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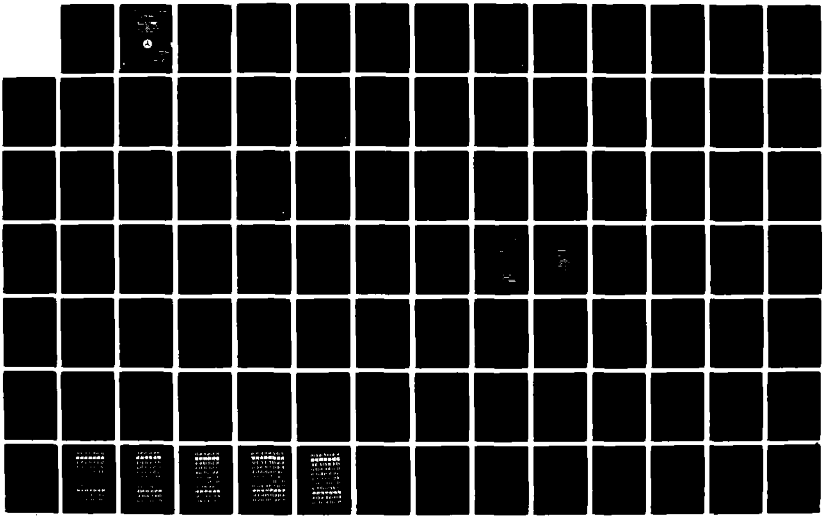

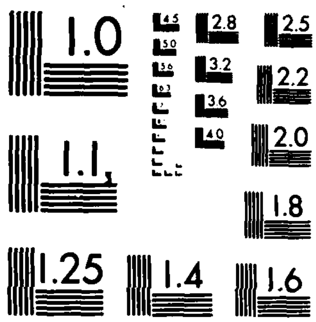

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TECHNICAL REPORT
SIMULATION EXPERIMENT

AD A128691

SIMULATORS FOR MARINER TRAINING AND LICENSING: FUNCTIONAL SPECIFICATIONS AND TRAINING PROGRAM GUIDELINES FOR A MARITIME CADET SIMULATOR

PREPARED FOR

U. S. DEPARTMENT OF TRANSPORTATION

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

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Project Managers: Dr. John Gardenier, USCG; Joseph Puglisi, CAORF; and Joseph Walsh, MarAd

Project Monitors: Arthur Friedberg, MarAd; CDR William R. Arnet, Jr., USCG

16. Abstracts

This report contains a functional specification for a ship's bridge/shiphandling simulator to be used in the training of maritime academy cadets in selected watchstanding skills. Also contained is cost information regarding the acquisition and operation of such a simulator. Training program guidelines are provided to assist the maritime academies in the implementation of a ship's bridge/shiphandling simulator within the existing academy curriculum.

17. Key Words and Document Analysis. 17a. Descriptors

Simulators
Ship's Bridge/Shiphandling Simulator
Maritime Cadet Simulator-based Training Systems
Maritime Cadet Training Objectives
Simulator Training Program Guidelines

17b Identifiers/Open-Ended Items

17c. COSATI Field/Group

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INTRODUCTION

BACKGROUND

In the United States as we enter the 1980s, there are three dominant factors that are affecting the traditional approaches by which we prepare our maritime cadets for their sea-going careers in the U.S. Merchant Marine. These factors are:

- The already high costs associated with at-sea training have been escalating rapidly, particularly the at-sea training conducted aboard dedicated training ships.
- The Intergovernmental Maritime Consultative Organization (IMCO) Standards of Training, Certification, and Watchkeeping Convention, Regulation II/4, recommends 12 months at-sea experience as a prerequisite for a third mate's license. This guideline has resulted in an atmosphere of self scrutiny here in the U.S. since the majority of cadets currently receive 6 to 10 months of at-sea training.
- Recent advances in simulator technology appear to make the shiphandling/ship bridge simulator a viable means for training many third mate skills. Past experiences with radar simulator training have provided an indication of the potential benefits associated with simulators for mariner training.

The IMCO Convention which recommends 12 months at-sea time for cadets does not intend to hold back the development of more effective training programs by member nations. An amount of at-sea time is easily specified and monitored, and presumably assumes some minimal amount of skill and knowledge acquisition and resultant proficiency. Specification of an amount of at-sea time eliminates the need to adequately define training objectives. In the absence of well-defined training objectives this may be the best alternative, although it certainly does not assure that the cadets in fact achieve the necessary skills and knowledge. A far more effective approach would be to identify the specific skills and knowledge to be achieved via maritime cadet training in the form of training objectives. The various maritime academies could then construct their individual training programs to attain or surpass the individual training objectives by the most cost-effective media such as classroom, small vessel, at-sea, and simulator training. The mix of these media would likely differ for each academy, but would nonetheless successfully achieve the identified training objectives and hence meet or surpass the minimum standards. One perspective of this report is that it assists in the development of a greater insight into the proper utilization of the shiphandling/ship bridge simulator within the multiple media approach to cadet training that is presently employed at U.S. maritime academies today.

REPORT OBJECTIVES

During the past several years the Computer Aided Operations Research Facility (CAORF) has been involved in the Training and Licensing Project which is jointly funded by the U.S. Coast Guard and Maritime Administration. The overall purpose of the project is the determination of the proper role of simulators in the mariner training and licensing process. As part of this research effort several experimental training programs for maritime cadets were developed and conducted on the CAORF simulator. This report describes the utilization of the information obtained during these prototype training programs as a basis for the definition of the role of the shiphandling/ship bridge simulator at the cadet level within the maritime academy curriculum. The specific objectives were:

- Development of a functional specification for a maritime academy shiphandling/ship bridge simulator.
- Development of training program guidelines which define the most advantageous manner for the integration of this type of training into the maritime academy curriculum.

The accomplishment of these objectives involved the application of guidelines defined in a previous report of this project. "Guidelines for Deck Officer Training Systems" presented information on the three major elements of the training system – simulator design, the training program structure and instructor qualifications. This information was provided to assist persons interested in shiphandling/ship bridge simulator training to evaluate available simulator training courses. The effort detailed in this report represents the implementation of those guidelines.

APPROACH

The approach taken to achieve these objectives was consistent with the overall approach and findings throughout the Training and Licensing Project, which indicate that the design and utilization of a training simulator should be based on the specific skills to be achieved via the device. As a result, the identification and analysis of maritime cadet training objectives were critical aspects of this research effort. The specific approach taken involved the following sequential steps:

1. **Identification of Maritime Cadet Training Objectives.** Based on third mate watchstanding tasks along with the skill and knowledge requirements for proficiently performing these tasks, a listing of specific maritime cadet training objectives were identified.

2. **Analysis of Maritime Cadet Training Objectives.** The identified cadet training objectives were then allocated to various training media available for maritime cadet training (i.e., classroom, small vessel, at-sea, or simulator). Those training objectives which were identified as being achieved best via simulator were designated as the goals of the simulator-based training system design process.

3. **Establishment of Simulator Functional Requirements.** "Guidelines for Deck Officer Training Systems" identified the critical characteristics of a simulator for mariner training and documented appropriate design guidelines. Utilizing this information, the functional requirements for a maritime cadet simulator were developed to meet the identified training objectives.

4. **Development of Training Program Guidelines.** Once the functional requirements for the cadet simulator were established, guidelines for the integration of this type of training into the academy curriculum, the structure of the training program itself, and the qualifications for the instructor were developed.

FINDINGS AND PRODUCTS

TRAINING OBJECTIVE ANALYSIS

- Based on analysis of third mate **watchstanding tasks only**, 113 cadet training objectives were identified and are contained in Appendix A, Table A-2. These training objectives were grouped into eleven (11) categories:

  – General
  – Relative motion
  – Rules of the Road
  – Collision avoidance
  – Shiphandling/seamanship
  – Celestial navigation
  – Piloting
  – Electronic navigation
  – External vessel communications
  – Watchstanding/bridge procedures

- Allocation of the cadet training objectives to classroom, small vessels, at-sea and simulator training media resulted in a number of pertinent observations and conclusions which relate to maritime cadet training. These are summarized below and discussed further in Section II.

- The majority of the identified cadet training objectives can be trained at-sea although this may not be the most effective training medium for many of the desired skills.

- A number of the cadet training objective, such as the observation, plotting and evaluating of celestial fixes under operational watch conditions can be effectively trained only at-sea.

- Other cadet training objectives can be trained best at-sea, although other training media may be available.

- Every cadet training objective can be trained without the shiphandling/ship bridge simulator although some advocates will argue the effectiveness of other training media for a number of training objective, such as emergency shiphandling principles, is extremely marginal.

- Simulator-based training can improve the training of a number of cadet training objectives as indicated by the substantial number of training objectives which were considered to be trained best via simulator.

- The various training media to train the identified cadet training objectives have considerable potential for reinforcement of each other since many of the training objectives can be effectively trained via multiple training media.

- Simulator-based training has the potential to improve the quality of the maritime academy training program within the United States.

- A full mission shiphandling/ship bridge simulator should be considered for training selected skills within the following categories: Collision Avoidance, Shiphandling, External Vessel Communications, Piloting, and Watchstanding/Bridge Procedures.

- Simulator training should be used to supplement not replace the traditional training media, particularly at-sea training.

CADET SIMULATOR FUNCTIONAL SPECIFICATION

Fourteen critical characteristics have been identified for the functional design of a shiphandling/ship bridge simulator. A specific level for each of these characteristics has been recommended as a minimum for meeting the needs of cadet training, on the basis of their cost and training effectiveness (i.e., ability to meet the needs of the highly critical *simulator-best training objectives*). Table 5 in Section 3.4, provides a summary listing of the critical characteristics, their recommended level and specifications. A brief explanation and rationale summary for selection of each level of these critical characteristics follows:

- **Visual scene time of day** – Night – much of the requisite cadet training could be achieved under either night or day conditions; the day/night capability is estimated to cost about 2.5 times the night only capability; the academies have a limited amount of time available, and nighttime is the more difficult condition.

- ***Visual scene geographic area*** – *Coastal* – the majority of highly crictical simulator-best training objectives for cadets do not require shiphandling skill in restricted waters; cost is substantially less for coastal.

- **Visual scene horizontal field of view** – 180 Degrees – adequate horizontal separation of geographic objects across a sufficient number of training exercises is necessary to ensure proper development and generalizability of the associated visual position-fixing skills; will cover all the critical meeting and fine crossing situations called for by training objectives; and is necessary for coastal navigation/piloting skills.

- **Visual scene vertical field of view** – 20 Degrees – several critical training objectives require a moderate vertical field of view to handle close-in traffic vessels; a large vertical field of view is unnecessary in a nighttime situation since the upper and lower bounded edges would be unnoticeable.

- **Visual scene color** – Multicolor – a night only visual scene should have multicolor; research indications are that color is desirable for high workloads; the additional cost for multicolor under nighttime conditions may not be substantial.

- **Visual scene quality** – Moderate Quality – this characteristic depends upon the interaction of many parameters, each of which could vary widely and be acceptable depending upon the level of the other interacting parameters (e.g., brightness and contrast ratio); the complexity of the visual scene, the large number of relevant parameters, and the lack of definitive research information precludes detailed specification at this time; rather, specific proposed visual scenes should be evaluated for their quality at the time of proposal evaluation; guidance principles for evaluating visual scene quality are included in the main body of the report.

- **Radar presentation** – Low Fidelity – the acceptable low fidelity radar would be a real-time updated picture generated by a general purpose computer-display system, with the display located in the wheelhouse in place of a commercially available radar unit; low fidelity radar presentation would be satisfactory for achievement of nearly all highly critical training objectives; high fidelity radar would require a nearly four-fold increment in cost; the academies have high fidelity radar simulators presently for part-task training.

- **Bridge configuration** – Full Bridge – the full bridge would consist of a normal pilot house layout with appropriate equipment and instruments; adequate bridge size is required to handle the anticipated bridge team; a reduced bridge size may result in irregular third mate behavior due to an abnormal pilothouse layout; detailed functional requirements for bridge equipment are contained in the main body of the report.

- **Ownship characteristics and dynamics** – Deep Water – deep water is sufficient for training the majority of the highly critical training objectives; the additional cost for shallow water effects does not appear warranted in view of the minimal training objectives gained; additional hydrodynamic requirements are specified in the main body of the report.

- **Exercise control** – Instructor Exercise Control – this level enables the traffic vessels and other conditions to be controlled in real-time from an instructor/operator console, rather than have all aspects of the problem always preprogrammed; substantially greater simulator flexibility at a relatively small increase in cost; necessary capability for future expansion of the simulator system. Specific requirements for this capability are provided in the main body of the report.

- **Traffic vessel control** – Independently Maneuverable Traffic – necessary for interaction between ownship and traffic vessels, particularly intership communications (e.g., radiotelephone); this would be a very minor increase in cost above the lower fidelity levels for this characteristic in several simulation technologies.

- **Training assistance technology** – Remote Monitoring – displays and readouts placed in a classroom to enable a group of students to monitor and discuss the scenario situation and activities of the bridge team while the problem is in progress; would enable the simultaneous training of multiple bridge teams; research has shown this to be a highly effective capability.

- **Training assistance technology** – Feedback Displays – a display located in the classroom presenting detailed information concerning the just completed simulator exercise; enables a variety of training/investigative activities to take place in the classroom; research has shown this to greatly increase the cost-effectiveness of training.

- **Availability** – the simulator design goal is for operational training to be conducted thirty hours per week with 95 percent availability; an additional 10 hours per week is allotted to maintenance time; vendor support of the simulator is recommended with assistance from an academy staff technician.

Considerably more rationale and descriptive information is contained in the main body of the report.

CADET SIMULATOR COST

In order to estimate cadet simulator training costs, the functional requirements developed were reviewed by a number of individuals on the CAORF staff, who were recognized as knowledgeable in this area. Based on their input the following estimates appear to be appropriate for the maritime cadet simulator described in this report.

- Initial System Procurement

Lowest possible cost = \$1.5M
Highest possible cost = \$3.5M
Most Likely cost = \$2.7M

The above figures are provided in 1982 dollars. They assume that a suitable building exists at the specific maritime academy to house the simulator facility. For additional assumptions and discussions of this procurement cost estimate, please refer to Section 3.5.

- Annual Operating/Maintenance

Lowest possible cost = \$180K
Highest possible cost = \$320K
Most Likely cost = \$220K

The above figures are provided in 1982 dollars. They assume that the single instructor required for training/system operation and the single technician required for maintenance will be obtained from the academy's staff, or the above estimates increased accordingly.

PROCUREMENT STRATEGIES

In Section 3.5 of the report a number of procurement strategies for obtaining the maritime cadet simulator are identified and discussed. These strategies include both ownership and leasing in a variety of forms. This analysis is not intended to be an indepth financial analysis of the procurement of a maritime cadet simulator training system. It is intended to provide a broad perspective of several potential alternative procurement strategies which are available today. MarAd and the various maritime academies should consider it as one of several sources of information when they establish their own specific procurement strategies, which may vary from institution to institution. From the project team's analysis, it would appear that the following recommendations are in order:

- In the present financial environment MarAd and the various state academies should seriously consider leasing a simulator training system in lieu of ownership. A leasing strategy allows the user of the training system to conserve short-term capital resources. It also allows a private individual or corporation to take advantage of ownership benefits, such as tax credits and depreciation schedules, which could be applied to reduce the total cost of the venture.

- MarAd should not be constrained in its thinking solely to the appropriation of funds through the budgetary process, but should continue to explore the utilization of other governmental assets, such as a federal mortgage insurance program discussed in this report in order to assist the maritime academies in providing simulator-based training.

- MarAd should consider investigating the "mobile simulator" concept discussed in this report as (a) a potential alternative of several permanently installed simulators and (b) a means of advancing the technological development of a cadet simulator training system that would be suitable for leasing on a more permanent basis.

TRAINING PROGRAM GUIDELINES

In order to establish a common basis for the effective integration of simulator-based training into the maritime academy curriculum, the curricula of the state academies were compared. As a result of this comparison a number of observations were made which form the basis for the training program guideline recommendations contained in this report. The following is a summary of these observations:

- Each of the state maritime academies appear to have four distinct training periods within their curricula. These training periods are:

  - From academy entry to first at-sea period
  - From first at-sea period to second at-sea period
  - From second at-sea period to third at-sea period
  - From third at-sea period to graduation

- Each academy offers a radar observer course utilizing its radar simulator training facility. This course is usually given in the junior (2nd class) year, although one academy offers the course to seniors (first class).

- Several academies have indicated concern relating to the integration of additional simulator training into the already intensive cadet schedule.

After careful consideration of the similarities identified above and with due respect for the individual state academy's ability to determine the proper means of integrating shiphandling/ship bridge simulator training into their own curriculum, the following guidelines are recommended:

- The academies should consider grouping the training objectives previously identified into four training modules which are described in Section 4.2.2:

  - Modu[illegible] 1: Basic Watchstanding
  - Modu[illegible]: Coastal Navigation
  - Modu[illegible]. Collision Avoidance
  - Modu[illegible]: Advanced Watchstanding

- Each t[illegible] module should consist of a series of simulator exercise periods, each approximately 3 hours in duration. The individual academy staff should have the option to either (a) integrate these simulator exercise periods into the existing course as laboratory periods or (b) provide all the simulator exercise periods with each training module as a new course.

- The simulator training should be related to the types of tasks that the cadet will be performing during the next at-sea period.

  - Module #1: Basic Watchstanding . . . prior to first at-sea period
  - Module #2: Coastal Navigation . . . prior to second at-sea period
  - Module #3: Collision Avoidance . . . after radar simulator course, prior to third at-sea period
  - Module #4: Advanced Watchstanding . . . prior to graduation

- A carefully structured training program should be employed for maritime cadet training. Section 4.3 provides appropriate guidance for the following critical training program characteristics as applied for cadet training:

  - Training Objectives
  - Training Techniques
  - Instructor's Guide

- Classroom Support Materials
- Simulator/Classroom Mix
- Training Program Duration
- Class Size
- Scenario Design

- The simulator-based training instructor is extremely critical for effective training. Section 4.4 lists and discusses the following critical instructor qualifications/characteristics to assist in the proper selection and preparation of instructors:

  - Mariner Credentials
  - Instructor Credentials
  - Nautical Science Knowledge
  - Instructor Skills
  - Instructor Attitude
  - Student Rapport
  - Instructor Training
  - Number of Instructors
  - Instructor Evaluation

- The maritime academies should view their experience with radar simulators as a valuable basis for the successful management of a shiphandling/ship bridge simulator facility. However, they should also realize that there are important differences between the two types of simulators, and hence the management of their facilities.

- There appear to be two types of decisions involved with any simulator training facility: initial decisions and operating day-to-day management decisions. The maritime academies should realize that many of the decisions involved in procuring and setting up the facility significantly impact the operating decision and ultimately the effectiveness of training. As a result careful consideration should be given to these initial decisions.

SECTION I

INTRODUCTION

1.1 BACKGROUND

In the United States as we enter the 1980s, three dominant factors are impacting the traditional approaches by which we prepare our maritime cadets for their seagoing careers in the U.S. Merchant Marine. First, the costs of maintaining and operating the training vessels, which provide all cadets (except those at the U.S. Merchant Marine Academy) with their at-sea training, have been escalating rapidly. This is due in part to the advanced age of many of these vessels, some of which are in need of substantial renovations, and also the dramatic increases in the cost of fuel oil for the training cruises. Although it is well recognized that at-sea training is required, this factor has raised questions concerning the specific benefits associated with this costly training, the minimum amount of sea time required to obtain these benefits, and the availability of other training means to cost-effectively augment at-sea training in achieving a qualified third mate.

The second factor impacting traditional U.S. approaches is the new Inter-Governmental Maritime Consultative Organization (IMCO) resolution which calls for high standards of deck watch officer proficiency within the fleets of its member nations. Although the resolution recognizes the jurisdiction and responsibility of the individual authorities within each nation to establish their own curriculum for meeting this objective, it recommends a minimum of 12 months at-sea experience as a prerequisite for a third mate's license. This guideline has resulted in an atmosphere of self-scrutiny here in the U.S. since the majority of cadets currently receive only six to ten months of at-sea experience aboard training vessels. The purpose of this self-scrutiny is to ensure that although the U.S. maritime cadet training program does not contain the recommended amount of at-sea experience, its content meets or exceeds the intent of the IMCO resolution through the carefully structured use of multiple training media. Training media may range from the classroom with its various instructional materials to the dedicated training ship.

Finally, the third factor impacting traditional U.S. approaches for training maritime cadets is the recent advance in simulator technology which appears to make the shiphandling/ship bridge simulator a viable means for training many third mate skills. Simulator technology has progressed to the point that it appears to be a cost effective means for the enhancement of practical training and the attainment of specific certification requirements. The principal advantages generally associated with shiphandling simulators range from a high degree of control over the training process, where ship parameters, scenarios, etc., can be easily varied to suit training needs, to the improved safety resulting from the reduced risk for both vessel and crew, particularly when training emergency shiphandling maneuvers.

The ramifications of a move towards the use of simulators in place of, or in addition to, traditional instructional methods within existing mariner training programs was of concern to both the U.S. Maritime Administration and U.S. Coast Guard. From MarAd's perspective, a simulator represents a considerable expenditure of funds and, as an innovative training technique, would require that teaching staffs be provided guidance for the effective integration of simulator training into the established curriculum. The cost for each simulator, as can be seen from Section 3, may be several million dollars. The actual cost, however, is totally dependent on the simulator design which in turn is dependent on the shiphandling skills to be trained using the simulator. Thus, an indepth analysis of the cadet/third mate skills to be developed via simulator-based training appears desirable before a simulator design is developed and the simulator procured.

Obviously, much forethought is required prior to implementation of a simulator-based training program and appropriate guidelines would be a necessity. From the Coast Guard's perspective, the utilization of a shiphandling simulator may impact the quality of instruction received at each academy and hence the principal prerequisite qualification for the third mate license examination. In addition, the utilization of a shiphandling simulator within the maritime academy curriculum emphasizes the U.S. approach to training cadet skills, the use of multiple, cost-effective training media to achieve specific well-defined training objectives, which is different than IMCO's recommendation of 12 months at-sea time.

The IMCO convention which recommends 12 months at-sea time for cadets does not intend to hold back the development of more effective training programs by member nations, and hence allows for individual nations to depart from its recommendations to achieve training programs beyond its standards of effectiveness. Training program standards should rightfully address the proficiency level of skills and knowledge to be achieved by each trainee as their end result, thus assuring a minimum level of competency. Various training program designs could be configured to successfully achieve such specified training objectives. This approach has, in fact, been recently followed by IMCO in several areas when feasibly possible (e.g., ARPA training). The difficulty in addressing cadet training standards in terms of requisite skills and knowledge was the heretofore absence of adequately defined training objectives. An amount of at-sea time is easily specified and monitored, and presumably assumes some minimal amount of skills and knowledge acquisition and resultant proficiency. Thus, specification of an amount of at-sea time eliminates the need to adequately define training objectives, and presumably results in their adequate achievement. In the absence of well-defined training objectives this may be the best alternative, although it certainly does not assure that the cadets in fact achieve the necessary skills and knowledge. A far more effective approach, if available, would be to identify the specific skills and knowledge to be achieved via training. The amount of at-sea time would thus be traded-off with other training media to configure the most cost-effective training strategy to achieve the requisite training objectives and meet the other requirements of each nation's training program. The standards should focus, therefore, not on an amount of time which may or may not be relevant, but rather should focus on precisely those skills and knowledge that are necessary.

An approach to achieving minimum training standards, allowed by IMCO and set forth by the various schools' own governing bodies, would be that of Instructional Systems Development (ISD). This approach has been developed, refined, and used by the U.S. Air Force, Navy and Army. Following this approach, the minimum training program standards would be defined in terms of training objectives to be achieved by the cadets. Each school would then construct their training program to attain or surpass the training objectives by the most cost-effective media. This would include, for example, making tradeoffs between at-sea school ship, at-sea commercial vessel, small boat handling, simulator (various types), and classroom training media. The mix of these media would likely differ for each academy, but would nonetheless successfully achieve the requisite training objectives, and hence meet or surpass the minimum standards. As noted above, this approach has been used successfully by other industries. It is suggested, furthermore, that this approach would yield more pertinent training standards, and thus ensure to a greater extent the proficiency of entry-level third mates.

The approach taken in this report does not imply that at-sea training is unnecessary. On the contrary, it is expected that at-sea training would be found as the only medium or the most cost-effective medium for achievement of many cadet training objectives. The at-sea training program for each academy, therefore, would be tailored to achieve those specific training objectives allocated for such training. The amount of at-sea time encountered by cadets would, thus, be a by-product of an effective training strategy rather than the primary consideration of training. The skills and knowledge achieved by the cadets would constitute the primary objectives of training.

If this approach is followed, a minimum amount of at-sea time would be required to 1) achieve those training objectives allocated to at-sea training and 2) to assure that each cadet has sufficient exposure to the aspects of life at sea. This latter requirement is well recognized as a major objective of cadet training. Its achievement requires some minimal amount of time at sea. Additionally, the specification of cadet training objectives will likely always have some error; hence, some minimal amount of at-sea training is necessary to presumably cover those skills and knowledge inadequately addressed otherwise.

The approach suggested herein requires that cadet training objectives be specified, and appropriate training media (including at-sea training) be selected by each academy to cost-effectively tailor their respective training programs to achieve those objectives. At-sea training should be a part of each resulting academy curriculum, but the amount and timing of such training would depend on the particular training strategy followed by each academy. It is believed that this approach is superior to simply specifying an amount of at-sea time, which does not necessarily address the real issue of cadet/third mate skills and knowledge.

Following from the above approach, media other than at-sea training (e.g., ship bridge simulator) may be more cost-effective for achieving certain training objectives. This project delineates, at a high level, cadet/third mate training objectives and evaluates several available media, including the ship bridge simulator, with regard to cost and effectiveness in achieving each training objective. Its purpose is to determine the potential role of the ship bridge simulator in training cadets, develop a functional specification for an appropriate simulator, and develop guidelines for its integration into curricula of the state and federal academies.

Thus, the U.S. Maritime Administration and the U.S. Coast Guard embarked on a joint project to investigate these developments. The Training and Licensing project was to study a wide range of questions relating to the ship's bridge simulator. Research and experimentation were conducted to investigate simulator applications at both the master and cadet level. Cadet training research was initiated in the second phase of the Training and Licensing Project with the first cadet simulator-based training program to be conducted in the U.S. The program was conducted at the Computer Aided Operations Research Facility (CAORF) and involved three groups of cadets, two from the U.S. Merchant Marine Academy at Kings Point, New York and one from the New York State Maritime Academy, Fort Schuyler, New York. The effectiveness of the training received was determined via a simulator pretest and post-test which documented first class cadet skill levels. This subject group supplied an excellent indication of third mate entry level skills since the training program was conducted in the spring of the first class year. In addition, one simulator variable and one training method variable were investigated – day-only versus night-only visual scene and distributed versus concentrated training (6-week versus 1-week training period). A second cadet experiment was conducted the following year at CAORF with horizontal field of view as the experimental variable. Two groups of six first class cadets each from the U.S. Merchant Marine Academy served as subjects. As a result of the summary of these experiments, the U.S. Merchant Marine Academy has made a simulator-based training course mandatory for all deck cadets.

Based on the foundation of these cadet level investigations, the development of a functional specification for a cadet level simulator was initiated. This report represents the culmination of the cadet level research accomplishment of Phase 3 of the Training and Licensing Project. It contains the functional specification of a maritime cadet shiphandling simulator and training program guidelines concerning its utilization.

1.2 OBJECTIVE

The goal of this effort was to conduct an analysis of simulator-based training at the cadet level to define the role of the shiphandling simulator within the maritime academy curriculum. Specifically, the objectives are (1) to develop a functional specification for a maritime academy shiphandling/ship bridge simulator, and (2) to develop training program guidelines which define the most advantageous manner for the integration of this type of training into the maritime academy curriculum. It should be noted that simulator-based training is not an unfamiliar training medium for the academies since all have radar simulators and some have cargo handling simulators. However, none of the academies have a full mission shiphandling/ship bridge simulator, nor do they have experience with the operation of this potentially powerful training device which may be many times as complex as the normal radar simulator.

1.3 APPROACH

In an earlier report of the project, "Guidelines for Deck Officer Training Systems" the critical characteristics of a simulator for training senior level deck officer skills were identified. These characteristics provided a potential base from which to initiate a design for a simulator appropriate for the training of third mate skills. However, the most cost-effective design results from tailoring the simulator's characteristics to the specific skills to be achieved via cadet training. Hence the earlier developed guidelines, as well as the broad information base developed during earlier efforts of this project, served as the departure point for the effort addressed herein.

The approach taken to accomplish these objectives was very similar to the approach utilized during Phase I of the project which evaluated the potential of simulator-based training for developing senior mariner skills (Hammell, Williams, Grasso, and Evans, 1980). First, the watchstanding tasks that a new third mate is required to perform were identified. The skills and knowledge required to perform these tasks were then delineated as the basis for developing the cadet training objectives to be achieved by the training system. These training objectives describe the goals of the training program, namely that the student upon completion of his training, will demonstrate the desired watchstanding characteristics expected of a third mate when he reports to his first vessel. The training objectives were then analyzed and allocated to either of the following training media: (1) classroom (2) small vessel (3) at sea and (4) simulator. Figure 1 is a graphic description of this process.

TASK E APPROACH

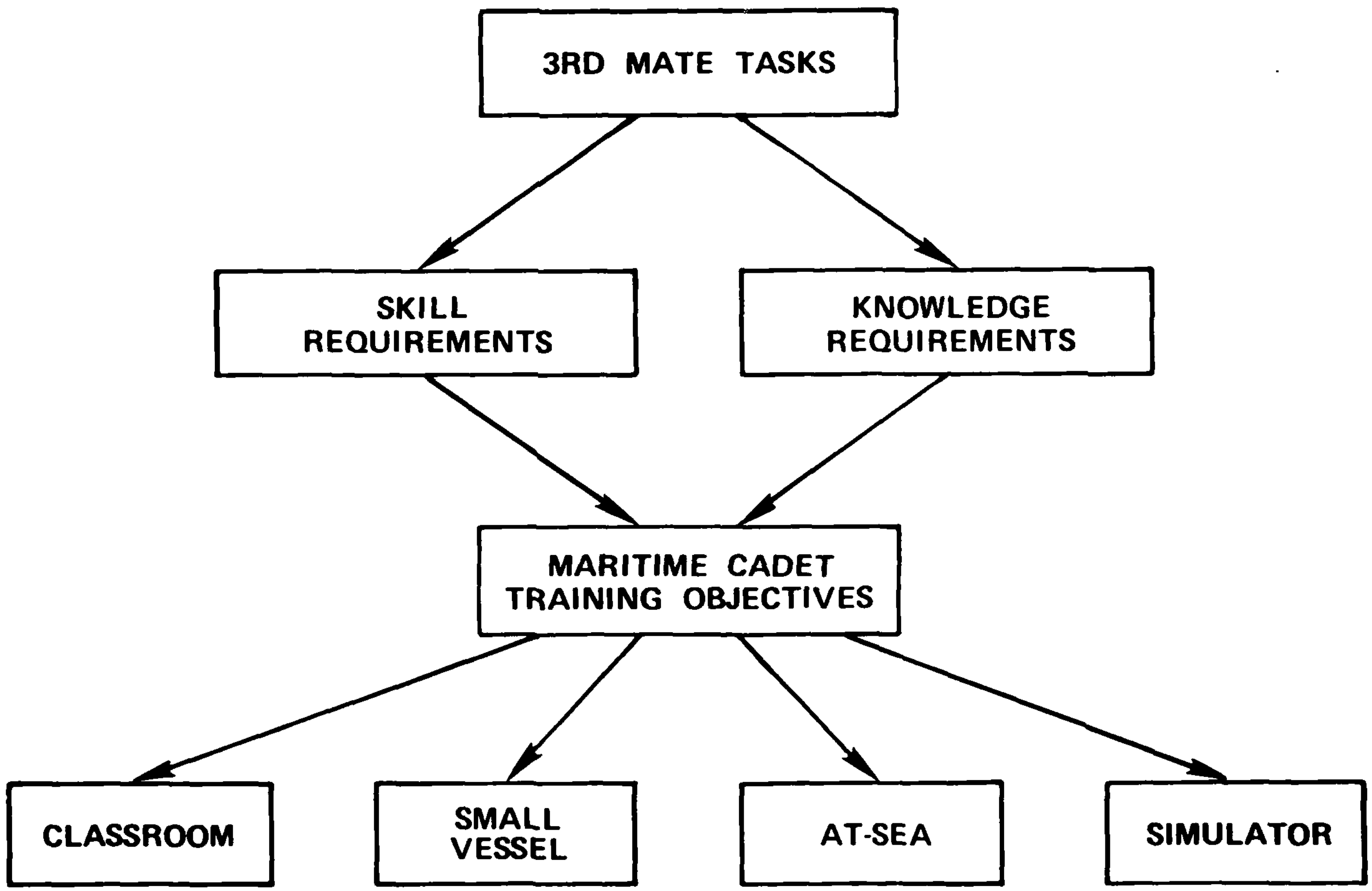


Figure 1. Task E Approach

Each training medium category was subdivided into "appropriate," "best," and "only" and the 113 training objectives were allocated accordingly. A training objective appearing in an "appropriate" column of a training medium category would indicate that training medium as appropriate for accomplishing the training objective listed; if the training objective (TO) appears in the best category, that training medium is seen as the best possible medium for accomplishing the TO; and if the TO appears in the "only" category, that training medium is seen as the only medium capable of accomplishing the training goal. Those training objectives in the simulator "best" category were then evaluated for their criticality in a cadet training program. Those training objectives found to be highly critical were accepted as the training objectives driving the design of a cadet-level shiphandling simulator.

The specific simulator functional characteristics recommended for cadet training were derived from analysis of requirements related to cost-effectively achieving the "highly critical" training objectives in the "simulator best" category. First, the necessary fidelity level was determined for each simulator characteristic on the basis of effectively achieving each training objective; this process involved evaluations by experienced mariners and training personnel. It, furthermore, required integration across the set of requisite TOs to achieve a single fidelity level for that characteristic. For example, the minimum visual scene horizontal field of view (e.g., 120 degrees, 180 degrees, etc.) was determined for each TO; many TOs could be acceptably achieved with the lowest level of fidelity considered (i.e., 120 degrees), while other TOs require a greater level of fidelity (e.g., 240 degrees), for complete achievement. The resulting recommended level of fidelity was determined by combining these individual requirements across all of the TOs. Other factors in addition to training effectiveness, however, were included in the analysis to arrive at the recommended level for each simulator characteristic. Cost was one such factor. An estimated cost ratio is given for most of the simulator characteristics listed by this report. This cost ratio is on a scale which transcends technologies. For example, the cost of color in a visual scene varies greatly with the type of visual scene generation technique utilized by the simulator; however, only one cost ratio is suggested, since the figures represent an average across possible technologies. A summary of these types of considerations relating to specific technologies is provided in Section III.

Other considerations which influenced the recommendation of a level of asimulator subsystem were curriculum and time constaints. The academies may be hard pressed to find time periods within the present curriculum for simulator-based training. This fact was recognized and accounted for in arriving at the recommendations.

Training program guidelines were developed to assist the academies in integrating simulator-based training into their curricula, and in implementing effective training programs. The ship bridge simulator represents a change in the traditional methods of mariner training. It is a powerful training tool, but in the wrong hands could be a detriment instead of an improvement. The importance of instructor qualifications is recognized and accounted for within these guidelines. Further details regarding the methodologies used are provided in the following sections relating to the respective areas of investigation.

1.4 SUMMARY

The present report represents the culmination of part of a multi-year research project investigating the role of simulators in mariner training and licensing processes conducted by the U.S. Maritime Administration and U.S. Coast Guard. The objective of this part of the project was the development of a simulator functional design specification and training program guidelines for a maritime academy cadet simulator-based training program.

The first step in attaining this objective was the determination of third mate entry level training objectives. These training objectives were verified and subsequently matched with appropriate training media (classroom, small vessel, at sea, or simulator). The highly critical training objectives contained in the "simulator best" category served as the basis for design of the simulator's functional characteristics. The selection of fidelity levels for each major simulator characteristic was based on training effectiveness, cost, and logistics considerations. Training program guidelines were also developed to facilitate the implementation of simulator-based training programs, using the identified simulator design, in the maritime academy curriculum.

The following sections provide the details (methodology, results, and recommendations as appropriate) for each area addressed by this effort.

- Section II. Identification and Analysis of Cadet Training Objectives
- Section III. Development of a Simulator Functional Specification For Maritime Cadet Training
- Section IV. Guidelines For the Utilization of the Maritime Cadet Simulator

SECTION II

IDENTIFICATION AND ANALYSIS OF CADET TRAINING OBJECTIVES

The identification of the desired characteristics or attributes of a new third mate is not an easy accomplishment. While there are numerous sources which cite the duties and responsibilities of third mates or their Coast Guard license requirements, no single document currently exists that provides a listing of desired characteristics of third mates in a form that could be employed during this analysis. The third mate training objectives, therefore, had to be developed from a variety of information sources. This report delineates the training objectives for the junior deck officer level (i.e., third mate).

The identification of training objectives is important when analyzing any training system since they constitute the goals for which the training system is designed and implemented. Some facilities utilize the terms "output characteristics" or "terminal behavioral objectives" to describe the specific skills and knowledge associated with their graduates. Once these goals are clearly and concisely identified, along with the skills and knowledge possessed by the entering students (sometimes referred to as input characteristics), the training strategies and training media to be employed during the program can be defined.

The first step in the development of cadet level training objectives was the documentation of the tasks that a third mate performs at sea. During Phase I of the Training and Licensing Project training objectives for senior mariners (i.e., masters, chief mates) were developed and carefully scrutinized by the project's working group which consisted of representatives from various elements of the maritime community. Ship operators, maritime labor unions, and various training facilities were represented on this working group. During Phase I several data bases were employed to identify senior mariner tasks leading to development of the training objectives. The integrated data base of the Phase I report was utilized as a starting point for the development of the third mate task listing. This developmental process was conducted by a team consisting of several members with either maritime or training backgrounds and included one member who is presently active as a merchant marine deck officer. Initially, all third mate tasks were identified. However, because of the nature of this investigation, which is directed towards the role of shiphandling/ship bridge simulator training within the maritime academy curriculum, the research effort subsequently concentrated on a thorough documentation of only the **watchstanding tasks**. The list of third mate tasks which resulted is contained in Appendix A, Table A-1.

2.1 CADET TRAINING OBJECTIVES

The skills and knowledge requirements necessary for the new third mate to perform each of the watchstanding tasks were identified as an initial step in the development of cadet training objectives. These skill and knowledge requirements were then translated into the 113 training objectives contained in Appendix A, Table A-2. It should be noted that these are the desired characteristics of a new third mate upon graduation from a maritime academy and entry into the merchant marine, **for watchstanding tasks only**. The training and education provided by the U.S. Merchant Marine Academy and the various state academies is obviously much broader than this listing. The graduate of one of these facilities is also provided with the basis for successfully performing non-watchstanding tasks (e.g., cargo handling) and eventually growing into more responsible positions with the U.S. Merchant Marine whether at-sea or ashore (e.g., master, port captain). It should also be noted that although this listing of training objectives may not be perfect, it represents an accurate portrayal of the goals of the maritime academy curriculum in this area, and provided an appropriate data base for analysis within this project.

The cadet training objectives were grouped into eleven (11) categories in order to assist the reader. The categories are:

- General
- Relative Motion
- Rules of the Road
- Collision Avoidance
- Shiphandling/Seamanship
- Celestial Navigation

- Piloting
- Electronic Navigation
- External Vessel Communications
- Watchstanding/Bridge Procedures

2.2 ANALYSIS OF CADET TRAINING OBJECTIVES

The cadet training objectives were analyzed and allocated to four training media to achieve the most advantageous use of shiphandling/ship bridge simulator within the maritime academy curriculum. This analysis was conducted on the basis of the perceived effectiveness of these training media to achieve the training of each specific training objective. The resulting allocation, therefore, represents the optimum training environment. This may be viewed as the ideal training media mix for this particular set of training objectives. It will obviously be modified in practice due to scheduling and cost constraints, and particular requirements of each academy. However, it does provide insight as to the direction that should be considered in order to maintain and improve the high deck officer standards of the U.S. Merchant Marine.

2.2.1 TRAINING MEDIA

Prior to the allocation of cadet training objectives to the various training media, each training medium must be carefully defined since the analysis is sensitive to the description of each training medium. For example, a small vessel that contains a comprehensive suite of electronic navigation equipment could be utilized for training the development of the skills associated with the use of such equipment. If the vessel did not have such a suite, it obviously could not be considered for use as a training medium for these skills. A description of each of the four training media considered in this analysis follows:

- Classroom – A professionally designed, constructed, furnished and maintained classroom with appropriate training aids such as blackboard, overhead projector, slides, etc. Appropriate laboratories and existing part-task trainers such as LORAN simulators, satellite navigation simulator, radar simulators, etc., are also considered in this medium.

- Small Vessel – A wooden, fiberglass, or metal vessel approximately 30 to 65 feet in length with inboard propulsion (probably diesel). The vessel may be either single or twin screw. Its navigation equipment consists of a magnetic compass, appropriate charts/plotting equipment, echo depth finder, and radiotelephone.

- At-sea – A large at-sea vessel containing appropriate navigation and communication equipment. A representative state academy training vessel such as the "Golden Bear" which is dedicated to the training of California Maritime Academy cadets. While it is recognized that at-sea training can be effectively provided aboard merchant vessels actively engaged in revenue producing activities, this type of at-sea training is not directly addressed herein. At-sea training on active merchant vessels is essentially employed only at the U.S. Merchant Marine Academy (USMMA). Since the USMMA has access to CAORF, it is not considered as a principal candidate for a full mission shiphandling simulator that would result from this investigation. Further analysis reveals that while substitution of at-sea training on active merchant vessels for that on dedicated training vessels does alter somewhat the allocation of training objectives to training media, it does not appear to substantially change any of the observations or conclusions related to allocation of the training objectives.

- Shiphandling Simulator – A full mission shiphandling/ship bridge simulator with a pilothouse, an appropriate visual scene capability, radar, navigation equipment, radiotelephone, etc.

2.2.2 ALLOCATION TO TRAINING MEDIUM

A determination was made as to which training medium was either (1) "appropriate" (2) the "best" or (3) the "only" medium for each training objective. A particular training objective could be assigned to multiple training media as "appropriate" although only one of these training media could be considered as the "best." If a particular training objective was only capable of being achieved via one training medium, it was assigned to the "only" category under that medium. For example, training objective number 59, "The trainee shall be able to observe, calculate, and plot a celestial star fix under operational conditions," was placed in the "At-sea Only" category. Table 1 contains the complete tabulation for all identified cadet training objectives utilizing these conventions for the allocation of training objectives.

For those training objectives allocated to the simulator-best category, a further test of appropriateness as a candidate for simulator-based training was made. Each training objective of the simulator best category was ranked according to its perceived criticality in a cadet training program. (See Table 2.) Table 3 is a listing of those highly critical cadet TOs best suited for simulator training along with their

TABLE 1. ALLOCATION OF CADET TRAINING OBJECTIVES (TOs) TO TRAINING MEDIUMS

CLASSROOM			SMALL VESSEL			AT-SEA			SHIPHANDLING SIMULATOR		
CLASSROOM APPROPRIATE	CLASSROOM BEST	CLASSROOM ONLY	SMALL VESSEL APPROPRIATE	SMALL VESSEL BEST	SMALL VESSEL ONLY	AT-SEA APPROPRIATE	AT-SEA BEST	AT-SEA ONLY	SIMULATOR APPROPRIATE	SIMULATOR BEST	SIMULATOR ONLY
2,3,5,6,7,9,10,13,15, 16,17,18,34,35,36, 38,39,53,54,56,97, 98,101	1,4,11,12,19,20,21, 22,23,24,25,26,40, 41,42,43,44,45,46, 60,61,62,63,64,65, 66,67,68,69,70,71, 85,86,87,91,92,93, 94,99		3,14,30,31,32,33,35, 36,37,52,53,54,55, 56,61,64,65,67,68, 69,72,73,74, 75,77,78,79,83,84, 90,95,96,97,98,100, 102,103,104,105, 106,107,108,109, 110,112,113	34,38,39		1,4,7,9,11,12,15,16, 17,18,19,20,21,22, 23,24,25,26,27,28, 29,30,31,32,33,34, 35,36,37,38,39,40, 41,42,43,44,45,46, 60,61,62,63,64,65, 66,67,68,69,70,71, 72,73,74,75,76,77, 78,79,80,81,82,83, 84,85,86,87,88,89, 90,91,92,93,94,95, 96,99,104,105,106 107,108,109,110, 111,112	2,3,5,6,10,13,14,52, 53,54,55,56,57,97, 98,100,101,102,103, 113	8,47,48,49,50,51, 58,59,	3,4,5,13,25,26,34, 52,53,54,55,57,65, 66,67,68,69,71,91, 97,102,	7,15,16,17,18,27,28, 29,30,31,32,33,35, 36,37,72,73,74,75, 76,77,78,79,80,81, 82,83,87,88,89, 94,95,96,104,105, 106,107,108,109, 110,111,112	

TABLE 2. CRITICALITY OF CADET TRAINING OBJECTIVES

Criticality	Effectiveness: Simulator Appropriate	Effectiveness: Simulator Best
High	3, 25, 26, 65, 66, 67, 68, 69, 71, 91, 102	7, 15, 16, 17, 18, 27, 28, 29, 30, 31, 32, 33, 35, 37, 72, 73, 74, 75, 76, 77, 78, 81, 88, 89, 94, 95, 96, 104, 105, 106, 107, 108, 109, 110
Medium	4, 5, 13, 34, 52, 53, 54, 57,	36, 79, 80, 81, 82, 83, 111, 112
Low		

respective conditions and performance standards. These conditions and standards will assist the academies in the development of detailed simulator-based training program curricula (e.g., lesson plans, exercises). The standards state *the minimally acceptable level of cadet performance* for each behavior after training on a shiphandling simulator. The conditions under which the cadet should perform the behavior to the requisite standard are also specified.

2.2.3 OBSERVATIONS

Based on an analysis of the allocation of cadet training objectives in Table 1 to either classroom, small vessel, at sea, or simulator-based training, the following observations are made:

- The majority of the identified cadet training objectives can be trained at sea although this may not be the most effective training medium for many of the desired skills. This is consistent with the historical development of maritime cadet training from the days when the deck officer candidate worked his way up through a shipboard apprentice program.

- A number of cadet training objectives, such as the observation, plotting, and evaluating of celestial fixes under operational watch conditions, can be effectively trained only at sea. It should be noted that an understanding of the celestial triangle and the procedures for reducing/plotting can be successfully taught in the classroom. However, the application of this knowledge to the navigational process can be gained only at sea.

- Other cadet training objectives can be trained best at sea, although other training media may be available. For example, the ability to interpret the impact of marine weather on ownship and to take appropriate action (e.g., notification of master, securing vessel for heavy weather) can be discussed in the classroom or experienced to a certain degree of small vessels. However, as most experienced mariners will agree, there is no substitute for the experience gained during a storm at sea.

- Every cadet training objective can be trained without the shiphandling/ship bridge simulator although some advocates will argue that the effectiveness of the other training media for a number of training objectives, such as emergency shiphandling principles, is extremely marginal. Generations of mariners have successfully handled their vessels under a majority of the emergency situations that they encountered during their careers at sea without the benefit of simulator-based training. One key question may be "Are we still willing to accept the risks associated with the utilization of only the traditional training methods?"

- Simulator-based training can improve the training of a number of cadet training objectives as indicated by the substantial number of training objectives which were considered to be trained best via simulator. This is already being done in a limited sense as evidenced by the success of the radar observer simulator training program. As previously mentioned, the strength of the simulator lies primarily in its flexibility and control over the training process. It appears that cadet training can be further improved via simulator-based training (in addition to the radar observer program) for selected training objectives in the following categories: Collision Avoidance, Shiphandling, Piloting, External Vessel Communications, Watchstanding and Bridge Procedures.

- The various training media utilized to train the identified cadet training objectives have considerable potential for reinforcement of each other. Many of the cadet training objectives can be effectively trained via multiple training media. As a result of this type of reinforcement, retention of the desired skills and knowledge is improved. Integration of simulator-based training into the maritime academy curriculum will further improve this situation.

TABLE 3. SIMULATOR BEST, HIGH PRIORITY TRAINING OBJECTIVES

Desired Behavior	Primary Conditions	Performance Standards
GENERAL		
*7. The trainee shall be able to correctly operate and utilize each piece of equipment normally found on the bridge of a commercial vessel (e.g., gyrocompass helm, EOT, radar).	Geographic Area: Coastal; Open sea Traffic Density: Light (1-5 contacts) Time of Day: Day; Night Visibility: Unlimited to limited	Compliance with manufacturer's instructions and accepted navigational practice
RELATIVE MOTION		
15. The trainee shall demonstrate an understanding of the function, operations, and limitations of radar as regards collision avoidance.	Geographic Area: Coastal; Open sea Traffic Density; Medium (6-10 contacts) Time of Day: Day; Night Visibility: Unlimited to limited Weather: Clear, rain, snow Sea States: 0-3; 4-5; over 5	Compliance with manufacturer's instructions and accepted navigational practice
16. The trainee shall demonstrate an understanding of relative motion concept including maneuvering and rapid radar plotting techniques.	Geographic Area: Coastal; Open sea Traffic Density: Medium (6-10 contacts)	Successful completion of USCG license requirement
17. The trainee shall demonstrate an understanding of the use of masthead and side lights to assist in determining traffic vessel aspect.	Geographic Area: Open sea Traffic Density: Low (1-5 contacts) Traffic Vessel Range: 10 nm; 5 nm; 2 nm Time of Day: Day; night Visibility: Unlimited to limited	90 percent correct determination of traffic vessel aspect

*Numbers refer to training objectives listed in Table A-2.

TABLE 3. SIMULATOR BEST, HIGH PRIORITY TRAINING OBJECTIVES (Continued)

Desired Behavior	Primary Conditions	Performance Standards
RELATIVE MOTION (Continued) 18. The trainee shall demonstrate an understanding of the use of visual bearings in establishing and assessing risk of collision.	Geographic Area: Open Sea Traffic Density: Medium (6-10 contacts) Traffic Vessel Range: 10 nm; 5 nm; 2 nm Time of Day: Day; night Visibility: Unlimited to limited	100 percent correct determination of risk of collision
COLLISION AVOIDANCE 27. The trainee shall be able to accurately maintain a radar plot of multiple contacts simultaneously under operational watch conditions.	Geographic Area: Coastal; Open sea Traffic Density: Medium (6-10 contacts) Time of Day: Day; night	Equivalent to the proficiency of an experienced third mate
28. The trainee shall be able to accurately assess each contact's potential for risk of collision and filter contacts with low risk of collision under operational watch conditions.	Geographic Area: Coastal; Open sea Traffic Density: Heavy (over 10 contacts) Time of Day: Day; night Visibility: Unlimited to limited	Equivalent to the proficiency of an experienced third mate
29. The trainee shall be able to accurately determine contact CPA, course, speed, etc., utilizing either maneuvering board or rapid radar plotting techniques under operational watch conditions.	Geographic Area: Coastal; Open sea Traffic Density: Medium (6-10 contacts Time of Day: Day; night Visibility: Unlimited to limited	Equivalent to the proficiency of an experienced third mate
30. The trainee shall be able to properly recognize, interpret, and evaluate visual contacts as to type, aspect, and relative motion under operational watch conditions.	Geographic Area: Coastal; Open sea Traffic Density: Medium (6-10 contacts) Time of Day: Day; night Visibility: Unlimited to limited	Equivalent to the proficiency of an experienced third mate

TABLE 3. SIMULATOR BEST, HIGH PRIORITY TRAINING OBJECTIVES (Continued)

Desired Behavior	Primary Conditions	Performance Standards
COLLISION AVOIDANCE (Continued)		
31. The trainee shall be able to use a visual bearing circle, telescopic alidade, or pelorus to determine contact bearing and contact bearing drift.	Geographic Area: Coastal; Open sea Traffic Density: Medium (6-10 contacts) Time of Day: Day; night Visibility: Unlimited to limited	100 percent correct contact bearing within ±1° tolerance; 100 percent correct direction of bearing drift
32. The trainee shall be able to integrate available information and apply the Rules of the Road to a particular situation under operational watch conditions.	Geographic Area: Coastal; Open sea Traffic Density: Medium (6-10 contacts) Time of Day: Day; night Visibility: Unlimited to limited	Equivalent to the proficiency of of an experienced third mate
33. The trainee shall be able to maneuver ownship to pass at a safe distance, according to the procedures outlined in the Rules of the Road and the master's standing/night orders.	Geographic Area: Coastal; Open sea Traffic Density: Medium (6-10 contacts) Time of Day: Day; night Visibility: Unlimited to limited Wind: Less than 50 knots Current: Less than 3 knots	Equivalent to the proficiency of an experienced third mate
SHIPHANDLING/SEAMANSHIP		
35. The trainee shall demonstrate an understanding of emergency shiphandling principles (e.g., Williamson turn, crash stop).	Geographic Area: Coastal; Open sea Traffic Density: Medium (6-10 contacts) Time of Day: Day; night Visibility: Unlimited to limited Wind: Less than 50 knots Current: Less than 3 knots	100 percent successful execution of the emergency shiphandling principles discussed in Knight's **Modern Seamanship**

TABLE 3. SIMULATOR BEST, HIGH PRIORITY TRAINING OBJECTIVES (Continued)

Desired Behavior	Primary Conditions	Performance Standards
SHIPHANDLING/SEAMANSHIP (Continued)		
37. The trainee shall be able to determine "safe vessel speed" under a variety of operational conditions (e.g., reduced visibility).	Geographic Area: Coastal; Open sea Traffic Density: Medium (6-10 contacts) Time of Day: Day; night Visibility: Unlimited to limited Wind: Less than 50 knots Current: Less than 3 knots	Equivalent to the proficiency of an experienced chief mate
PILOTING		
72. The trainee shall be able to layout and interpret dead reckoning tracklines on a chart under operational conditions.	Geographic Area: Coastal Traffic Density: Low (1-5 contacts) Time of Day: Day; night Visibility: Unlimited to limited Wind: Less than 50 knots Current: Less than 3 knots	Compliance with accepted navigational practice as defined by BOWDITCH's **American Practical Navigator**
73. The trainee shall be able to analyze a dead reckoning track for potential navigational hazards under operational conditions.	Geographic Area: Coastal Traffic Density: Low (1-5 contacts) Time of Day: Day; night Visibility: Unlimited to limited Wind: Less than 50 knots Current: Less than 3 knots	Equivalent to the proficiency of an experienced third mate
74. The trainee shall be able to visually identify charted objects suitable for visual lines of position under both day and night operational watch conditions.	Geographic Area: Coastal Traffic Density: Low (1-5 contacts) Time of Day: Day; night Visibility: Unlimited to limited	Equivalent to the proficiency of an experienced third mate

TABLE 3. SIMULATOR BEST, HIGH PRIORITY TRAINING OBJECTIVES (Continued)

Desired Behavior	Primary Conditions	Performance Standards
PILOTING (Continued)		
75. The trainee shall be able to determine vessel position by means of visual fixes under both day and night operational watch conditions.	Geographic Area: Coastal Traffic Density: Low (1-5 contacts) Time of Day: Day; night Visibility: Unlimited to limited	Equivalent to the proficiency of an experienced third mate
76. The trainee shall be able to determine vessel position by means of radar fixes under operational watch conditions.	Geographic Area: Coastal Traffic Density: Low (1-5 contacts) Visibility: Limited	Equivalent to the proficiency of an experienced third mate
77. The trainee shall be able to compare the new fix position (e.g., radar, visual) with the charted DR position, evaluate discrepancies and establish present position under operational watch conditions.	Geographic Area: Coastal Traffic Density: Low (1-5 contacts) Time of Day: Day; night Visibility: Unlimited to limited Wind: Less than 50 knots Current: Less than 3 knots	Equivalent to the proficiency of an experienced third mate
78. The trainee shall be able to determine compass error using charted ranges under operational watch conditions.	Geographic Area: Coastal Traffic Density: Low (1-5 contacts) Time of Day: Day; night	Deviation less than ±0.5°
ELECTRONIC NAVIGATION		
87. The trainee shall be able to determine, plot, and evaluate the vessel's position by utilizing any of the following systems under operational watch conditions.	Geographic Area: Coastal; Open sea Traffic Density: Low (1-5 contacts) Time of Day: Day; night Visibility: Unlimited to limited Wind: Less than 50 knots Current: Less than 3 knots	Compliance with manufacturer's instructions and accepted navigational practice

TABLE 3. SIMULATOR BEST, HIGH PRIORITY TRAINING OBJECTIVES (Continued)

Desired Behavior	Primary Conditions	Performance Standards
ELECTRONIC NAVIGATION (Continued)		
88. The trainee shall be able to determine, plot, and evaluate a radio direction finder line of position under operational watch conditions.	Geographic Area: Coastal; Open sea Traffic Density: Low (1-5 contacts) Time of Day: Day; night Visibility: Unlimited to limited Wind: Less than 50 knots Current: Less than 3 knots	Compliance with manufacturer's instructions and accepted navigational practice
89. The trainee shall be able to utilize a line of soundings to assess the accuracy of his navigational position information under operational watch conditions.	Geographic Area: Coastal Traffic Density: Low (1-5 contacts) Time of Day: Day; night Visibility: Unlimited to limited Wind: Less than 50 knots Current: Less than 3 knots	Equivalent to the proficiency of an experienced third mate
EXTERNAL VESSEL COMMUNICATION		
94. The trainee shall be able to properly monitor the appropriate radiotelephone frequencies under operational watch conditions.	Geographic Area: Coastal; Open sea Traffic Density: Medium (6-10 contacts) Time of Day: Day; night Visibility: Unlimited to limited	Equivalent to the proficiency of an experienced third mate
93. The trainee shall be able to properly transmit/receive the following types of messages via radiotelephone: • distress • urgency • safety	Geographic Area: Coastal; Open sea Traffic Density: Medium (6-10 contacts) Time of Day: Day; night Visibility: Unlimited to limited	Compliance with accepted radiotelephone procedures

TABLE 3. SIMULATOR BEST, HIGH PRIORITY TRAINING OBJECTIVES (Continued)

Desired Behavior	Primary Conditions	Performance Standards
EXTERNAL VESSEL COMMUNICATION (Continued)		
96. The trainee shall be able to utilize radiotelephone information to establish and assess the safety of ownship relative to other vessels and navigational hazards.	Geographic Area: Coastal; Open sea Traffic Density: Medium (6-10 contacts) Time of Day: Day; night Visibility: Unlimited to limited	Equivalent to the proficiency of an experienced third mate
WATCHSTANDING/BRIDGE PROCEDURE		
104. The trainee shall demonstrate the ability to maintain a vigilant lookout in accordance with standing orders and normal routine, monitoring internal and external situations for potential problems or hazardous situations that may put the vessel personnel in jeopardy and take appropriate action to assure that safe conditions exist.	Geographic Area: Coastal; Open sea Traffic Density: Medium (6-10 contacts) Time of Day: Day; night Visibility: Unlimited to limited Wind: Less than 50 knots Current: Less than 3 knots	Equivalent to the proficiency of an experienced third mate
105. The trainee shall demonstrate the ability to notify the master accurately and concisely of traffic vessels with possible risk of collision, as defined by the standing order criteria, under operational watch conditions.	Geographic Area: Coastal; Open sea Traffic Density: Medium (6-10 contacts) Time of Day: Day; night Visibility: Unlimited to limited	100 percent notification within standing order criteria
106. The trainee shall demonstrate the ability to notify the master of all navigational hazards which may impact the safety of the vessel (e.g., engineering casualties, heavy weather).	Geographic Area: Coastal; Open sea Traffic Density: Low (1-5 contacts) Time of Day: Day; night Visibility: Unlimited to limited Wind: Less than 50 knots Current: Less than 3 knots	100 percent notification of all situations which impact the safety of ownship

TABLE 3. SIMULATOR BEST, HIGH PRIORITY TRAINING OBJECTIVES (Continued)

Desired Behavior	Primary Conditions	Performance Standards
WATCHSTANDING/BRIDGE PROCEDURES (Continued)		
107. The trainee shall demonstrate the ability to notify the master in accordance with the standing orders of the occurrence of anticipated events (e.g., landfall).	Geographic Area: Coastal Traffic Density: Low (1-5 contacts) Time of Day: Day; night Visibility: Unlimited to limited	100 percent notification of all anticipated occurrences required by standing orders
108. The trainee shall demonstrate the ability to orally communicate with other mates concerning the status of the vessel during watch relief.	Geographic Area: Coastal; Open sea Traffic Density: Medium (6-10 contacts) Time of Day: Day; night Visibility: Unlimited to limited	Successful communication of all critical watch information
109. The trainee shall demonstrate the ability to instruct/supervise as appropriate other members of the bridge watch in their duties and responsibilities (e.g., helmsman, lookout).	Geographic Area: Coastal; Open sea Traffic Density: Medium (6-10 contacts) Time of Day: Day; night Visibility: Unlimited to limited	Novice bridge ream members satisfactorily perform their duties after supervision
110. The trainee shall demonstrate the ability to issue/verify appropriate helm orders using proper terminology in order to safely navigate ownship.	Geographic Area: Coastal; Open sea Traffic Density: Low (1-5 contacts) Time of Day: Day; night	Equivalent to the proficiency of an experienced third mate

2.3 CONCLUSIONS

The identification of cadet level training objectives and their allocation to appropriate training media was the first step to provide a basis for the development of a functional simulator specification and training program guidelines. As a result of this analysis and the associated observations, the project team drew three conclusions concerning the potential role that shiphandling/ship bridge simulators could play in the training process for maritime academy cadets.

1. Simulator-based training has the potential to improve the quality of the maritime academy training program within the United States. The radar observer training has provided an indication regarding this improvement. This analysis indicates that a full mission shiphandling/ship bridge simulator has the potential to provide more effective training than the traditional training methods in a number of areas beyond the development of radar plotting and evaluative skills.

2. A full mission shiphandling/ship bridge simulator should be considered for training selected skills within the following categories: Collision Avoidance, Shiphandling, External Vessel Communications, Piloting, and Watchstanding/Bridge Procedures. (See Table 1 for the specific training objectives within the "simulator best" catetory.) These desired skills or training objectives can thus serve as the design goals for the development of the functional simulator specification. Alternative designs however would be necessary if any additional skills need to be trained, such as at the master mariner level. (See Section 3.)

3. Simulator training should be used to supplement not replace the traditional training media, particularly at-sea training. During this current project no indication was found that at-sea time could be reduced if simulator training were implemented. In fact, it is recommended that at-sea training remain at least at its present level; but that additional resources to upgrade cadet training be considered for simulator-based training in lieu of increasing at-sea time as indicated by the IMCO resolution. This approach is recommended since it appears that it will result in a more effective overall maritime cadet training program. Simulator-based training would be an effective complement to the current at-sea training programs of the academies, enabling practical hands-on training to be expanded to more fully address certain training objectives and thus improve the entering third mate's shiphandling proficiency. While the procurement of appropriate simulator-based training systems would be preferable, procurement of simulator time for training purposes at existing or planned simulator facilities should also be considered.

SECTION III

DEVELOPMENT OF A SIMULATOR FUNCTIONAL SPECIFICATION FOR MARITIME CADET TRAINING

3.1 BACKGROUND

A ship's bridge simulator is inherently an expensive training device to procure, operate, and maintain. Because of this high cost, its design should undergo strict scrutiny to eliminate any aspects which might be considered "frills" and to obtain the highest possible quality for the dollar spent. It should be noted that many mariners desire a high fidelity simulation which replicates as closely as possible the at-sea environment in every respect. Previous research in the Training and Licensing Project has indicated that lower fidelity simulators can be utilized for effective training as long as the critical cues for desired skill development are present (Hammell, Gynther, Grasso, and Gaffney, 1981). In other words, the specific characteristics of a simulator should be determined by the specific deck officer skills to be achieved on the simulator.

The complexity of the simulator demands that its design not be developed in a vacuum, isolated from the concerns and input of the maritime community. During this project, the project team discussed and solicited comments from each of the maritime academies through a variety of means including a briefing at the Annual Superintendent's Conference, visits to two state academies, written correspondence with each academy, and personal discussions with a variety of maritime personnel. It is hoped that this continuing interaction with those individuals who train and employ our new third mates will ensure the compatibility of the simulator design with the needs and objectives of the U.S. maritime community.

3.2 APPROACH

In Section II of this report, a number of cadet training objectives for achievement via simulator training within the maritime academy curriculum was identified. Earlier in the Training and Licensing Project in the report entitled "Guidelines for Deck Officer Training Systems," the critical characteristics of a shiphandling/ship bridge simulator were identified and discussed (Gynther, Hammell, Grasso, and Pittsley, 1981). A listing of these critical characteristics are contained in Table 4. These two bodies of information were then utilized as the departure point for the development of the cadet simulator functional specification.

The first step in this developmental process was the evaluation of the effectiveness of the various fidelity levels of the critical simulator characteristics to train each training objective identified in Section II. Achievement of these training objectives is the design goal of the simulator. The results of this process are contained in tabular form in Table A-3 of Appendix A. In reviewing these tables, the question that the reader should keep in mind is "How

TABLE 4. 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

effective will a simulator with this level of this critical characteristic be when it is employed for the training of this particular training objective?" The principal purpose of these tables is to identify in quantifiable terms the differential in training effectiveness benefits associated with each level of a critical simulator characteristic.

The second step in the developmental process was the identification of the relative cost ratio between each level of a critical simulator characteristic. One level of each characteristic was designated as the basis for comparison and the cost of the other levels identified relative to its cost. It should be noted that gross cost scales across technologies were utilized since at this point in the process it was not desired to constrain the functional specification to one particular technology (e.g., computer generated imagery, model board, or spot-light). It is recognized that variations in these cost ratios do exist depending on the technology selected and that the eventual selection of a technology for the engineering specification is an interactive process involving many factors. The cost ratios identified and utilized in this section of the report, do, however, assist in factoring into the analysis the impact of cost.

Next, using the training effectiveness and cost information described above, a recommended level for each critical simulator characteristic was identified across all training objectives and its supporting rationale documented. The project team then identified, as appropriate for each critical simulator characteristic, any additional functional requirements. After this process was completed all of the requirements identified for the cadet simulator were summarized. (See Section 3.4)

Finally, the costs of procuring, operating, and maintaining the system for cadet training were estimated. Several procurement strategies for implementing simulator-based training at the various maritime academies were then identified and discussed with appropriate recommendations.

3.3 CADET SIMULATOR CRITICAL CHARACTERISTICS

Prior to discussing the specific critical simulator characteristics, one point should be addressed. Some readers may question the requirement for a visual scene when training cadets. Previous research has documented the need for a visual scene to train cadets in the use of multiple information sources when assessing a shiphandling problem. For *example*, cadets appear to have a tendency to neglect visual information during collision avoidance maneuvers while apparently relying heavily on radar. It should be noted that the research also indicates a tendency of cadets to neglect maneuvering and warning whistle signals. Since the *International Rules of the Road* (Rule 34) state that these types of signals should be sounded when vessels are in sight of one another, this also indicates a visual scene requirement for such training (Hammell, Gynther, Grasso, and Lentz, 1981; Gynther, Hammell, and Grasso, 1981).

For each characteristic a summary of the relevant information contained in the "Guidelines for Deck Officer Training Systems" is provided, followed by a relative cost factor. A recommended level of the characteristic is then suggested followed by the rationale for this suggestion. A synopsis of the previously described structured process for determining levels for each of the characteristics listed in Table 4 is also given. Finally, additional functional requirements are specified for each characteristic as appropriate.

It should be noted that in the past the design of a simulator has been highly subjective based on the perceived requirements of mariners and the ability of the design engineers to meet their interpretation of the perceived requirements. For the most part, hard objective data is not available for determining design characteristics. Hence, subjective data must be relied upon. The recommended characteristic levels are thus the result of a highly structured design process, drawing upon both objective and subjective data. Subjective analysis is still required in part, but every effort has been made to structure and define the design process. The resulting functional requirements, which represent a number of compromises between training effectiveness and cost, have been derived based on the following factors:

a. The results of previous Training and Licensing Project research:

- Phase 1: The Role of Simulators in the Mariner Training and Licensing Process
- Phase 2: Investigation of Simulator Characteristics for Training Senior Mariners
- Phase 2: Investigation of Simulator-based Training for Maritime Cadets
- Phase 3: Investigation of Horizontal Field of View Requirements for Simulator-based Training of Maritime Cadets
- Phase 3: Guidelines for Deck Officer Training System

b. The research literature cited in the bibliography of this report (e.g., Hanley, Hammell, Davis, Kurtz, and Macris, 1982) and in the comprehensive literature review conducted during the earlier Phase 1 of the project (Hammell, Williams, Grasso, and Evans, 1980).

c. The project team's judgment as outlined in the analysis of the identified cadet training objectives contained in Appendix A.

d. The project team's judgment as discussed in the rationale which derives these functional requirements.

3.3.1 TIME OF DAY

Guideline Summary: The "Guidelines for Deck Officer Training Systems" notes that previous research has indicated that skills should be trained on the simulator under the same ambient lighting conditions that they will be utilized at sea. This usually indicates a requirement for both day and night training (Hammell, Gynther, Grasso, and Gaffney, 1981; Hammell, Gynther, Grasso, and Lentz, 1981). However, if economic or logistic constraints allow training only under one condition, it would appear desirable to train under the more difficult lighting condition, which would usually be the nighttime condition. The report also identified three levels of this simulator characteristic and discussed their impact on simulator training. These three levels are, listed in increasing order of sophistication, (1) night only, (2) day only, and (3) day/night.

	Night	Day	Day/Night
Estimated Cost Ratio:	1.0	2.25	2.5

Recommended Level: Night only

Rationale: Evaluation of the high priority skills for maritime cadet simulator-based training indicates that it would probably be desirable to train the majority of these skills under both day and night conditions (see Table A-3). However, a night only capability is recommended for the cadet simulator for two principal reasons. First, the high cost of a day/night capability over the night only capability (2.5:1) may result in pricing simulator training for cadets from the realm of the possible to the realm of the impossible. It appears that such increased risk is not worth the increased benefits associated with day training. Discussion with a number of maritime academy personnel indicated that, for the majority of skills to be developed via simulator training, nighttime skill development should receive substantially greater emphasis than daytime skill development. The greater benefit of nighttime training can also be seen in Table A-3. Second, due to the limited time available for the integration of simulator training into the maritime cadets' already intensive schedule, it appears that prudent practice may dictate that the academies train cadets only under the more difficult nighttime condition, even if a day/night capability were available. The reader is reminded that it is desirable to provide daytime training for cadets in addition to nighttime training. If the cost ratio between the night only capability and day/night capability is substantially reduced through technological advance, then it may become advisable to procure a day/night capability for the development of daytime shiphandling skills in lieu of relying on other training media (e.g., at-sea training) to accomplish this aspect of the cadets' training.

Finally, if additional revenue-producing training is required to financially support the maritime academy simulator facility, the report "Guidelines for Deck Officer Training Systems" indicates that the night only capability can provide beneficial training to senior mariners in a number of critical training categories, such as Navigation Management, Communications, and Rules of the Road. If day training is desired for specific skills, such as arrival in or departure from a particular port that the trainee would not normally be expected to operate in at night, then a day/night capability should be considered.

It should also be noted that a silhouette capability is desirable but not required in the night visual scene for cadet training. Evaluation of the cadet training objectives indicate that the majority of training scenarios envisioned would involve traffic vessels and geographic objects at ranges when few visual cues would normally be obtained from silhouette information. Silhouettes would probably be more critical when training senior mariners in more restricted waters.

It is also recommended that the cadet simulator have the capability for simultaneous display of the lighting configurations for at least five traffic vessels and six coastal navigation lights. The flexibility for trade-offs between traffic vessel lights and navigation lights to enhance either capability is also desirable, but not required. The five traffic vessel and six coastal navigation lights requirement should cover all the anticipated cadet training objectives. Additional background or cultural lights should be used as appropriate for realism.

3.3.2 GEOGRAPHIC AREA

Guideline Summary: 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. The "Guidelines for Deck Officer Training Systems" identifies three levels of this characteristic: (1) open sea, (2) coastal, and (3) restricted waters. One level was not recommended over another, since the geographic area requirements should be determined by the specific scenarios required to meet the identified training objectives. The open sea visual scene contains no land, although traffic ships and buoys may be represented as appropriate. In the coastal geographic area capability, distant land and a limited number of traffic vessels may be represented. Radar presentation and water depth data are also available. The restricted waters capability is capable of depicting landmass and numerous traffic vessels close aboard in the visual scene. In addition, a correspondingly complex environmental data base utilizing water depth, wind, and current may also be employed.

Estimated Cost Ratio:	**Open Sea**	**Coastal**	**Restricted Waters**
	0.3	0.6	1.0

Recommended Level: Coastal

Rationale: Analysis of Table A-3 indicates that nearly all the high priority training objectives for cadets, which were judged to be completed best via simulator, are capable of being developed utilizing the coastal geographic area capability. The more impressive, more costly restricted waters capability does not appear to be required for the development of the identified third mate skills. At the other extreme, the lower cost open sea capability is simply unacceptable for training the required third mate piloting skills. Since most mariners would agree that piloting skills in the context of coastal navigation are critical at the third mate level, a coastal navigation capability appears required for the maritime academy shiphandling simulator.

If revenue-producing training of senior mariners is necessary to financially support the maritime academy simulator facility, the more sophisticated restricted waters capability should be considered. However, it should be noted that the report "Guidelines for Deck Officer Training Systems" indicates that the coastal capability can be effectively employed for the training of many senior mariner skills. As a result, an additional investment for senior mariner training as regards this critical simulator characteristic may not be required.

Finally, for maritime cadet training, it would appear that the scenarios required for the development of the identified training objectives would not require ownship to approach within 2 nautical miles of land. However, the simulated visual scene should have the capability of simulating traffic vessels which approach ownship relatively close aboard.

3.3.3 HORIZONTAL FIELD OF VIEW

Guideline Summary: The horizontal field of view should be wide enough to contain the important visual cues within the training exercises for the development of the high criticality skills. Research has indicated that for the development of rules of the road/collision avoidance skills, it is desirable to take visual bearings in order to establish bearing drift and to estimate traffic aspect using the vessel's running lights. This is particularly desirable for situations, such as meeting and fine crossing, which involve high closing rates since they have limited time for situation assessment and action (Hammell, Gynther, Grasso, and Lentz, 1981; Aranow, Hammell, and Pollack, 1977). When developing piloting skills, specifically visual position-fixing skills, it is necessary to have a horizontal field of view that is conducive to the selection of geographic objects which have adequate horizontal separation in order to minimize the potential error associated with the fix (Maloney, 1978; Bowditch, 1977).

In certain situations, it may be desirable to reduce the horizontal field of view in order to focus the trainee's attention on particular visual cues during training (i.e., range lights ahead of ownship). However, prudent training practice would indidcate 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.

Relative Cost Ratio:	**120°**	**180°**	**240°**	**360°**
	0.4	0.6	1.0	2.0

Recommended Level: 180°

Rationale: As a result of the critical piloting skills identified during the previous training objective analysis, a minimum horizontal field of view of 180 degrees is recommended in order to obtain adequate horizontal separation of geographic objects for a sufficient number of training exercises to ensure proper development and generalizability of the associated visual position-fixing skills. Smaller horizontal field of views can be employed such that adequate horizontal separation of geographic objects can be obtained. However, substantial danger may then exist that the visual position-fixing skills developed may not be generalizable to other than the few unique situations observed during training (Hammell, Gynther, Grasso, and Lentz, 1981).

As regards the rules of the road/collision avoidance skills, a horizontal field of view of 180 degrees would cover all the critical meeting and fine crossing stiuations. Research has indicated that visual contact in the broader crossing and overtaking situations is not as critical due to the slower relative speeds and greater assessment times involved (Hammell, Gynther, Grasso, and Lentz, 1981).

If revenue-producing training is required at a particular facility, 180 degrees horizontal field of view should provide the capability for training many of the identified senior mariner training objectives.

3.3.4 VERTICAL FIELD OF VIEW

Guideline Summary: In choosing a level of this characteristic as with many of the critical simulator characteristics, the principal consideration is the specific training objectives and the necessary visual cues to train those objectives. If the visual scene requirements for the training objectives are at or near the horizon (e.g., distant landmass or traffic vessels), then a relatively narrow vertical field of view would probably suffice. It should be noted that in utilizing a narrow vertical field of view, particularly under daytime conditions, the fidelity of the simulation is reduced considerably when a daytime scene is bounded top and bottom with large dark bands. If the visual scene requirements are contained over a larger angular sector (e.g., 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 to the vertical field of view.

Estimated Cost Ratio:	**10°**	**20°**	**30°**
	0.6	1.0	1.6

Recommended Level: 20°

Rationale: Review of Table A-3 indicates that a number of maritime cadet skills, including coastal navigation/piloting skills, could be successfully developed via a simulator with only a 10 degree vertical field of view. Since a night only presentation has been previously recommended, the reduction in the fidelity of the visual simulation using a limited field of view would be minimized since the closely bounded edges of the visual field would not be noticeable. The visual scene area not covered by the screen can be successfully blended into the nighttime presentation. A vertical field of view of only 10 degrees, however, is not satisfactory for several of the training objectives involving traffic vessels passing close aboard. Because of the criticality of these training objectives, which involve relative motion, collision avoidance, and shiphandling skills, a 20 degree vertical field of view is recommended.

Once again, a review of the report "Guidelines for Deck Officer Training Systems" indicates that this requirement for the vertical field of view of the maritime cadet simulator would be satisfactory for the development of many senior mariner skills, if additional revenue-producing training is appropriate for the particular simulator facility. It should be noted however, that a 20 degree vertical field of view will probably be inadequate for simulation of docking scenarios.

3.3.5 COLOR VISUAL SCENE

Guideline Summary: The "Guidelines for Deck Officer Training Systems" indicates that multicolor in the visual scene, in lieu of black and white, may not be required for the development of many shiphandling skills (Hammell, Gynther, Grasso, and Gaffney, 1981). The specific training objectives should be analyzed for critical color cues which should then be provided during the simulated exercises. Two historically important color cues in maritime operations are the colors associated with aids to navigation and traffic vessel sidelights. Mariners have been successfully trained in situations where the information associated with a color characteristic is transmitted via a flash code. However, this is an unrealistic cognitive process in many scenarios and may create problems in high cognitive workload situations (e.g., heavy traffic) in which the mariner should obtain instantaneous recognition of the red color of a port sidelight in lieu of processing the flash rate of a simulated port sidelight over time.

Estimated Cost Ratio:	**Black and White**	**Multicolor**
	1.0	1.5

Recommended Level: Multicolor

Rationale: Since a number of the high priority training objectives for cadets, which were judged to be completed best via simulators, involve the interaction with traffic vessels, sometimes under high cognitive workload situations, a multicolor visual scene appears to be required for the maritime cadet simulator. Since a night only requirement was previously identified, this multicolor presentation will involve only colored lights and not a requirement for a multicolor daytime scene. This may minimize the additional cost for multicolor over black and white. The estimated cost ratio identified above was derived for a day/night capability and should be somewhat lower for a night only presentation, although this will vary as previously discussed depending on the visual scene generating technology selected.

3.3.6 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 considerations listed below are satisfied.

The difficulty inherent in specifying the visual scene quality is that the many relevant factors interact in their impact on the visual scene. For example, research has shown that birghtness and contrast ratio interact with regard to achieving an acceptable visual image; that is, the requirement for contrast ratio depends upon the level of brightness required, and vice versa. It is, therefore, difficult to specify levels of each factor impacting the visual scene quality with regard to their effect on achievement of the cadet training objectives. Rather, it is their combination into the final visual scene that is important. Hence, it is necessary to evaluate each proposed visual scene with regard to its acceptable quality. At the time purchase of a simulator becomes a reality, a panel of experts should be formed to judge the relative merits of the alternatively proposed visual scenes for training. It would appear prudent for such a panel to consist of representatives with appropriate backgrounds in the following areas: marine operations, training technology, and simulation technology. Careful consideration should be given to the selection of this panel and the test procedures employed in order to ensure that the quality of the visual scene is sufficient for proper student motivation and effective training.

Guidance is presented below regarding functional characteristics of relevance to the visual scene quality that should be considered in such an evaluation.

- When viewed from all normal work stations within the pilothouse, traffic vessels, aids to navigation, and distant landmass should appear (1) readily recognizable in the proper size and perspective, and (2) consistent with the visual cues normally available in similar scenarios at sea. The contractor should select the locations of the normal work stations for his specific bridge layout subject to the approval of the government. These designated viewing positions should be related to the normal watchstanding positions for the type of training scenarios envisioned. (See also Bridge Configuration.)

- The sensitivity of the visual scene to disortion as the deck officer moves away from the designated viewing positions described above (i.e., work stations) should not significantly impact his normal movement within the pilothouse during the scenarios envisioned. The government should consider evaluating this distortion and its potential impact on deck officer performance using the panel described above to make judgments on parameters such as relative bearing deviation, color variation, and brightness fall-off.

- The apparent size and perspective of traffic vessels, aids to navigation, and distant landmass should change as they would in similar scenarios at sea when motion is introduced into the simulation.

- The motion of traffic vessels, aids to navigation, and distant landmass in the visual scene should appear in a relatively smooth sequence and at velocities and accelerations equivalent to their motion in similar scenarios at sea. The government should consider evaluating the quality of the simulation and its potential impact on deck officer performance using the panel described above.

- Discontinuities and color matching between projected images/screens in the visual scene should be minimal and not impact deck officer performance.

- The intensity and hues of critical color cues (e.g., traffic vessel sidelights) should be acceptable to the experienced mariner. Published technical standards such as the chromaticity of navigation lights contained in the **Navigation Rules** (CG-169) should be used as a guide.

- The intensity and detectability of lights should appear to vary as a function of their range from ownship according to the physical relationships encountered in the at-sea environment when observed by an experienced deck officer with his naked eye. The development of deck officer skills in the use of binoculars is **not** considered for training via the shiphandling simulator. They should be considered for development during either at sea or small vessel training.

- Auxiliary views[1] of a particular segment of the projected (or unprojected) visual scene are **not** required for a maritime cadet shiphandling simulator.

- Table 5 provides additional information concerning "current engineering design practice" as regards key *parameters* based on (a) review of successful simulator training programs involving the type of skills identified, (b) a review of several of perceptual research reports (Henry, Jones, and Mara, 1968; Marino, Smith, and Bertsche, 1981), and (c) the experience of the researchers. The reader is cautioned that these values should be used as broad guidance only. Achievement of such *values does not necessarily* mean the achievement of an acceptable visual scene for training. The interactions of these parameters with numerous other factors such as screen gain, type of projection system, etc., must be carefully considered during the design process.

3.3.7 RADAR PRESENTATION

Guideline Summary: The type of radar equipment required on a shiphandling 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 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 guidelines identify and discuss three levels of radar presentation: Level I, No Radar; Level II, Low Fidelity Radar which is a synthetic radar presentation on an appropriate CRT display with required radar or CAS functions; Level III, High Fidelity Radar which is actual radar or collision avoidance hardware interfaced with the simulation.

The presence of noise (e.g., sea clutter or false echoes) on the simulated radar presentation should be employed if appropriate for the training objectives. Likewise, the simulation of line of sight considerations (e.g., masking) should be accomplished as required by the specific training objectives.

TABLE 5. CURRENT ENGINEERING PRACTICE FOR SELECTED VISUAL SCENE PARAMETERS* (NIGHTTIME VISUAL SCENE)

Contrast ratio	At least 10:1
Resolution	At least 3.6 minutes of arc
Update rate	At least 30 Hertz
Brightness	Comparable to a dark moonless night
Color	Red, green, white, yellow as appropriate to simulate vessel navigation lights and lighted aids to navigation
Screen to eye distance	At least 3 meters

*These values should be used with caution. Their attainment does not guarantee an acceptable visual scene for training. Other factors must also be considered.

Estimated Cost Ratio:

No Radar	Low Fidelity Radar	High Fidelity Radar
0.00	0.25	1.00

Recommended Level: Low Fidelity Radar

Rationale: Analysis of the high priority cadet training objectives which were evaluated to be appropriate for simulator training indicates that nearly all training objectives can be effectively trained with a low fidelity radar presentation (Table A-3). The few training objectives for which the high fidelity equipment would provide a substantial increase in training effectiveness do not appear to warrant the estimated four-fold increase in cost. The development of skills relating to the use of actual radar equipment should be accomplished via at-sea training or the existing radar simulators.

From the analysis of the identified cadet training objectives, the project team believes that the maritime academy shiphandling simulator should have a low fidelity radar presentation with at least the following capability:

[1] An auxiliary view is a secondary screen display other than the normal visual scene to present relevant visual information, normally available at-sea but not available in the simulated visual scene due to design constraints.

- Sixteen inch diameter plotting surface mounted at an appropriate angle and height for normal commercial shipboard utilization.

- Display to cover 360 degrees in bearing about ownship.

- Multiple range scales (24 nm, 12 nm, 6 nm, 3 nm, 1.5 nm).

- Range measurement in nautical moles and bearing measurement in gyro bearings should correlate with the visual scene to within the accuracy specified by the Inter-Governmental Maritime Consultative Organization for shipboard navigational radars (i.e., range error not greater than 1.5 percent of the range scale in use; bearing error not more than ±1 degree) (IMCO, 1976). These accuracies should be maintained over the duration of the largest anticipated scenario (e.g., 3 hours).

- Provision to manually select contacts for range and bearing measurements

- Provision to manually select either north-up presentation or heading-up presentation

- Provision to manually adjust the display brightness within a tolerance acceptable to an experienced mariner

- Simultaneous display of 15 contacts such as, traffic vessels and aids to navigation including racons.

- Coastline generation capability of six designated geographic areas to a level of information detail acceptable to an experienced mariner as equivalent to that provided by a standard commercial shipboard radar under at-sea conditions. This may be achievable via line image drawing of the coast line. It should be noted that (1) since ownship will not approach any closer than 2 nautical miles to land, and (2) high density traffic situations in confined waters are not envisioned, the project team sees no justifiable requirement for line of sight considerations (e.g., masking) to be incorporated into the cadet shiphandling simulator.

- Provision for the instructor to adjust the amount of noise (e.g., rain clutter and sea return) prior to and during the simulator exercise is desired but not required. The development of radar signal evaluation skills under noise conditons should be developed either at sea or via the existing radar simulator training. Radar noise in scenarios on the full mission simulator is desirable as one additional means of adjusting scenario complexity utilizing common operational distractions.

- Manual tasks associated with shifting range scales, determining range and bearing to selected contacts, selecting north-up versus heads-up presentation, etc., should be equivalent in complexity and duration to the performance of those same tasks on a standard commercial shipboard radar under at-sea conditions, but not necessarily duplicate the precise controls.

3.3.8 BRIDGE CONFIGURATION

Guideline Summary: The physical characteristics of the simulated bridge and the hardware located on same are related to a certain degree to the specific training objectives to be accomplished. In addition, it is important that 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 for two reasons. First, abnormal pilothouse layouts may introduce extraneous factors into the training process that could reduce the likelihood of training transfer to the at-sea situation. Second, it may detrimentally affect the trainee's confidence in the simulator and hence his motivation during the training program (Hammell, Gynther, Grasso, and Gaffney, 1981). The three levels of pilothouse fidelity identified and discussed by the guidelines are (1) reduced bridge, (2) full bridge, and (3) replication bridge. The reduced bridge configuration is substantially smaller than an actual bridge and ocntains only essential equipment. The full bridge is a full size pilothouse and contains the majority of hardware normally found on similar vessels at sea. The replication bridge is an exact duplicate of the pilothouse for a specific vessel class.

Estimated Cost Ratio:

Reduced Bridge	Full Bridge	Replication Bridge
0.7	1.0	1.7

Recommended Level: Full Bridge

Rationale: The replication of the pilothouse of a specific vessel is not warranted for the training of cadets. Since the graduates of the maritime academies initially report to, and may eventually serve on, a multitude of vessel types, the pilothouse of a cadet simulator should be representative of a variety of standard commercial ship bridges. At the low end of the spectrum, the reduced bridge does not appear desirable for cadet training due to (1) the lack of physical space in the pilothouse for a cadet bridge team to operate, (2) the danger that irregular behavior may result from training in an abnormal pilothouse layout, and (3) the danger that the low fidelity pilothouse environment may reduce the cadets' motivation during training.

From the analysis of the identified cadet training objectives, it is believed that the maritime academy shiphandling simulator should have a pilothouse that meets the following functional requirements.

Size

It is desired that the pilothouse for the cadet simulator be a full-size pilothouse or representative of the pilothouses on operating commercial tank vessels of approximately 30,000 dwt subject to the approval of the government. However, recognizing that such a pilothouse will substantially increase the cost of the simulator, only the following minimum dimensions are specified: 3 meters (depth x 4 meters (width). Bridge wings are desired but not required for cadet training.

Equipment

A. Steering Stand. This console should be such that its appearance, design, basic operation, and performance is similar to those units found aboard operating commercial vessels. It should contain as a minimum the following displays and controls:

- Helm
- Helm angle indicator
- Rudder angle indicator
- Gyro compass repeater
- Magnetic compass
- Steering plant selector switch for selection of port or starboard steering system

B. Propulsion Control Panel. This panel should be such that its appearance, design, basic operation, and performance is similar to those units found aboard operating commercial vessels. It should contain as a minimum the following displays a' d controls:

- Pilothouse monitoring displays and larms for main diesel engine

- Pilothouse controls for main diesel engine

- Shaft direction and RPM indicator

- Engine order telegraph unit for engineroom control of main diesel engine

C. Additional Ship Control Indicators. These indicators should be such that their appearance, design, basic operation, and performance is similar to those units found aboard operating commercial vessels. They should be located overhead on the forward bulkhead of the pilothouse or other appropriate locations for deck officer use. These additional ship control indicators should include:

- Rudder angle indicator
- Shaft direction and RPM indicator
- Gyro repeater

D. Electronic Navigation Equipment. The maritime cadet shiphandling simulator suite of electronic navigation equipment should contain the devices listed below. Each device should be such that its appearance, design, basic operation, and performance is similar to those units found aboard commercial operating vessels.

- Speed log
- Echo depth finder
- Radio direction finder
- LORAN C

E. Visual Bearing Capability. A visual bearing circle mounted on a gyro repeater at an appropriate location such that the deck watch officer can observe gyro bearings to selected geographic objects in a manner similar to the at-sea operation (Hammell, Gynther, Grasso, and Lentz, 1981; Gynther, Hammell, and Grasso, 1981). This visual bearing capability should be designed and constructed such that the visual bearings obtained to selected geographic objects in the visual scene are within ±0.5 degree to the true bearings of the objects (assuming 0 degrees gyro error).

F. Digital Clock. To provide an indication of exercise problem time in units of hours, minutes and seconds under automatic control. The digital clock shall be initialized to the starting time of an exercise and shall be controlled during the run and freeze modes automatically.

G. Chart Table Facilities. One chart table with a surface area of approximately 55 by 42 inches should be provided in the pilothouse. It should be covered with an appropriate plotting surface material. Provision for either low level white or red illumination should be included. This lighting system should be adjustable and be controlled separately from the rest of the pilothouse. Provisions should also be made for storage of various plotting instruments and at least 50 nautical charts.

H. Navigation Status Board. A status board approximately 24 by 36 inches should be provided for various navigation/collision avoidance information. The board should be suitable for grease pencil entries and include low level red illumination.

I. Radiotelephone Equipment. A multichannel VHF transceiver, or an equivalent simulated device, should be provided in the pilothouse and interconnected with the instructor/control station. The unit should include a handset or microphone with a push to transmit button, a loudspeaker within the console mounted unit with volume control and on/off switch. As a minimum, the following channels should be available: 6, 8, 12, 13, 14, 16, 22A, WX1. Operation of the transceiver unit at the *instructor/control* station is discussed later in this report.

J. Internal Shipboard Communications. At least one intercom unit should be provided in the pilothouse, preferably mounted in the principal bridge console. The pilothouse intercom unit(s) should be connected to the instructor/control station. It should contain a handset or microphone with functional push to talk button; loud speaker mounted in the unit with volume control; on/off switch; and station selector switch for captain's quarters, engineroom, public address, and other shipboard locations.

K. Ship's Whistle. An appropriate lever for manual control of ownship's whistle should be located on the principal bridge console. The audio characteristics of ownship whistle should meet the requirements specified in the **Navigation Rules** (CG-169) for a vessel greater than 75 but less than 200 meters in length.

L. Traffic Ship Whistles. An appropriate simulation of traffic ship's whistles should be provided within the pilothouse environment. The frequency (related to vessel size in CG-169), relative bearing, and intensity (related to traffic vessel range) should be controllable from the instructor/control station.

M. General Emergency Alarm. An appropriate lever for manual control of ownship's general emergency alarm should be located on the principal bridge console. The audio characteristics of this alarm should meet U.S. Coast Guard requirements.

Equipment Layout

The arrangement of the bridge equipment described above within the confines of the pilothouse should be accomplished, according to standard shipboard practice for operating commercial tank vessels of approximately 30,000 dwt subject to the approval of the government. The physical wheelhouse should be of solid construction and provide satisfactory support of the ceiling with its ambient lighting units. The bulkheads should provide satisfactory support for the mounting of the various bridge equipment.

3.3.9 OWNSHIP CHARACTERISTICS AND DYNAMICS

Guideline Summary: As with the other critical characteristics of a shiphandling/navigation simulator, the sophistication of the required maneuvering response is related to the specific skills to be developed during the trainig program. The guidelines identify three levels for this characteristic: (1) deep water, (2) shallow water, and (3) special effects. The deep water hydrodynamic level 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. The shallow water hydrodynamic level includes the above capabilities in addition to appropriate shallow water modifications and corresponding water depth data bases of the particular geographic areas modeled. Low speed (e.g., 2 knots) may also be available. The third and most sophisticated hydrodynamic level includes all the previously mentioned capabilities plus bank effects, passing ship effects, tug forces, reverse motion, kick effect, bow thrusters, and anchor forces.

Estimated Cost Ratio:

Deep Water	Shallow Water	Special Effects
1.0	1.5	3.0

Recommended Level: Deep Water

Rationale: Inspection of the effectiveness chart, Table A-3, reveals that the deep water hydrodynamic model could be employed to effectively train the majority of the training objectives. Only three of the 34 training objectives identified as being trained "best" via the simulator received an effectiveness rating of below 80 percent with the deep water capability. One of these training objectives (89) requires a water depth data base when utilizing a line of soundings to assess the accuracy of other navigational information. The water depth data base capability was included under the shallow water hydrodynamic level due to its association with the calculation of the shallow water effect. It could easily be developed with the deep water model in order to satisfy the requirements of this training objective. This alteration may also improve the effectiveness of several other training objectives which require sounding data. The only two training objectives remaining are the training objectives dealing with shiphandling. It is the opinion of the project team that the effect of shallow water should be considered for training via other training media (e.g., classroom, small vessel) and that the additional expense for shallow water capability only be incurred if revenue-producing training involving senior mariners is envisioned.

Based on a review of the training objectives, it is recommended that the hydrodynamic model capability for the maritime cadet simulator meet the following functional requirements:

- Deep water hydrodynamic coefficients for at least the following vessels under a variety of load and trim conditions should be operational in the simulation model:
  - 30,000 dwt tanker
  - 80,000 dwt tanker
- The aerodynamic and hydrodynamic coefficients for these vessels are available from the Computer Aided Operations Research Facility (CAORF), Kings Point, New York
- Aerodynamic coefficients for these same vessels under a variety of load and trim conditions should also be operational in the simulation model.
- The construction of the simulation model should be such that the CAORF coefficients for these vessels and any additional vessels specified by the government are compatible for operation in the model.
- The performance of the simulation model should be such that it is within ±1 percent of the CAORF model's performance over a wide range of wind and current conditions for the following maneuvers:
  - Turning circle
  - Zig-zag maneuver
  - Crash stop
- Shallow water effects are desirable, but not required in the simulation model. Shallow water coefficients for the vessels listed above are also available at CAORF.

3.3.10 EXERCISE CONTROL

Guideline Summary: 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 the system. The three levels of this capability identified by the guidelines document are (1) exercise selection for which the instructor's control of the exercise is limited to the initial selection of the training scenario; (2) instructor preprogrammed exercise control which allows modification of a scenario at the time of selection; (3) instructor exercise control which encompasses all the capabilities discussed above plus the capability of modifying a scenario durings it conduct.

Estimated Cost Ratio:

Exercise Selection	Instructor Preprogrammed Control	Instructor Exercise Control
1.0	1.2	1.5

Recommended Level: Instructor Exercise Control

Rationale: Instructor preprogrammed control would probably suffice for the majority of maritime cadet training objectives (Table A-3). However, since traffic vessel control is critical as discussed in 3.3.11, the instructor exercise control level of sophistication is recommended (Hammell, Gynther, Grasso, and Gaffney, 1981). This capability will also assist the instructor in timing the occurrence of shipboard casualties such as loss of steering, loss of propulsion, etc. Instructor control of wind, current, and other scenario parameters, during the exercise is not required although it is desirable for the instructor to have the capability of modifying these prior to the exercise. The principal reason for this would be that the proper structure, geometry, complexity, etc., for each training scenario would have to be designed into the system initially or the services of an appropriate contractor procured to refine the scenarios after the academy has some experiece with the system. The academy staff would probably not have the computer programming expertise to modify the scenarios themselves if appropriate user access is not considered during system development. This capability would allow the academy's instructional staff to modify the scenarios either prior to each training exercise or at periodic intervals during the life of the system.

Based on a review of the identified training objectives, the following functional requirements are recommended for the exercise control capability of the maritime adet simulator.

- The user access to the maritime cadet simulator should be designed such that members of the Nautical Science Department staff at the various maritime academies can effectively operate the system after one day of instruction. The system itself should not require any additional personnel resources to support the single instructor required for the conduct of training.

- The user access to the maritime cadet simulator should be designed such that members of the Nautical Science Department staff at the various maritime academies can develop and modify training scenarios after two days of instruction.

- The user access to the maritime cadet simulator should include the capability to accomplish the following operations prior to the commencement of a training exercise:

  – Select or modify the geographic gaming area for the exercise. Data bases for at least one open sea and six coastal gaming areas should be available. The specifications for the coastal gaming areas should be provided by the government. In no case should ownship be located within 2 nautical miles of the landmass.

  – Select or modify ownship type and loading condition. See section entitled "Ownship Characteristics and Dynamics" for additional information on ownship types and loading conditions.

  – Select or modify the number and type of traffic vessels. At least four types of traffic vessels should be available; specifically tanker, cargo ship, fishing vessel, tug and tow. The capability of developing other traffic vessel navigational lighting configurations should also be available.

  – Select or modify ownship or traffic vessel locations within selected gaming area with an accuracy of 0.001 nautical miles.

  – Select or modify ownship or traffic vessel initial course and speed. The course accuracy should be 1.0 degree and the speed accuracy should be 0.5 knots.

  – Select or modify traffic vessel course and speed alterations at preselected times within the scenario. The course accuracy should be 1.0 degree and the speed accuracy should be 0.5 knots. The user should also be able to adjust the rate of the specified course and speed alterations in addition to determining the final value.

  – Select or modify wind direction with an accuracy of 1.0 degree and wind magnitude with an accuracy of 1.0 knot.

  – Select or modify current direction with an accuracy of 1.0 degree and current magnitude with an accuracy of 0.5 knots.

  – Select or modify water depth grid with an accuracy of 1.0 feet. The size of elements in the water depth grid should be contained in the specifications for the coastal gaming areas.

  – Select or modify the location and characteristics of key aids to navigation within the coastal gaming area. Location accuracy should be at least 0.001 nautical mile. As regards light characteristics, ten flash patterns representative of those contained in the **U.S. Light List** should be available. The user should also be able to determine the intensity of the light, its color, its visible sector, its height and its meteorological range of visibility.

- The user access to the maritime cadet simulator should include the capability to accomplish the following during the scenario exercise: (a) alter the course and speed of any traffic vessel and (b) initiate the occurrence and timing of the several ship casualties: loss of steering engines, loss of propulsion power, loss of shipboard electrical service, loss of gyro compass, loss of radar, and erroneous readings from various electronic navigation equipment.

- The user access to the maritime cadet simulator should include the capability of freezing the exercise at any time and then restarting it.

- The user access to the maritime cadet simulator should include the capability of terminating the exercise at any time and commencing a second exercise. The system should be designed such that the time from termination of one exercise to the commencement of a second exercise is less than 1 minute if no instructor modifications are performed.

- The user access to the maritime cadet simulator should be such that a single properly trained member of the Nautical Science Department can light off, calibrate and adjust the system for training within thirty minutes. It should take this same individual no more than ten minutes to properly secure the system.

3.3.11 TRAFFIC VESSEL CONTROL

Guideline Summary: This characteristic refers to the amount of control that the instructor has over the selection, position, courses, and speeds of the 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, the guidelines discuss it separately. Four levels of traffic vessel control are identified: (1) canned traffic, (2) preprogrammed traffic, (3) independently maneuverable traffic, and (4) interactive bridges. Canned traffic describes the capability in which the instructor can only select traffic vessel motion from a limited number of tracks prior to the scenario. Preprogrammed traffic describes the capability in which the instructor can select any traffic vessel motion that he desires prior to the scenario. Under both canned traffic and preprogrammed traffic, the instructor cannot alter the course and speed of the traffic vessel during the scenario regardless of the interaction with ownship. This may at times result in unusual situations. However, the instructor can use such situations to demonstrate the sometimes *irregular behavior* observed at sea. The independently maneuverable traffic capability provides the instructor with the opportunity to alter traffic vessel motion during the exercise in addition to the initial set-up. Fin_ the interactive bridge capability involves the use of two (or more) simulated ownships each controlled from its own pilothouse to interact in the same gaming area.

Estimated Cost Ratio:

Canned	*Preprogrammed*	Independent	Interactive
1.0	1.2	1.5	40

Recommended Level: Independently Maneuverable Traffic

Independently maneuverable traffic control appears to be required for a maritime cadet simulator because it is necessary to effectively train the proper utilization of radiotelephone information during collision avoidance maneuvers. The canned and preprogrammed traffic control capabilities have a serious limitation in this area (Hammell, Gynther, Grasso, and Gaffney, 1981). Specifically, the traffic vessel does not respond to the agreement made via radiotelephone unless it happens to be the same as that which is entered into the simulation prior to the exercise. This may be beneficial in that it reinforces that traffic vessel motion should be monitored closely even after a radiotelephone agreement. However, it also increases the risk that the cadet will neglect to utilize the radiotelephone since the traffic vessel will do what it is programmed to do regardless of the communications. The project team believes that the capability to alter traffic vessel motion during a scenario is important in order to add at-sea credibility to the simulation for the above mentioned skill development and to prevent false trainee impressions concerning traffic vessel motion at sea. Proper instructor use and interpretation is critical to ensure effective training even with the independently maneuverable traffic control capability.

The specific functional requirements for the traffic vessel control capability of the maritime cadet simulator are outlined in the previous section, "Exercise Control." It should also be noted that traffic vessel response to course and speed changes should be in accordance with a simplified math model. Approximate handling characteristics are acceptable for traffic vessel response during cadet training.

3.3.12 TRAINING ASSISTANCE TECHNOLOGY

Guideline Summary: 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 (Gynther, Hammell, and Grasso, 1981; Hammell, Manning, and Ewalt, 1979). The "Guidelines for Deck Officer Training Systems" identifies and discusses four types of training assistance technology: (1) remote monitoring, which provides the opportunity for students not participating in the exercise to observe action at another location where the instructor can provide a more comprehensive evaluation without disturbing the on-watch bridge team; (2) feedback displays, which provide appropriate computer-generated graphic analysis of key scenario variables to assist the instructor in explaining not only **what** happened, but **why** it happened; (3) instructor alerts/prompts which provide the instructor with beneficial visual or audio cues at critical points in the scenario in order to reduce the instructor's burden during training and result in more standardized instruction; and (4) training management technology which involves the computer's capability to store and analyze trainee performance at critical points within the training program in order to evaluate the effectiveness of both the training program and individual instructors.

Estimated Cost Ratio:

Remote Monitoring	Feedback Displays	Instructor Alerts Prompts	Training Management Technology
1.5	1.0	0.3	0.7

Recommended Levels: Remote Monitoring, Feedback Displays

Rationale: In contrast to the other characteristics, selection of one level does not prohibit the selection of other levels since the training assistance technology features discussed above are complementary to each other. It is recommended that a maritime cadet simulator have a remote monitoring capability for two principal reasons. First, it allows class size to be increased without causing crowding in the pilothouse. This is critical when attempting to provide a relatively large number of cadets with the benefits of simulator training. Second, remote monitoring gets the instructor off the bridge allowing the cadets to have an appropriate sense of responsibility for the watch. This is an important benefit of simulator training over watchstanding during at-sea training where the responsibility remains with the licensed deck officer.

It is also recommended that the maritime cadet simulator include at least a basic feedback display capability. Research has indicated that substantially greater training effectiveness occurs when cadets are provided with this type of information during the critique session (Gynther, Hammell, and Grasso, 1981). 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. It should be noted that the basic feedback display is more than merely a feedback display. Rather, it must contain a variety of supporting software programs to generate the appropriate information for feedback, as well as information to be used during prebriefing sessions and general classroom sessions. The appropriate view of the feedback display is that of an automated classroom capability, backed up by a fast-time model program and appropriate displays (Hammell, Ewalt, Hayes, and Henry, 1980; Hammell, 1981).

Based on a review of the identified training objectives, the following functional requirements are recommended for the remote monitoring capability.

- Parallel radar monitoring display at least 16 inches in diameter. This system may be simply an electronic slave to the radar system in the pilothouse.
- Low light level, wide angle, closed circuit T.V. system, or government approved equivalent system, for monitoring the actions of the personnel on watch in the pilothouse.
- Audio monitoring system for monitoring the conversations of the personnel on watch in the pilothouse. The design and sensitivity of this system should be such that it picks up and transmits conversations of normal intensity levels which occur within the confines of the pilothouse.
- T.V. monitors placed in parallel with the visual simulation projectors, or government approved equivalent system, for monitoring the simulated visual scene observed by personnel on watch in the pilothouse.
- Radiotelephone transceiver of similar construction and operation as described for the pilothouse unit under "Bridge Configuration." This system composed of the pilothouse and classroom units, should be configured to allow the instructor or selected members of the off watch bridge team to simulate traffic vessel VHF communications with the cadets on watch in the pilothouse.
- Internal ship communications panel of similar construction and operation as described for the pilothouse unit under "Bridge Configuration." This system, composed of the pilothouse and classroom internal ship communications panels, should be configured to allow the instructor or selected members of the off watch bridge team to simulate communications with the cadets on watch in the pilothouse from several shipboard stations (e.g., Captain's cabin, engineroom).

- Traffic vessel whistles described under "Bridge Configuration" should be capable of being controlled from the remote station.

- Control of the simulation in accordance with the various functional requirements described under "Exercise Control" should be capable of being accomplished from the remote station.

- Equipment or functional capabilities described above should be controlled from an appropriately designed console, located in a classroom that comfortably accomodates at least 12 students. This console should have plotting surfaces of sufficient area to layout three nautical charts.

Based on a review of the identified training objectives, the following functional requirements are recommended for the feedback display capability:

- Projected image of feedback display at least 3 feet by 3 feet and situated in the classroom such that it is easily readable by the instructor and all students.

- Feedback displays should be developed for each of the following generic types of training scenarios: collision avoidance, piloting, shiphandling. The format of each generic feedback display should be approved by the government prior to incorporation into the training system.

- These feedback displays should have (1) the capability of presenting historical data of key situation parameters and of relating these to ownship performance in the previous scenarios and (2) the capability of presenting the impact of alternative, hypothetical ship control actions on these key parameters; the software should facilitate easy modification of the feedback display formats.

- A fast-time model capability should be available to generate problem scenarios in the classroom, and the alternative action tracks noted above; this model should generate the necessary situation, ownship, and traffic vessel information used for feedback.

- Generation of a variety of performance measures (e.g., CPA, swept width in the channel) during the exercise for later feedback in the classroom, and during investigation of alternative actions in the classroom; this simulator software should have the capability for easily modifying the performance measures.

- All operationally related situation, ownship, and traffic vessel parameters (e.g., speed, heading, rudder angle, ranges, and bearings to other vessels) should be recorded during the exercise for later classroom feedback; the recording time increment should be at least every 30 seconds.

- These feedback displays should utilize color as appropriate to highlight critical concepts on the display.

- These feedback displays need **not** be used simultaneously with the simulator. Their utilization is planned for the post-exercise critique session.

- The feedback displays should be controlled by the single instructor without significant interruption to the training process/discussion within the classroom. The user access for the feedback displays should be such that a member of the Nautical Science Department staff can effectively use the system after one day's instruction.

3.3.13 AVAILABILITY

Although the academies may have found their radar simulators to provide few availability problems, they are cautioned that this may not be the case with a shiphandling simulator due primarily to its substantially greater complexity. Various precautions should be taken during design and maintenance to minimize simulator downtime. However, in spite of precautions some unprogrammed downtime may be experienced and contingency lesson plans should be prepared to maximize the training benefit to be received from a degraded system. The "Guidelines for Deck Officer Training Systems" identifies and outlines the considerations that should be taken for three general levels of shiphandling simulator availability. These levels are (1) moderate availability, (2) high availability, and (3) very high availability. The level of availability that appears most appropriate for maritime cadet training is the "moderate availability" level, which should be designed to meet the functional requirements described below. It may be appropriate to upgrade these requirements if the facility is to be utilized for senior mariner, revenue-producing training in addition to cadet training.

- The design goal for the maritime cadet simulator should be that the simulator is operational for training 30 hours per week with 95 percent availability. The remaining 10 hours per week are available for maintenance. The system should be designed such that it takes considerably less than 10 hours per week to properly maintain it. The maritime cadet simulator should be considered operational for training when it can be effectively utilized for the conduct of specific training that has been scheduled for a particular class period.

- The contractor should design and construct the training system using hardware and procedures associated with best commercial manufacture.

- The contractor should train one technically oriented member of the Nautical Science Department selected by the particular academy to perform routine maintenance, diagnostic troubleshooting, and repair such that this individual can correct 90 percent of the casualties within 1 hour. This training should not exceed 2 weeks duration.

- The contractor should provide at least three copies of an appropriate maintenance, troubleshooting, and repair manual. This manual should be written for the individual described above.

- The contractor should conduct an appropriate analysis to identify spare parts for high usage or critical components to the satisfaction of the government. The level of spares should be such that the other requirements stated in this section are accomplished.

- The contractor should provide the identified inventory of these spare parts when the system is delivered. The cost of these spare parts should be negotiated as part of the initial system procurement.

- The contractor should provide an appropriately qualified repairman onsite during actual training for the first semester (16 weeks) of operation. The cost of this individual should be negotiated as part of the initial system procurement.

- The contractor should obtain for the government during the first year of operation an appropriate service contract with the manufacturer of the simulation computer. The cost of this service contract should be negotiated as part of the initial system procurement.

3.4 SUMMARY OF FUNCTIONAL REQUIREMENTS

One goal of this phase of the Training and Licensing Project has been the development of a functional specification for a maritime cadet simulator. Table 6 contains a summary of the functional requirements identified and discussed above in Section 3.3. For additional details, including the rationale for the selection of the principal simulator characteristics, the reader is referred to that section of the report.

As regards this functional specification, several points should be noted. First, this is a functional specification, not an engineering design specification. Its purpose is to identify the characteristics and their levels of fidelity required in the design of a cost-effective simulator for training maritime cadets, not **how** to meet these requirements with a specific engineering design, although "current design practice" guidance as regards several elements of the training system is provided. This functional specification, for example, informs the reader that a horizontal field of view of at least 180 degrees is required for cadet training. It does not describe the construction, manufacture, or mounting of the visual scene screen, since these details would constitute an engineering specification. It is possible for MarAd or the various state academies to utilize this functional specification to commence the procurement process with contractors responding with engineering proposals to meet these identified requirements. On the other hand, it may be desirable for MarAd or the various state academies to develop an engineering specification prior to requesting bids from potential contractors. Each approach has its advantages and disadvantages. It is recommended that MarAd or the academies carefully evaluate the options with contract/legal personnel who are familiar with the procurement of similar technological systems.

Second, this functional specification was designed for training maritime academy cadets in the development of the specific skills identified in Table 3. It is **not** a panacea for cadet training. Other training media, particularly at-sea training, are still required for the achievement of many training objectives as discussed in Section II. The purpose of the shiphandling/ship bridge simulator training is to enhance and supplement, not replace, other traditional training media. Table 7 indicates that none of the identified cadet training objectives can be achieved 100 percent via the shiphandling/ship bridge simulator. For many training objectives, such as "The trainee shall be able to maneuver ownship to pass at a safe distance, according to the procedures outlined in the Rules of the Road and the master's standing/night orders . . . ," at-sea training is still required to completely achieve these objectives under (a) daytime conditions and (b) actual at-sea conditions. The shiphandling/ship bridge simulator, by achieving these training objectives to the 70 percent, 80 percent, or 90 percent level, will allow the limited at-sea training time to be more

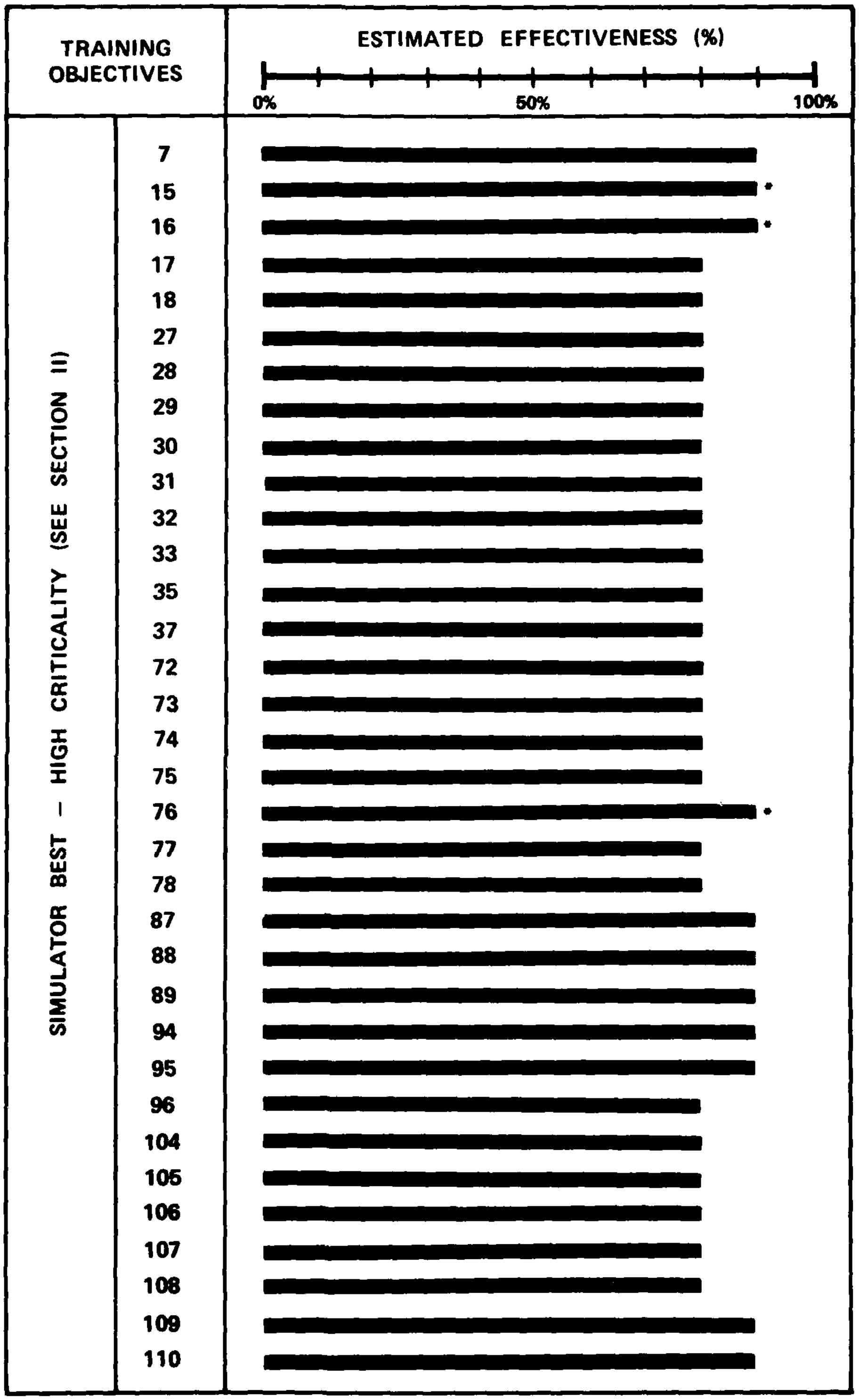
TABLE 6. SUMMARY OF FUNCTIONAL REQUIREMENTS FOR MARITIME CADET SIMULATOR

Critical Characteristic	Recommended Level	Additional Comments
1. Visual Scene		Day desirable but not required
• Time of day	Night only	Simultaneous display of: • 5 traffic vessels • 6 coastal navigation lights Background/cultural lights as appropriate for realism Silhouettes desirable but not required
• Geographic area	Coastal	Land mass > 2.0 nm distant Traffic vessels: close aboard
• Horizontal field of view	At least 180 degrees	
• Vertical field of view	At least 20 degrees	
• Color	Multi-color	
• Visual scene quality	No undesired visual effects adequate realism to accomplish training objectives	Evaluated by panel consisting of several mariners, simulation and training experts Use of binoculars not required
2. Radar Presentation	Low fidelity	Synthetic presentation 16-inch plotting surface 15 contacts (e.g., traffic vessels, aids to navigation) Coastline generation of six selected geographic areas Normal radar functions CAS functions not required Noise desired but not required
3. Bridge Configuration	Full bridge	Desire full-size pilothouse; 3M (depth) x 4M (width) minimum dimensions Gyrocompass repeaters Steering stand Propulsion control panel Visual bearing capability Speed log Depth sounding device RDF Loran-C Digital clock Chart table Radiotelephone Internal shipboard communications Ownship/traffic ship whistles
4. Ownship Characteristics and Dynamics	Deep water	Hydrodynamic model compatible with CAORF coefficients Shallow water effects desired but not required Wind and current forces required

TABLE 6. SUMMARY OF FUNCTIONAL REQUIREMENTS FOR MARITIME CADET SIMULATOR (Continued)

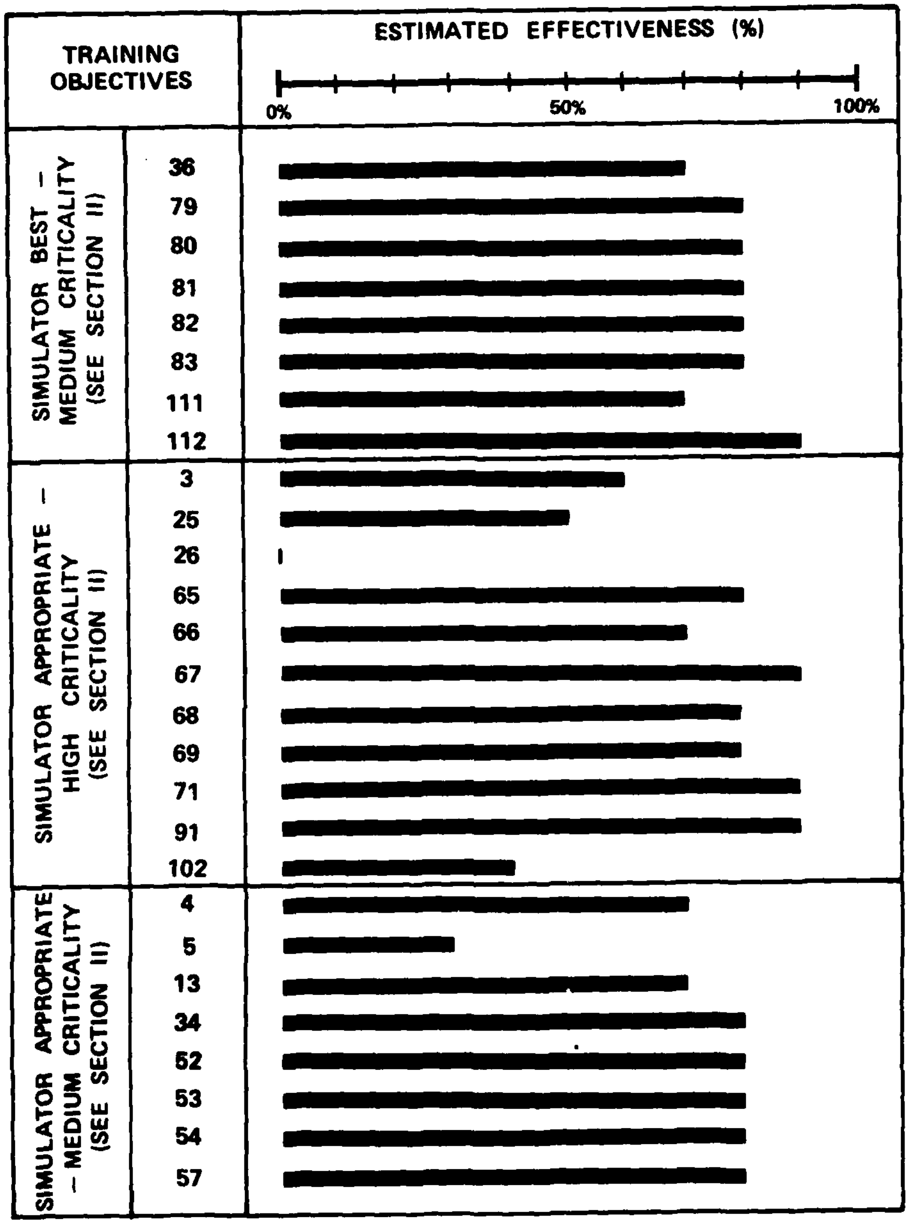
Critical Characteristic	Recommended Level	Additional Comments
5. Exercise Control	Instructor exercise control	Capability to select exercise Capability to modify exercises prior to initiation Capability to alter traffic vessel motion during exercise Capability to initiate shipboard casualties during exercise Capability to freeze and restart exercises Instructor: sole system operator
6. Traffic Vessel Control	Independently maneuverable traffic	Capability to alter traffic vessel motion prior to initiation of exercise Capability to alter traffic vessel motion during exercise Traffic vessel characteristics and dynamics – simplified math model – approximate handling characteristics
7. Training Assistance Technology	Remote monitoring	Located in classroom Slave radar presentation Close circuit TV system Audio monitoring system Visual scene monitors Radiotelephone Internal ships communication Traffic vessel whistle control Simulation control
	Feedback displays	Located in classroom Minimum 3′ x 3′ screen Multi-color projection Three generic displays ● Collision avoidance ● Coastal navigation ● Shiphandling Presents selected ship parameters recorded during exercise in graphic format Presents impact of alternative ownship actions Generates performance measures Generates fast-time model in classroom Hardcopy plotter desired but not required
8. Availability	Design goal: Operational training 30 hours per week with 95% availability; 10 hours per week maximum maintenance time	Best commercial manufacture One onsite technician from Academy staff Contractor to train Academy technician Maintenance/repair manual Spare inventory negotiated during initial procurement Contractor to provide one qualified technician onsite for first semester Service contract for simulator computer

TABLE 7. ESTIMATED EFFECTIVENESS OF FUNCTIONAL SPECIFICATION IN ACHIEVING IDENTIFIED TRAINING OBJECTIVES



* NOTE: ASSUMES EXISTING RADAR SIMULATOR UTILIZED AS PART TASK TRAINER.

TABLE 7. ESTIMATED EFFECTIVENESS OF FUNCTIONAL SPECIFICATION IN ACHIEVING IDENTIFIED TRAINING OBJECTIVES (Continued)



effectively utilized in refining and adapting these skills to the at-sea environment. The addition of a shiphandling/ship bridge simulator to the maritime academy's repertoire of available cadet training media will, therefore, undoubtedly upgrade the proficiency of maritime academy graduates, particularly if the at-sea training time remains at the same level.

Third, Table 7 also indicates that although the cadet training objectives identified in Section II as "simulator best – high criticality" were employed as the simulator design goals, this training device will also be able to be effectively utilized to achieve many of the training objectives previously identified as either "simulator best – medium criticality," "simulator appropriate – high criticality," and "simulator appropriate – medium criticality." In fact, economics would dictate the utilization of the simulator for many of these secondary training objectives, once MarAd or a particular maritime academy made the investment and obtained such a training device. All other cadet skills should continue to be developed utilizing the traditional methods.

Lastly, this functional specification was not designed for training senior mariners. If the training of senior mariners as a revenue producing activity is desired, it is anticipated that the simulator described in this report will have the capability of training a number, but not all, identified senior mariner training objectives. The interested reader is referred to the Training and Licensing Project report "Guidelines for Deck Officer Training Systems" in order to make an appropriate assessment of this functional specification's potential for senior mariner training.

3.5 PROCUREMENT STRATEGIES

Shiphandling/ship bridge simulators are expensive training devices to procure, operate, and maintain. MarAd's past efforts to obtain funds for the procurement of several of these simulators through the budgetary process have not been successful. It appears that a principal reason for this difficulty is the magnitude of the funds necessary for initial acquisition – several million dollars for each simulator. Annual operating and maintenance funds are also difficult to obtain but these may be less of a problem due to the smaller magnitudes of funds involved and the potential of other revenues to contribute significantly to the reduction of this cost.

In the present budgetary climate, it is forecast that authorization of these funds for cadet simulators, particularly the initial acquisition funds, will continue to be difficult. Since the integration of simulator-based training appears to be a vital step in ensuring high standards of deck officer proficiency for maritime academy graduates, every effort has been made to hold down the cost of the simulator previously described. In this section of the report, the costs associated with the cadet simulator have been estimated, alternative procurement strategies have been identified and discussed, and appropriate recommendations have been made in order to make simulator training for cadets a reality.

- **Simulator Costs.** In order to estimate cadet simulator training costs, the functional requirements developed were reviewed by a number of individuals on the CAORF staff, who were recognized as knowledgeable in this area. Based on their input the following estimates appear to be appropriate for the maritime cadet simulator described in this report.

- Initial System Procurement

Lowest possible cost	=	$1.5M
Highest possible cost	=	$3.5M
Most likely cost	=	$2.7M

The above figures are provided in 1982 dollars. They assume that a suitable building exists at the specific maritime academy to house the simulator facility. They also assume an appropriate multiple system procurement or the capability of the manufacturer to amortize his development costs. If the manufacturer gears up for a single procurement and has no other vehicle for amortizing all, or a major percentage of, his development costs, these procurement cost estimates may be increased significantly. The lower end of this procurement cost spectrum would reflect a technology similar to a spotlight projection system with a high quality nighttime visual scene (e.g., resolution of 1.0 minute of arc; contrast ratio of 100:1), but a very limited capability for daytime expansion. The higher end of this spectrum would reflect a technology similar to a computer generated image (CGI) system with a lower quality nighttime visual scene (e.g., resolution of 3 minutes of arc; contrast ratio of 10:1) but a much greater capability for daytime expansion.

- Annual Operating/Maintenance

Lowest possible cost	=	$180K
Highest possible cost	=	$320K
Most likely cost	=	$220K

The above figures are provided in 1982 dollars. They assume that the single instructor required for training/system operation and the single technician required for maintenance will be obtained from the academy's existing staff. Several academies indicated that they would require additional personnel resources for the cadet simulator. However, due to the unknown costs of appropriate personnel at each academy and the expected variation between academies, this factor was **not** included in the estimate.

3.5.1 TRADITIONAL GOVERNMENT STRATEGIES

Traditionally when a training device or training service was required, MarAd or the individual state academies have sought authorization of the necessary funds through the budgetary process. These funds were then paid to a contractor who would provide the training device or training service. Each procurement strategy has its advantages and disadvantages. Two alternatives are considered below.

3.5.1.1 Ownership. This strategy provides maximum control of the use of the asset thus allowing the academies maximum flexibility in scheduling the simulator's utilization within the curriculum or modifying the device without the approval of others. However, ownership also has its disadvantages. For example, it ties up large amounts of financial resources in the cost of initial procurement, which could be utilized effectively elsewhere in the curriculum. It also involves the responsibility of operation and maintenance without the additional advantages of ownership available to a private individual or corporation, namely tax advantages.

3.5.1.2 Leasing. This strategy provides use of the asset (i.e., simulator) for a specified period of time for an established annual fee. Although this annual fee is usually greater than the annual operating/maintenance cost associated with ownership, it may be the proper strategy particularly if initial procurement funds are difficult to obtain. Lease financing may also be more advantageous to federal or state government institutions than simply borrowing funds for the initial procurement, because the private individual or corporation who owns the training device can take appropriate advantage of tax credits, depreciation schedules, etc., which are usually not available to government institutions. These savings can then be passed on to the academy. Lease financing is becoming increasingly attractive in the private sector as a means of conserving working capital. Lease financing can be obtained through a lease corporation when the hardware manufacturer does not desire or is unable to enter the business of financing the training device.

Many institutions are involved in leasing computer systems. Appropriate consideration should be given to leasing as a means of obtaining a simulator-based training system for maritime cadet training. MarAd should consider encouraging the design of simulators to incorporate considerations which improve their viability for lease financing. For example, modular construction for easier assembling when the lease period is commenced and easier disassembling when the lease is terminated. Such financing and construction would also have the additional advantage of improving the academy's flexibility to eventually upgrade their system.

3.5.2 ALTERNATIVE GOVERNMENT STRATEGIES

3.5.2.1 Mortgage Insurance. Several academies have seriously investigated the financing of a shiphandling/ship bridge simulator for maritime cadet training. One conclusion that they all have appeared to reach is that either MarAd (or some other government agency) will have to contribute substantial funding or they will have to conduct external training for additional revenues in order to make simulator training for maritime cadets a reality. As regards external training, several academies indicated that a viable external market appears to exist in their locale. However, since they lack firm commitments from their potential external training customers, financial institutions, entrepreneurs, or other sources of capital appear unwilling to accept the risk and invest in such a venture. It should be noted that this venture may be either (a) the academy obtaining ownership of the simulator via an appropriate mortgage, or (b) the academy leasing a simulator from an individual or corporation in the private sector.

One key concept to keep in mind for commercial enterprises is that the rate of return on invested capital is a primary consideration in the decision to undertake any project. A second key concept is that government in the interest of promoting a given activity has the ability to "change the rules." Tax credits, tax deferments, or accelerated amortization schedules reduce the tax cost and theoretically the total cost of the venture. Low interest loans reduce the cost of capital, and hence the total cost of the venture. Long term contracts with guaranteed levels of revenue reduce the risk of the venture making slower rate of return on invested capital over several years more acceptable.

Such incentives to the private sector are not new. For example, accelerated amortization schedules have been employed for defense industries during WW II and the Korean War, and more recently for domestic producers of oil and minerals. The key point is that MarAd should not be constricted in its thinking solely to the appropriation of funds through the budgetary process, but should continue to extensively explore the utilization of other governmental assets in order to provide this vital training.

Given the situation described above, that is, financial institutions, entrepreneurs, or other sources of capital being unwilling to accept the risk involved in a shiphandling/ship bridge venture for maritime cadet training; it may be appropriate that MarAd place its influence not in obtaining funds to procure maritime cadet simulators, but in providing mortgage insurance to cover the external training portion of an appropriately qualified simulator training facility's budget.

The involvement of MarAd in subsidizing new technology that has vital importance to the country as a whole is not new. Most recently in 1980, to support the potential developers/operators of ocean thermal energy conversion facilities, Congress passed Public Law 96-320 which amended the Merchant Marine Act of 1936 to include ocean thermal energy conversion plants as vessels "operated in the foreign commerce of the United States." This then qualified ocean thermal energy conversion facilities to apply for various subsidies, which federal mortgage insurance being specifically identified in the statute. This federal mortgage insurance guarantees to an investor that a facility is economically viable and as such can pay its mortgage premiums even if its revenues do not achieve expectations.

Through Public Law 96-320 the Federal Ship Financing Fund was enlarged from $10 billion to $12 billion with the additional $2 billion earmarked for an Ocean Thermal Energy Conversion Demonstration Fund. Financing for the fund is as follows. Initial allocation of $2 billion. Premiums for insurance and application fees are calculated on a sliding scale depending on the value of the plant. When there are outstanding notes against the Demonstration Fund all proceeds received by the fund go to pay off those notes. Once the balance exceeds total guarantees any excess will accrue to the parent fund (i.e., the Federal Ship Financing Fund).

The express purpose of this act was to encourage industry to participate in the capital intensive, experimental stage of technological development, in this case, the technology of ocean thermal energy conversion. The number of facilities applying for and receiving this aid is limited by law to five. This type of federal mortgage insurance appears to be a suitable model for the situation previously described with simulators for maritime cadet training. Using this model an academy or private corporation would establish a simulator for cadet training, make unused time available for commercial purposes, and have insurance protection in the event that the facility is unable to seel the unused time for commercial purposes. As previously discussed, the maritime academy or private corporation would normally have to take a large risk and may very easily assess that risk as undesirable. Here the government, as in the case of ocean thermal energy conversion facilities, could assist by insuring the venture if it meets certain predetermined requirements.

Once again, the key point is not the federal mortgage insurance program described above, but that MarAd should not be constrained in its thinking solely to the appropriation of funds through the budgetary process, and should continue to extensively explore the utilization of other governmental assets in order to provide this vital training.

3.5.2.2 Mobile Simulator. A mobile cadet simulator may be an attractive alternative to the procurement of permanently installed simulators for the various maritime academies. The principal advantage of a mobile simulator is that it could, theoretically, provide training services to the cadets at several academies during the year in lieu of just one. This would allow the allocation of the cost of the training device over a greater number of cadets, thereby reducing the simulator training cost per individual cadet. However, the specific economic advantages of transporting such a training device from one academy to another in lieu of (a) procuring individual simulators, or (b) transporting students from several academies to a single simulator facility, remain to be established with any degree of confidence. This is due primarily to the uncertainty associated with the costs of design, manufacture, transportation, and operation of an appropriate "mobile simulator." The development of an engingeering specification for such a simulator, based on the functional specification contained herein, appears to be an appropriate vehicle for better understanding the technical risks and true costs associated with this training device.

One should be cautioned that the cost of a mobile cadet simulator is **not** necessarily cheaper than that of a permanent installation. Projectors and computers are sensitive devices. Appropriate precautions should be taken during design and manufacture to reduce the system's vulnerability to periodic transportation hazards. For example, higher quality components which meet ruggedized or military specifications may be required in order to ensure sufficient reliability. This may add substantially to the cost of such a training device depending on the magnitude of the problem.

This report recommends a horizontal field of view of at least 180 degrees for the cadet simulator due primarily to the development of selected cadet piloting skills, where prudent navigational practice emphasizes the importance of obtaining adequate horizontal separation of geographic objects when visually fixing the position of ownship. The technical risk associated with packaging a simulator with this type of horizontal field of view into a mobile van appears moderate to high. This is particularly true if minimal visual scene distortion is required when the visual scene is observed from multiple conning/observation positions within the pilothouse.

Finally, the logistical constraints of coordinating simulator training within a cadet's already intensive schedule is not an easy task at each individual academy. This was indicated as a potential problem during correspondence with several academies. The complexity of these logistics appears to be considerably compounded when this training must be coordinated between several academies. While this is not an insurmountable problem, it warrants further analysis and consideration.

It should also be noted that a mobile cadet simulator probably would not be able to provide the amount of training time to cadets that a more permanent installation at the academy could provide as discussed in this report. This is due primarily to the limited amount of time that it would be available at each individual academy during the year. However, it would probably provide a substantial amount of vital training. In this regard, a mobile simulator does not appear to be the ideal solution for maritime cadet simulator training. However, it is a potentially cost-effective solution. The development of an engineering specification for a mobile simulator would also advance the technological development of a cadet simulabor-based training system that would be suitable for leasing on a more permanent basis as previously discussed.

3.5.3 RECOMMENDATIONS

The preceding discussion is not intended to be an indepth financial analysis of the procurement of a maritime cadet simulator training system. It is intended to provide a broad perspective of several potential alternative procurement strategies which are available today. MarAd and the various maritime academies should consider it as one of several sources of information when they establish their own specific procurement strategies, which may vary from institution to institution. From the project team's analysis, it would appear that the following recommendations are in order:

1. In the present financial environment MarAd and the various state academies should seriously consider leasing a simulator training system in lieu of ownership. A leasing strategy allows the user of the training system to conserve short-term capital resources. It also allows a private individual or corporation to take advantage of ownership benefits, such as tax credits and depreciation schedules, which could be applied to reduce the total cost of the venture.

2. MarAd should not be constrained in its thinking solely to the appropriation of funds through the budgetary process, but should continue to explore the utilization of other governmental assets, such as a federal mortgage insurance program, in order to assist the maritime academies in providing simulator-based training.

3. MarAd should consider investigating the "mobile simulator" concept as (a) a potential alternative to several permanently installed simulators and (b) a means of advancing the technological development of a cadet simulator training system that would be suitable for leasing on a more permanent basis.

SECTION IV

GUIDELINES FOR THE UTILIZATION OF THE MARITIME CADET SIMULATOR

4.1 INTRODUCTION

A training system is more than a shiphandling/ship bridge simulator that enables the practice of tasks to improve deck officer skills (Hammell, 1981). The overall training system should be designed to utilize and enhance the capabilities of the simulator within the training process. Therefore, the structure of the training program and the qualifications of the instructor are also very critical for the achievement of effective training. These non-simulator elements represent factors that are usually overlooked as a result of everyone's natural fascination with a sophisticated shiphandling simulator.

This section of the report addresses guidelines for the utilization of the cadet simulator described in Section III. All maritime academies have had experience with radar simulators, and several have had experience with cargo handling simulators. These past experiences will prove to be very valuable to each academy when they commence the integration of shiphandling/ship bridge simulator training into their curricula. However, there are a number of important differences between a shiphandling/ship bridge simulator and a radar or cargo shiphandling simulator. For example, the shiphandling simulator has the capability of training a substantially greater number of maritime cadet skills than either the radar or cargo handling simulators. With this greater capability, there exists a greater tendency to use the simulator for obtaining experience, and not utilizing it as a powerful tool within an organized training process. This section of the report will highlight and discuss such differences, with recommendations made for appropriate practices relating to cadet training.

Section 4.2 will specifically discuss the integration of shiphandling/ship bridge simulator training into the maritime academy curricula. The organization of the previously identified training objectives into training modules, their sequence with respect to each other, and their schedule within the four-year curriculum will be discussed.

Sections 4.3 and 4.4 will identify and discuss the critical characteristics of the training program structure and instructor qualifications, respectively. Specifically, this section will tailor the information that is presented in the Training and Licensing Project report "Guidelines for Deck Officer Training Systems" for cadet application.

Finally, Section 4.5 addresses a number of the issues associated with the management and operation of a shiphandling/ship bridge simulator training facility. It is interesting to note that some experts estimate a shiphandling simulator as being ten times more complex than a radar simulator, and therefore has several problems which are different than previously experienced with the radar facility.

4.2 INTEGRATION INTO ACADEMY CURRICULUM

4.2.1 SIMILARITIES BETWEEN STATE MARITIME ACADEMY CURRICULA

The curricula of the state maritime academies were compared and common elements identified to form a single baseline from which to make recommendations that pertain to the academies in general. This was accomplished by reviewing course material and developing a schedule of courses over the 4-year program for a representative cadet at each academy (see Appendix B). These schedules were developed from course catalogs and other material furnished to the project team by the academies. They are the project team's interpretation of the course schedule for a representative cadet. It is recognized that at a particular academy the schedule of courses may vary among cadets depending on many factors. The accuracy, or inaccuracy, of these schedules should be viewed solely as to its ability to impact the following observations:

- **Similar Watchstanding Skills.** Each of the state maritime academies appear to be training similar skills. The training objectives identified earlier in this report, which were based on third mate watchstanding tasks, appear to be successfully addressed in the curriculum at each of the academies. It should be pointed out that although the various academies appear to be training similar watchstanding skills, they may not all use the same techniques to accomplish this training.

- **Four Distinct Training Periods.** Each of the state maritime academies appear to have four distinct training periods within their curricula. Traditionally, these distinct training periods have been viewed as the four years within the curriculum: Freshman (4th class), Sophomore (3rd class), Junior (2nd class), Senior (1st class). The project team developed another breakdown of the curriculum into four distinct trainng periods, which appears more appropriate for this analysis. These training periods are:

  – From academy entry to first at-sea period

  – From first at-sea period to second at-sea period

  – From second at-sea period to third at-sea period

  – From third at-sea period to graduation

- **Radar Observer Course.** As most readers are aware, each academy offes a "radar observer course" utilizing its radar simulator training facility. This course is usually given in the junior (2nd class year, however, one academy offers the course to seniors (1st class). The timing of this "radar observer course" is critical because it should be considered a prerequisite course for certain skills on the shiphandling/ship bridge simulator.

- **Already Intensive Cadet Schedule.** During written correspondence and discussions with the various academies, the potential problem of incorporating additional simulator training into a cadet's already intensive schedule was raised by several academies. Most academies agree that simulator training is valuable, but they are uncertain as to the best alternative for accommodating it within the curriculum. Some favor incorporating simulator laboratory periods within existing courses while others feel that there should be a separate simulator training course.

4.2.2 RECOMMENDATION – FOUR TRAINING MODELS

After careful consideration of the similarities identified above and with due respect for the individual state academy's ability to determine the proper means of integrating shiphandling/ship bridge simulator training into their own curriculum, the following guidelines are recommended:

4.2.2.1 Training Module Concept. The academies should consider grouping the training objectives previously identified into four training modules, which are described below. Each training module should consist of a series of simulator exercise periods, approximately 3 hours in duration. The individual academy staff should have the option of either (a) integrating these simulator exercise periods into existing courses as laboratory periods or (b) providing all the simulator exercise periods within each training module as a new course. The individual academy staffs should attempt to follow the sequence and schedule of these training modules as outlined below.

Module #1: Basic Watchstanding

Principal Topics: Bridge Equipment Function and Operations; Lookout Duties and Responsibilities; Helmsman Duties and Responsibilities; Shipboard Terminology.

Critical Training Objectives: 3, 7, 17, 18, 30, 31, 36, 104

Minimum Number of Laboratory Periods: Four 3-hour periods

Comments: Simulator exercises should be conducted prior to the first at-sea training. The topics should first be covered in normal classroom periods. The simulator may be used initially for overview demonstrations to large groups of cadets, giving them a general feel for the bridge, wheelhouse operations, and vessel interactions.

Module #2: Coastal Navigation

Principal Topics: Selected Piloting Techniques; Dead-Reckoning; Visual Position Fixing; Vessel Characteristics; Safe-Vessel Speed; Watchstanding Procedures

Critical Training Objectives: 34, 36, 37, 72, 73, 74, 75, 76, 77, 78, 87, 88, 89, 104, 106, 107, 109, 110

Minimum Number of Laboratory Periods: Each 3-hour periods

Comments: Simulator exercises should be conducted after the topics are covered in normal classroom periods and prior to the second at-sea training period

Module #3: Collision Avoidance

Principal Topics: Relative Motion; Radar Plotting; Application of Rules of the Road; Vessel-to-Vessel Communications; Shiphandling/Emergency Shiphandling; Watchstanding Procedures

Critical Training Objectives: 15, 16, 17, 18, 27, 28, 29, 30, 31, 32, 33, 34, 35, 37, 94, 95, 96, 104, 105, 108, 109, 110

Minimum Number of Laboratory Periods: Eight 3-hour periods

Comments: Simulator exercises should be conducted after the topics are covered in normal classroom periods and completion as a "radar observer course," and prior to the third at-sea training period.

Module #4: Advanced Watchstanding

Principal Topics: All previous topics

Critical Training Objectives: All previous training objectives are assumed to have been achieved as a prerequisite to this module. The principal training objective of this module is the integration of the requisite skills and knowledge to achieve consistent and coordinated shiphandling.

Minimum Number of Laboratory Periods: Four 3-hour periods

Comments: Simulator review problems representatively spanning the breadth of training objectives should be conducted prior to graduation.

4.2.2.2 Training Module Schedule. The training modules identified above should be considered for training within the time periods identified in Figure 2. The simulator training should be related to the types of tasks that the cadet will be performing during his next at-sea period. This sequencing of appropriate simulator training prior to at-sea training should enhance the benefits associated with the at-sea period, the cadet should be provided with the simulator training described in Training Module #1: Basic Watchstanding. Prior to his second at-sea period, he should be provided with the simulator training described in Training Module #2: Coastal Navigation. Prior to his third at-sea period, he should be provided with the simulator training described in Training Module #3: Collision Avoidance. This training module should also occur after the cadet has received the "radar observer course." Finally, prior to graduation, the cadet should be provided with the Training Module #4: Advanced Watchstanding, which provides for integration and an appropriate review of all critical third mate watchstanding skills.

4.3 TRAINING PROGRAM STRUCTURE (CRITICAL CHARACTERISTICS)

As previously noted the structure of the training program should be viewed as a very critical aspect of effective cadet simulator training. The report, "Simulators For Mariner Training and Licensing: Guidelines for Deck Officer Training Systems," provides information on the development of a structured training program. This section of this report amplifies on that information by providing specific guidance for the cadet application. This amplification is based on (a) the experiences gained by the project team in conducting a number of simulator-based training programs, particularly at the cadet level (e.g., Hammell, Gynther, Grasso, and Lentz, 1981), (b) previous training research conducted by members of the project team for the Navy (e.g., Pesch, Hammell, and Ewalt, 1974) and (c) the published literature where cited (e.g., U.S. Navy, DI-H-2102A, 1978).

4.3.1 TRAINING OBJECTIVES

The training objectives associated with the recommended modules address the content of each module, and recommend a sequencing of modules for training (i.e., 1 through 4 in order). This sequencing is based on the broad content of each module with respect to the general academy curriculum organization and at-sea training periods. These training objectives are not developed to the refined level necessary for development and sequencing of instructional activities within each module. To fully develop the training module the instructional staff of each academy must translate these module-level training objectives into more detailed and refined topic-level training objectives in accordance with an appropriate training strategy (e.g., identification of the detailed content to be addressed, the sequencing of the topic learning objectives, the identification of specific exercise objectives, and so on). The topic level learning objectives should be detailed to the extent that they specify each aspect of information and skill to be achieved during a particular hour of training. It should be cautioned, that a general tendency has been observed in simulator-based training for the instructional staff to attempt to achieve many training objectives during each

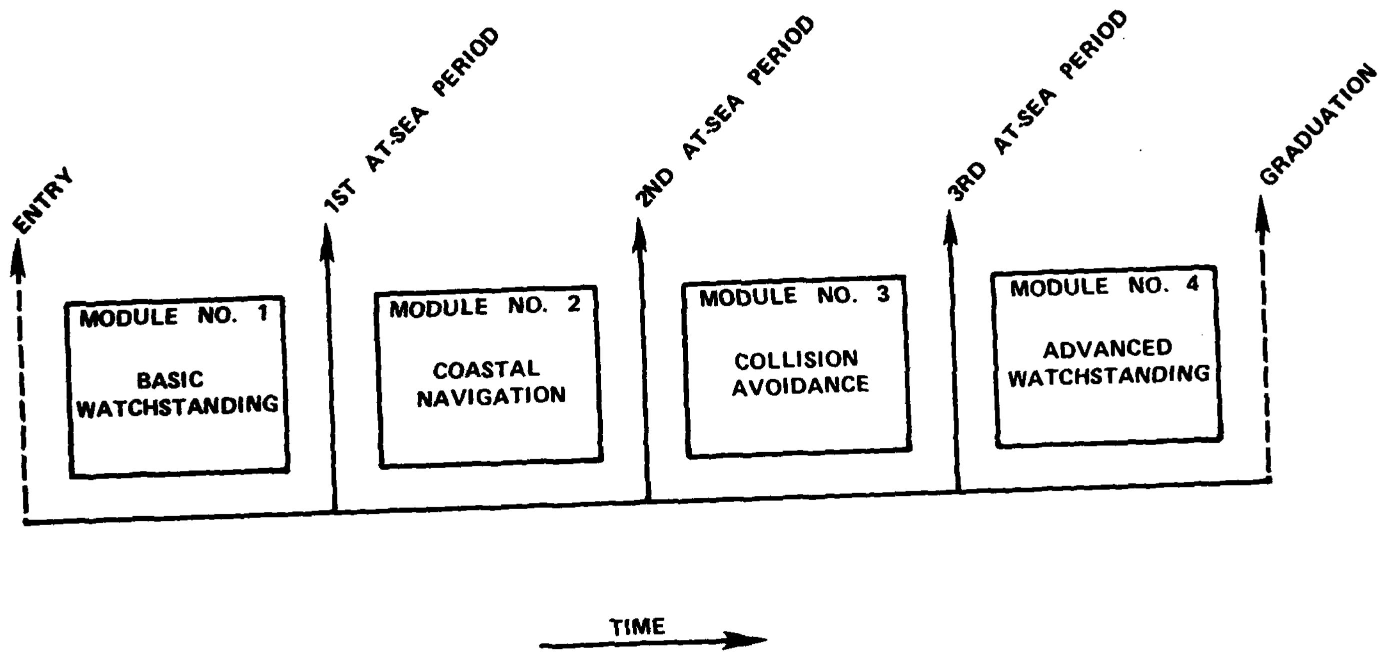


Figure 2. Integration of Simulator Training with Maritime Cadet Curriculum

simulator exercise, since most such exercises present relatively comprehensive encounter situations. It is essential that only those training objectives identified for a particular exercise be focused on during that exercise, even to the detriment of other shiphandling skills. The well designed and effective training program will provide for achieving all the necessary training objectives in the appropriate sequence over the duration of the training program.

4.3.2 TRAINING TECHNIQUES

No single training technique will suffice when conducting simulator-based training programs (Eclectech Associates, Inc., 1981). Multiple techniques are available and their use should be tailored to the characteristics of the particular training situation. As exercises are developed, selection of training techniques should be based upon:

- Cadet skills possessed prior to training
- Desired skills after training
- The training objectives/subject matter addressed
- The time available for training
- Training aid (i.e., simulator) capabilities, limitations and availability
- Overall training cost
- Differences in the effectiveness of available techniques

Although there are a number of training techniques that may be utilized during a cadet simulator-based training program, three of the most relevant techniques are described below.

4.3.2.1 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 and exploration of appropriate solutions). The purpose of this training technique is to eliminate the element of surprise from the training process until the cadet acquires the basic skills required to perform the task. Once the basic skills have become inherently acquired, it would then be appropriate to give no prior knowledge of requirements so as to add the element of surprise. An example would be training in how to handle a rudder failure. An appropriate technique would be to demonstrate the various options available when encountering a power failure and to place a cadet into an exercise situation in which he knows he will have a power failure. Thus, a cadet can concentrate on developing the skill to handle the power failure. After having acquired the necessary skill for handling different types of power failures, the training should focus on the detection of a power failure and subsequent quick response. In these latter scenarios the cadet would not have prior knowledge of the power failure, but rather have it occur at a time when he presumably is not expecting such an event. Thus he would learn to detect the failure and to decide on the appropriate action for which he already possesses the necessary skill.

4.3.2.2 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 prior to or during the exercise as regards the proper considerations and actions to be taken. This technique will assist the cadet in making the essential link between critical information (i.e., range/closing rate) and appropriate deck officer action (i.e., range at which maneuver is initiated). This approach seeks to have the cadet perform correct actions most of the time, with appropriate reinforcement following his correct actions. By so doing, the cadet will rapidly learn the correct actions to take in the various situations. This approach is often superior to allowing the cadet to make mistakes, then providing negative feedback regarding those mistakes, i.e., trial and error. This technique has the disadvantage of not reinforcing the correct actions. Note, however, that it often may be desirable to allow the cadet to make mistakes so as to learn his limitations and that it is often not feasible to use positive guidance techniques for a variety of reasons.

Positive guidance should be employed early in the training process to ensure that the essential behaviors are correctly learned, and to avoid the danger that inappropriate behavior may be reinforced if no positive guidance is given. Once the appropriate behaviors are learned, positive guidance can then be removed and feedback on student performance should be provided solely by the postexercise 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.

There are various ways in which positive guidance can be administered. The instructor can simply explain to the cadets the appropriate behavior to be demonstrated during the exercise. This can be done either before the exercise is to begin (also called preexercise brief) or during the actual exercise. The explanation may also be accompanied by a brief demonstration on the simulator by the instructor. The preexercise brief can vary from a simple verbal explanation to a detailed presentation with audio visual aids. (See Section 3.3.12, "Training Assistance Technology.")

4.3.2.3 Postexercise Critique. Postexercise critique is a method of providing feedback regarding actions performed by the trainee in each simulator exercise. Using this technique detailed feedback should be given regarding performance immediately after the simulator exercise. This is essential, particularly in the training of inexperienced cadets who may be unfamiliar with the appropriate behaviors or control actions required to achieve successful performance. During the postexercise critique, the instructor should:

- Emphasize and reinforce correct procedures and desirable behavior
- Point out specific errors in procedures/behavior and explain their relationship to vessel performance (e.g., resulting CPA)
- Provide specific instructions on alternative procedures and behavior in order to improve performance on future exercises
- Provide a discussion and, if appropriate, a demonstration of the benefits of correct procedures and behavior. Learning by example is a powerful technique. This discussion/demonstration may also be facilitated by training assistance technology features (see Section 3.3.12).

Also during the postexercise critique, the instructor should *encourage student* questions in the analysis of the previous exercise. This is particularly true when training cadets who may be unfamiliar with the appropriate behavior, given varying circumstances.

In providing feedback to the trainee on performance during an exercise the instructor may be apt to dely the postexercise critique until all the exercises have been run (delayed feedback). This is not recommended, since inappropriate behavior may be reinforced by repetition in subsequent exercises. Furthermore, intervening exercises may interfere with and substantially reduce the effectiveness of the feedback. Feedback immediately following the exercise, either in the classroom or on the bridge, is the preferred approach for cadet training. Again, the form which this feedback takes, can be enhanced by training assistance technology. It should be noted that immediate feedback, that which immediately follows a particular action by the cadet/trainee, usually results in the greatest training gain. However, trainees often learn to depend on such feedback in operational situations in which it would not be available. Thus, it is recommended that immediate feedback, where possible, be provided to the cadets during the initial stages of achieving the respective training objectives using whatever aids are available (i.e., such as providing display information on the bridge during the exercise, verbally talking to the student, etc.). As training progresses feedback should be delayed until immediately following conclusion of the scenario. Hence, the feedback in latter stages of training should not be provided to the cadet/student on the bridge immediately following his actions, but should be delayed until termination of the scenario, and then as soon as possible.

4.3.3 INSTRUCTOR'S GUIDE

An instructor's guide should be developed and provided to all instructors who are to conduct the cadet simulator-based training program. The guide should set forth (1) the training program structure – the overall plan of simulator training across the cadets' 4-year program, (2) the training process strategy for each course – detailed methodology and timetable for each course, (3) the detailed lesson plan for each hour of the course – topic level learning objectives, content outline for the hour, (4) the supporting materials – visual aids, student explanatory handouts (e.g., explanation of rudder size effect on slow-down in a turn), and (5) the simulator exercises – scenario objectives, scenario set-up and expected time-line events, instructor and cadet/student tasks during the exercise, pertinent instructor cues for initiating action, pertinent performance measures, and instructional feedback guidance (e.g., points to stress, displays to use in classroom following exercise). 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.

Below is an outline for an Instructor's Guide for a cadet simulator based training program, which was adapted from the outline specified in the "Guidelines for Deck Officer Training Systems," drawing *upon various standards* (e.g., U.S. Navy, DI-H-2102A):

I. Program Introduction

   A. Description of the training program
   B. Schedule of labs for the applicable training categories
   C. Bridge Team Assignments – (if applicable) on and off watch bridge team locations (e.g., on-watch team is on bridge; off-watch team is at remote observation station)

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 *each set of labs* (Section 4.4.2 discusses this concept). 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 segment of classroom instruction, *each simulator session*, and each feedback session (approximately 1-hour segments).

      1. Each segment of classroom instruction should have detailed:

         a. The specific topic learning objectives 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. A detailed outline of all points to be addressed during the session, including coordination with supporting materials as necessary

         d. Identification of all training materials/media to be used during this classroom segment – e.g., visual slides, student handouts, etc.

         e. The number code of the exercises associated with the particular topic addressed

      2. Each exercise should have detailed:

         a. The specific training objectives to be achieved, including the appropriate performance measures and standards

         b. The training methodology to be used (i.e., demonstration or trainee hands-on)

         c. A description of each scenario, including appropriate diagrams, set-up geometry, and a time-line history of events.

         d. A time-line listing of expected cadet/trainee tasks

         e. A time-line listing of instructor tasks

         f. Identification of instructor cues for initiating action (e.g., too early initiation of a stand-on vessel maneuver may require the instructor to intercede immediately)

         g. A listing of pertinent performance measures (e.g., resultant closest point of approach and range of maneuver initiation when training rules-of-the-road)

3. Each feedback session following a simulator exercise should have detailed:

   a. Identification of appropriate issues to address relevant to the training objectives

   b. Identificatic. of points to address regarding aspects of cadet performance, including performance measures to key on

   c. Suggested feedback displays to use, if the system has this capability available

   d. Contrasting examples to bring up, using an automated computer-display system if available, to illustrate alternative issues and approaches

   e. Classroom visual aids (e.g., hand-outs or slides) to use if automated capabilities are inappropriate or unavailable

   f. Summary of factors indicating acceptable and unacceptable performance relative to the above issues

C. Course Evaluation

1. Upon completion of each training module within the program, the trainees should be given the opportunity to verbally evaluate that program segment. They should also be required to complete an evaluation questionnaire regarding the various aspects of training. It is recommended that this questionnaire request the following information:

   a. Simulator comments (e.g., realism of visual scene, radar)

   b. Training program comments (e.g., lab organization, instructor effectiveness)

   c. General comments (e.g., improvements in the course segment completed)

2. Appropriate summary records should be kept with which to evaluate the training effectiveness achieved during each module. This evaluation should be periodically updated to modify aspects of the training module (e.g., training techniques, exercises) so as to continually improve the training effectiveness.

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 the training program lab schedule, standing orders, ownship handling characteristics, description of the bridge configuration, and the evaluation questionnaire to be administered upon completion of each segment of the training program

   b. Any written tests and homework assignments

   c. Appropriate description of test and training scenarios

   d. List of reference texts used or case studies employed.

4.3.4 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 cadet simulator-based training program (Eclectech Associates, 1981). Several types of material/media that have been successfully employed in the past and should be considered for use at various points throughout any simulator-based 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 tape synchronized with a series of 35mm slides)
- Computer-generated graphic feedback displays*

*Note: See Section 3.3.12

- Remote monitoring of pilothouse personnel and key navigation parameters*

- Videotape monitoring of pilothouse personnel and key navigation parameters*

- Actual charts used during an exercise

- Computer generated track charts of the previous exercise

*Note: See Section 3.3.12

As noted in "Guidelines for Deck Officer Training Systems," the selection of proper classroom support material and 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 may range from traditional materials to advanced technological aids. However, training materials require careful advanced preparation by the instructor. This preparation can not be emphasized too much. Proper preparation, in addition to better materials, will result in a more polished teaching style for the instructor, enhanced student confidence in the training, and ultimately a more effective training program.

4.3.5 SIMULATOR/CLASSROOM MIX

The proper combination of simulator and classroom time is important for effective simulator-based training. At the cadet level, it is extremely important to provide adequate classroom time (i.e., preexercise brief and postexercise critique) in order to:

- Provide the trainees with the necessary background knowledge required to adequately perform in and complete the simulator exercise.

- Provide appropriate information and guidance to the trainees regarding various considerations, the acceptable actions to be performed in a specific situation, and so on. For example, the instructor might discuss the effect of alternative course changes and initiation points for the maneuver by ownship to avoid collision with a potential threat vessel and obtain an acceptable CPA, and also make an appropriate maneuver recommendation prior to the simulator exercise.

- Provide the opportunity for seminar-type discussion in order to increase student involvement and draw on the at-sea training experiences of the cadets.

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

For cadet training, whether the simulator training modules previously discussed are employed as laboratory periods for existing courses or as separate training courses, it is recommended that at least 30 percent of the training program time be devoted to classroom instruction. It is anticipated that the majority of cadet simulator exercise periods should be 20 to 30 minutes in length with 10 to 15 minutes devoted to postexercise critique and preexercise briefing. It is expected that several simulator exercises and associated classroom periods will comprise each cadet simulator latorabory period/training session (i.e., several 20 to 30 minute exercises and 10 to 15 minute classroom periods during each 3-hour session).

Failure to maintain at least 30 percent classroom instruction will probably indicate that the simulator is being utilized primarily as a device for student trial and error learning. This is not the most effective utilization of the simulator, particularly for cadet training. The most effective utilization is as a powerful tool for an active instructor to instill important concepts and foster the development of specific cognitive skills. The project team believes that for the instructor to assume this vital role, at least 30 percent classroom time is required.

4.3.6 TRAINING PROGRAM DURATION

Previous research has indicated that it is preferable to distribute simulator-based training over an academic quarter/semester than to concentrate the training within a short period of time, such as in a 1 week simulator dedicated training program. The maritime academies are fortunate in that their academic schedules are organized for distributed learning in the majority of their courses. It is recommended that the academies consider the integration of simulator training into their distributed academic schedule in lieu of conducting short-duration, concentrated training programs during non-academic periods in the curriculum, such as the week prior to or after at-sea training. While such short courses may be necessary or desirable, an effort should be made to not have them form the primary basis of the cadet simulator training program.

In integrating simulator training into the cadet curriculum, the 2 to 3 hour laboratory periods similar to those presently utilized for other courses appear appropriate. The project team recommends the 3 hour laboratory period since it will allow sufficient time to adequately explore issues of shiphandling with contiguous participation in several relevant exercises.

The number of laboratory periods in each of the training modules previously identified should be sufficient to accomplish the specific training objectives. This number may vary from academy to academy due to many factors such as cadet skill levels prior to training, duration of individual laboratory periods, and class size.

4.3.7 CLASS SIZE

The number of students in a simulator-based training program is another important training program characteristic. For cadet training, it is recommended that classes of six to nine cadets be employed. This will allow the cadets to be organized into two or three bridge teams. An individual cadet's time can then be effectively divided between simulator exercise participation and observation. The approach followed in the past has been to divide the class of approximately six or eight students into two teams. While one team is actively participating in the exercise on the bridge, the other team is observing from either the rear of the bridge or from an off-bridge observation station. The team actively participating in the simulator exercise is divided into three or four operator stations (e.g., mate on watch and in charge of the vessel, radar plotter, navigation plotter). The individuals manning the specific positions rotate with each exercise. Furthermore, the two teams generally alternate between active participation and observation with each exercise. This approach allows those cadets who are on the team actively engaged in the exercise to participate in a hands-on manner even though they may not be the mate on watch. They thus take part in the overall assessment and decision-making process, and assist the mate who is on watch; this certainly provides them with a benefit from a hands-on experience standpoint. The team that is in the observation mode would benefit greater if they could be located at an off-bridge observation station provided with remote TV monitoring of the bridge team, the visual scene, and other relevant information such as radar. Research has shown that this off-bridge monitoring station achieves substantially more effective training than locating the observation team in the rear of the wheelhouse. If such an off-bridge station is available, the observation team should be actively engaged in the problem by plotting appropriate contacts, discussing options available, discussing actions of the actively engaged bridge team, and otherwise interacting with the instructor to thoroughly analyze the situation.

When it is appropriate to utilize the simulator for concept demonstration in lieu of skill development, such as during initial freshman (4th class) indoctrination, substantially larger class sizes (e.g., 15 to 20) may be acceptable.

4.3.8 EXERCISE DEVELOPMENT

The maritime academies should give considerable thought to the development of the exercises within their shiphandling/ship bridge simulator training programs. Many of the principles that they have developed with their radar simulator training may also apply to this new area of training. The following are several principles that the project team recommends based on their experience with shiphandling/ship bridge simulator training:

- The exercises within the training program should be based on the identified training objectives. Care should be taken to assure that too many training objectives are not attempted in any one exercise.

- Exercises should be designed and organized within the training program such that the complexity level is progressively increased as later exercises are presented.

- High stress exercises should only be presented to the trainee after he has acquired the prerequisite skills (Eysench, 1976).

- There should be an appropriate number of exercises within a simulator-based training program in order to allow sufficient practice of the various sequence of tasks required to meet the identified training objectives.

- Additional exercises are also desirable to improve the confidence of the trainee, provide a greater depth of skills, assure greater skill generalizability, and promote greater skill retention.

For a greater explanation of these aspects of scenario design, the interested reader is referred to the report

"Simulators for Mariner Training and Licensing: Guidelines for Deck Officer Training Systems" and specifically the sections dealing with scenario design, number of scenarios, stress, and overlearning.

4.4 INSTRUCTOR QUALIFICATIONS (CRITICAL CHARACTERISTICS)

As previously noted, the qualification of the instructor and the instructional techniques that he employs during training are critical for effective simulator training. Previous research has indicated that the instructor is as important, if not more important, than many simulator fidelity issues, once a minimum level of simulation fidelity is achieved (Hammell, Gynther, Grasso, and Gaffney, 1981). The instructor is the individual who conducts the training process and transforms the simulator into an effective training device.

The various maritime academies have been successful over the years in selecting qualified individuals as instructors for their respective training programs. In addition, each academy has had experience in selecting instructors for radar simulator training. Much of this experience will be valuable when selecting individuals to serve as instructors for the shiphandling/ship bridge simulator training.

The document "Guidelines for Deck Officer Training Systems" identifies and discusses a number of critical characteristics for an instructor. A summary of these characteristics along with recommendations are provided below. The interested reader should refer to the above report for additional information.

4.4.1 CRITICAL CHARACTERISTICS (SUMMARY)

- **Mariner Credentials.** The license level and at-sea experience of the instructor is important to ensure the creditability of the training program with the student. The project team recommends that at the cadet level the instructor possess at least a second mate/chief mate license with a minimum of 2 to 5 years at-sea experience. While it is not imperative that the instructor have this license level and at-sea experience, lack of such a credential could provide a handicap that the instructor would then have to overcome.

- **Instructor Credentials.** A fundamental background/experience in teaching or instructional techniques is another important characteristic for an instructor. It is recommended that instructors for cadet simulator-based training have additional, specialized training beyond the normal nautical science instructor credentials. This specialized training, which is described later in this section, should involve the operation of the simulator and its use as an additional sophisticated tool within the training process.

- **Nautical Science Knowledge.** The instructor should have a high level of understanding in any particular subject area (e.g., shiphandling) in order to effectively communicate the concepts involved and, in some cases, their subtle applications. It is desirable for the instructor to possess sufficient knowledge related to:

  - All fundamental shiphandling and navigation principles (e.g., advance of transfer and visual position fixing)

  - Advanced shiphandling and navigation principles (e.g., anchoring procedures and radar parallel indexing)

  - The above principles for a variety of vessel types in a cross section of operational situations

  - The historical development/evolution of present shipboard equipment, operational procedures, and regulations

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

- **Instructor Skills.** The ability of the instructor to utilize the training techniques previously discussed in order to accomplish the identified training objectives is another critical characteristic. Specifically, the instructor should possess sufficient skills pertaining to the:

  - Organization and conduct of a preexercise briefing to direct the cadets' attention to the key concepts to be experienced/observed during the exercise

  - Monitoring and supervision of the cadets in a constructive manner during the exercise

  - Organization and conduct of a postexercise critique in an effective and constructive manner that enhances student motivation

  - Identification of students requiring special attention and provide same without diverting the entire class for long periods of time

- Management of the training program, and being able to compensate for a variety of student, simulator, and schedule problems likely to be encountered during the training program

- **Instructor Attitude.** The enthusiasm of the instructor for the training program 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 is also the vehicle by which discrepancies or obstacles in the training process are successfully overcome. The instructor should have an attitude that enables him to:

  - Convey subject matter in a positive, professional manner

  - Stimulate student participation during classroom discussions

  - Motivate students to attain the proficiencies specified in the course objectives

- **Student Rapport.** The instructor should have the ability to develop personal relationships with the trainees which are conducive to the learning process. While it is not necessary that the instructor be well-liked by the students, it is important that they respect him as a professional. The instructor should have the following type of rapport with his students:

  - Instructor recognized as possessing the professional skills and knowledge of the material being trained within the 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

4.4.2 INSTRUCTOR TRAINING

As previously mentioned, it would probably be appropriate for the maritime academies to provide their potential simulator instructors with additional training. A special instructor's course should be developed to prepare the instructor for the conduct of an effective training process using the simulator. This program should include training in the operation of the simulator itself since it is recommended in this report that the system be designed for effective operation by a single operator/instructor. Additional personnel resources, however, should be available for maintenance of the training device as noted in Section III.

This special instructor course should also address 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, make it prudent that the instructors be well-versed in the use of their expensive training device. The issues and recommendations contained above in these training program guidelines would form a good starting framework for this part of the course.

4.4.3 NUMBER OF INSTRUCTORS

It is recommended that each maritime academy conducting shiphandling/ship bridge simulator training have at least two instructors trained in the use of the simulator; a primary instructor and an alternative or back-up instructor. It is not recommended that every instructor in the Nautical Science Department be trained as a simulator-based training instructor, however. Some instructors have training styles and methods that are not conducive to simulator training. In addition, the use of a small number of instructors for simulator-based training would allow the selected individuals to enhance their simulator instructional skills and improve the effectiveness of the training within the limited time available. While it may not be possible, or desirable, to dedicate an instructor to only simulator training, the number of instructors involved in the use of this sophisticated trainer should be limited.

4.4.4 INSTRUCTOR EVALUATION

The performance of the instructor should be periodically evaluated to ensure a consistently high quality of instruction and to provide the individual instructor with diagnostic information upon which he can improve his effectiveness. Each maritime academy should develop and implement its own procedures regarding evaluation intervals and evaluation criteria. The project team recommends that instructor performance be evaluated (a) on a continuing basis by monitoring cadet proficiency on post-training test scenarios and (b) on a periodic basis via simulator and classroom observation by several appropriately qualified individuals including the Nautical Science Department Head.

4.5 FACILITY MANAGEMENT

4.5.1 RADAR SIMULATOR EXPERIENCE

Since all the maritime academies have experience with the operation and maintenance of a radar simulator, it is recognized that a solid base of knowledge exists at the academies for the successful management of a shiphandling/ship bridge simulator training facility. Academy personnel should be cautious, however, in assuming that successful practices for radar facility management will also be successful for shiphandling/ship bridge simulator facility management. The latter facility is substantially more difficult to operate and maintain. As a result, problems may arise that were never an issue with the radar simulator. For example, most shiphandling/ship bridge simulators require periodic adjustment of the visual scene projectors. At many facilities this is required daily. This adjustment should be accomplished only by staff personnel who have received appropriate training. It is an additional management responsibility to ensure that sufficient personnel on the simulator facility staff have this training to cover for periodic illness, etc.

It is recommended that personnel from each academy visit and discuss the management of a shiphandling/ship bridge simulator with the staff of at least one presently operating shiphandling/ship bridge simulator facility such as CAORF, Ship Analytics, Inc., or the Maritime Institute of Technology and Graduate Studies (MITAGS) in order to gain a better appreciation for the problems associated with the management of these training devices.

4.5.2 INITIAL DECISIONS

When initially setting up a shiphanding/ship bridge simulator facility, a number of decisions are made which affect the operation of the facility over its lifetime. These decisions are usually drive by financial considerations. For example, should the individual academy own or lease its simulator? Should additional revenue-producing training be conducted? The answers to these types of decisions affect the design of the simulator itself. If senior mariner training is desirable for additional revenue, then it may be cost-effective to add a limited daytime capability to the simulator in order to attract additional business. These decisions also affect the operating decisions, or day-to-day management decisions, of the simulator facility. They impact the size of the staff required and the organizational relationship of this staff with the other academy elements. For example, should the shiphandling/ship bridge simulator come under the Nautical Science Department or should it be a separate department? This decision probably hinges on the size of the staff required which is related to several factors including the operation and maintenance requirements of the specific simulator design and whether or not external training is conducted. This report does not purport to answer these questions. It does hope to remind the academies that the initial decisions made when setting up a shiphandling/ship bridge simulator facility will impact many of the operating decisions over the life of the training device. Appropriate care should, therefore, be exercised during this important planning phase in order that simulator training for maritime cadets is cost effective training.

4.5.3 OPERATING DECISIONS

Several operating decisions which appear of particular concern for a shiphandling/ship bridge simulator at the cadet level are:

- What are the best means of attracting and retaining qualified instructors within available resources? This appears to be a general problem for many maritime academies since the salaries that they can offer are pale compared to the salaries that these same individuals can be making at-sea. As previously discussed, a well-qualified instructor is extremely important for effective simulator training.

- What is the best allocation of resources to ensure high standards of training and to obtain Coast Guard approval of this training? A previous Training and Licensing Project report, "Guidelines for Deck Officer Training Systems," provides an indication of potential Coast Guard approval issues and procedures. Until the Coast Guard publishes proposed rules for the approval of shiphandling/ship bridge simulator training, the guidelines document should be consulted.

- What is the best allocation of resources to ensure high availability of the shiphandling/ship bridge simulator? Availability has not been a problem with radar simulators. Academy staff should expect it to be more of a problem with the shiphandling simulator due primarily to its greater complexity. Appropriate precautions should then be taken by the academy staff in this area. It will be extremely important that maritime academy personnel receive proper training in the operation and maintenance of these training devices.

- What is the optimum schedule for cadet training, revenue-producing training (if appropriate), and simulator maintenance? This will probably vary from academy to academy due to several factors, such as the cadet schedule of classes and the amount of time available for simulator laboratory periods. It will become considerably more complicated if revenue-producing training is required.

4.5.4 SUMMARY

- The maritime academies should view their experience with radar simulators as a valuable basis for the successful management of a shiphandling/ship bridge simulator facility. However, they should also realize that there are important differences between the two types of simulators, and hence the management of their facilities.

- There appear to be two types of decisions involved with any simulator training facility: initial decisions and operating/day-to-day management decisions. The maritime academy should realize that many of the initial decisions involved in procuring and setting up the facility will significantly impact the operating decisions and ultimately the cost-effectiveness of training. As a result, careful consideration should be given to these initial decisions.

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APPENDIX A

THIRD MATE WATCHSTANDING TASKS AND TRAINING OBJECTIVES

This appendix contains three tables: (1) third mate watchstanding tasks, (2) cadet level training objectives, and (3) critical simulator characteristics matched to training objectives. The third mate watchstanding tasks were derived largely from the previously assembled task analysis information during Phase 1 of the Training and Licensing Project (Hammell, et al., 1980). This task listing expands that of the earlier report; the tasks of the earlier analysis were investigated with regard to the third mate and additional tasks added as necessary.

The training objectives contained in Table A-2 were derived from several information sources: (1) the task listing of Table A-1, which form the primary source of information, along with the skills and knowledge derived from that table; (2) a review of the curricula from the state and federal maritime academies; (3) information provided by all of the state and federal maritime academies, and (4) discussions with academy personnel and experienced mariners. This set of training objectives is intended to comprehensively address the broad range of skills required for shiphandling by third mates. It is, however, only one subset of the training objectives required to be achieved during the four-year academy curriculum. Other training objectives not included in this table would address, for example, celestial navigation, maritime law, and so on. This set of training objectives, therefore, is representative of those which would be achieved via at-sea training, small boat shiphandling training, simulator-based training, and by other such media. Other training objectives not contained in this table may also be appropriate for at-sea training, such as handling lines when docking; however, these objectives were deemed inappropriate for potential training on a ship bridge simulator. The final set of training objectives contained in Table A-2 thus represents a subset of those that must be achieved during the four-year academy curriculum, and also a subset of those that must be achieved via at-sea training.

It should also be noted that the training objectives were developed at a high level for the purposes of determining the ship bridge/shiphandling simulator functional characteristics and for the development of guidelines for the integration of simulator-based training into academy curricula. They have not been developed to the level of detail necessary for the development of an instructor's guide, lesson plans, and so on. Their detail of development is between that of course objectives and section objectives; detailed topic learning objectives would have to be developed from these to appropriately construct the necessary detailed instructional materials. It is expected that the content and number of courses using the simulator, and the objectives they address, the training strategies for each course, etc., would differ for each academy. It should also be noted that if using these objectives as the basis for the development of topic learning objectives, careful attention should be given to the development of associated conditions and performance standards for each topic learing objective.

Table A-3 lists the critical simulator characteristics addressed by the functional specification. Several levels of fidelity for each of these characteristics were investigated for each identified training objective. The factors considered in this subjective evaluation are contained in Table A-4. Table A-3 contains the composite results of the evaluation of each critical simulator characteristic for each training objective, with a bar-chart representation for each fidelity level showing estimated 0 percent to 100 percent effectiveness in achieving the particular training objective. For example, four levels of fidelity were investigated with regard to the visual scene horizontal field of view (i.e., 120 degrees, 180 degrees, 240 degrees, 360 degrees). Table A-3 shows the estimated effectiveness of achieving each training objective (e.g., TO #16, #17, etc.) by using each of the four levels of horizontal field of view fidelity. The analysis of Table A-3 shows, for example, that the lowest fidelity field of view (i.e., 120 degrees) would be completely adequate for the achievement of training objective #17 (i.e., the bar-chart for 120 degrees field of view on TO #17 shows 100 percent). This lowest field of view would also be completely adequate for achieving many of the other training objectives, such as #18, #27, etc. Also note in this example that the higher levels of fidelity would also be adequate; thus 180 degrees, 240 degrees, and 360 degrees would also be adequate. However, these higher levels of fidelity are unnecessary for achieving training objective #17, since 120 degrees is sufficient. Inspection of training objective #28 shows that the lowest level of fidelity (i.e., 120 degree horizontal field of view) would not be adequate for completely achieving that training objective (i.e., only 80 percent effective). Hence, a higher level of fidelity is necessary for this particular training objective (i.e., at least 180 degrees field of view). This is the type of information contained in Table A-3 pertaining to each of the major simulator characteristics, their respective levels of fidelity, and each of the training objectives for which the simulator functional specification was designed.

TABLE A-1. IDENTIFICATION OF THIRD MATE WATCHSTANDING TASKS

OPEN SEA

Changing Watch (Before Relieving)

1. Check standing and night orders and special information; acknowledge by signature.
2. Check vessel's position on chart.
3. Evaluate course line projected for duration of watch.
4. Check vessel's speed.
5. Determine if any hazardous potential exists with traffic.
6. Evaluate weather and sea conditions for danger.
7. Check running lights.
8. Check personnel assigned to watch.
9. Check compasses.
10. Determine status of electronic navigational aids.
11. Determine status of VHF monitoring.
12. Check course recorder.
13. Check chronometers.
14. Receive appropriate watch information and relieve mate of watch.

Change of Watch (Being Relieved)

1. Enter appropriate information into ship log.
2. Plot dead reckoning track (DR).
3. Check status of all navigational equipment.
4. Update radar plot of traffic.
5. Orally transfer information regarding status of vessel to relieving mate.
6. Verify that relieving mate has accepted responsibility for the watch.

TABLE A-1. IDENTIFICATION OF THIRD MATE WATCHSTANDING TASKS (Continued)

OPEN SEA (Continued)

Visual Monitoring Tasks

1. Instruct lookout as to duties.
2. Clean and adjust binoculars.
3. Scan horizon with binoculars for detecting traffic or navigational aids.
4. Determine type aspect, and relative motion of contacts.
5. Utilize azimuth circle to take bearings.
6. Maintain watch on ownship smoke, weather changes, watertight openings, gear secured, personnel on deck, etc.

Collision Avoidance Tasks

1. Adjust/operate radar, CAS.
2. Delete/erase plots of past threat contacts.
3. Monitor radar for contacts.
4. Plot and maintain bearing and range of contacts on radar.
5. Plot targets on maneuvering board.
6. Receive reports of visual contact (lookout).
7. Communicate with the engineering watch as appropriate.
8. Observe visual bearings of visual contacts.
9. Determine CPA and collision avoidance maneuver.
10. Communicate on VHF to threat vessel.
11. Inform master of situation and intentions.
12. Execute collision avoidance maneuver.

Navigation Tasks

1. Observe azimuth of celestial body.
2. Determine gyro error and magentic deviation.
3. Obtain position by use of Omega, Decca, or Loran receiver.
4. Obtain position by use of satellite navigation system.
5. Compare (3) or (4) with DR position.
6. Determine current set and drift – vessel's speed.
7. Observe and plot sun sight – obtain altitude and intercept.

TABLE A-1. IDENTIFICATION OF THIRD MATE WATCHSTANDING TASKS (Continued)

OPEN SEA (Continued)

Navigation Tasks (Continued)

8. Determine time of meridian transit.
9. *Observe meridian altitude.*
10. Determine celestial fix — using sun lines.
11. Calculate and execute appropriate course changes based on navigation fix information.
12. Determine days run and speed.
13. Monitor radar for detecting aids to navigation or other charted positions.
14. Plot radar fix.
15. Determine ETA to pilot station.
16. Use RDF for check of position.
17. Use Fathometer for check of position.
18. Monitor navigational aids: Fathometer, gyrocompass, Satellite Navigator, and Loran.
19. Introduce waypoints in Satellite Navigator.

Communication Tasks

1. Use sound powered phone to call master, engine room, standby, etc.
2. Monitor channels 16 and 13 on VHF radiotelephone.
3. Use VHF radiotelephone to initiate a safety/urgency/distress message.
4. Receive and record broadcasts from weather forecast/USCG security, etc.
5. Interpret and reply to flag signals of other vessel.
6. Receive, record, and send flashing light message.
7. Sound ship's whistle as appropriate for maneuvers, emergency, etc.

Ship Control Tasks

1. Change steering mode from auto to manual.
2. Maneuver vessel to clear other vessel(s).
3. Maneuver vessel as needed to clear smoke (blowing tubes).
4. Reduce vessel's speed.
5. Maneuver vessel for man overboard.
6. Maneuver vessel to make lee for small boat (e.g., pilot boat).

TABLE A-1. IDENTIFICATION OF THIRD MATE WATCHSTANDING TASKS (Continued)

OPEN SEA (Continued)

Safety/Casualty Tasks

1. Respond to man overboard emergency.
2. Respond to engine, steering failure, etc.
3. Monitor vessel for personnel/loose gear/watertightness, etc.
4. Participate in lifeboat and emergency drills.
5. Respond to specific equipment alarms (e.g., gyrocompass casualty).
6. Administer first aid as required while onboard the vessel.

Miscellaneous

1. Wind and compare chronometers.
2. Observe and record marine weather observations.
3. Prepare weather report.
4. Maintain miscellaneous logs and records.
5. Obtain an appropriate marine weather map from a radio facsimile receiver.

RESTRICTED WATERS

Changing Watch (Before and Upon Relief)

The changing of the watch in restricted waters would include the same tasks as noted in the open sea condition. Greater emphasis would be needed regarding specific information acquired from radar plotting for detecting traffic or aids to navigation.

Visual Monitoring Tasks

The tasks required in restricted waters for visual monitoring would be identical to those for the open sea condition with the addition of:

1. Observe and identify specific aids to navigation.
2. Be alert for local traffic.
3. Observe and plot visual lines of position for visual fix.

Collision Avoidance Tasks

Tasks noted in collision avoidance for the open sea condition are essentially the same as required for restricted waters with the addition of:

1. Identify demarcation of COLREGS.

TABLE A-1. IDENTIFICATION OF THIRD MATE WATCHSTANDING TASKS (Continued)

RESTRICTED WATERS (Continued)

Navigation

Task items contained in the open sea condition would be applied for a coastwise or harbor approach navigation. Particular items (i.e., 2-6-9-10-11-16-18) would receive more emphasis in restricted waters depending on circumstances. Other tasks that would be encountered at this time are:

1. Predict zone time of sunset/sunrise for ETA at pilot station.
2. Determine ETA at berth.
3. Determine vessel's clearance with bottom at berth.
4. Predict time of sighting specific aids to navigation.

Communication Tasks

These tasks would be practically identical to those noted in the open sea condition. At the approach of a harbor, additional specific communication tasks would be required:

1. Inform pilot of vessel condition upon arrival (e.g., equipment status).
2. Order proper flags to be hoisted.
3. Notify own vessel personnel of arrival information.
4. Place/receive calls via Public Coast Stations.

Miscellaneous Tasks

1. *Preparing for* U.S. Harbor Entry.

Anchoring/Docking/Undocking

1. Monitoring navigation process – assisting master and pilot as required.
2. Checking appropriate equipment before entering or getting underway.
3. Stand anchor watch.

TABLE A-2. CADET LEVEL TRAINING OBJECTIVES

A. GENERAL

1. The trainee shall be able to accurately describe the standard shipboard organizations along with the duties and responsibilities of the personnel billets found aboard commercial vessels.

2. The trainee shall be able to accurately state his duties and responsibilities as third mate during each of the following emergency shipboard evolutions:
   - fire
   - lifesaving
   - abandon ship
   - pollution abatement

3. The trainee shall be able to effectively communicate verbally with other shipboard personnel using proper shipboard terminology.

4. The trainee shall be able to accurately transcribe information using proper shipboard terminology.

5. The trainee shall be able to accurately describe normal shipboard routine including watch organization, meals, and duties.

6. The trainee shall demonstrate a working knowledge of general U.S. Maritime union regulations.

7. The trainee shall be able to correctly operate and utilize each piece of equipment normally found on the bridge of a commercial vessel (e.g., gyrocompass, helm, EOT, radar).

8. The trainee shall be able to effectively participate in lifeboat and emergency drills using the appropriate gear, and adhering to appropriate safety regulations relating to these drills.

9. The trainee shall be able to effectively utilize the standard shipboard firefighting equipment found on board a commercial vessel; describe the methods/equipment for combating a wood and paper fire, an inflammable liquid fire, and an electrical fire.

10. The trainee shall be able to state the circumstances under which each piece of lifesaving equipment found on board a commercial vessel would be used as well as to effectively utilize it when deemed necessary.

11. The trainee shall be able to accurately demonstrate use of appropriate first aid techniques for:
    - drowning
    - fracture
    - head injuries
    - exposure
    - electric shock
    - excessive bleeding
    - burns

12. The trainee shall demonstrate an understanding of vessel construction, stability, and watertight integrity.

13. The trainee shall demonstrate the ability to receive/transmit information via sound-powered phones using proper terminology and procedures.

14. The trainee shall demonstrate the ability to operate and monitor a walkie-talkie for various shipboard evolutions.

B. RELATIVE MOTION

15. The trainee shall demonstrate an understanding of the function, operation, and limitations of radar as regards collision avoidance.

16. The trainee shall demonstrate an understanding of relative motion concepts including maneuvering board and rapid radar plotting techniques.

17. The trainee shall demonstrate an understanding of the use of masthead and side lights to assist in determining traffic vessel aspect.

18. The trainee shall demonstrate an understanding of the use of visual bearings in establishing and assessing risk of collision.

C. RULES OF THE ROAD

19. The trainee shall demonstrate an understanding of purpose and intent of the International and Inland Rules of the Road.

20. The trainee shall demonstrate an understanding of the differences between International and Inland Rules of the Road and the geographic demarcation of their jurisdiction.

21. The trainee shall demonstrate an understanding of the various lighting and day shape requirements for ownship and other vessel types under the Rules.

22. The trainee shall demonstrate an understanding of "risk of collision" and describe its legal ramifications.

23. The trainee shall demonstrate an understanding of ownship maneuvering responsibilities in various situations under the Rules.

24. The trainee shall demonstrate an understanding of the legal requirements concerning "safe vessel speed."

D. COLLISION AVOIDANCE

25. The trainee shall be able to properly tune and operate the standard shipboard radar/collision avoidance system.

26. The trainee shall be able to discriminate contacts from unwanted signals or clutter.

27. The trainee shall be able to accurately maintain a radar plot of multiple contacts simultaneously under operational watch conditions.

28. The trainee shall be able to accurately assess each contact's potential for risk of collision and filter contacts with low risk of collision under operational watch conditions.

29. The trainee shall be able to accurately determine contact CPA, course, speed, etc., utilizing either maneuvering board or rapid radar plotting technique under operational watch conditions.

TABLE A-2. CADET LEVEL TRAINING OBJECTIVES (Continued)

30. The trainee shall be able to properly recognize, interpret, and evaluate visual contacts as to type, aspect, and relative motion under operational watch conditions.

31. The trainee shall be able to use a visual bearing circle, telescopic alidade, or pelorus to determine contact bearing and contact bearing drift.

32. The trainee shall be able to integrate available information and apply the Rules of the Road to a particular situation under operational watch conditions.

33. The trainee shall be able to maneuver ownship to pass at a safe distance, according to the procedures outlined in the Rules of the Road and the master's standing/night orders.

E. SHIPHANDLING/SEAMANSHIP

34. The trainee shall demonstate an understanding of fundamental shiphandling principles (e.g., turning circles, advance and transfer).

35. The trainee shall demonstrate an understanding of emergency shiphandling principles (e.g., Williamson turn, crash stop).

36. The trainee shall demonstrate an understanding of the effect of weather (i.e., wind, current, seas) on shiphandling and course keeping characteristics.

37. The trainee shall be able to determine "safe vessel speed" under a variety of operational conditions (e.g., reduced visibility).

38. The trainee shall demonstrate an understanding of the function and proper use of anchors and ground tackle.

39. The trainee shall demonstrate an understanding of the function and proper use of mooring lines and mooring line configurations.

F. CELESTIAL NAVIGATION

40. The trainee shall demonstrate an understanding of the basic concepts concerning nautical time (e.g, GMT, LZT).

41. The trainee shall demonstrate an understanding of the function and operation of the shipboard chronometer.

42. The trainee shall demonstrate an understanding of the concepts associated with the navigational triangle and its solution including the use of the Nautical Almanac and the Navigational Tables.

43. The trainee shall demonstrate an understanding of the function and use of a marine sextant.

44. The trainee shall demonstrate an understanding of the principles used in the identification of celestial bodies.

45. The trainee shall demonstrate an understanding of the techniques of using celestial lines of position to obtain celestial fixes (e.g., star fix, running fix using sun lines, LAN, etc.).

46. The trainee shall demonstrate an understanding of the techniques of using celestial bodies to calculate gyro error (e.g., azimuth, amplitude).

TABLE A-2. CADET LEVEL TRAINING OBJECTIVES (Continued)

47. The trainee shall be able to determine gyrocompass error from celestial observations.

48. The trainee shall be able to compare the calculated amount of gyrocompass error with the previous error and establish the reliability of the gyro for the type of navigation to be encountered during the watch.

49. The trainee shall be able to observe, calculate, and plot a sun line of position.

50. The trainee shall be able to determine the time of meridian transit and observe, calculate, and plot a meredian altitude.

51. The trainee shall be able to plot and evaluate a celestial fix under operational conditions.

52. The trainee shall be able to determine course made good and speed made good under operational conditions.

53. The trainee shall be able to estimate future current set and drift based on course made good, speed made good, weather observations, and weather forecasts.

54. The trainee shall be able to determine appropriate alterations to course and speed in order to compensate for current set and drift.

55. The trainee shall be able to calculate and plot future dead reckoning positions from the previous fix.

56. The trainee shall be able to utilize a marine sextant under operational conditions.

57. The trainee shall be able to determine Greenwich Mean Time (GMT) under operational watch conditions.

58. The trainee shall be able to identify celestial bodies for navigational observations under operational conditions.

59. The trainee shall be able to observe, calculate, and plot a celestial star fix under operational conditions.

G. PILOTING

60. The trainee shall demonstrate an understanding of chart projections, chart scales, symbols, and notation.

61. The trainee shall demonstrate an understanding of dead reckoning principles.

62. The trainee shall demonstrate an understanding of the navigational instruments for piloting and dead reckoning.

63. The trainee shall demonstrate an understanding of the function and operation of both shipboard gyro and magnetic compasses.

63. The trainee shall demonstrate an understanding of the concepts associated with compass error.

65. The trainee shall demonstra' an understanding of the use of visual lines of position in piloting.

66. The trainee shall demonstrate an understanding of the use and limitations of radar in piloting.

67. The trainee shall demonstrate an understanding of the use of sounding information in piloting.

TABLE A-2. CADET LEVEL TRAINING OBJECTIVES (Continued)

68. The trainee shall demonstrate an understanding of the function of various types of aids to navigation in piloting.

69. The trainee shall demonstrate an understanding of the procedures for correct identification and utilization of aids to navigation (e.g., light list, visibility range of lights).

70. The trainee shall demonstrate an understanding of the procedures and publications used for calculating tidal height and tidal current.

71. The trainee shall demonstrate an understanding of the proper elements of a port approach plan, including the use of the Coast Pilot/Sailing Directions.

72. The trainee shall be able to layout and interpret dead reckoning tracklines on a chart under operational conditions.

73. The trainee shall be able to analyze a dead reckoning track for potential navigational hazards under operational conditions.

74. The trainee shall be able to visually identify charted objects suitable for visual lines of position under both day and night operational watch conditions.

75. The trainee shall be able to determine vessel position by means of visual fixes under both day and night operational watch conditions.

76. The trainee shall be able to determine vessel position by means of radar fixes under operational watch conditions.

77. The trainee shall be able to compare the new fix position (e.g., radar, visual) with the charted DR position, evaluate discrepancies and establish present position under operational watch conditions.

78. The trainee shall be able to determine compass error using charted ranges under operational watch conditions.

79. The trainee shall be able to determine when ownship intersects COLREGS demarcation line under operational watch conditions.

80. The trainee shall be able to determine ETA to the sighting of a lighted aid to navigation from a radar fix under operational watch conditions.

81. The trainee shall be able to determine ETA to pilot station or berth from a radar fix under operational watch conditions.

82. The trainee shall be able to determine tidal height and tidal current for arrival at pilot station or berth under operational watch conditions.

83. The trainee shall be able to determine LZT of sunset/sunrise for arrival at pilot station or berth under operational watch conditions.

H. ELECTRONIC NAVIGATION

84. The trainee shall demonstrate an understanding of the function, operation, and limitation of:
    - LORAN
    - OMEGA
    - DECCA
    - Satellite Navigation System

85. The trainee shall demonstrate an understanding of the function, operation, and limitation of a radio direction finder (RDF).

86. The trainee shall demonstrate an understanding of the function, operation, and limitations of a Fathometer.

87. The trainee shall be able to determine, plot, and evaluate the vessel's position by utilizing any of the following systems under operational watch conditions:
    - LORAN
    - OMEGA
    - DECCA
    - Satellite Navigation System

88. The trainee shall be able to determine, plot, and evaluate a radio direction finder line of position under operational watch conditions.

89. The trainee shall be able to utilize a line of soundings to assess the accuracy of his navigational position information under operational watch conditions.

I. EXTERNAL VESSEL COMMUNICATIONS

90. The trainee shall demonstrate an understanding of the function, operation, and limitations of radiotelephone communications.

91. The trainee shall demonstrate an understanding of the proper use of the ship's whistle for maneuvering and warning signals in accordance with the Rules of the Road.

92. The trainee shall demonstrate an understanding of the proper procedures for the use of flag hoist communications.

93. The trainee shall demonstrate an understanding of the proper procedures for the use of flashing light communications.

94. The trainee shall be able to properly monitor the appropriate radiotelephone frequencies under operational watch conditions.

95. The trainee shall be able to properly transmit/receive the following types of messages via radiotelephone:
    - distress
    - urgency
    - safety

97. The trainee shall be able to properly interpret other vessel's flags and respond appropriately.

98. The trainee shall be able to properly transmit/receive a flashing light message.

99. The trainee shall demonstrate a basic understanding of basic marine weather principles, observation parameters, and forecasting techniques.

100. The trainee shall be able to monitor the appropriate NOAA station to receive and accurately record weather broadcasts.

101. The trainee shall be able to operate a radio facsimile receiver to obtain an appropriate marine weather map.

102. The trainee shall be able to interpret the impact of the marine weather forecast on ownship and take appropriate action (e.g., notification of master, securing vessel for heavy weather).

103. The trainee shall be able to accurately observe marine weather parameters (e.g., wind, sea state, barometric pressure) and record as appropriate.

K. WATCHSTANDING/BRIDGE PROCEDURES

104. The trainee shall demonstrate the ability to maintain a vigilant lookout in accordance with standing orders and normal routine, monitoring internal and external situations for potential problems or hazardous situations that may put the vessel or personnel in jeopardy and take appropriate action to assure that safe conditions exist.

105. The trainee shall demonstrate the ability to notify the master accurately and concisely of traffic vessels with possible risk of collision, as defined by the standing order criteria, under operational watch conditions.

106. The trainee shall demonstrate the ability to notify the master of all navigational hazards which may impact the safety of the vessel (e.g., shipboard engineering casualties, heavy weather).

107. The trainee shall demonstrate the ability to notify the master in accordance with the standing orders of the occurrence of anticipated events (e.g., landfall).

108. The trainee shall demonstrate the ability to orally communicate with other mates concerning the status of the vessel during watch relief.

109. The trainee shall demonstrate the ability to instruct/supervise as appropriate other members of the bridge watch in their duties and responsibilities (e.g., helmsman, lookout).

110. The trainee shall demonstrate the ability to issue/verify appropriate helm orders using proper terminology in order to safely navigate ownship.

111. The trainee shall demonstrate the ability to communicate with the engineering watch on the status of the shipboard engineering plant.

112. The trainee shall demonstrate the ability to accurately record all pertinent data in the deck log, radiotelephone book, and compass record book in accordance with accepted procedures and standing orders.

113. The trainee shall demonstrate the ability to properly adjust and effectively utilize binoculars.

TABLE A-3. TRAINING EFFECTIVENESS OF SELECTED SIMULATOR CHARACTERISTICS

TOs	TIME OF DAY	GEOGRAPHIC AREA	HORIZONTAL F/V	VERTICAL F/V	COLOR VISUAL SCENE	RADAR PRESENTATION	BRIDGE CONFIGURATION	OWNSHIP DYNAMICS	EXERCISE CONTROL	TRAFFIC VESSEL CONTROL	TRAINING ASSIST TECH
7	NIGHT DAY D/N	OPEN SEA COASTAL RESTRICTED WATERS	120° 180° 240° 360°	10° 20° 30°	B&W COLOR	NO LOW HIGH	REDUCED FULL REPLICATION	DEEP SHALLOW SPECIAL	SELECTION PREPROGRAM CONTROL	CANNED PREPROGRAM INDEPENDENT INTERACTIVE	NO REMOTE FEEDBACK
15	NIGHT DAY D/N	OPEN SEA COASTAL RESTRICTED WATERS	120° 180° 240° 360°	10° 20° 30°	B&W COLOR	NO LOW HIGH	REDUCED FULL REPLICATION	DEEP SHALLOW SPECIAL	SELECTION PREPROGRAM CONTROL	CANNED PREPROGRAM INDEPENDENT INTERACTIVE	NO REMOTE FEEDBACK
16	NIGHT DAY D/N	OPEN SEA COASTAL RESTRICTED WATERS	120° 180° 240° 360°	10° 20° 30°	B&W COLOR	NO LOW HIGH	REDUCED FULL REPLICATION	DEEP SHALLOW SPECIAL	SELECTION PREPROGRAM CONTROL	CANNED PREPROGRAM INDEPENDENT INTERACTIVE	NO REMOTE FEEDBACK
17	NIGHT DAY D/N	OPEN SEA COASTAL RESTRICTED WATERS	120° 180° 240° 360°	10° 20° 30°	B&W COLOR	NO LOW HIGH	REDUCED FULL REPLICATION	DEEP SHALLOW SPECIAL	SELECTION PREPROGRAM CONTROL	CANNED PREPROGRAM INDEPENDENT INTERACTIVE	NO REMOTE FEEDBACK
18	NIGHT DAY D/N	OPEN SEA COASTAL RESTRICTED WATERS	120° 180° 240° 360°	10° 20° 30°	B&W COLOR	NO LOW HIGH	REDUCED FULL REPLICATION	DEEP SHALLOW SPECIAL	SELECTION PREPROGRAM CONTROL	CANNED PREPROGRAM INDEPENDENT INTERACTIVE	NO REMOTE FEEDBACK
27	DAY NIGHT D/N	OPEN SEA COASTAL RESTRICTED WATERS	120° 180° 240° 360°	10° 20° 30°	B&W COLOR	NO LOW HIGH	REDUCED FULL REPLICATION	DEEP SHALLOW SPECIAL	SELECTION PREPROGRAM CONTROL	CANNED PREPROGRAM INDEPENDENT INTERACTIVE	NO REMOTE FEEDBACK
28	NIGHT DAY D/N	OPEN SEA COASTAL RESTRICTED WATERS	120° 240° 180° 360°	10° 20° 30°	B&W COLOR	NO LOW HIGH	REDUCED FULL REPLICATION	DEEP SHALLOW SPECIAL	SELECTION PREPROGRAM CONTROL	CANNED PREPROGRAM INDEPENDENT INTERACTIVE	NO REMOTE FEEDBACK

TABLE A-3. TRAINING EFFECTIVENESS OF SELECTED SIMULATOR CHARACTERISTICS (Continued)

TO#	TIME OF DAY	GEOGRAPHIC AREA	HORIZONTAL F/V	VERTICAL F/V	COLOR VISUAL SCENE	RADAR PRESENTATION	BRIDGE CONFIGURATION	OWNSHIP DYNAMICS	EXERCISE CONTROL	TRAFFIC VESSEL CONTROL	TRAINING ASSIST TECH
29	NIGHT DAY D/N	OPEN SEA COASTAL RESTRICTED WATERS	120° 180° 240° 360°	10° 20° 30°	B&W COLOR	NO LOW HIGH	REDUCED FULL REPLICATION	DEEP SHALLOW SPECIAL	SELECTION PREPROGRAM CONTROL	CANNED PREPROGRAM INDEPENDENT INTERACTIVE	NO REMOTE FEEDBACK
30	NIGHT DAY D/N	OPEN SEA COASTAL RESTRICTED WATERS	120° 180° 240° 360°	10° 20° 30°	B&W COLOR	NO LOW HIGH	REDUCED FULL REPLICATION	DEEP SHALLOW SPECIAL	SELECTION PREPROGRAM CONTROL	CANNED PREPROGRAM INDEPENDENT INTERACTIVE	NO REMOTE FEEDBACK
31	NIGHT DAY D/N	OPEN SEA COASTAL RESTRICTED WATERS	120° 180° 240° 360°	10° 20° 30°	B&W COLOR	NO LOW HIGH	REDUCED FULL REPLICATION	DEEP SHALLOW SPECIAL	SELECTION PREPROGRAM CONTROL	CANNED PREPROGRAM INDEPENDENT INTERACTIVE	NO REMOTE FEEDBACK
32	NIGHT DAY D/N	OPEN SEA COASTAL RESTRICTED WATERS	120° 180° 240° 360°	10° 20° 30°	B&W COLOR	NO LOW HIGH	REDUCED FULL REPLICATION	DEEP SHALLOW SPECIAL	SELECTION PREPROGRAM CONTROL	CANNED PREPROGRAM INDEPENDENT INTERACTIVE	NO REMOTE FEEDBACK
33	NIGHT DAY D/N	OPEN SEA COASTAL RESTRICTED WATERS	120° 180° 240° 360°	10° 20° 30°	B&W COLOR	NO LOW HIGH	REDUCED FULL REPLICATION	DEEP SHALLOW SPECIAL	SELECTION PREPROGRAM CONTROL	CANNED PREPROGRAM INDEPENDENT INTERACTIVE	NO REMOTE FEEDBACK
35	DAY NIGHT D/N	OPEN SEA COASTAL RESTRICTED WATERS	120° 180° 240° 360°	10° 20° 30°	B&W COLOR	NO LOW HIGH	REDUCED FULL REPLICATION	DEEP SHALLOW SPECIAL	SELECTION PREPROGRAM CONTROL	CANNED PREPROGRAM INDEPENDENT INTERACTIVE	NO REMOTE FEEDBACK

TABLE A-3. TRAINING EFFECTIVENESS OF SELECTED SIMULATOR CHARACTERISTICS (Continued)

TO#	TIME OF DAY	GEOGRAPHIC AREA	HORIZONTAL F/V	VERTICAL F/V	COLOR VISUAL SCENE	RADAR PRESENTATION	BRIDGE CONFIGURATION	OWNSHIP DYNAMICS	EXERCISE CONTROL	TRAFFIC VESSEL CONTROL	TRAINING ASSIST TECH
37	NIGHT DAY D/N	OPEN SEA COASTAL RESTRICTED WATERS	120° 180° 240° 300°	10° 20° 30°	B&W COLOR	NO LOW HIGH	REDUCED FULL REPLICATION	DEEP SHALLOW SPECIAL	SELECTION PREPROGRAM CONTROL	CANNED PREPROGRAM INDEPENDENT INTERACTIVE	NO REMOTE FEEDBACK
72	NIGHT DAY D/N	OPEN SEA COASTAL RESTRICTED WATERS	120° 180° 240° 300°	10° 20° 30°	B&W COLOR	NO LOW HIGH	REDUCED FULL REPLICATION	DEEP SHALLOW SPECIAL	SELECTION PREPROGRAM CONTROL	CANNED PREPROGRAM INDEPENDENT INTERACTIVE	NO REMOTE FEEDBACK
73	NIGHT DAY D/N	OPEN SEA COASTAL RESTRICTED WATERS	120° 180° 240° 300°	10° 20° 30°	B&W COLOR	NO LOW HIGH	REDUCED FULL REPLICATION	DEEP SHALLOW SPECIAL	SELECTION PREPROGRAM CONTROL	CANNED PREPROGRAM INDEPENDENT INTERACTIVE	NO REMOTE FEEDBACK
74	NIGHT DAY D/N	OPEN SEA COASTAL RESTRICTED WATERS	120° 180° 240° 300°	10° 20° 30°	B&W COLOR	NO LOW HIGH	REDUCED FULL REPLICATION	DEEP SHALLOW SPECIAL	SELECTION PREPROGRAM CONTROL	CANNED PREPROGRAM INDEPENDENT INTERACTIVE	NO REMOTE FEEDBACK
75	DAY NIGHT D/N	OPEN SEA COASTAL RESTRICTED WATERS	120° 180° 240° 300°	10° 20° 30°	B&W COLOR	NO LOW HIGH	REDUCED FULL REPLICATION	DEEP SHALLOW SPECIAL	SELECTION PREPROGRAM CONTROL	CANNED PREPROGRAM INDEPENDENT INTERACTIVE	NO REMOTE FEEDBACK
76	NIGHT DAY D/N	OPEN SEA COASTAL RESTRICTED WATERS	120° 240° 180° 300°	10° 20° 30°	B&W COLOR	NO LOW HIGH	REDUCED FULL REPLICATION	DEEP SHALLOW SPECIAL	SELECTION PREPROGRAM CONTROL	CANNED PREPROGRAM INDEPENDENT INTERACTIVE	NO REMOTE FEEDBACK

TABLE A-3. TRAINING EFFECTIVENESS OF SELECTED SIMULATOR CHARACTERISTICS (Continued)

TOs	TIME OF DAY	GEOGRAPHIC AREA	HORIZONTAL F/V	VERTICAL F/V	COLOR VISUAL SCENE	RADAR PRESENTATION	BRIDGE CONFIGURATION	OWNSHIP DYNAMICS	EXERCISE CONTROL	TRAFFIC VESSEL CONTROL	TRAINING ASSIST TECH
77	NIGHT DAY D/N	OPEN SEA COASTAL RESTRICTED WATERS	120° 180° 240° 360°	10° 20° 30°	B&W COLOR	NO LOW HIGH	REDUCED FULL REPLICATION	DEEP SHALLOW SPECIAL	SELECTION PREPROGRAM CONTROL	CANNED PREPROGRAM INDEPENDENT INTERACTIVE	NO REMOTE FEEDBACK
78	NIGHT DAY D/N	OPEN SEA COASTAL RESTRICTED WATERS	120° 180° 240° 360°	10° 20° 30°	B&W COLOR	NO LOW HIGH	REDUCED FULL REPLICATION	DEEP SHALLOW SPECIAL	SELECTION PREPROGRAM CONTROL	CANNED PREPROGRAM INDEPENDENT INTERACTIVE	NO REMOTE FEEDBACK
87	NIGHT DAY D/N	OPEN SEA COASTAL RESTRICTED WATERS	120° 180° 240° 360°	10° 20° 30°	B&W COLOR	NO LOW HIGH	REDUCED FULL REPLICATION	DEEP SHALLOW SPECIAL	SELECTION PREPROGRAM CONTROL	CANNED PREPROGRAM INDEPENDENT INTERACTIVE	NO REMOTE FEEDBACK
88	NIGHT DAY D/N	OPEN SEA COASTAL RESTRICTED WATERS	120° 180° 240° 360°	10° 20° 30°	B&W COLOR	NO LOW HIGH	REDUCED FULL REPLICATION	DEEP SHALLOW SPECIAL	SELECTION PREPROGRAM CONTROL	CANNED PREPROGRAM INDEPENDENT INTERACTIVE	NO REMOTE FEEDBACK
89	NIGHT DAY D/N	OPEN SEA COASTAL RESTRICTED WATERS	120° 180° 240° 360°	10° 20° 30°	B&W COLOR	NO LOW HIGH	REDUCED FULL REPLICATION	DEEP SHALLOW SPECIAL	SELECTION PREPROGRAM CONTROL	CANNED PREPROGRAM INDEPENDENT INTERACTIVE	NO REMOTE FEEDBACK
94	DAY NIGHT D/N	OPEN SEA COASTAL RESTRICTED WATERS	120° 180° 240° 360°	10° 20° 30°	B&W COLOR	NO LOW HIGH	REDUCED FULL REPLICATION	DEEP SHALLOW SPECIAL	SELECTION PREPROGRAM CONTROL	CANNED PREPROGRAM INDEPENDENT INTERACTIVE	NO REMOTE FEEDBACK
95	NIGHT DAY D/N	OPEN SEA COASTAL RESTRICTED WATERS	120° 240° 180° 360°	10° 20° 30°	B&W COLOR	NO LOW HIGH	REDUCED FULL REPLICATION	DEEP SHALLOW SPECIAL	SELECTION PREPROGRAM CONTROL	CANNED PREPROGRAM INDEPENDENT INTERACTIVE	NO REMOTE FEEDBACK
96	NIGHT DAY D/N	OPEN SEA COASTAL RESTRICTED WATERS	120° 180° 240° 360°	10° 20° 30°	B&W COLOR	NO LOW HIGH	REDUCED FULL REPLICATION	DEEP SHALLOW SPECIAL	SELECTION PREPROGRAM CONTROL	CANNED PREPROGRAM INDEPENDENT INTERACTIVE	NO REMOTE FEEDBACK

TABLE A-3. TRAINING EFFECTIVENESS OF SELECTED SIMULATOR CHARACTERISTICS (Continued)

TOs	TIME OF DAY	GEOGRAPHIC AREA	HORIZONTAL F/V	VERTICAL F/V	COLOR VISUAL SCENE	RADAR PRESENTATION	BRIDGE CONFIGURATION	OWNSHIP DYNAMICS	EXERCISE CONTROL	TRAFFIC VESSEL CONTROL	TRAINING ASSIST TECH
104	NIGHT DAY D/N	OPEN SEA COASTAL RESTRICTED WATERS	120° 180° 240° 300°	10° 20° 30°	B&W COLOR	NO LOW HIGH	REDUCED FULL REPLICATION	DEEP SHALLOW SPECIAL	SELECTION PREPROGRAM CONTROL	CANNED PREPROGRAM INDEPENDENT INTERACTIVE	NO REMOTE FEEDBACK
105	NIGHT DAY D/N	OPEN SEA COASTAL RESTRICTED WATERS	120° 180° 240° 300°	10° 20° 30°	B&W COLOR	NO LOW HIGH	REDUCED FULL REPLICATION	DEEP SHALLOW SPECIAL	SELECTION PREPROGRAM CONTROL	CANNED PREPROGRAM INDEPENDENT INTERACTIVE	NO REMOTE FEEDBACK
106	NIGHT DAY D/N	OPEN SEA COASTAL RESTRICTED WATERS	120° 180° 240° 300°	10° 20° 30°	B&W COLOR	NO LOW HIGH	REDUCED FULL REPLICATION	DEEP SHALLOW SPECIAL	SELECTION PREPROGRAM CONTROL	CANNED PREPROGRAM INDEPENDENT INTERACTIVE	NO REMOTE FEEDBACK
107	NIGHT DAY D/N	OPEN SEA COASTAL RESTRICTED WATERS	120° 180° 240° 300°	10° 20° 30°	B&W COLOR	NO LOW HIGH	REDUCED FULL REPLICATION	DEEP SHALLOW SPECIAL	SELECTION PREPROGRAM CONTROL	CANNED PREPROGRAM INDEPENDENT INTERACTIVE	NO REMOTE FEEDBACK
108	NIGHT DAY D/N	OPEN SEA COASTAL RESTRICTED WATERS	120° 180° 240° 300°	10° 20° 30°	B&W COLOR	NO LOW HIGH	REDUCED FULL REPLICATION	DEEP SHALLOW SPECIAL	SELECTION PREPROGRAM CONTROL	CANNED PREPROGRAM INDEPENDENT INTERACTIVE	NO REMOTE FEEDBACK
109	DAY NIGHT D/N	OPEN SEA COASTAL RESTRICTED WATERS	120° 180° 240° 300°	10° 20° 30°	B&W COLOR	NO LOW HIGH	REDUCED FULL REPLICATION	DEEP SHA' 'OW SPECIAL	SELECTION PREPROGRAM CONTROL	CANNED PREPROGRAM INDEPENDENT INTERACTIVE	NO REMOTE FEEDBACK
110	NIGHT DAY D/N	OPEN SEA COASTAL RESTRICTED WATERS	120° 240° 180° 300°	10° 20° 30°	B&W COLOR	NO LOW HIGH	REDUCED FULL REPLICATION	DEEP SHALLOW SPECIAL	SELECTION PREPROGRAM CONTROL	CANNED PREPROGRAM INDEPENDENT INTERACTIVE	NO REMOTE FEEDBACK

TABLE A-4. SIMULATOR CHARACTERISTICS EVALUATION FACTORS

Individual Evaluation	
• Common Factors:	Training objective behavior Training objective conditions Training objective standards Type of training exercises required Number of training exercises required Experimental evidence Trainee acceptance Experienced mariner acceptance Accepted training practice
• Time of Day:	Nighttime visual cues Daytime visual cues Accepted bridge procedures
• Geographic Area:	Visual cues available for shiphandling Aids to navigation Radar information Echo sounding information Accepted bridge procedures
• Horizontal Field of View:	Azimuth of visual cues Angle of crossing situations Angular separation of visual lines of position Accepted bridge procedures
• Vertical Field of View:	Range to traffic vessels Frequency of range to traffic vessels Range to aids to navigation Frequency of range to aids of navigation Height of eye – ownship
• Color Visual Scene:	Color visual cues Color traffic vessel lights Color aids to navigation Utilization of flash coding
• Radar Presentation:	Radar collision avoidance information Radar navigation information Radar plotting procedures Radar operation tasks
• Bridge Configuration:	Number of bridge team members Location of work stations Movement within pilothouse Accepted bridge procedures

TABLE A-4. SIMULATOR CHARACTERISTICS EVALUATION FACTORS (Continued)

• Ownship Dynamics:	External forces on ownship Proximity to land Water depth Wind and current accuracy Use of tugs
• Exercise Control:	Traffic vessel interaction Alteration of wind and current Initiation of shipboard casualties
• Traffic Vessel Control:	Traffic vessel interaction Traffic proximity Radio telephone contact
• Training Assistance Technology:	Size of class Requirement for instructor on bridge Bridge team tasks Accepted bridge procedures Shiphandling performance measures Navigation performance measures

Composite Evaluation*

- Overall estimated training effectiveness *across training objectives*
- Relative cost between characteristic levels
- Absolute cost between characteristic levels
- Interaction between characteristics . . . regarding both cost and training effectiveness
- Iterative analysis of overall design

*A summary of the specific results of this process is provided in the text rationale for each recommended characteristic level.

APPENDIX B

REPRESENTATIVE SCHEDULE OF PROFESSIONAL COURSES/TRAINING AT VARIOUS STATE MARITIME ACADEMIES

REPRESENTATIVE SCHEDULE OF PROFESSIONAL COURSES/TRAINING AT CALIFORNIA MARITIME ACADEMY

4TH CLASS			3RD CLASS			2ND CLASS			1ST CLASS		
FALL	WINTER	SPRING	FALL	WINTER	SPRING	FALL	WINTER	SPRING	FALL	WINTER	SPRING
D-111 "SEAMANSHIP" •EQUIPMENT •EMERGENCY PROCEDURES	D 102 "SMALL BOAT OPERATIONS"	D 116 "SHIPBOARD LABORATORY" •CARGO HANDLING	D 101 "MANAGEMENT"	D 501 "SEA TRAINING" •BRIDGE PROCEDURES •SEAMANSHIP •EXTERNAL VESSEL COMMUNICATION •RULES OF THE ROAD	D 204 "MANAGERIAL FINANCE"	D-201 "NAVIGATION" •CELESTIAL NAVIGATION	D-401 "SEA NAVIGATION LABORATORY" •CELESTIAL NAVIGATION	D 202 "NAVIGATION" •CELESTIAL •ELECTRONIC •MARINE WEATHER	D-301 "NAVIGATION" •CELESTIAL	D 425 "SHIP ORGANIZATION AND MANAGEMENT LABORATORY"	D-512 "LICENSE SEMINAR"
D-115 "SHIPBOARD LABORATORY" •VESSEL OPERATION AND MAINTENANCE		D-203 "SPHERICAL TRIGONOMETRY"	D-108 "NAVIGATION" •PILOTING		D-210 "NAVAL ARCHITECTURE" •STABILITY AND TRIM	D-205 "CONCEPTS OF LEADERSHIP"	D-502 "SEA TRAINING" •WATCHSTANDING BRIDGE PROCEDURES •CARGO OPERATIONS •EXTERNAL VESSEL COMMUNICATION •RULES TO THE ROAD	D-212 "RULES OF THE ROAD" •INTERNATIONAL •INLAND •COLLISION AVOIDANCE	D-303 "METEOROLOGY" •MARINE WEATHER	D-503 "SEA TRAINING" •WATCHSTANDING/ BRIDGE PROCEDURES •COLLISION AVOIDANCE •CELESTIAL/ ELECTRONIC NAVIGATION •MARINE WEATHER	
PE-101 "BOAT HANDLING" •LIFEBOATS •OAR •SAIL			D-207 "NAVAL ARCHITECTURE" •SHIP CONSTRUCTION		D-215 "SEAMANSHIP LABORATORY" •DECK MACHINERY MAINTENANCE	D-223 "COMMUNICATIONS/ RULES OF THE ROAD" •EXTERNAL VESSEL COMMUNICATION •INTERNATIONAL AND INLAND RULES		D-310 "TRANSPORTATION MANAGEMENT II" •BULK LIQUID CARGO	D-304 "ADMIRALTY LAW"		
						D-226 "SHIP OPERATIONS" •EMERGENCY SHIPBOARD EVOLUTIONS		D-315 "APPLIED SEAMANSHIP" •SHIPHANDLING •COLLISION AVOIDANCE •EMERGENCY DRILLS	D-305 "RADAR" * •RELATIVE MOTION •COLLISION AVOIDANCE		
						D-309 "TRANSPORTATION MANAGEMENT I" •DRY CARGO		D-325 "MARINE SUPERVISORY LABORATORY"	D-311 "SEAMANSHIP" •CARGO GEAR •DAMAGE CONTROL		
								D-360 "ADVANCED MANAGEMENT TECHNIQUES"	D-323 "COMMUNICATIONS" •EXTERNAL VESSEL		
									D-326 "MARINE MANAGEMENT LABORATORY"		
									*RADAR OBSERVER COURSE		

REPRESENTATIVE SCHEDULE OF PROFESSIONAL COURSES/TRAINING AT MAINE MARITIME ACADEMY

FRESHMAN			SOPHOMORE			JUNIOR			SENIOR	
SEMESTER I	SEMESTER II	SEA TERM	SEMESTER I	SEMESTER II	SEA TERM	SEMESTER I	SEMESTER II	SEA TERM	SEMESTER I	SEMESTER II
NS-1 "DECK INDOCTRINATION" BASIC NOMENCLATURE NAVIGATIONAL INSTRUMENTS LOCATION/USE SHIPBOARD DRILLS	NS-2 "SHIP STRUCTURE"	TRAINING SHIP CRUISE •WATCHSTANDING (HELMSMAN LOOK-OUT) •VESSEL OPERATION AND MAINTENANCE	NS-5 "METEOROLOGY" •MARINE WEATHER	NS-3 "DECK DRAWING"	MERCHANT VESSEL CADET SHIPPING TRAINING •VESSEL OPERATIONS •CARGO HANDLING •SEAMANSHIP (DECK MACHINERY) •EXTERNAL VESSEL COMMUNICATION	NS-4 "STABILITY"	NS-7 "CARGO I" •DRY CARGO	TRAINING SHIP CRUISE •WATCHSTANDING/BRIDGE PROCEDURES •COLLISION AVOIDANCE •PILOTING •CELESTIAL/ELECTRONIC NAVIGATION •MARINE WEATHER	NS-8 "CARGO II" •TANK VESSELS •BULK CARRIERS	NS-6 "METEOROLOGY II"
			NS-10 "SEAMANSHIP I" (CARGO GEAR, GROUND TACKLE)	NS-11 "SEAMANSHIP II" •SMALLBOAT/POWER BOAT HANDLING •EXTERNAL VESSEL COMMUNICATIONS		NS-12 "SEAMANSHIP III" •POWER PLANTS •PROPELLERS AND FORCES •SHIPHANDLING	NS-17 "RULES OF THE ROAD II" (INLAND AND PILOT)		NS-14 "RULES AND REGULATIONS"	NS-9 "DECK MATHEMATICS"
			NS-30 "PILOTING AND NAUTICAL ASTRONOMY" •PILOTING •CELESTIAL NAVIGATION	NS-16 "RULES OF THE ROAD" (INTERNATIONAL)		NS-32 "NAVIGATION-SAILINGS"	NS-33 "CELESTIAL NAVIGATION III"		NS-18 "RULES OF THE ROAD III" •MARINE COLLISION LAW	NS-13 "SEAMANSHIP IV" •WATCHSTANDING/BRIDGE PROCEDURES
				NS-22 "MARLINSPIKE"			NS-50* "ELECTRONIC NAVIGATION" •RELATIVE MOTION •ELECTRONIC NAVIGATION		NS-20 "COMMUNICATIONS"	NS-19 "RULES OF THE ROAD IV" (INLAND, PILOT, INTERNATIONAL)
				NS-31 "CELESTIAL NAVIGATION I" (LINES OF POSITION, RUNNING FIX)			* SERIES FOR RADAR OBSERVER COURSE		NS-51* "ELECTRONIC NAVIGATION II" •COLLISION AVOIDANCE	NS-21 "COMMUNICATIONS II"
									NS-36 "GENERAL NAVIGATION I" •PILOTING	NS-37 "GENERAL NAVIGATION II" •PILOTING •CELESTIAL NAVIGATION
										NS-40 "SHIP BUSINESS AND INDUSTRIAL RELATIONS"
										NS-52* "ELECTRONIC NAVIGATION III" •COLLISION AVOIDANCE

REPRESENTATIVE SCHEDULE OF PROFESSIONAL COURSES/TRAINING AT MASSACHUSETTS MARITIME ACADEMY

FRESHMAN			SOPHOMORE			JUNIOR			SENIOR	
SEMESTER I	SEMESTER II	SEA TERM I	SEMESTER I	SEMESTER II	SEA TERM II	SEMESTER I	SEMESTER II	SEA TERM III	SEMESTER I	SEMESTER II
"INTRODUCTION TO MARINE TRANSPORTATION" • SHIPPING INDUSTRY • SHIPS • SHIPPING SPECIFICS		• WATCHSTANDING: BRIDGE PROCEDURES • EXTERNAL VESSEL COMMUNICATION • SEAMANSHIP (EQUIPMENT)	"METEOROLOGY" • MARINE WEATHER	"RULES OF THE ROAD" • INTERNATIONAL • INLAND	• CELESTIAL NAVIGATION • SEAMANSHIP (DECK MACHINERY) • RULES OF THE ROAD • EMERGENCY SHIPBOARD EVOLUTIONS	"RADAR OBSERVER" * • RELATIVE MOTION	"ADVANCED SEAMANSHIP" • SHIPHANDLING • DAMAGE CONTROL	• RULES OF THE ROAD • SEAMANSHIP • PILOTING • MARINE WEATHER	"MARINE SAFETY" • RULES OF THE ROAD LAWS	"NAVAL ARCHITECTURE II" • STABILITY AND TRIM
			"SEAMANSHIP I" • BLOCK AND TACKLE • SAFETY EQUIPMENT • EMERGENCY PROCEDURES • SMALL BOAT HANDLING	"PILOTING"		"CARGO I"	"CELESTIAL NAVIGATION I"		"ELECTRONIC NAVIGATION" • COLLISION AVOIDANCE • EXTERNAL VESSEL COMMUNICATION • ELECTRONIC NAVIGATION	"MARINE TRANSPORTATION II" • LABOR UNION • INSURANCE • SHIP'S BUSINESS
						"NAUTICAL ASTRONOMY" • CELESTIAL NAVIGATION	"CARGO II"		"CELESTIAL NAVIGATION II"	
							"RADAR OBSERVER II" • COLLISION AVOIDANCE		"NAVAL ARCHITECTURE I" • SHIP CONSTRUCTION	
						* RADAR OBSERVER COURSE				

REPRESENTATIVE SCHEDULE OF PROFESSIONAL COURSES/TRAINING AT STATE UNIVERSITY OF NEW YORK MARITIME COLLEGE

4TH CLASS		3RD CLASS			2ND CLASS			1ST CLASS		
SEMESTER I	SEMESTER II	SEA TERM I	SEMESTER I	SEMESTER II	SEA TERM II	SEMESTER I	SEMESTER II	SEA TERM III	SEMESTER I	SEMESTER II
NAUT SCI 101 "OPERATIONS I" • SEAMANSHIP (EQUIPMENT, MECHANICAL APPLIANCES, GROUND TACKLE) • SHIP ORGANIZATION/ ROUTINE	NAVIGATION 205 "TERRESTRIAL NAVIGATION" • PILOTING	"SHIP OPERATION AND MANAGEMENT I, INTRODUCTION" • EXTERNAL VESSEL COMMUNICATIONS • PILOTING • BASIC RULES OF THE ROAD	NAUT SCI 206 "OPERATIONS II" • CARGO HANDLING • SEAMANSHIP (GROUND TACKLE) • EXTERNAL VESSEL COMMUNICATIONS • SHIPHANDLING	NAVIGATION 301 "NAUTICAL ASTRONOMY AND CELESTIAL NAVIGATION"	"SHIP OPERATION AND MANAGEMENT II, INTERMEDIATE" • EXTERNAL VESSEL COMMUNICATIONS • CELESTIAL NAVIGATION • SEAMANSHIP (WINCHES, GROUND TACKLE) • INTERMEDIATE RULES OF THE ROAD • PILOTING	MARINE TRANS. 201 "MARINE CARGO OPERATIONS I"	MARINE TRANS 202 "MARINE CARGO OPERATIONS II"	"SHIP OPERATIONS AND MANAGEMENT III, ADVANCED" • WATCHSTANDING/ BRIDGE PROCEDURES • EXTERNAL VESSEL COMMUNICATIONS • MARINE WEATHER • CELESTIAL/ ELECTRONIC NAVIGATION • PILOTING	LAW 403 "MARITIME LAW I"	LAW 404 "MARITIME LAW II"
				METEOROLOGY 311 • MARINE WEATHER		NAUT. SCI. 304 "RULES OF THE NAUTICAL ROAD" • COLLISION AVOIDANCE • RELATIVE MOTION	NAUT. SCI. 306 "OPERATIONS III" • RULES AND REGULATIONS • EMERGENCY SHIPBOARD EVOLUTIONS		NAUT. SCI. 408 "LICENSE SEMINAR"	MARITIME TRANS. 402 "TRANSPORTATION INSURANCE"
						NAVIGATION 311 "MARINE ELECTRONIC SYSTEMS" • CIRCUIT COMPONENTS/ ELEMENTS • COMMUNICATION CHARACTERISTICS • RDF	NAVIGATION 312 * "ELECTRONIC NAVIGATION SYSTEMS" • GYRO • LORAN • DECCA • OMEGA • RADAR		NAVIGATION 402 "ADVANCED NAVIGATION" • PILOTING • CELESTIAL NAVIGATION • ELECTRONIC NAVIGATION	NAVAL SCI. 406 "NAVAL SCIENCE AND THE MERCHANT MARINE OFFICER II" • WEAPONS SYSTEM • DAMAGE CONTROL • COMMUNICATION
							*RADAR OBSERVER COURSE		NAVAL SCI. 405 "NAVAL SCIENCE AND THE MERCHANT MARINE OFFICER" • DUTIES/ RESPONSIBILITIES	

REPRESENTATIVE SCHEDULE OF PROFESSIONAL COURSES/TRAINING AT TEXAS A&M UNIVERSITY AT GALVESTON

FRESHMAN			SOPHOMORE			JUNIOR			SENIOR	
SEMESTER I	SEMESTER II	SEA TERM	SEMESTER I	SEMESTER II	SEA TERM	SEMESTER I	SEMESTER II	SEA TERM	SEMESTER I	SEMESTER II
NAUT 103 "MARITIME ORIENTATION AND LIFE SAVING" SHIPBOARD NOMENCLATURE CARGO LIFESAVING TRAINING	NAUT 203 "SEAMANSHIP I" •SEAMANSHIP (BLOCK AND TACKLE) (CARGO GEAR) •INTERNATIONAL RULES OF THE ROAD NAUT 204 "TERRESTRIAL NAVIGATION" • PILOTING	NAUT 200 BASIC COMMUNICATIONS, NAVIGATION AND SEAMANSHIP" •EXTERNAL VESSEL COMMUNICATIONS •PILOTING • SEAMANSHIP •RULES OF THE ROAD		NAUT. 301 "SEAMANSHIP II" •SEAMANSHIP (MECHANICAL APPLIANCES) •EXTERNAL VESSEL COMMUNICATIONS NAUT. 303 "CELESTIAL NAVIGATION"	NAUT 300 "INTERMEDIATE COMMUNICATIONS, NAVIGATION AND SEAMANSHIP" •EXTERNAL VESSEL COMMUNICATIONS •PILOTING •CELESTIAL NAVIGATION •SEAMANSHIP •RULES OF THE ROAD	NAUT 201 "NAVAL ARCHITECTURE I"	NAUT 202 NAVAL ARCHITECTURE II" NAUT 304 "ELECTRONIC • NAVIGATION" •RELATIVE MOTION •COLLISION AVOIDANCE •ELECTRONIC NAVIGATION * RADAR OBSERVER COURSE	NAUT 400 "ADVANCED COMMUNICATIONS NAVIGATION AND SEAMANSHIP" •WATCHSTANDING/ BRIDGE PROCEDURES •PILOTING •CELESTIAL/ ELECTRONIC NAVIGATION •RULES OF THE ROAD	NAUT 404 THE NAVIGATOR" •ELECTRONIC NAVIGATION •CELESTIAL NAVIGATION •PILOTING NAUT 302 "SEAMANSHIP III" •PROPULSION AND STEERING •SHIPHANDLING	