommended that the U.S. Coast Guard or any potential customer interested in evaluating the effectiveness of simulator training consider testing a sample of graduates on a simulator other than the device employed for training. This second simulator should have high fidelity with the at-sea environment for the particular training objectives which have been selected for evaluation. Utilization of a second simulator would provide greater assurance that the skills acquired during training and evaluated during the test scenario are transferable to the at-sea environment and not specific to the training simulator.

Use of both the design guidelines and performance testing criteria for evaluating simulator-based training would ensure greater validity and reliability of the evaluation. However, it would also be a more costly undertaking than employing either of the criteria separately. The necessity for employing both criteria should be carefully considered in light of this additional cost.

5.2 TEST SCENARIOS

The scenarios employed for establishing the proficiency levels of the graduates of a particular training facility should be carefully designed based on the more important training objectives within the training program. The training objectives contained in paragraph 2.5 may be employed for this purpose in the absence of training objectives from a specific training program. The guidance contained in paragraph 3.3.10 should be considered when developing the test scenario itself. It may be desirable to organize the test scenario into several discrete segments. Each segment would address the evaluation of trainee proficiency on a limited number of training objectives. For master-level training, such test scenario segments may be developed based on several critical points during a vessel's transit within an actual or hypothetical port. The type of scenario, its complexity, and the performance measures employed should discriminate between acceptable and unacceptable shiphandling/navigation performance. Williams et al. (1982) have conducted research on the CAORF simulator regarding the development of one such test scenario.

If a second simulator other than the training simulator is employed as recommended in paragraph 5.1, it is important that the trainees be provided adequate familiarization with the simulator prior to being administered the test scenario. In addition, it is also prudent that the trainees not be allowed to observe other test scenarios prior to their test scenario. If formal scientifically-based procedures are desired for handling trainees in order to ensure the objectivity of the results, it is recommended that CAORF be contacted since its personnel have extensive experience in handling test subjects for simulator-based research.

5.3 PERFORMANCE MEASURES

Evaluation of shiphandling performance is not an easy task. The "bottom-line" performance measures, such as collisions or groundings, are usually not discriminatory, since they are rare events at sea. Any scenario which indicates several such events in the small sample sizes envisioned (see paragraph 5.4) would be extremely difficult, allowing the shiphandler such a small margin for error that the scenario may not be acceptable to the operational community as an appropriate test for the evaluation of shiphandling proficiency. Other available performance measures must then be utilized to evaluate performance and provide an indication of the inherent safety of the navigation process. Other performance measures that have been successfully employed at CAORF to evaluate master-level shiphandling include but are not limited to the following performance measures:

- CPA to other ships
- CPA to charted objects (e.g., shoals, piers)
- Recognition of buoy off station
- Mean deviation from centerline
- Maximum deviation from centerline
- Mean deviation from average trackline
- Maximum deviation from average trackline
- Maximum swept path
- Time/distance to reduce speed
- Number of course/rudder orders
- Magnitude of course/rudder orders
- Number of engine orders
- Magnitude of engine orders
- Range of maneuver
- Direction of course change
- Magnitude of course change
- Use of VHF communications
- Use of whistle signals
- Number of visual bearings

It is recommended that shiphandling performance in the test scenarios be evaluated based on the analysis and interpretation of multiple performance measures. This allows the assessment of the trainee's shiphandling proficiency to be made from several perspectives. Although this can complicate the analysis, when the performance measures point to conflicting interpretations, it usually provides a reliable assessment of the trainee's shiphandling proficiency.

5.4 PERFORMANCE STANDARDS

Once trainee performance is measured by means of techniques such as outlined in paragraph 5.3, it still must be evaluated to establish whether or not the proficiency levels exhibited by the trainees from a particular training program are acceptable. This evaluation may involve the comparison of pre-training performance with post-training performance in order to establish that beneficial training has occurred. More appropriately, it may involve comparison of post-training performance against an established standard. Overall trainee performance above this established standard could be conceivably desirable for accreditation of a particular simulator-based training program. Williams et al. (1982) employed pilots, operating without local knowledge in geographic areas other than their own, to establish the performance standards for the master-level shiphandling skills in a prototype test scenario.

The comparison of trainee performance, whether it be pre-training to post-training or post-training to established standard, should employ recognized statistical techniques in order to establish significant differences in trainee performance. Such statistical techniques include but are not limited to: analysis of variance (ANOVA), "t"-test, Mann-Whitney U test, Chi Square test, etc.

5.5 SAMPLE SIZE

As many graduates as possible from a particular training program should be evaluated to establish the proficiency levels to be associated with that program at the training facility in question. Logistics and economics will limit the number of trainees evaluated, particularly if a second simulator is employed as recommended in paragraph 5.1. However, it is recommended that at least 12 graduates be utilized to establish the proficiency levels associated with any training program. Although smaller sample sizes may produce valid results, experience and prudent practice would appear to indicate that at least 12 graduates be evaluated in order to ensure reasonably reliable results. If several training programs at a particular facility are being evaluated, it is recommended that at least 12 graduates be employed for each training program. These graduates should not all be selected from the same offering of the training program but selected randomly from different offerings over the accreditation/evaluation period.

5.6 TESTING INTERVAL

Whenever a training system is evaluated, it should be periodically reviewed to ensure that the desired standards are being maintained. The frequency of this reevaluation should be based on anticipated changes in the critical training system characteristics identified and discussed in Chapter 3, particularly turnover in the instructional staff.

In addition, the Coast Guard or potential simulator-based training facility operator/user should frequently monitor several critical design characteristics to determine if a more comprehensive evaluation is warranted.

Since the accreditation/evaluation process, whether design criteria or performance test criteria, can be an expensive proposition, if thoroughly conducted, the interval between evaluations should be maximized. It should be noted that the performance test criteria could have the advantage of distributing this cost by scheduling the testing of facility graduates over the accreditation/evaluation period. This may make the cost of such accreditation/evaluation more palatable to the parties concerned.

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