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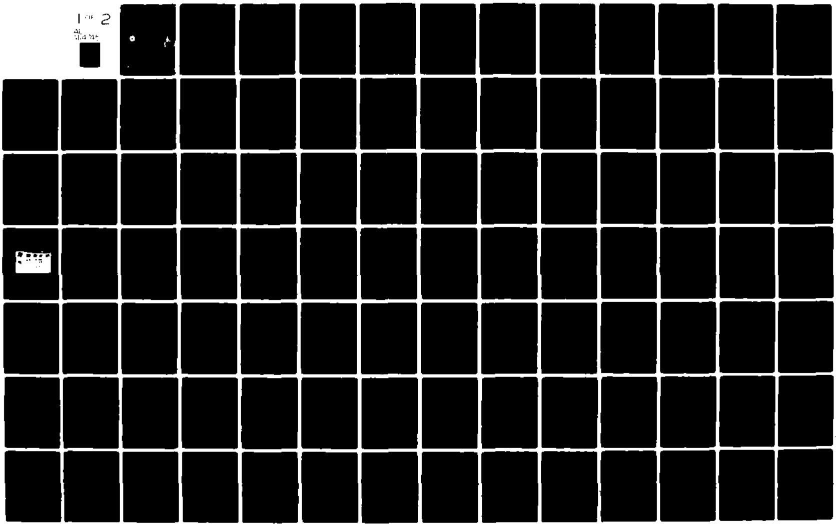

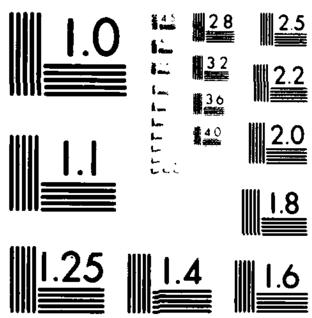

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SIMULATORS FOR MARINER TRAINING AND LICENSING

PHASE 2: INVESTIGATION OF SIMULATOR-BASED TRAINING FOR MARITIME CADETS

OCTOBER 1981

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16. Abstracts

Merchant vessel bridge/shiphandling simulators have been used for the training of deck officers during the past decade. This training has generally addressed the shiphandling skills of the advanced level deck officer and pilot. Those positions have the greatest need for such skill. Due primarily to the recent IMCO Standards of Training and Watchkeeping Convention, July 1978, which established the basis for 3rd mate training standards, simulator-based shiphandling training has been increasingly viewed as a supplement to existing training programs at the cadet/midshipment level. This document describes the approach taken in the development and conduct of the prototype cadet-simulator based training program in the United States. The issues investigated during this prototype training program were: input characteristics of cadets, the effectiveness of simulator-based training, day/night simulation, and distributed/concentrated training.

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17b Identifiers/Open-Ended Items

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EXECUTIVE SUMMARY

GENERAL

What is believed to be the first ship bridge simulator training program for cadets was given experimentally to volunteers from the graduating classes of the U.S. Merchant Marine Academy (Kings Point) and the New York State Maritime College (Fort Schuyler) in 1979. The program was apparently effective in improving specific skills of the cadets for:

- Perception and decisionmaking in applying Rules of the Road
- Port approach navigation and shiphandling
- Overall bridge procedures, including helm orders, VHF communications, bridge management, and notification of the master.

Whether such training transfers to the actual shipboard behavior of entry third mates will remain unknown until the pertinent shipboard studies can be completed.

BACKGROUND

Shiphandling/ship bridge simulators have been used increasingly in recent years for training by the maritime industry. The vast majority of this use has been at the advanced deck officer level, such as the master, with relatively little, if any, at the junior deck officer level. A jointly sponsored U.S. Coast Guard/U.S. Maritime Administration project is looking into the role of the shiphandling/ship bridge simulator in the deck officers' training and licensing process (Hammell, Williams, Grasso, and Evans, 1980). Figure A shows the overall project and, in bold outline, this effort.

This first cadet simulator-based training program was given at the Computer-Aided Operations Research Facility (CAORF), Kings Point, New York, in response to several factors:

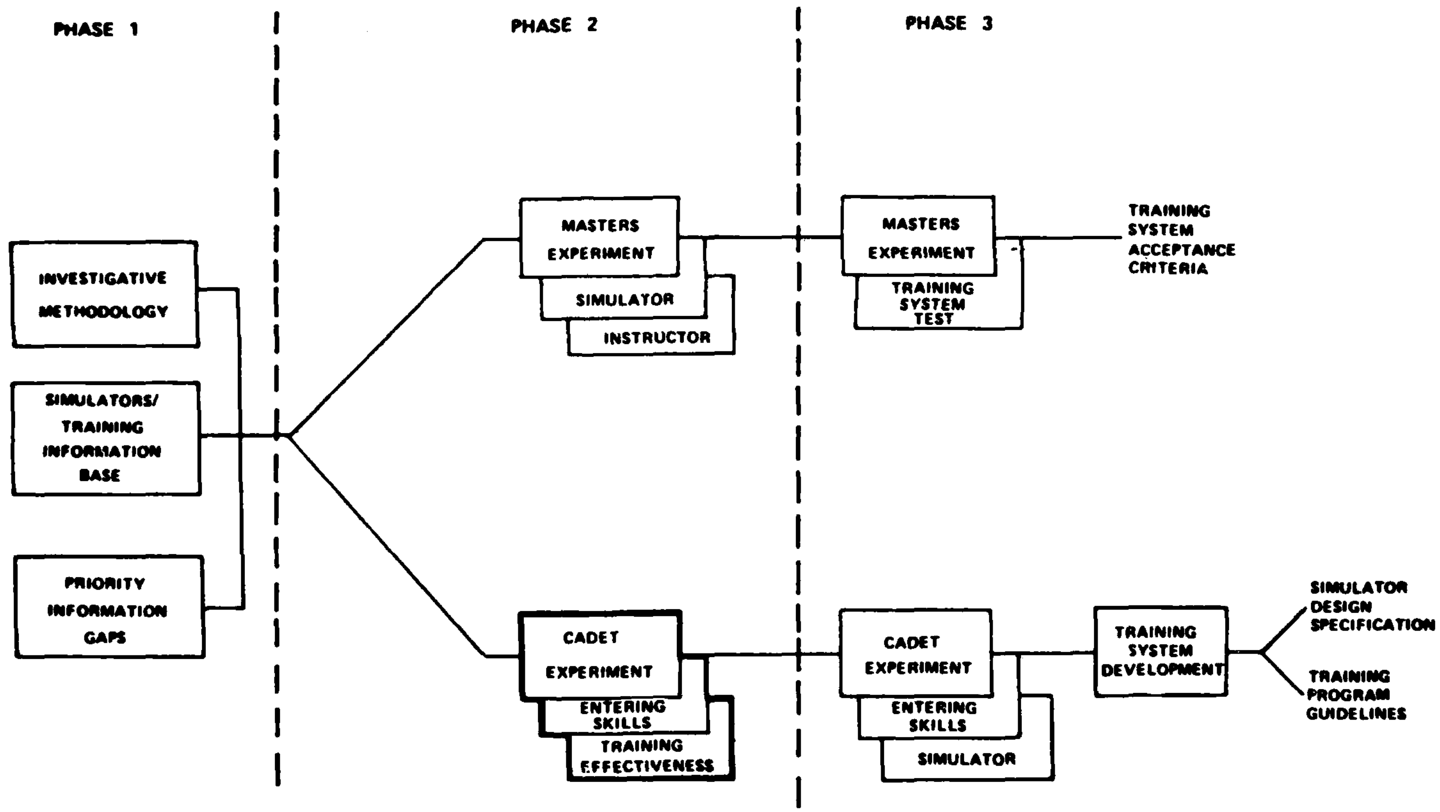

Figure A. Overview of Training and Licensing Project – Phases 1, 2 and 3

- First, the expense of at-sea training, particularly aboard dedicated training vessels, has been increasing rapidly.

- Second, shiphandling simulators are getting better and cheaper. Simulator training offers advantages in safety, training control and cost relative to non-revenue sailing for training. Revenue sailing distinctly limits the opportunities for the aspiring mate to perform a variety of maneuvers and generally lacks professional instruction.

- Third, the preparedness for shipboard duty of the entry 3rd mate has been the subject of international concern, resulting in an Intergovernmental Maritime Consultative Organization (IMCO) recommendation which would require an increase in the amount of at-sea time, or some equivalently effective means of gaining proficiency, for U.S. Maritime Academy graduates prior to obtaining their 3rd mate license (Regulation II/4 and Article IX, IMCO Standards of Training, Certification and Watchkeeping for Seafarers, 1978).

- Fourth, the Port and Tanker Safety Act of 1978 requires improved standards for the qualifications and training of officers and crew. It specifically calls for standards relating to the "qualification for licenses by use of simulators for the practice or demonstration of marine-oriented skills."

EXPERIMENT DESCRIPTION

This experimental training program had the following objectives:

- Evaluate the shiphandling-related skill levels of cadets who have completed 6 months of at-sea training and are ready to assume duties of a 3rd mate after passing the written examination.

- Evaluate the effectiveness of a simulator-based prototype training program for improving the skills of a cadet/entry 3rd mate.

- Evaluate the training effectiveness of daylight versus night visual scene on the simulator.

- Evaluate the effectiveness of distributed training (e.g., training spread out over six weeks) versus concentrated training (e.g., the same material covered in the same number of hours during one week).

- Provides a ship bridge simulator training course of cadets and learn their reaction to it.

The training covered two topics: (a) collision avoidance involving International Rules of the Road and (b) planning and conducting a Port Approach. Each group of cadets was subdivided into two teams of three for training. One team of three stood watch on the bridge during each scenario run. The three were:

- A senior watch officer
- A radar plotting officer
- A navigation recording officer.

The cadets rotated positions in the team after each scenario. While one bridge team was on the bridge, the other team in the group was viewing the scenario via television monitors at the human factors station. An instructor was providing evaluative commentary to the "off watch" cadets during the run.

Instructors for the training program were experienced mariners, members of the U.S. Merchant Marine Academy Nautical Science Staff.

The trainees were twelve cadets from the U.S. Merchant Marine Academy (Kings Point) and six cadets from the State University of New York Maritime College (Fort Schuyler). Because these cadets participated in the spring of their senior year just prior to graduation, it was assumed that the shiphandling/watchstanding behavior observed on their pre-training test scenarios were representative of a new third mate a few months later upon reporting aboard his or her first ship. Actually, the very small size of the sample and the fac' it was not selected at random make the assumption very tentative. Although statements are made concerning cadet characteristics and training at Kings Point and Fort Schuyler, it should be cautioned that the samples of cadets were small, allowing only very weak statistical inference.

CONCLUSIONS REGARDING TRAINING NEEDS OF CADETS

Each cadet in the training program took a pre-training test which consisted of standing watch alone on the bridge. The data collected represents, subject to the limitations noted above, the skill levels of cadets who are nearing graduation and will shortly receive their 3rd mate licenses. These findings are prior to and independent of the training program itself.

Observed performance involving specific skills appeared to provide room for substantial improvement via simulator training. Therefore, the potential appears to exist for a simulator-based training program to improve the skill of the entering 3rd mate significantly. This study does not address the many areas in which cadet performance was already excellent. Specific conclusions were:

- Although no collisions were experienced during the experiment, the CPA's achieved with traffic vessels under open sea conditions were less than 1 nm on the average and considered as only marginally acceptable. The instructors felt that substantially larger CPA's should be achieved by 3rd mates on watch in these situations. The achieved CPA represents the culmination of several aspects of man/ship system performance. Several of these contributory aspects of performance that impact the resultant CPA are addressed below.

- Stand-on vessel action under Rule 17 at night was, on the average, taken too early. The cadets appeared to lack confidence at night, with the result that their excessive caution conflicted with the intent of the Rules.

- Vessel handling problems were observed under high wind conditions (40 knots). It appears that this may be due to insufficient understanding of: (1) responsiveness of the vessel to various rudder angles, (2) effect of a high wind on a loaded tanker and/or (3) difficulty in position fixing.

- The available information was not fully utilized in evaluating and responding to problems. The cadets over-emphasized the radar information, while often neglecting visual information. This was probably due to: (1) proficient radar plotting skills after effective radar training courses; and (2) a lower level of visual skill explained by the lack of equivalent practical visual training. One notable example of the visual skill deficiency is that the cadets did not understand how to use range lights.

- Substantial room for improvement was observed in the communication and bridge procedures used by the cadets. Areas for improvement included notification of the master regarding an impending situation, communication of maneuvering orders to the helmsman, bridge management and VHF communications.

- Kings Point and Fort Schuyler cadet groups achieved similar results, but consistent differences were noted in their control actions and bridge procedures. This indicates that some differences in procedures and control actions of more senior personnel may stem, at least in part, from their academy training.

These conclusions derive from initial efforts at analysis of computer-collected data, supplemented by observations of the instructors and researchers involved. Thus, they represent the best knowledge available. More detailed and rigorous evaluations of cadet skills will have to await further development of performance measures and large samples of cadets. (See RECOMMENDATIONS FOR FURTHER RESEARCH.)

CONCLUSIONS REGARDING TRAINING EFFECTIVENESS

Ideally, after these initial skill needs were defined, the training program would be specifically tailored to training objectives aimed precisely at those deficiencies. The practical constraints of this experimental program, however, were such that the initial training program had to be in place before the cadets arrived for their pre-tests. Fortunately, some of the skill deficiencies found in the pre-tests were addressed by the training program; unfortunately, others were not. Specific conclusions were:

- The simulator training was effective in improving cadet skills, specifically:
  - Rules of the Road perceptive and decisionmaking skills
  - Port Approach shiphandling and navigation skills, especially use of visual bearings and cross-checking multiple navigation sources
  - Overall bridge procedures including helm orders, VHF communications, bridge team organization/communications, and notification of the master.

- The day and night Rules of the Road training programs both effectively improved cadet skill in bridge procedures and in handling threat traffic vessels. For the Port Approach segment, however, only the position fixing skills improved under nighttime training. In day training, both position fixing skills and shiphandling skills improved. Additional night training may be needed.

- Having the cadets in simulator training one day a week over six weeks (distributed training) appeared to be more effective than having the identical training concentrated into one week. This conclusion is consistent with research results from other training situations and with the general theories of learning. The difference was not tested rigorously here, however, because there were several other ways in which the relevant groups were different, apart from the training schedules.

- Cadets find ship bridge simulator training in general to be of substantial benefit as a supplement to their at-sea training. Even this initial, experimental training program was considered to be of substantial benefit.

RECOMMENDATIONS FOR CADET TRAINING

- The training program at King's Point should be revised and expanded to provide meaningful training for the full cadet population, or as many as feasible.

- Pre-training test scenarios are an excellent vehicle for focusing a simulator-based training program. Unfortunately, logistical constraints usually allow only extensive analysis of the results to benefit subsequent offerings of the course. Additional pre-training scenarios should be administered and additional information collected regarding entering 3rd mate proficiency in other skill areas.

- Specific areas of focus for cadet simulator-based training, based on the information collected during this investigation, are recommended below:

  - Proper use of VHF communications
  - Proper notification of the master regarding threat vessels
  - Use of visual bearing information, in addition to radar information when evaluating risk of collision
  - Use of multiple navigational information sources when establishing the geographic position of ownship
  - Both daytime and nighttime training should be provided; nighttime training should receive the greatest emphasis
  - Distributed training is recommended over concentrated training, where feasible.

- Simulators should be considered for training all cadets at the state and federal academies. It appears that these should be full bridge simulator with both day and night visual scene capability. This training, combining visual and electronic references, would supplement, not replace, classroom training and simpler training devices, such as radar or electronic navigation trainers.

- The following simulator capabilities were specifically found to be effective during this experiment and should be included in any cadet simulator. (Other capabilities not investigated in this limited research segement will undoubtedly also be found highly effective in subsequent research.)

  - Simulated VHF communications
  - Mate/master communications
  - Visual bearings capability (pelorus, for example)
  - Multiple navigation equipment: for example, radar, depth sounder, pelorus.

- Apart from the bridge itself, a remote observation station is very effective in improving the instruction, and, at the same time, it contributes to productivity by increasing the feasible class size for a given simulator configuration. Such a remote capability permits active discussion of on-going situations without disturbing the concentration of the bridge team "on watch."

RECOMMENDATIONS FOR FURTHER RESEARCH

- The most crucial need is for a program of research at-sea to accomplish the following:

  - Document the effectiveness of simulator-based training to assist maritime cadets in the development of skills that are beneficial under at-sea conditions (i.e., transfer-of training).

- Compare the shiphandling and watchstanding skills of new 3rd mates with alternative training backgrounds (e.g., training ship, commercial vessel), to determine the strengths and weaknesses of each type of training.
- Specify any additional skills and higher degrees of proficiency needed for new 3rd mates.

- The proper role of simulator-based training within the 4-year cadet curriculum should be determined. The simulator may cost-effectively address training for a variety of training objectives within the 4-year curriculum. Utilization of the simulator in this regard should be determined.

- Maritime cadet training objectives need to be identified and grouped into the forms of training that seem to be most cost-effective at each institution. These forms are:

  - Classroom and part task device training
  - Small vessel training
  - At-sea training on commercial vessels or training ships
  - Ship bridge simulator training

- Most extensive investigation of the training value of various simulator components is needed to assure a highly cost-effective design. For example, there is some recent evidence of high potential for in the use of equipment to extract performance data from the simulator computer, put it into easily understood graphical form, and display it to the students as feedback information either in real time or immediately after an exercise.

- The performance measures used to evaluate cadet performance, and to provide feedback during training, are inadequately defined. An effort is needed to improve and to validate the quantitative aspect of cadet skill evaluation.

- Simulator training standards being developed for senior mariner licensing may require additional research for adaptation to the cadet/3rd mate level.

The report and appendices which follow provide a more detailed description of the experimental training program and the details of the findings.

SECTION 1
INTRODUCTION

Until recently, "hands-on training" of merchant marine cadets has been provided through the use of training ships or by apprentice assignments on operating merchant ships. Increasingly, simulators are being used to supplement or replace some of the practical training periods. Simulators for collision avoidance, radar training, and radio navigation systems have been around for a considerable period of time. It is only in the past 10 years or so that bridge and cargo handling simulators have developed prominence in maritime training. The present state-of-the-art has made them technically feasible, and the new international requirements on standards of training have posed almost a necessity for their use.

Merchant vessel bridge/shiphandling simulators have been used for the training of deck officers during the past decade. This training has generally addressed the shiphandling skills of the advanced level deck officer and pilot, those positions having the greatest need for such skill. The maritime academy cadet, who is training to obtain a 3rd mate's license, represents the other end of the spectrum. The cadet has traditionally received little, if any, simulator-based training. Cadet training consists primarily of classroom instruction supplemented by 6 to 10 months of at-sea experience. The at-sea experience is typically achieved by serving aboard either a dedicated training vessel or a commercial vessel. Upon obtaining the 3rd mate's license, which is based on having completed the appropriate course of study and passing a written examination, the cadet can serve on any merchant vessel in this capacity. Typically, the master and other deck officers are unsure of the capabilities of the new 3rd mate for some period of time, due to his limited hands-on experience at sea. Hence, some additional at-sea time may be experienced prior to the new 3rd mate being given the responsibility of standing a bridge watch. The shiphandling simulator is under investigation regarding its potential contribution to the training of merchant marine academy cadets, both as a supplementary means of achieving the current required standards of performance and as a means of achieving increased standards.

Several developments have resulted in the investigation of cadet training with the aim towards its upgrading. The preparedness of the cadet/3rd mate has been the subject of international concern, resulting in an Inter-governmental Maritime Consultative Organization (IMCO) recommendation for a minimum amount of at-sea time required (i.e., 12 months) prior to obtaining a 3rd mate's license (IMCO International Convention on Standards of Training, Certification, and Watchkeeping for Seafarers, July 1978). The major international convention to upgrade merchant vessel personnel qualifications was held in London, 14 June to 7 July, 1978. At the conference, 72 nations agreed on the text of the world's first international convention establishing basic requirements on training, certification, and watch-keeping for masters, officers, and crews of seagoing merchant ships. Of critical importance to officer training programs was Regulation II/4 – "Mandatory Minimum Requirements for Certification of Officers in Charge of a Navigational Watch on Ships of 200 Gross Register Tons or More." Section 2 (c) of this regulation introduces a requirement for one "actual" year of seagoing service for original certification, and the year must include 6 months of bridge watchkeeping duties under the supervision of a qualified officer. This requirement poses a real problem to a number of existing officer training programs which do not include this required period of time. Among these are the programs at the maritime academies. Although the U.S. Merchant Marine Academy has a "nominal" year of seatime in its course of study, the actual time at sea is approximately 10 months. The various state schools, which utilize primarily the training ship cruise system, probably have a total sea time of considerably less than the required year.

Fortunately, the convention addresses itself to "Equivalents" in Article IX. Section (1) of this article reads as follows:

> "The Convention shall not prevent an administration from retaining or adopting other educational and training arrangements, including those involving sea-going service and shipboard organization, especially adapted to technical developments and to special types of ships and trades, provided that the level of sea-going service, knowledge, and efficiency ensures a degree of safety at sea and has a preventive effect as regards to pollution, at least equivalent to the requirements of this Convention."

The intent of the IMCO Convention recommendation is to provide sufficient experience for the cadet and, hence, provide him with a basic level of skill and understanding of the at-sea situation. The means of attaining sufficient experience can be through the carefully structured use of multiple training mediums (i.e., simulator-based training, at-sea training, small vessel handling training and classroom training).

Shiphandling simulator technology is a relatively recent development with constantly decreasing costs. Included among the many advantages of simulator-based training are safety, training control, and cost. Shiphandling simulators also have many limitations typically pertaining to technical simulation capabilities (e.g., low speed hydrodynamics). The application of simulation to training should depend solely on the cost effectiveness of such training as compared with alternative methods of acquiring the necessary skills and knowledge. The tradeoff, with regard to cadet training, would be that of the cost effectiveness of simulator-based training compared with cost effectiveness of at-sea training as pertains to the achievement of specific sets of skills and knowledge. It is probable that many cadet/3rd mate skills and knowledge would not be adequately achieved today on a simulator. However, it is also probable that some cadet skills and knowledge may be most cost effectively achieved today via simulator-based training. The cost effectiveness of simulator-based training should be determined with regard to achievement of specific skills desired for cadets and, hence, as a supplement to at-sea experience. Ideally, the mix between at-sea experience, classroom instruction, other training aids, and simulator-based training should be investigated such that the desired skills can be most cost effectively obtained.

The approach that should be taken would be to:

- Delineate those 3rd mate skills best obtained via at-sea experience and determine the amount of at-sea experience necessary to achieve the appropriate skill level.

- Delineate those skills best achieved via simulator-based training and determine the amount of such training necessary to achieve the appropriate skill level: similar evaluation should be made for classroom and other instructional aids.

A simulator/experience/classroom mix would then be determined for cadet training. It is possible that many of the skills and knowledge may be effectively achieved via several modes (e.g., simulator or experience). These could represent a gray area in which, for example, either simulator and/or experience mixes would be acceptable.

1.1 EQUIVALENCY TRAINING ON SIMULATORS

On the basis of the above, it seems reasonable to assume that the equivalency for some of the required sea time for original certification could be accomplished on bridge and shiphandling simulators. An ad hoc committee was set up in January 1979 to study the feasibility of using a bridge simulator for such equivalency. The committee, consisting of representatives of the Maritime Administration (MarAd), the U.S. Merchant Marine Academy (USMMA), the New York State Maritime Academy (SUNY), the National Maritime Reasearch Center (NMRC), CAORF, Sperry, and Eclectech Associates, met several times and reached some tentative conclusions. These included:

- Simulator-based training is different from at-sea experience, such that a period of time on a simulator is not equivalent to a period of time at sea; rather, they are comparable with regard to the achievement of specific skills, knowledge, and/or training objectives. Hence, simulator-based training time should be substituted for at-sea time on the basis of the respective time periods required to achieve the specific set of skills, knowledge, and/or training objectives.

- A bridge simulator could fulfill partial sea-year requirements.

- Equivalency should reflect a weighted factor to be determined in conjunction with the regulatory agencies.

- A description of bridge simulator specifications and characteristics should be developed as soon as possible.

- A description of such a simulator should concurrently be developed, outlining how it would be used, how scenarios and exercises should evolve, and how to get the most out of this arrangement vis-a-vis actual time aboard ship.

- A close concert should be held with the ongoing MarAd-Coast Guard study on the use of simulator for training and certification.

Several meetings were held to further explore the use of such simulators for equivalency. Several members of the committee had extensive background in the development and operation of simulators, including bridge simulators. Some had visited bridge simulators in England, Germany, Holland, and France and had the opportunity to compare and evaluate their characteristics. It was generally agreed that the following factors can be accepted on their face value:

- Simulator technology has progressed to the point that it may be a cost effective means for enhancement of practical training and certification requirements.

- The versatility of the bridge and shiphandling simulator gives it great advantages over the usual on-the-job training. Ship parameters, type of ship, events, encounters, scenarios, bridge layouts, and bridge routines can be varied to suit the present need. On the other hand, a cadet sailing for many months on one or more operating ships or training ships may not experience or observe any threat situation.

- The simulator will provide the cadet the opportunity to assume the various roles of ship's officers on the bridge, including that of the officer in command. He may be in exercises where he can perform some shiphandling. He will also have the opportunity to observe situations involving master-pilot relationships. In the real world, he would not be in a position of control of shiphandling until he assumes command of a real ship; yet, this vicarious experience will not be forgotten and will cause him to better evaluate the actions of command and shiphandling, between his time as a cadet and the time when he first assumes command.

- The simulator provides the services of committed, expert instuctors who plan the exercises, observe and guide the students, and join in the debriefing critiques. The ability to freeze situations or store an exercise for playback provides invaluable followup to the training program.

- The cost of the operation of ships is climbing astronomically, and the nature of the cargoes is becoming more sophisticated and, in certain cases, more hazardous to handle. Hence, it is unlikely that an operating ship would be used to stage events or exercises which involve considerable expense or incipient danger.

1.2 CADET TRAINING EXPERIMENT

A jointly sponsored U.S. Coast Guard/Maritime Administration training and licensing project (i.e., Hammell, Williams, Grasso, and Evans, 1980) has been investigating the role of shiphandling simulators in the deck officer training and licensing process. The first phase of this investigation centered on the advanced level deck officer (i.e., chief mate, master). A comprehensive information base was assembled addressing deck officer behavior, training technology, and the design and use of shiphandling simulators for training. Although the 3rd mate and cadet training areas were not directly addressed, much of the assembled information is directly relevant (e.g., many 3rd mate tasks were identified).

The training and licensing project is currently in its second phase. An experiment was designed on the basis of the Phase 1 findings to investigate six potentially high-cost simulator/training program variables: target maneuverability, color of visual scene, feedback technique, time of day, horizontal field of view, and instructor. The experiment which was run on CAORF sought to evaluate the training effectiveness of the simulator and training program characteristics in the context of the chief mates'/masters' training level.

Recent developments (the IMCO requirement for increased at-sea time availability of simulation technology, and interest in upgrading the skills of the 3rd mate) have increased the interest regarding the use of simulators for cadet training. An empirical investigation into the use of shiphandling simulators for cadet training was initiated as part of the second phase of the training and licensing project, drawing upon the assembled information as the foundation.

The investigation was designed to achieve several objectives:

- Evaluate the shiphandling-related skill level of cadets who have completed their at-sea training and are ready to assume the duties of a 3rd mate after successfully completing the written examination.

- Evaluate the effectiveness of a simulator-based prototype training program for improving the skills of an entry level 3rd mate.

- Evaluate the cost effectiveness of alternative simulator characteristics and other training-related factors with regard to improving the skills of an entry level 3rd mate.

- Provide a simulator-based training course in shiphandling for cadets.

In regard to the last objective, a training program (the midshipmen/cadet training experiment) was developed and offered to several groups of Kings Point and Fort Schuyler cadets. This document describes the approach taken in the development and conduct of the prototype cadet training program and delineates the analysis of the results.

SECTION 2
METHODOLOGY

2.1 APPROACH

The approach taken was to investigate the issues related to the use of simulators for cadet/midshipmen training and, at the same time, to integrate this with an effective training program for the cadets. Hence, a balance was drawn between experimental considerations (e.g., pretests and posttests) and training process considerations (e.g., available time and appropriate training objectives). The resultant program was determined to be responsive to both needs.

The investigation/training team consisted of several Kings Point instructors and several CAORF staff personnel. This team cohesively addressed all aspects of the project and developed the necessary training and experimentai materials. The considerations and results of the efforts in each of the relevant areas are discussed below.

2.2 COURSE CONSTRAINTS

A rules of the road/port approach planning course was to be offered as part of the standard curriculum at Kings Point. A 9-week period (6 weeks allotted for the Rules of the Road unit and 3 weeks for the Port Approach unit) was available for the course. Fort Schuyler decided to offer only the rules of the road course as an extracurricular activity, with a 1-week period available for the course. This structure was relevant to the experimental variables investigated (see Section 2.4 below).

Six hours of simulator time per week were available for the cadet training. It was decided that two groups of Kings Point midshipmen would be trained, with each group receiving 3 hours of simulator time per week. Each group participated in two meetings per week, with each meeting consisting of 1-1/2 hours of classroom time and 1-1/2 hours of simulator time. The Fort Schuyler group received an equivalent amount of simulator and classroom time for one unit of training, compressed into the 1-week period.

Little guidance was available with regard to the appropriate mix of classroom and simulator time. It was decided that the most cost effective utilization of the simulator would be achieved when supplemented with a relatively large amount of classroom time. Classroom time would be used for preparation prior to making runs on the simulator, as well as for detailed discussion and feedback subsequent to having completed the runs on the simulator. Hence, it was decided that an equal amount of classroom time (i.e., 1-1/2 hours at each meeting) would be provided. This was divided into 1 hour of classroom time prior to making the run on the simulator and 1/2 hour of classroom time subsequent to the run. The amount of classroom time was, of course, flexible depending on the particular needs of the different exercises. The intent was to provide a highly structured training program beyond simple experience on the simulator.

2.3 CADETS/TRAINEES

Three groups of cadets/trainees participated in the experiment/training program. The two groups from Kings Point received both the rules of the road and the port approach planning units of training, while the group from Fort Schuyler received the rules of the road unit of training. Each group consisted of six trainees. A minimum of six trainees was required in each group to achieve experimental validity. Conversely, a limited number of cadet trainees per group was desired to enable the cadets to have maximum exposure to hands-on simulator training. Hence, the number of six trainees per group represented an optimum tradeoff. Each group of cadets was further subdivided into three-man teams. A three-man team stood watch on the bridge during each scenario run. The three-man team was comprised of:

- A senior watch officer (SWO).

- A radar plotting officer.

- A navigation recording officer.

The cadets rotated positions in the team between each problem.

Cadet/midshipmen participation in the course was voluntary at the Kings Point and Fort Schuyler academies. The senior class cadets participated in the program during the quarter preceding graduation. Moreover, the simulator course for the Kings Point class was offered as a three-credit elective course. It should be noted that the number of cadets able to participate in the program was limited due to the considerations noted above; many more cadets had volunteered for the program.

2.4 EXPERIMENTAL VARIABLES

Several issues were under investigation during the experiment including: (a) the shiphandling skill level possessed by the graduating cadet, (b) the effectiveness of a simulator-based training program for improving a cadet's skills, and (c) the cost effectiveness of alternative simulator and training methodology variables regarding cadet training. The approach regarding each of these is summarized in Table 1 and is discussed below.

2.4.1 CADET SKILL. Little information is currently available regarding the shiphandling-related skills possessed by a graduating cadet. Discussions with academy personnel indicated that this is largely an unknown factor. Hence, it was decided to provide a series of tests which would investigate the skills and knowledge of a cadet entering this training program. Each of these tests is discussed in a later section. The information generated from these tests should begin to objectively delineate the skills and knowledge possessed by graduating cadets. This information will be particularly useful in evaluating the cost effectiveness of at-sea experience and that of at-sea experience versus simulator-based training.

2.4.2 TRAINING EFFECTIVENESS. The effectiveness of the simulator-based training program for cadets was evaluated by hands-on performance in tests preceding and following each unit of training. The two units of training, rules of the road and port approach planning, were selected on the basis of their relevancy and importance to cadets/3rd mates, and the judged areas of need for additional cadet training (specific training objectives and course units are discussed later). The improvement in hands-on shiphandling performance from the pretest to the posttest represents the measure of training effectiveness. These results will provide information regarding the cost effectiveness of simulator-based training, enabling comparison with at-sea experience.

TABLE 1. SUMMARY OF EXPERIMENTAL ISSUES AND APPROACH

Issue	Methodology	Training Unit	Cadet Groups
Shiphandling skill level of graduating cadets	Simulator pretests	Rules of the road	Kings Point Fort Schuyler
		Port approach planning	Kings Point
Simulator-based training program effectiveness	Simulator pretests versus posttests	Rules of the road	Kings Point Fort Schuyler
		Port approach planning	Kings Point
Day/night versus night only simulator	Simulator pretests versus posttests	Rules of the road Port approach planning	Kings Point
Distributed versus concentrated training	Simulator pretests versus posttests	Rules of the road	Kings Point Fort Schuyler

2.5 TRAINING METHODOLOGY AND SIMULATOR VARIABLES

Several simulator and training methodology variables were selected for the experiment in order to examine variables that: (a) have alternatives which vary widely in cost and thus can significantly impact simulator cost, (b) would reasonably pertain to simulators designed for cadet training, (c) may coincide with one or more variables being investigated in the chief mates' experiment of the training and licensing project, (d) are of particular interest in the design of the training program for cadets, and (e) have alternatives that would enable effective training to take place during this program. It should be noted that the final selection of the experimental variables was the result of discussions between the staffs of Kings Point and CAORF.

One simulator variable and one training methodology variable were selected. The simulator variable, night-only conditions versus day-only conditions, met the above criteria. The alternatives can represent large differences in simulator cost, and several existing simulators represent the two extremes of this variable. On the basis of cost, it is a logical choice for a cadet simulator. Where the relative effectiveness of the two alternatives is unclear, it is expected that day and night conditions would both be somewhat effective in the training of cadets.

The training methodology variable was distributed training (i.e., one Kings Point Rules of the Road unit of training spread over a 6-week period) versus condensed training (i.e., the Fort Schuyler Rules of the Road unit of training condensed into a 1-week period). This variable can definitely represent wide cost variations in the implementation of training. It is of interest to the international community and would likely be of significant interest in the use of a simulator for cadet training.

2.6 SIMULATOR

The experiment/training program was conducted on the CAORF simulator, which is located on the grounds of the U.S. Merchant Marine Academy, Kings Point, New York. The simulator, devoted to the conduct of research, has a wide degree of flexibility making it ideal for this type of research. In addition to a large, high fidelity bridge and visual scene, CAORF has a human factors station at which remote monitoring of the bridge activity and problems can take place as well as extensive data collection and analysis capabilities. These capabilities permitted a wide degree of flexibility in configuring the training program. For example, track charts of ownship actions during each scenario were generated to provide detailed feedback information to the trainees. Additionally, the evaluations of training effectiveness and the other variables will draw heavily upon the quantitative data collected on the computer during each scenario.

Several major subsystems of the CAORF simulator were used during the conduct of cadet training:

- One cadet/trainee team of three individuals was on the bridge and in control of the vessel during each scenario. The two teams comprising each group alternated in service on the bridge.

- The team not controlling the vessel on the bridge observed the bridge activity and scenario development from the human factors station, except during the pretest/posttest. This is accomplished via a variety of TV monitors with remotely controlled cameras and voice pickups. The instructor participated with this team, carrying on a discussion of the problem as it developed.

- The data collection and analysis capabilities of the simulator were used to generate, collect, present, and analyze information regarding the experiment/training program.

2.7 TRAINING OBJECTIVES

The selection of training objectives for the conduct of cadet training was perhaps the most important issue to be resolved in setting up the training program. This training program represents the first time a ship bridge simulator has been used for maritime cadet training in the United States. The relationship between simulator-based training and the at-sea training received by cadets was an issue of importance and represented a logical starting point for the selection of training objectives. That is: (a) some of the training objectives normally achieved via at-sea training may be achievable via simulator-based training; (b) training objectives not currently achievable for maritime academy cadets may be achievable via simulator-based training, thus representing a new group of cadet training objectives; and (c) training objectives currently achievable via classroom and other methods of training may be more cost effectively achieved via simulator-based training. The training objectives to be used for this prototype, as well as future cadet training courses, could be chosen from a combination of these three groups.

The selection of training objectives for this training program was further complicated by: (a) the constraints on the program in terms of simulator time available, (b) time to set up the course, and (c) lack of an acceptable set of detailed training objectives for maritime academy cadets. Neither the time nor the resources were available to adequately develop a comprehensive set of maritime academy cadet training objectives. This analysis should be conducted prior to the establishment of simulator-based cadet training programs. A comprehensive deck officer behavioral information base was assembled during the Phase 1 investigation of the training and licensing project which served as the single source of information documenting deck officer tasks and led to the identification of potential training objectives for cadets.

The objectives of the training program were selected based on available information, discussions with Kings Point instructor personnel and knowledgeable maritime training personnel, experimental constraints, and other resource limitations (e.g., availability of scenarios). The approach was to balance all of these factors in arriving at the overall objectives of the simulator-based training program. It was initially decided to structure the course in the form of two training units. This would accommodate both the Kings Point and Fort Schuyler logistical constraints. The rules of the road area was agreed upon by all members of the team as an area of training potential. Furthermore, scenarios were available from previous CAORF experiments and would require only minor adaptation. Hence, this was selected as the first unit of training, as a universally acceptable area of cadet/3rd mate training need. A variety of areas was considered for the second unit of training, including emergency shiphandling, navigation, fundamental ship maneuvers (e.g., Williamson turn), and port approach planning. Port approach planning was chosen as the second unit of training since it provided a unique opportunity to bridge the gap between classroom instruction and at-sea application. Port approach planning is a concept being advocated by several major shipping companies. Although not new, it represents the formal application of shiphandling theory to planning on a paper and pencil basis of the approach to a particular port. It brings together various elements of the bridge team including the master, the mate, the pilot, and the helmsman. After considerable discussion, it was decided that port approach planning represented a unique opportunity to use the simulator in introducing cadets to the application of classroom theory with regard to shiphandling.

It should be emphasized that this investigation of cadet training is not recommending the two units as representing the optimum application for the ship bridge simulator in cadet training. A more thorough investigation, directed at the specific issues, would be necessary to determine the most cost effective application of a ship bridge for cadet training. However, these two units of training were selected after a cursory investigation and with substantial thought given to the constraints surrounding the conduct of this initial program.

The detailed training objectives to be achieved as a result of these training programs are listed in Table 2. The conditions under which these objectives were to be achieved are also listed. The detailed training objectives pertain to the overall objectives, namely rules of the road and port approach planning, as well as other aspects of shiphandling and bridge operation necessary to the achievement of the overall objectives. These include intership communication, fundamentals of shiphandling, navigation, and radar plotting.

2.8 TESTS

The simulator pretests and posttests were the primary means by which actual shiphandling performance could be evaluated. Pretests were given at the start of each unit of training; posttests were administered immediately after each unit of training. Individual trainee pretests and posttests were administered in the rules of the road unit, while both individual and team tests were administered in the port approach planning unit. The rules of the road simulator pretest (Figure 1) consisted of a crossing situation scenario with ownship as the stand-on vessel. The giveway vessel, which was a high speed container ship (i.e., 25 knot speed), did not maneuver. Ownship was forced to take action to avoid the collision. The posttest was a similar situation. Both of these scenarios were adapted from the rules of the road experiment at CAORF during which both scenarios were constructed to be equivalent (Aranow, Hammell, and Pollack, 1978). This relatively difficult scenario situation encompassed most of the aspects being trained in the rules of the road unit.

TABLE 2. DETAILED TRAINING OBJECTIVES FOR THE PROTOTYPE CADET TRAINING PROGRAM

Conditions

Good weather with low wind
Excellent visibility
Open sea
Low to high traffic density for rules of the road; low traffic density for port approach planning
Day or night
Ownship is an 80,000 dwt tanker loaded
Closing rates of 20 to 40 knots with the potential collision vessel

RULES OF THE ROAD

1. The cadet will be able to recognize a potential collision situation in sufficient time (i.e., at least 12 minutes) to permit normal ownship actions in response.
2. The cadet will effectively integrate radar and visual information in arriving at a timely assessment of potential for collision (i.e., at least 12 minutes).
3. The cadet will take appropriate action in maneuvering ownship in response to a potential collision situation.
   a. Giveway vessel in crossing situation – maneuver early (i.e., between 5 and 7 nautical miles) and substantially (i.e., 10-degree or greater course change), achieving a closest point of approach (CPA) of at least 1 nautical mile with all vessels.
   b. Meeting situation – maneuver early (5 to 7 nautical miles), achieving a CPA of at least 1 nautical mile with all vessels.
   c. Stand-on vessel in crossing situation – stand-on until it is apparent that giveway vessel is not taking early and substantial action, then maneuver ownship according to rules and avoid the collision.
4. The cadet will be able to plot four target tracks on radar simultaneously, generating estimated CPA information for each to within an accuracy of 3 minutes and 1/4 nautical mile. Furthermore, he will continuously select the four highest priority contacts for plotting.
5. The cadet will understand the relationships between contact range, meeting angle, closing rate, ownship turning characteristics, and desired CPA in determining ownship maneuvers.
6. The cadet will exhibit effective communication and coordination behavior when interacting with other members of the bridge team.
7. The cadet, when acting as senior watch officer, will use appropriate and effective intership communications action (i.e., VHF and whistle).

PORT APPROACH PLANNING

1. The cadet will demonstrate an understanding of ownship turning characteristics.
2. The cadet will demonstrate an understanding of the detailed actions of ownship in entering and transiting a channel and making lee for a pilot.
3. The cadet will plan the detailed actions of ownship (i.e., turn initiation, amount of rudder, speed, ownship track) in approaching and transiting a channel.
4. The cadet will maneuver ownship to enter a channel in the absence of other traffic.
5. The cadet will compensate ownship actions for the effects of wind magnitude when entering a channel. Wind velocity will vary from 0 to 60 knots.
6. The cadet will understand the effect of wind on ownship maneuvering (i.e., the effects of wind velocity on ownship course and resultant necessary heading change).
7. The cadet will demonstrate effective communication and coordination behavior when interacting with other members of the bridge team.
8. The cadet will use range lights effectively as an aid in entering a channel leg and maintaining appropriate position within the channel.

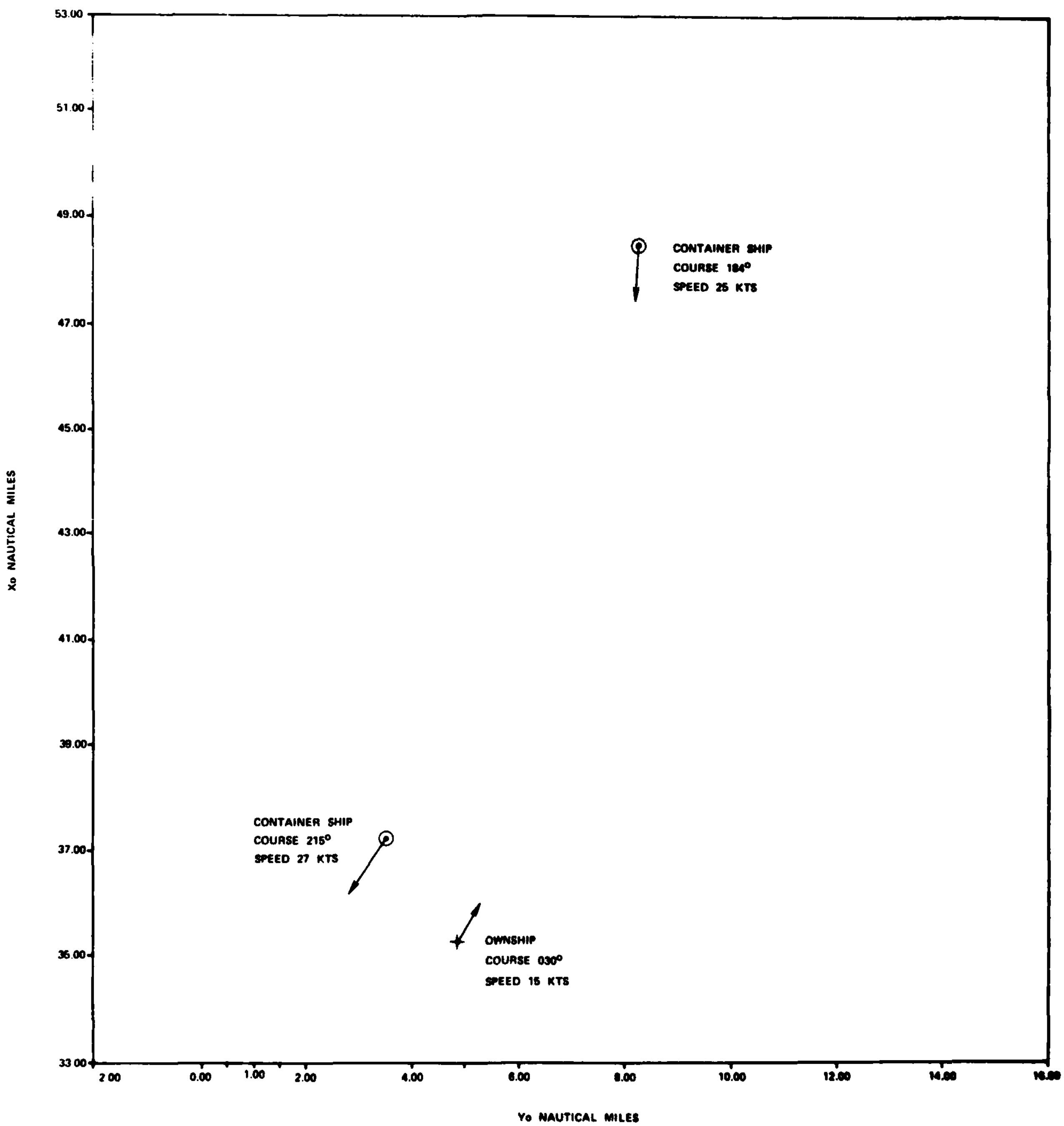

Figure 1. Phase 2 - Test Scenario (Rules of the Road)

A single port approach situation was investigated in the port approach planning unit, hence, the pretests and posttests were the same situation. The pretests and posttests represented a situation slightly different from that used during the training program itself; the difference was wind velocity. The pretest and posttest had a wind velocity of 40 knots while wind velocities during the training program itself ranged from zero knots (no wind) to 60 knots. (See Section 2.11 for a description of the port approach situation.)

Each cadet in the port approach planning unit took a paper and pencil pretest in the form of actually planning the port approach. The teams of three cadets each (senior watch officer, radar observer, navigator/logkeeper) also developed a port approach plan after which they actually brought the vessel into the channel. Similarly, the individuals and teams developed the port approach plan on paper immediately preceding their final entrance into the channel with the vessel. Hence, the paper and pencil pretests and posttests were closely integrated with the actual performance on the simulator.

2.9 TRAINING PROGRAM CONTENT

The simulator-based training program was divided into two units: rules of the road and port approach planning. Each unit was developed as an independent training module specifically for cadet training. The training strategy was determined separately for each unit and was based on traditional training strategies, the capabilities and limitations of the CAORF simulator, and accepted training technology concepts. The resulting strategy represented a potentially effective approach to cadet training.

The development of the detailed course outline and the specific supporting material was a joint CAORF/USMMA effort. Both elements of this team participated in all phases of course development and course conduct. Much of the material was specifically developed for this course although existing material was used where possible (e.g., scenarios for the simulator). The USMMA staff was the predominant contributor to the classroom material while the CAORF staff was the predominant contributor to the simulator material. It should be stressed that this was a closely integrated joint CAORF/USMMA venture; however, the primary interests of CAORF involved the empirical research while those of the USMMA involved providing simulator training.

Both units of training had a 50/50 mix of classroom and simulator time. This mix was selected because of a firm belief that cost effective simulator training must be aligned with substantial classroom time for preparation and feedback and also because there was a lack of data providing guidance regarding simulator/classroom mix. The simulator sessions were configured in 1-1/2 hour blocks. The length of these sessions was believed to provide sufficient time to achieve in-depth investigation, while not extending the period beyond the point of high training effectiveness.

A 1-hour classroom period preceded each simulator session. This provided time for lecture material, preparation for the simulator session to follow, and other discussions. A 30-minute classroom period followed each simulator session to provide postrun feedback. Additional feedback time was available and occasionally used. This approach sought to minimize discussions while on the simulator bridge between runs and thus maximize the amount of on-bridge time spent in running scenarios. This should result in the most cost effective utilization of the simulator.

Simulator familiarization was given to each subject by means of:

- Steering ownship (loaded 80,000 dwt tanker) thorugh a series of anchored vessels (Figure 2).

- A slide presentation.

- A "walk-through" tour of the bridge equipment.

2.10 RULES OF THE ROAD (INTERNATIONAL)

The rules of the road unit addressed vessel handling when in a potential collision situation (see Section 2.7). The three basic ownship situations studied were:

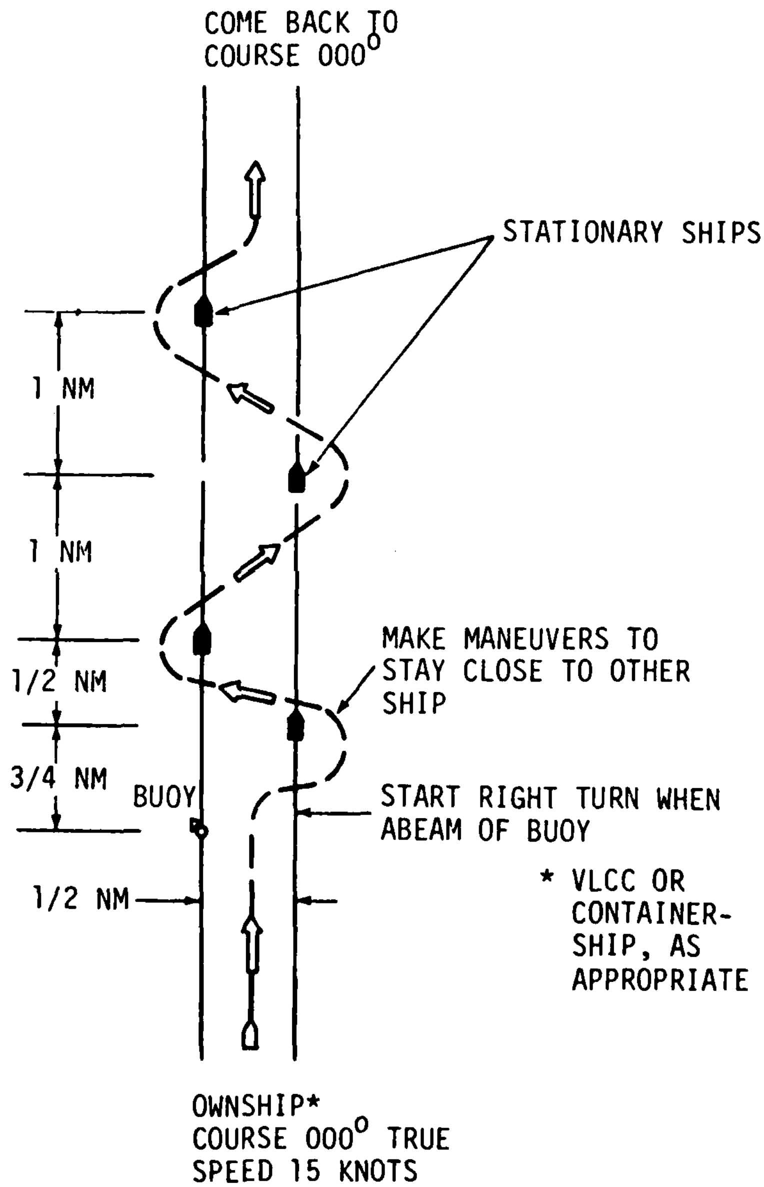

Figure 2. Maneuver Familiarization Diagram

- Crossing situation with ownship as the giveway vessel.

- Crossing situation with ownship as the stand-on vessel, in which the giveway vessel did not maneuver.

- Meeting/ambiguous situation

The rules of the road unit was achieved during 6 weeks of operation for the Kings Point Group and 1 week for the Fort Schuyler group. Lesson plans, audio/visual aids, and case studies were developed for the above situations. There were a total of 12 open-sea training scenarios including a pretest and a posttest. They were of varying difficulty consisting of two to six other ships in the visual and radar scene.

Furthermore, all runs were videotaped and data recorded by automated means and by an observer at the human factors monitoring station (Figure 3). The subjects (except for during the pretests/posttests) were divided into groups of three. Each group included a senior watch officer, a radar observer, and a navigator. Positions were rotated on alternate runs. In addition, a helmsman was provided to ensure consistency across training and to avoid the possibility of negative training due to an inexperienced helmsman.

The specific issues addressed in this unit were:

- Interpretation of the rules.

- Determination of threat vessel(s).

- When to call the master.

- When to initiate a maneuver.

- Type and amount of maneuver.

- Achieved CPA.

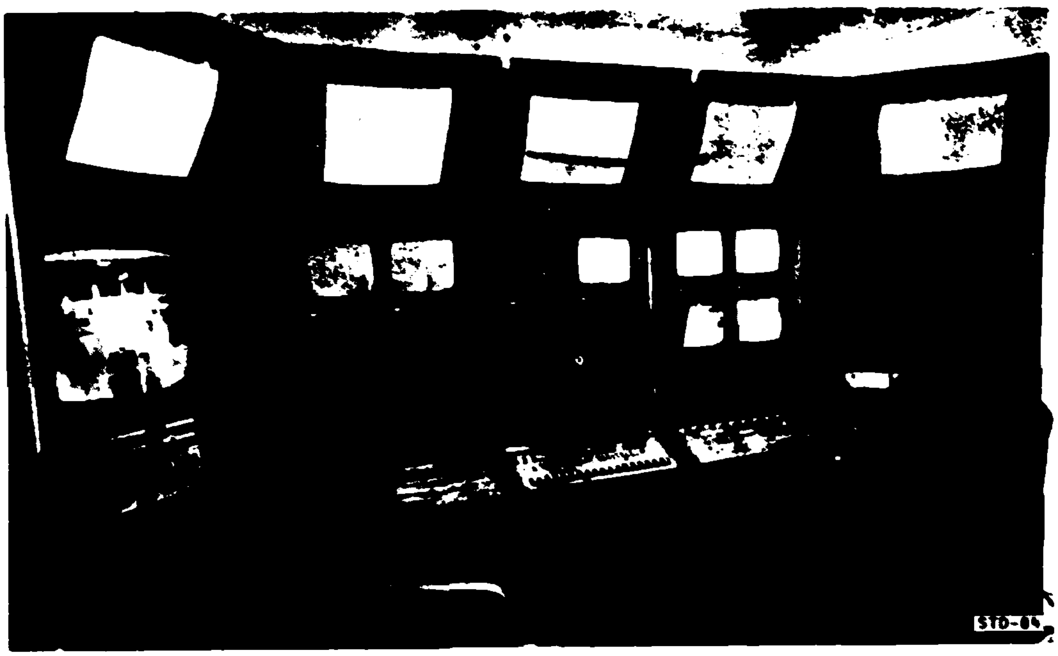

Figure 3. Human Factors Monitoring Station

- Bridge procedures.

- Shiphandling characteristics.

Performance data were recorded during each scenario. These consisted of: (a) the objective ownship and target parameter information automatically recorded on the computer, (b) observation data collected at the human factors station, and (c) instructor evaluations. An instructor's checkoff list (Figure 4) was used to evaluate the trainees during each run and to provide information for the postrun discussion.

2.11 PORT APPROACH PLANNING

A single port approach area was investigated. The basic situation in port approach planning was always the same: approach, enter, and transit a channel for several miles to a point at which ownship will make lee for a pilot. The program involved navigating an 80,000 dwt tanker (loaded) into and through a channel (Figure 5) under the following wind conditions:

- 310 degrees true/40 knots.

- 310 degrees true/60 knots.

- No wind.

The pretest and posttest conditions were: wind 310 degrees true/40 knots. The various training objectives (see Section 2.7) were addressed with regard to this situation.

The midshipmen were required to plan every segment of the "voyage" including: courses to steer, estimated time of arrival (ETA), effects of wind on vessel, use of navigational aids, and VHF communications. They also had to follow port regulations. Due to time constraints, the vessel was navigated through only two turns.

UNITED STATES MERCHANT MARINE ACADEMY

KINGS POINT, NEW YORK

D460 BRIDGE SHIPHANDLING SIMULATION COURSE

GRADING & CHECKOFF LIST (RATING 0-10)

1. DETERMINATION OF GREATEST THREAT ____________
2. DETERMINATION OF RELATIVE MOTION LINE ____________
3. COMPLIANCE WITH STANDING & NIGHT ORDERS ____________
4. PROPER USE OF VHF COMMUNICATIONS ____________
5. CALCULATION OF CPA & SPEED TRIANGLE ____________
6. MANEUVERING - TIME AND RANGE ____________

6a. MANEUVERING - MAGNITUDE OF RUDDER & SPEED CHANGES ____________

7. ACHIEVING OF PLANNED CPA ____________
8. RESULT OF MANEUVER ____________
9. TEAM COORDINATION ____________
10. SENIOR WATCH OFFICER'S COMPOSURE ____________
11. PROPER WHEEL COMMANDS ____________
12. PROPER COMMANDS TO TEAM ____________

TOTAL RATING ____________

____

MIDSHIPMAN'S NAME

Figure 4. Instructor's Checkoff List

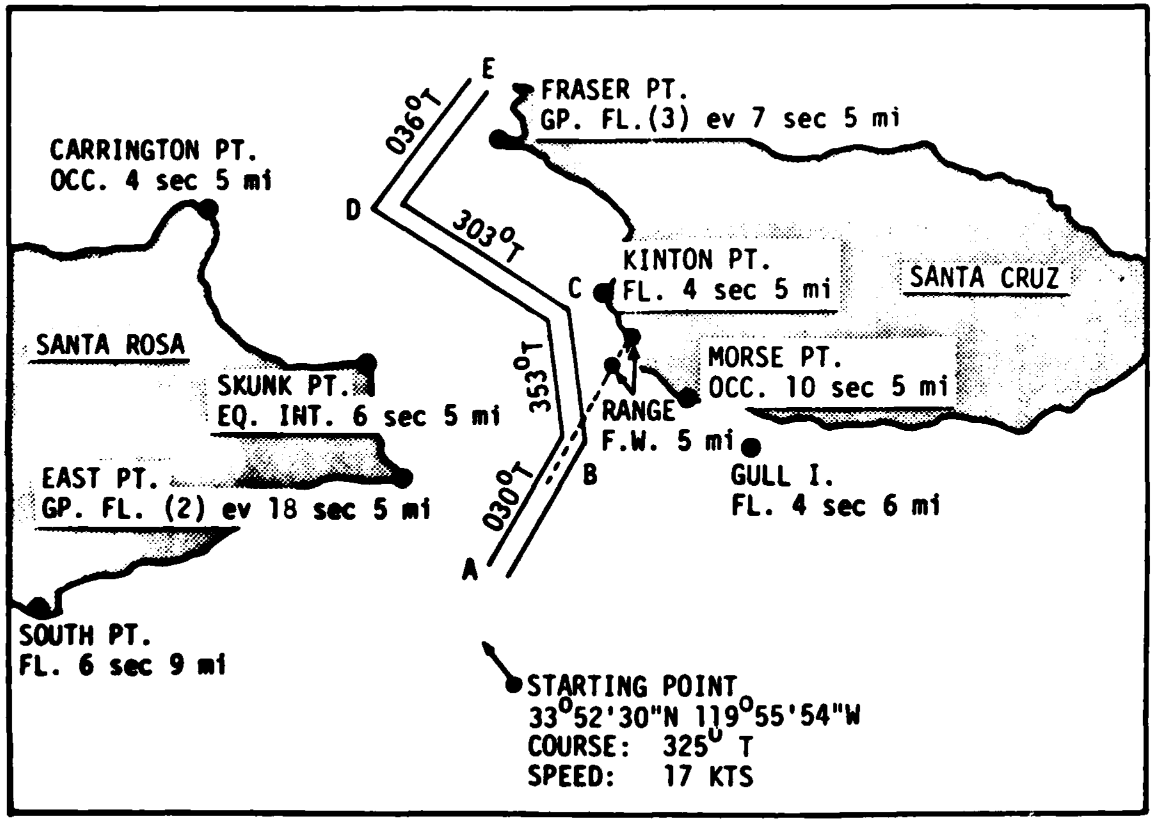

Figure 5. Port Approach Area

The instruction addressed specific issues such as:

- The approach plan.
- Any necessary departure from the plan.
- Shiphandling (e.g., maneuvering information).
- Wind load effects.
- Bridge procedures.

The midshipmen were divided into teams of three. Each team included a senior watch officer, a radar observer, and a navigator who rotated duties on alternate runs. Each run was videotaped. Critiques on the team members' performance were made using a checkoff list (see Figure 4). Computer generated and observational data were collected during each run, along with the instructor checkoff lists. The latter were used to provide information for the postrun discussions.

2.12 PROCEDURE

Three groups of cadets received one or both units of training as shown in Figure 6. Each group of cadets received identical treatment, with differences due only to the experimental variables. The procedural steps carried out independently for each group are summarized below:

a. Administer course introduction – classroom overview.

b. CAORF familiarization – 20 minutes in classroom followed by 1 hour on the simulator bridge.

c. Simulator pretest for rules of the road – approximately 25 minutes per cadet; each cadet was alone on the bridge.

d. Rules of the road training, Unit 1. Approximately 24 hours of training were administered, divided equally between classroom and simulator sessions.

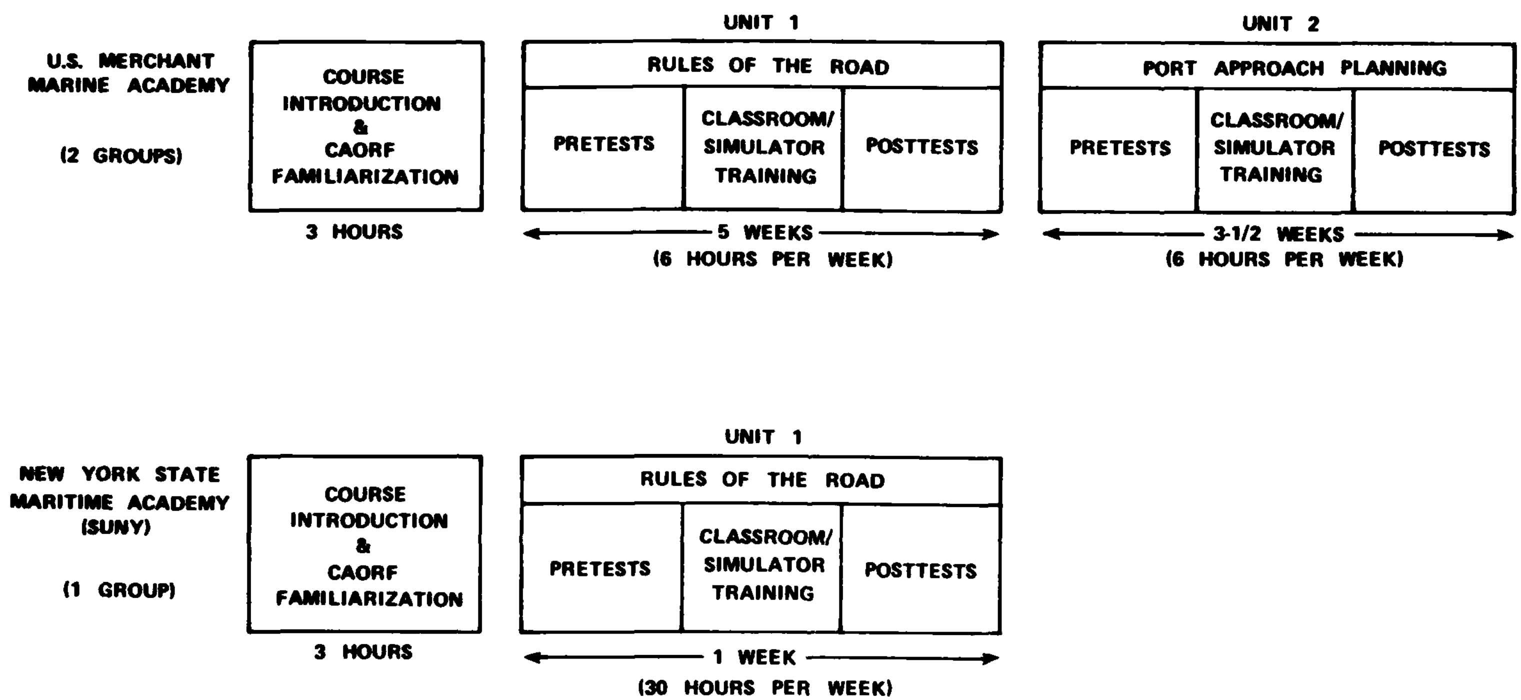

Figure 6. Training Unit Schedule

- Each group was subdivided into two teams of three cadets each (senior watch officer, radar observer, and navigator).

- Both teams participated together during the classroom sessions.

- Each team alternated between the simulator bridge and the human factors observation station during the simulator sessions. The team members' functions were to navigate the vessel or to discuss the situation and actions.

- The team operating on the bridge had three specific functions to perform, one by each cadet. They performed as the senior watch officer, the radar plotter, and the navigator/data logger.

e. Simulator posttest for rules of the road – similar to pretest.

f. The Fort Schuyler group was now finished; the Kings Point groups continued into Unit 2.

g. Introduction to port approach planning – unit overview; individual port approach plan development (pretest); team port approach plan development.

h. Administration of pretest scenario to cadet bridge teams.

i. Port approach plan training, Unit 2. Approximately 18 hours of training were administered, equally divided between classroom and simulator sessions. Group/team functions were similar to those of rules of the road unit. Additionally, each team prepared a detailed port approach plan prior to each simulator run and discussed concurrences, discrepancies, etc., after each run.

j. Administration of posttest scenario to cadet bridge teams.

k. All cadets participated in debriefing sessions to discuss aspects of the training program.

l. Data was automatically collected by the simulator during each run. Instructor observations were also recorded. These will form the basis of the subsequent analysis.

2.13 DATA ANALYSIS

2.13.1 GENERAL. The first step of the data analysis was to identify the measures to be used in evaluating the cadets' performance on the rules of the road unit and the port approach unit. These performance measures are defined in detail in Sections 2.13.2 and 2.13.3. Once the performance measures for the two training units were identified, they were tabulated on both the pretest and posttest scenarios, for each cadet (rules of the road unit) and each bridge team (port approach unit).

The cadets' performances on the pretest were used to identify their input characteristics or their proficiency prior to training. The differences between their scores on the pretest and posttest were used to establish the effectiveness of the simulator-based training program for the given experimental treatment conditions. Statistical tests (i.e., t-test) were used to establish the significance of the observed training effectiveness and to establish the significance of the observations between experimental treatment conditions (i.e., distributed training versus concentrated training).

2.13.2 PERFORMANCE MEASURES (RULES OF THE ROAD). The following performance measures were used to evaluate cadet performance on the rules of the road test scenarios.

CPA. The closest point of approach between ownship and any traffic vessel, as measured from the "skin" of ownship to the "skin" of the traffic vessel.

Collision. An impact between ownship and any traffic vessel. Measured on a binary scale: yes = collision; no = no collision.

Range of Maneuver. The distance between ownship and the threat traffic vessel when ownship initiates an evasive ship control action (e.g., rudder order, course order, speed change).

Magnitude of Course Change. The difference between ownship's base course, measured in degrees, and the new course ordered as an evasive ship control action to reduce the risk of collision with the threat traffic vessel.

Number of Course Orders. The number of course orders given by the subject navigating the vessel during the entire test scenario.

Number of Rudder Orders. The number of rudder orders given by the subject navigating the vessel during the entire test scenario.

Master Notified. The act of informing the master of the presence of a traffic vessel with whom risk of collision exists based on the criteria set forth in the vessel's standing orders. Measured on a binary scale: yes = master notified; no = master not notified.

Range Master Notified. The distance between ownship and the threat traffic vessel at that instant of time when the master was notified of the existing risk of collision.

VHF Communications. The act of attempting to establish voice radio communications with the threat traffic vessel. Measured on a binary scale: yes = VHF communications attempted; no = no VHF communications attempted.

Range VHF Communications. The distance between ownship and the threat traffic vessel at that instance of time when VHF communications were attempted.

Number of Visual Bearings. The number of visual bearings taken using the azimuth circle to establish risk of collision with the threat traffic vessel during the entire test scenario.

Number of Radar Requests. The number of requests made by the subject who aids navigating the vessel, to the radar observer during the entire test scenario.

2.13.3 PERFORMANCE MEASURES (PORT APPROACH PLANNING). The following performance measures were used to evaluate cadet performance on the port approach test scenarios.

Channel Excursion. The act of navigating ownship such that its geographic position exceeds the specified channel boundaries. Measured on a binary scale: yes = channel excursion; no = no channel excursion.

Maximum Track Deviation. The greatest distance between ownship's track and the channel centerline over the entire test scenario. Measured perpendicularly from the channel centerline to ownship's center of gravity.

Mean Track Deviation. The mean distance between ownship track and the channel centerline measured at 30-second time intervals over the entire test scenario. Measured perpendicularly from the channel centerline to ownship's center of gravity.

Number of Track Crossings. The number of times ownship track intersects the channel centerline during the entire test scenario.

Number of Course Orders. The number of course orders given by the subject navigating the vessel during the entire test scenario.

Number of Rudder Orders. The number of rudder orders given by the subject navigating the vessel during the entire test scenario.

Number of Engine Orders. The number of engine orders given by the subject navigating the vessel during the entire test scenario.

VHF Communications. The act of attempting to establish voice radio communications with the vessel traffic system, the pilot station, other ships and the tugs as appropriate during the test scenario. Measured on a binary scale: yes = VHF communications attempted; no = no VHF communications attempted.

2.13.3.1 Turn 1. The following performance measures were used to evaluate cadet performance during turn 1 of the port approach test scenarios.

Rudder Order Deviation (Planned/Actual). The difference between the rudder angle planned for turn 1 and that actually used. The planned rudder angle is given first, followed by the actual rudder angle. All measurements are expressed in degrees.

Initial Range Offset. The distance from the range line in leg 1 that ownship acquired as a result of its performance in turn 1. Measured perpendicularly from the channel centerline to ownship's center of gravity.

2.13.3.2 Leg 1. The following performance measures were used to evaluate cadet performance during leg 1 of the port approach test scenarios.

Course Made Good Deviation (Planned/Actual). The difference between the course made good planned for leg 1 and that actually made good in leg 1. The planned course made good is given first, followed by the actual course made good. All measurements are expressed in degrees.

Course to Steer Deviation (Planned/Actual). The difference between the course to steer planned for leg 1 and that actually used in leg 1. The planned course to steer is given first, followed by the actual course to steer. All measurements are expressed in degrees.

Navigational Plot. The act of maintaining a navigational plot of ownship's position during the test scenario. Measured on a binary scale: yes = navigational plot; no = no navigational plot.

Navigation Fix Error. The mean distance between each geographic position plotted by the cadet navigator on the navigational plot and the vessel's actual position at the same instant in time.

2.13.3.3 Turn 2. The following performance measures were used to evaluate cadet performance during turn 2 of the port approach test scenario.

Rudder Order Deviation (Planned/Actual). The difference between the rudder angle planned for turn 2 and that actually used. The planned rudder angle is given first, followed by the actual rudder angle. All measurements are expressed in degrees.

Initial Centerline Offset. The distance from the channel centerline in leg 2 that ownship acquired as a result of its performance in turn 2. Measured perpendicularly from the channel centerline to ownship's center of gravity.

SECTION 3
RESULTS AND DISCUSSION:
RULES OF THE ROAD RELATED SKILLS

3.1 GENERAL

The Phase 2 cadet training experiment actually contained two experiments: one experiment evaluating the experimental objectives discussed in Section 1 for rules of the road related skills, and one experiment evaluating these experimental objectives for the port approach related skills. Each of these categories of skills was evaluated, trained, and reevaluated in its corresponding training module. In order to effectively communicate the findings of each experiment, the results and discussion of the rules of the road training module are presented in this section of the report while the results and discussion of the port approach training module are presented in the next section of the report (Section 4). Section 5 contains an overall discussion, combining the results of both training modules, along with the conclusions for the entire Phase 2 cadet training experiment.

In analyzing certain results of this experiment, one should exercise caution since the observed results may be influenced by one particular uncontrolled experimental factor. The structured experimental training program, the first of its kind, was developed by the project staff in conjunction with the USMMA Nautical Science Department. It was administered by several instructors from the Nautical Science Department as an extracurricular responsibility. Due to the logistics of providing instructors after working hours, all experimental groups, although receiving similar instruction, may not have received identical instruction. The importance of the instructor for effective mariner simulator-based training at the master level has been recently documented (Hammell, Gynther, Grasso, and Gaffney, 1980). It is postulated that the instructor may also heavily influence the effectiveness of simulator-based training at the cadet level. Hence, the observed differences between experimental groups after training may be influenced by the differences in the instruction each group received during the training program. This factor does not affect the results of the pretraining tests, which have been utilized to describe cadet input characteristics. Nor does it affect the documented success of the training program to upgrade the proficiency level of the cadets who participated.

The discussions below separately address (1) input characteristics, including day and night situations; and (2) training effectiveness, including day, night, and distributed/concentrated conditions.

3.2 INPUT CHARACTERISTICS

Relatively little information is documented about the specific capabilities of graduating maritime academy cadets with regard of their performance on the bridge of a merchant vessel. The cadets receive 4 years of college level education, coupled with a period of at-sea training. Previously, the at-sea training has consisted of 6 to 10 months of experience on a merchant vessel or an academy training vessel. The requirements for at-sea training of cadets will be extended to 12 months as the result of the recent IMCO agreements on the standards of training and watchkeeping (IMCO, 1978). The pretest data collected during this experiment provide insight into the performance of cadets on the bridge of a vessel. This shiphandling performance information pertains to both nighttime conditions and daytime conditions and to two different academy training programs. The proficiency of shiphandling performance is expected to differ somewhat between the experimental groups of cadets due to these factors. Detailed summaries of the pretest shiphandling performance for each group are presented in Appendix A. A summary of these data is presented in Table 3.

The situation encountered during the pretest scenario was that of ownship, an 80,000 dwt tanker, encountering a containership in a crossing situation with a high closing rate. In this situation, the giveway vessel did not maneuver; ownship, as the stand-on vessel, was required to take action to avoid the collision. The international rules of the road applied.

The pretest findings (i.e., cadet skill level entering the course) are presented below as follows:

Day (Kings Point)
Day (Fort Schuyler)
Kings Point/Fort Schuyler Comparison
Night (Kings Point)
Day/Night Comparison

TABLE 3. SUMMARY OF CADET INPUT CHARACTERISTICS (SEE APPENDIX A)

Cadet Group	Mean Pretest Results									
	CPA (nm)	Range of Maneuver (nm)	Course Change Magnitude (deg)	Course Order Frequency	Rudder Order Frequency	Master Notified (percent)	Master Notified Range (nm)	VHF Communications (percent)	Number of Visual Bearings	Number of Radar Requests
Day (Kings Point Group A)	0.828	5.49	51.7	3.33	1.33	83	7.5	16.7	1.83	3.17
Day (Fort Schuyler)	0.923	7.00	15.0	3.33	2.33	100	11.97	66.7	4.50	2.00
Night (Kings Point Group B)	0.895	9.02	18.3	5.17	2.67	100	11.68	16.7	4.83	4.83

3.2.1 DAY (KINGS POINT). During the pretraining test scenario, the Kings Point group A, which was tested under daylight conditions, had a mean closest point of approach (CPA) of 0.83 nautical miles. There were no collisions. After training, the Kings Point group A had a mean CPA of 1.57 nautical miles on an equivalent scenario (Figure 7). This improvement was statistically significant ($t = 2.95$; $p \leq 0.01$). It should be noted that a goal was not given to the students with regard to CPA, although the standing orders required them to notify the master 10 minutes prior to CPA if the CPA would be less than 2 miles. Upon notification, the master would acknowledge the report, tell the cadet to take appropriate action, and request that he be kept advised. As a result, the CPAs obtained on the test were a function of both the cadet's perception of a safe CPA and his ability to meet or exceed that CPA. It would appear from this discussion that it would be beneficial to give the cadets additional instruction on rules of the road situations under daylight conditions. This analysis does not indicate whether this instruction should be directed toward "what is a safe CPA" or "how does one maneuver the vessel to obtain a safe CPA."

The CPA represents the end result of actions taken by the mate on watch. The primary actions that he takes in this test situation which affect CPA are (a) the range at which the stand-on vessel initiates its action and (b) the magnitude of the course change made by the stand-on vessel. The mean range of maneuver for the day Kings Point group was 5.5 nautical miles. Because the give-way vessel would be expected to maneuver between 5 and 6 nautical miles (nm), any stand-on vessel maneuver at a range greater than 5 nm is excessive. A new 3rd mate might reasonably maneuver more conservatively than a seasoned master, but the give-way vessel could not know that a new 3rd mate was on watch on the stand-on vessel. Thus, a range of maneuver in the range of 4.5 to 4.9 nm would be understandable for junior personnel, whereas the actual average range of maneuver by the seasoned professionals was 4.04 nm in prior research on this rather difficult scenario (Aranow, Hammell, and Pollack, 1978).

The magnitude of course change was the second major factor under direct control of the cadets that had a substantial impact on the attained CPA. The range of maneuver and the magnitude of maneuver act together to produce the CPA. The relatively large mean course change (i.e., 51.7 degrees) made by the day Kings Point group was viewed by the instructors as not only acceptable, but necessary. It is also

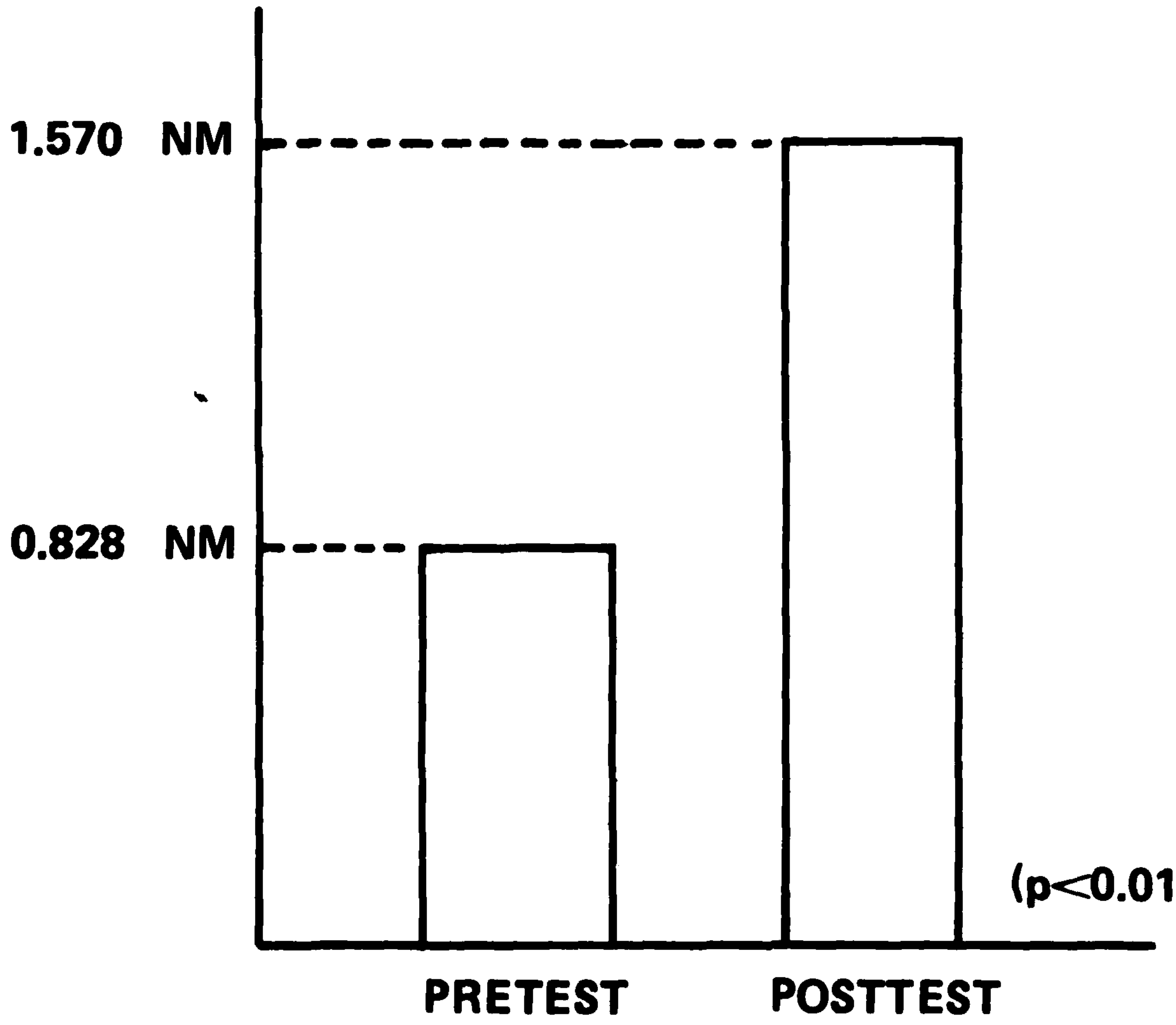

Figure 7. Pretest/Posttest Comparison: CPA - Kings Point Group A (Day)

interesting to note that the masters evaluated during the rules of the road experiment had a mean course change of 55 degrees (Aranow, Hammell, and Pollack, 1978). Fast time computer simulations of this scenario indicated that course changes of 70 to 90 degrees would be necessary to achieve the maximum physically possible CPA. That CPA would be between .75 and .95 nm given a maneuver range of 4 nm, closing speeds of about 40 knots and closing angles of 5 to 25 degrees (Aranow, Hammell, and Pollack, 1978). Because turns on the order of 80 degrees will take almost all way off a VLCC and leave it nearly unmaneuverable, experienced masters generally avoid that great a course change. In summary, the Kings Point cadets made an appropriate maneuver, but made it a little too early to be in full conformance with the intent oi Rule 17.

Several points with regard to the cadet bridge procedures on the pretest scenario during daylight operations should be made:

- Only 83 percent (5/6) of the students in the Kings Point Day Group notified the master even though the CPA was well below the 2 mile standard set forth in the standing orders. Furthermore, when notifying the master of a possible threat situation, important data (e.g., range, relative bearing, bearing drift) were omitted or not communicated in a clear, concise manner. The accuracy and format of the information that was forwarded to the master was classified by the instructors as needing improvement.

- Only 16.7 percent (1/6) of the cadets attempted to contact the traffic vessel by VHF communications. The instructors classified the format and accuracy of the information passed as needing improvement, particularly with regard to the timeliness, clarity, and conciseness of information transmitted.

- Very few visual bearings were taken on the pretest. In fact, the mean number of visual bearings for the group was only 1.83, below the minimum number (i.e., 2) required to establish bearing drift. It appears that the cadets would benefit from additional instruction in how to make proper use of the information in the visual scene to assess risk of collision during daylight operations.

The cadets may have been overly dependent on the radar during the pretest. Since the posttest results indicate a significant reduction in radar requests (Figure 8). This may be the influence of the required radar simulator course, which has

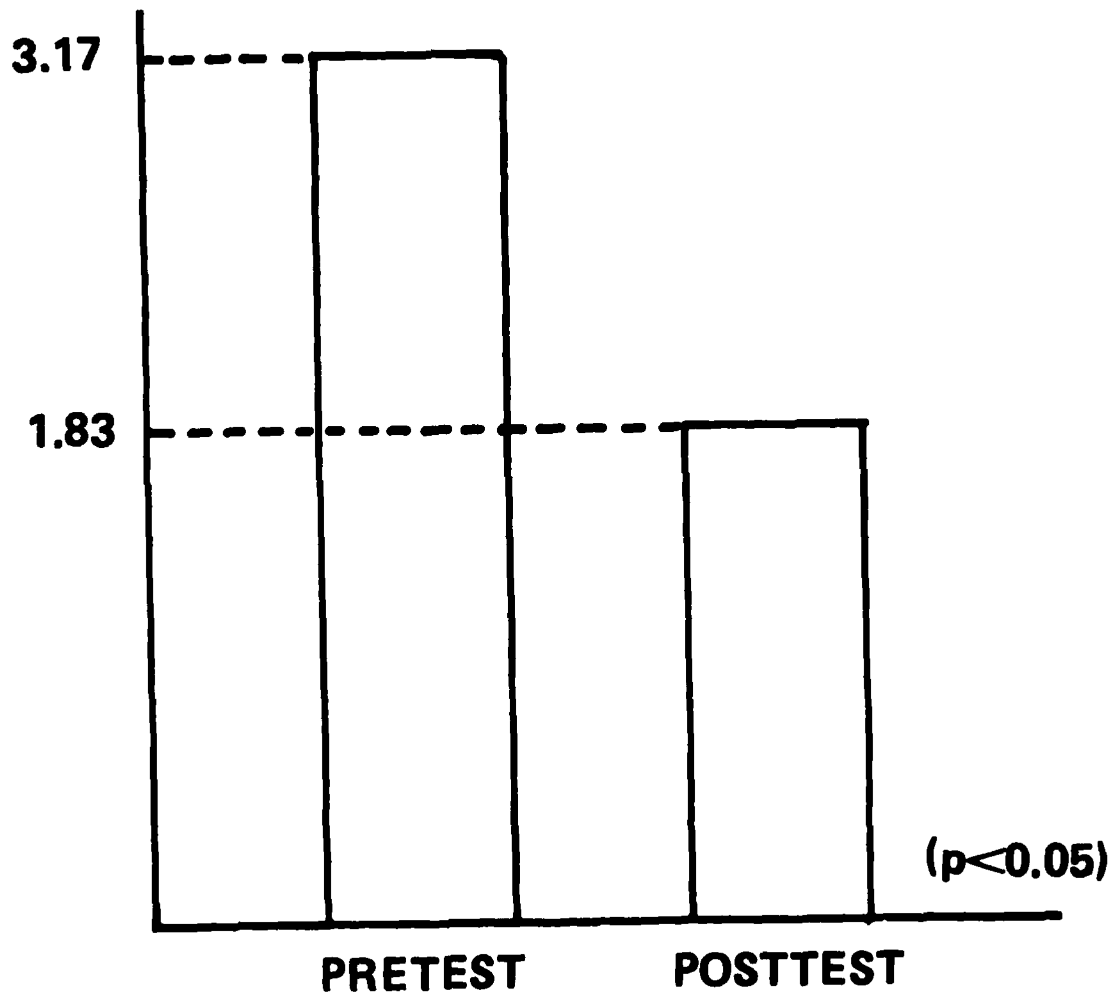

Figure 8. Pretest/Posttest Comparison: Number of Radar Requests
Kings Point Group A (Day)

traditionally been accepted as beneficial to training radar plotting skills for all weather/visibility conditions. The radar simulator course has undoubtedly been very successful in improving radar plotting skills for restricted visibility conditions. However, this result could indicate that for daylight operations under unlimited visibility, the radar simulator course may be training the students to rely too heavily on the radar and neglect the proper use of the information in the visual scene. Hence, it may be desirable, or even necessary, to supplement the radar training with appropriate visual skills training. The proper role of the radar simulator may be as a part-task trainer in support of a full-mission simulator or more intensive at-sea training. These are two possible training mediums through which the students could acquire the proper balance between visual and radar information sources during daylight operations.

3.2.2 DAY (FORT SCHUYLER). During the pretraining test scenario, the Fort Schuyler group (which was also tested under daylight conditions) had a mean CPA of 0.923 nautical miles. There were no collisions. As with the Kings Point group A, this CPA is viewed as minimally acceptable.

The mean range at which the day Fort Schuyler group initiated action was 7.0 nautical miles. In light of the opinion expressed by many masters during the rules of the road experiment that the giveway vessel will usually initiate a maneuver at a range of about 5 to 6 miles, this stand-on vessel range of maneuver appears to be early. In fact, it may be construed by some to be an infringement on Rule 17(a)(ii) since at 7.0 nautical miles it cannot be determined ". . . that the vessel required to keep out of the way is not taking appropriate action in compliance with these Rules." (COLREGS, 1972). The conservative interpretation of an acceptable range of maneuver for the stand on vessel under Rule 17 is given by Cockcroft and Lamaijer (1976) at 2 to 3 nm. The more liberal interpretation cited in Church (1974) is the expectation that courts might interpret the appropriate range at about 2 1/2 nm to 5 nm depending on the circumstances, sizes, and speeds of the vessels involved. Again, 5 nm appears to be the absolute outer limit of acceptable stand-on vessel action under Rule 17 once the threat of collision has been deemed to exist.

Apart from formal commentary on Rule 17, informal discussions with some masters indicates a body of opinion which states that a VLCC should never allow itself to become a stand on vessel in open waters. Such masters maneuver sufficiently early (probably at greater than 12 nm), that they consider no "risk of collision" to have occurred and thus Rule 17 to have never been in force. The concern expressed by opponents of that philosophy is that early maneuvering will lessen the predictability of traffic and thus increase the risk of collision. Church tells us that when the Rules were being debated, the final decision was that no Rule could or should be provided for such an action. Instead, if the action is in fact sufficiently early, then it is a matter independent of the COLREGS."

In discussing the criterion for the outer range at which "risk of collision" should be considered to exist, Cockcroft and Lamaijer put that in the interval of 5 to 8 nm, consistent with their interpretation that stand-on vessel action is permitted only at 2-3 nm. Given the more liberal possibility that 5 nm could be an outer limit of permitted stand-on vessel action for a very large vessel in a very high speed closing, it is apparent that consistency would require a substantially greater range for risk of collision than 8 nm.

The mean magnitude of course change which was initiated by the day Fort Schuyler group (i.e., 15 degrees) is viewed as being too small. A course change of 20 degrees or more would have been more appropriate in order to ensure that the other vessel recognizes the course alteration and to reduce the risk of collision through the attainment of a larger CPA.

Several findings are notable with regard to bridge procedures practiced by the Fort Schuyler group:

- They had a 100 percent (6/6) notification of the master, which occurred at a mean range of 11.67 nautical miles. As with the day Kings Point group, the accuracy and format of the information fowarded to the master was classified by the instructors as needing improvement.

- A total of 66.7 percent (4/6) attempted VHF communications with the threat vessel. This was the highest percentage of any group on the pretest.

- They had a mean of 4.5 visual bearings to establish risk of collision. This was viewed as acceptable.

3.2.3 KINGS POINT/FORT SCHUYLER COMPARISON. Two factors are readily apparent in comparing the performance on the pretest scenario of the day Kings

Point group with that of the day Fort Schuyler group: (a) there was no significant difference in CPAs between the groups, and (b) Kings Point control actions and bridge procedures differed substantially from Fort Schuyler control actions and bridge procedures.

The Fort Schuyler group notified the master significantly farther out than their Kings Point counterparts concerning the risk of collision (Figure 9): Fort Schuyler at a range of nearly 12 nautical miles; Kings Point at a range of 7.5 nautical miles ($t = 6.098$; $p \leq 0.005$). Furthermore, 100 percent (6/6) of the Fort Schuyler cadets notified the master, while 83 percent (5/6) of the Kings Point cadets did so. The reasons for these differences are unclear from these data. It may be due to different bridge procedures stressed by the schools, or other factors. It should be remembered that these findings were obtained from a small sample of students from both schools, and may not be representative of the overall student population. Nevertheless, these data do present a starting baseline to assess cadet/entering 3rd mate characteristics.

The Kings Point group had a greater magnitude of course changes than the Fort Schuyler group: 51.7 degrees compared to 15.0 degrees for Fort Schuyler ($t = 2.72$; $p \leq 0.025$). This coincides with the differences in range of maneuver noted above. Hence, the two groups had significantly different range/course maneuvers as stand-on vessel, which offset to achieve approximately similar CPAs. This presents another example of differences in the actions of both groups, although the resultant outcome was similar.

Several other findings are worth comparing:

- The use of VHF communications differed substantially between the group (i.e., 66.7 percent (4/6) of the Fort Schuyler cadets attempted communications while 16.7 percent (1/6) of the Kings Point group did so).
- Fort Schuyler cadets took significantly more visual bearings (Figure 10): 4.50 visual bearings compared to 1.83 for Kings Point cadets ($t = 2.15$; $p \leq 0.05$). Kings Point had significantly more radar requests: 3.17 compared to 1.17 for Fort Schuyler ($t = 1.95$; $p \leq 0.05$).

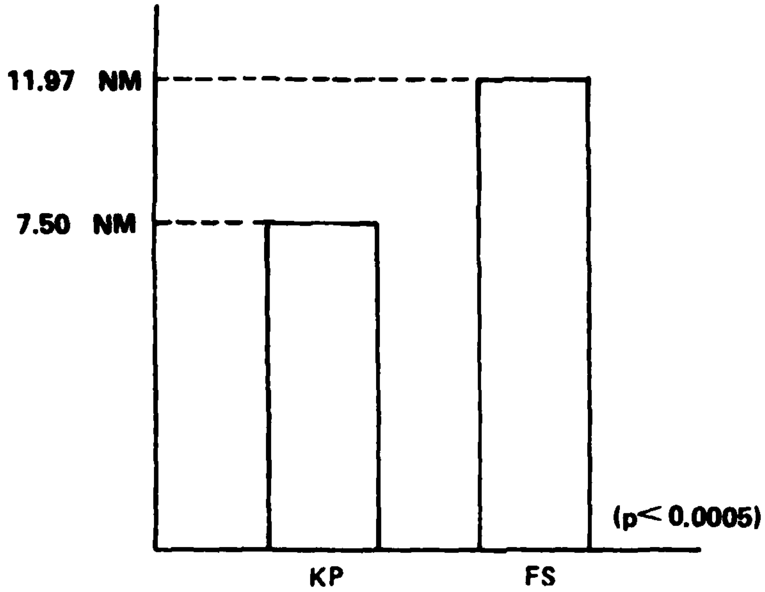

Figure 9. Input Characteristic: Range Master Notified, Kings Point Group A (Day) Versus Ft. Schuyler Group (Day)

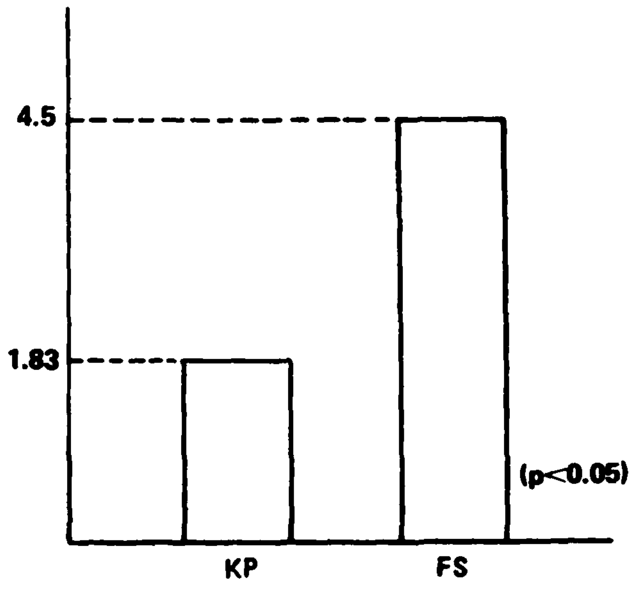

Figure 10. Input Characteristic: Number of Visual Bearings, Kings Point Group A (Day) Versus Ft. Schuyler Group (Day)

It appears from these results that although Kings Point and Fort Schuyler are graduating 3rd mates of equivalent proficiency, the two academies are not producing a standardized product. The control actions and bridge procedures that a midshipman acquires at Kings Point differ substantially from the control actions and bridge procedures that a cadet acquires at Fort Schuyler. Part of the reason for this difference may be the manner in which cadets at each academy get their at-sea experience. Kings Point midshipmen serve apprentice-type periods onboard commercial vessels. The Fort Schuyler cadets get their at-sea training on a dedicated training vessel. No attempt is made to identify the better training program, but it is simply stated that the two programs are producing 3rd mates who utilize different control actions and bridge procedures. Since a large segment of the merchant marine industry in this country utilizes the "rotary shipping" concept in handling its personnel, it would appear to be desirable to standardize the bridge procedures of 3rd mates. Such standardization should enhance the safety of a given bridge team which may be together for only a few months prior to the transfer of one or more individuals.

3.2.4 NIGHT (KINGS POINT). The night Kings Point group (which was tested under nighttime conditions) had a mean CPA of 0.895 nautical miles in the pretest scenario. There were no collisions. This CPA, as was the case for both day groups, was viewed as minimally acceptable. Hence, it would appear to be beneficial to give the cadets additional instruction in rules of the road situations under nighttime conditions. This analysis, as noted earlier, does not indicate whether this instruction should be directed towards "what is a safe CPA" or "how does one maneuver the vessel to obtain a safe CPA."

The mean range at which the night group maneuvered was 9.0 nautical miles. In view of the previously cited opinion expressed by many masters during the rules of the road experiment that the giveway vessel will usually initiate a maneuver at a range of about 6 miles, this 9-mile range of maneuver appears extremely early. It may be a violation of Rule 17 since at 9.0 nautical miles (a) risk of collision probably exists, and (b) it is not apparent that the giveway vessel is not taking appropriate action. It should be noted that some mariners have expressed the view that risk of collision does not exist at 9 miles, and hence neither vessel is yet stand-on or give way. In a relatively high closing rate situation of this type, however, only about 15 minutes remain until collision when at a range of 9 miles. As a result, at the 9.0

nautical mile range the stand-on vessel should most likely be maintaining course and speed.

The mean magnitude of course change initiated by the Kings Point group B was 18.3 degrees. This is considered as somewhat small for the situation in which the stand-on vessel must take action. A course change of 20 degrees or more would probably have been more appropriate. Furthermore, the more substantial course change would have resulted in a greater CPA, more in keeping with the standing orders.

The findings regarding cadet bridge procedures during nighttime operations are as follows:

- 100 percent (6/6) of the students in the night Kings Point group notified the master of the pending risk of collision. This may indicate that the cadets utilize greater caution during nighttime operations than they do for similar traffic encounters during the day. The instructors classified the format and accuracy of the information passed to the master as needing improvement, similar to that in the other cadet groups.

- Only 16.7 percent (1/6) of the cadets attempted to contact the traffic vessel by VHF communications, similar to the day Kings Point group. In addition, the format and accuracy of the information passed allowed room for improvement.

- A relatively high number of visual bearings (4.83) was taken. This may also indicate a higher level of caution at night than for similar daytime situations. It also indicates that the Kings Point cadets understood the concepts of monitoring risk of collision using visual bearings, although they did not exhibit this behavior during the daytime scenario (Section 3.2.1).

3.2.5 DAY/NIGHT COMPARISON. Neither the day Kings Point group nor the night Kings Point group was involved in a collision during the pretest. In addition, there was no significant difference between the CPAs. These results would appear to indicate that the cadets are equally proficient during day and at night. Despite this similarity in CPAs, however, the day group and the night group differed substantially in their control actions and bridge procedures.

These differences are summarized below:

- The night group maneuvered significantly farther out (Figure 11): 9.02 nautical miles compared to 5.49 nautical miles for the day group ($t = 2.62$; $p \leq 0.025$). They made significantly smaller maneuvers (i.e., 18.3 degrees at night versus 51.7 degrees during the day), however, resulting in the equivalent CPAs. Furthermore, the night group made significantly more course changes (i.e., 5.17 at night compared with 3.33 during the day) ($t = 1.34$, $p \leq 0.11$). Hence, the specific shiphandling actions differed substantially between night and day, although the resultant performance (i.e., CPA) was similar.

- The bridge procedures also differed between the groups. 100 percent (6/6) of the night group notified the master, while 83 percent (5/6) of the day group notified the master. Furthermore, the night group notified the master significantly farther out (Figure 12): 11.68 nautical miles compared to 7.50 nautical miles for the day group ($t = 5.59$; $p \leq 0.005$). These findings appear to indicate that the night group was more concerned with the developing situation than the day group.

- A large difference was found in the use of visual bearings (see Figure 13), although this difference was not found to be significant due to a wide variance between cadets in each group. A significant difference was found, however, in the use of radar bearings, with the night group using more than the day group (i.e., 4.83 compared with 3.17) ($t = 2.16$; $p \leq 0.05$). These findings support the earlier observation that the night group was apparantly more concerned with the emerging stand-on situation.

These differences in control actions and bridge procedures indicate several points concerning cadet input characteristics. First, cadets are generally more cautious during nighttime operations than during equivalent daytime operations. Note the greater range at which the night group notified the master and the greater range at which it initially maneuvered. Second, the cadets appeared to be less confident at night. They made significantly more course changes at night with significantly smaller magnitude of course orders. Third, cadets appear to require additional training during nighttime operations with regard to maneuvering the vessel to obtain a safe CPA. This conclusion is based on the following analysis: although the night

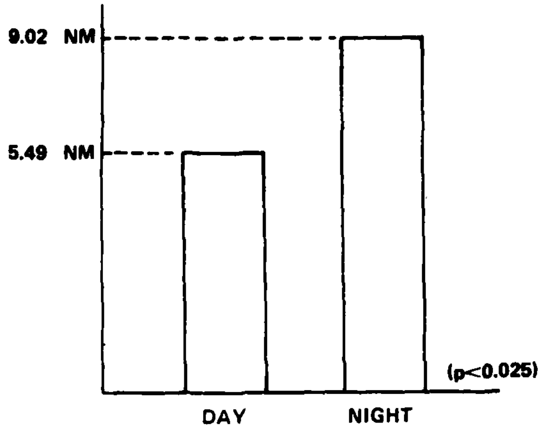

Figure 11. Input Characteristic: Range of Maneuver, Kings Point Group A (Day) Versus Kings Point Group B (Night)

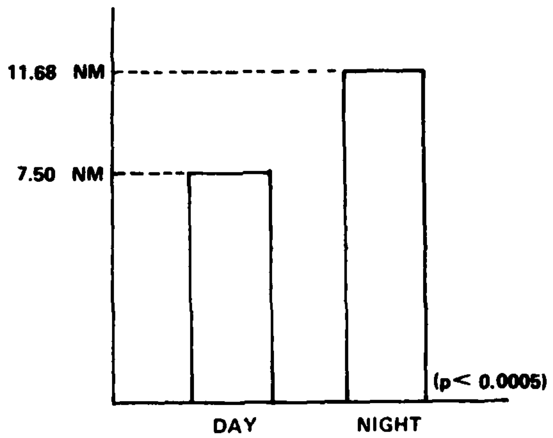

Figure 12. Input Characteristic: Range Master Notified, Kings Point Group A (Day) Versus Kings Point Group B (Night)

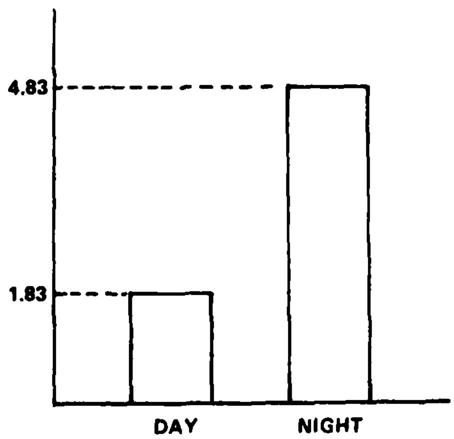

Figure 13. Input Characteristic: Number of Visual Bearings, Kings Point Group A (Day) Versus Kings Point Group B (Night)

group took action significantly earlier than the day group, it had equivalent CPAs. It appears reasonable to assume that in taking earlier action at night, the cadets desired to obtain a greater CPA at night. Since they did not obtain a significantly greater CPA at night, it would appear that they would benefit from additional training on maneuvering the vessel during nighttime operations.

3.3 TRAINING PROGRAM EFFECTIVENESS

The training program administered to the Kings Point and Fort Schuyler cadets during this experiment was the first known simulator-based training program for cadets in the world. It is hoped that this program not only documents some of the benefits to be derived from simulator-based training for cadets but also serves as a basis for future cadet training programs. In regard to the latter, it should be noted that the analysis described in Section 3.2 relating to cadet input characteristics was not available when this training program was designed. Future training programs should utilize this information on cadet input characteristics to direct the program toward strengthening the indicated weaknesses. It should also be noted that the results discussed below are a summary of the detailed results contained in Appendices A and B.

The training effectiveness findings are discussed below in the following subsections:

Day Training
Night Training
Concentrated Training
Day/Night Training Comparison
Distributed Versus Concentrated Training

3.3.1 DAY TRAINING. As a result of the simulator-based training program, the day Kings Point group increased its mean CPA from 0.828 nautical miles to 1.570 nautical miles (Figure 7). This increase in performance was significant ($t = 2.95$; $p \leq 0.01$). The range of maneuver increased from 5.49 nautical miles to 7.29 nautical miles ($t = 1.82$; $p \leq 0.06$). This increase in range of maneuver may be construed by some to be an infringement on Rule 17(a)(ii) since (as previously mentioned in Section 3.2.2) at 7.0 nautical miles it is difficult to determine ". . . that the vessel required to keep out of the way is not taking appropriate action . . . ." The instructor for this particular group believes that the larger range of maneuver is warranted in this particular scenario. The posttest performance of his students reflected his emphasis. There was no significant difference in magnitude of course change from pretest to posttest, which was initially acceptable. These findings demonstrate the effectiveness of the simulator-based training program in modifying the performance of the cadets. It should be noted that the training program used was developed for experimental purposes only, and hence does not necessarily represent the simulator-based training program that should be provided to cadets for formal training.

The range at which the master was notified of the pending risk of collision also increased from 7.50 nautical miles to 11.68 nautical miles (Figure 14). This significant increase ($t = 4.68$; $p \leq 0.005$) is viewed as an improvement since early notification of the master is essential in this scenario with its high closing rate. In addition, 100 percent of the cadets in this group notified the master after training compared to 83 percent prior to training. The accuracy and format of the information passed also improved substantially as a result of training. These findings directly show a performance improvement resulting from training.

As a result of training, this day group also significantly reduced the number of course orders from a mean of 3.33 on the pretest to a mean of 1.67 on the posttest ($t = 2.23$; $p \leq 0.05$). This reduction may indicate a better understanding of the vessel's characteristics during the posttest than during the pretest because fewer course orders on the posttest provide an indication of less trial and error technique to arrive at the proper course correction; they represent more decisive action by the deck officer.

There were significantly more visual bearings taken on the posttest (Figure 15): 5.17 as compared to 1.83 on the pretest ($t = 2.98$; $p \leq 0.01$). In addition, there were significantly fewer radar requests on the posttest (Figure 8): 1.83 as compared to 3.17 on the pretest ($t = 1.99$; $p \leq 0.05$). These results appear to indicate a more appropriate balance between the use of two important navigational information sources for the daytime, unlimited visibility scenario utilized. These findings also indicate an improvement following training.

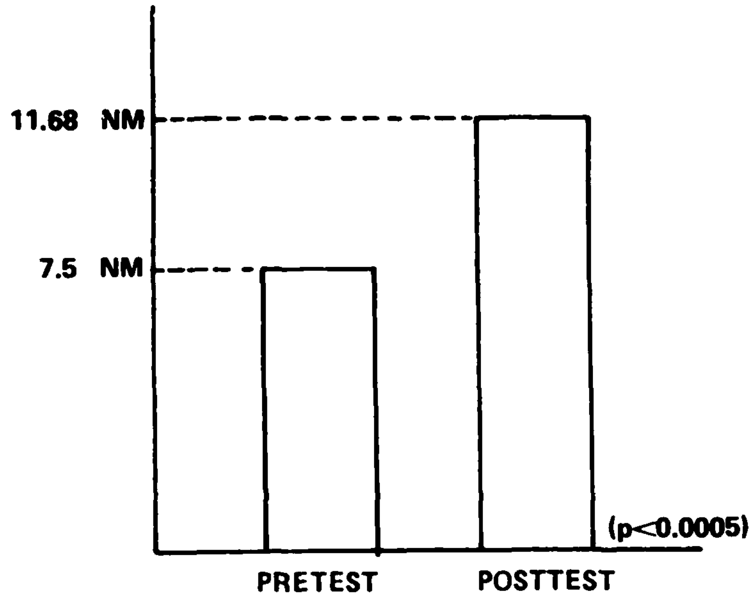

Figure 14. Pretest/Posttest Comparison: Range Master Notified, Kings Point Group A (Day)

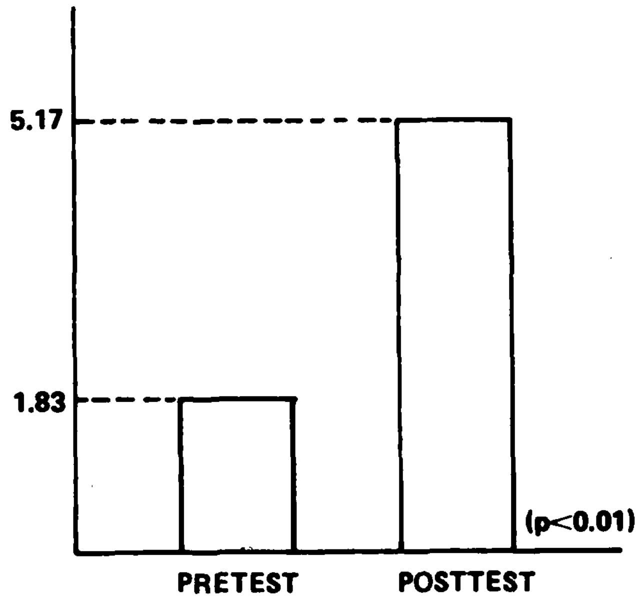

Figure 15. Pretest/Posttest Comparison: Number of Visual Bearings, Kings Point Group A (Day)

The above results demonstrate significant improvement in the cadets' performance under day conditions, as a result of the simulator-based training program. The improvement in this group was broad, spanning a variety of performance measures.

3.3.2 NIGHT TRAINING. The shiphandling performance improved as a result of training. The mean CPA for the night Kings Point group did not differ significantly between the pretests and posttests. However, the range at which the stand-on vessel maneuvered was significantly reduced from the pretest to posttest (i.e., 9.02 miles to 5.91 miles) ($t = 2.16$; $p \leq 0.05$). (See Figure 16.) This reduction in maneuver range to a reasonable distance for the stand-on vessel (i.e., from an excessive range) was accomplished without reducing the resultant CPA (see Section 3.2.4 for a discussion of maneuver range). The cadets used significantly greater course changes to accomplish the maneuver on the posttests: 27.5 degrees as compared to 18.3 degrees on the pretest ($t = 1.47$; $p \leq 0.10$). The posttest mean course change is also viewed as more appropriate for the circumstances. There were fewer course orders on the posttest (i.e., 2.83 compared to 5.17 on the pretest) ($t = 1.86$; $p \leq 0.05$) possibly indicating a better understanding of the vessel's maneuvering characteristics. Although the CPA did not increase, the other aspects of performance did improve significantly as a result of the simulator training program.

The bridge procedures improved from the training program. The use of VHF improved dramatically. Where as 16.7 percent (1/6) of the cadets used the VHF communications on the pretest, 83.3 percent (5/6) used it on the posttest. The high incidence of master notification on the pretest (i.e., 100 percent) was maintained. Furthermore, a substantial improvement in the quality of both types of communication was observed. The number of visual bearings used, which was already acceptable did not change on the posttest. However, there was a significant reduction in the number of radar requests: 1.83 after training compared to 4.83 prior to training ($t = 4.48$; $p \leq 0.05$). The implications of this reduction are unclear. It may represent an increase in confidence pertaining to the use of visual information, as well as to night operations in general.

The following conclusions have been reached from these results. First, the cadets were overly timid during the pretest. They notified the master and maneuvered extremely early. Such behavior may be viewed as inefficient and in violation of Rule 17, if it resulted at sea in maneuvers soon after risk of collision commenced.

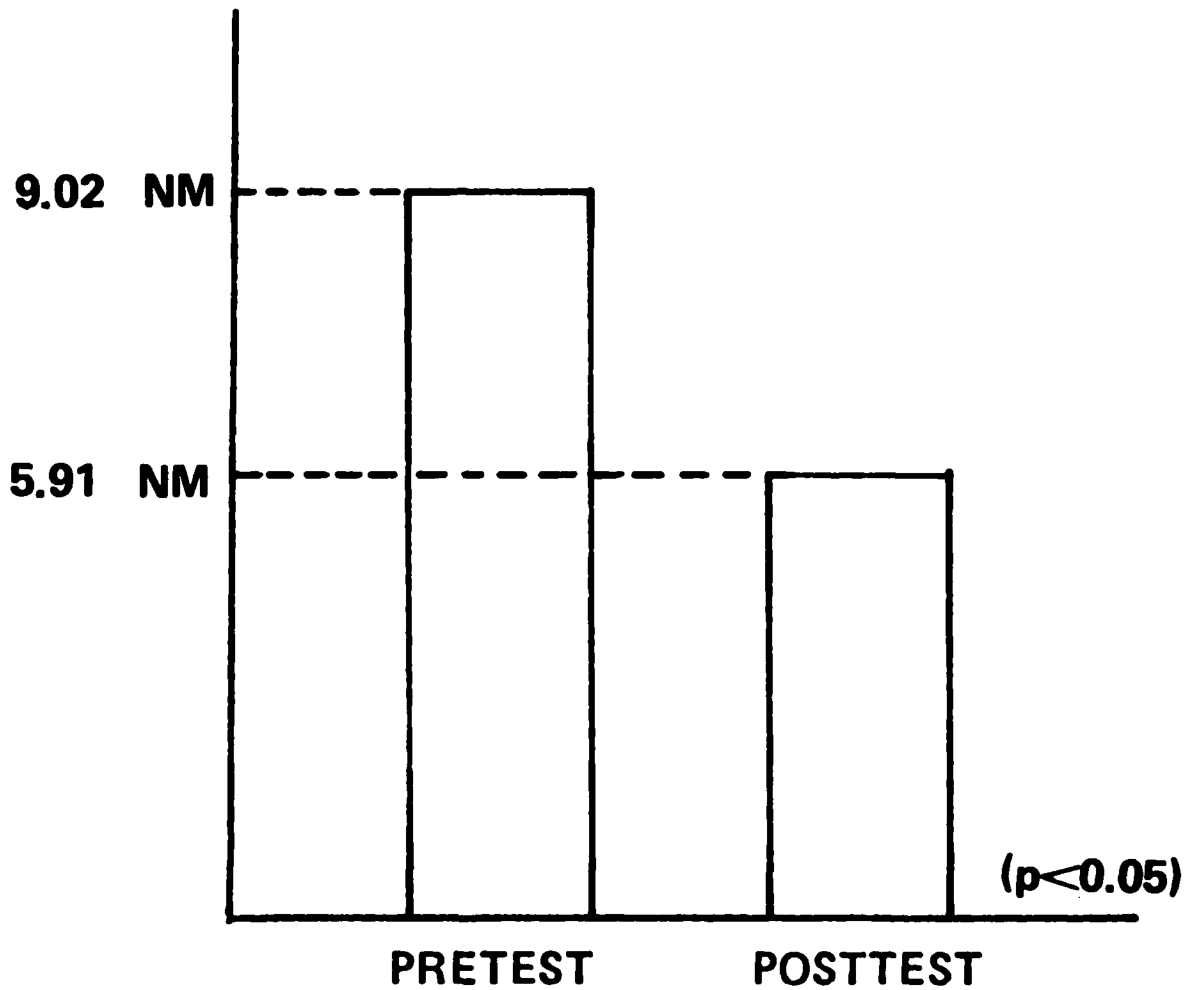

Figure 16. Pretest/Posttest Comparison: Range of Maneuver, Kings Point Group B (Night)

After completing the simulator-based training program, the cadets exhibited more confidence during the posttest. They analyzed the situation, notified the master, and took the corrective action at a more appropriate time. The cadets also were more deliberate with their course changes, using larger and fewer course changes. Finally, the cadets in the night Kings Point group also exhibited improved bridge procedures: 100 percent (6/6) master notification and 83.3 (5/6) percent use of VHF communications. These findings, similar to those discussed above for the day group, demonstrate substantial training effectiveness for the simulator-based training program.

3.3.3 CONCENTRATED TRAINING. The day Fort Schuyler group received a concentrated training program over a 5-day period; the Kings Point groups received the same rules of the road training program over a 5-week period. Similar to that discussed above for the two distributed training groups (i.e., day and night Kings Point), the day Fort Schuyler group improved their shiphandling performance as a result of the simulator-based training program. The CPA did not improve as a result of training. The range of maneuver, however, improved significantly from about 7 miles to 4.6 miles (Figure 17) ($t = 1.74$; $p \leq 0.07$). This is viewed as an improvement since, as discussed in Section 3.2.2, a maneuver at 7 nautical miles must be construed as an infringement of the rules of the road. The 4.6 nautical mile range of maneuver is reasonably larger than the mean range of maneuver the masters achieved under similar circumstances in the rules of the road experiment (Aranow, Hammell, and Pollack, 1978). However, some may feel that the new 3rd mates should be more conservative than masters in this situation and maneuver at a slightly greater range (i.e., 4.5 to 4.9 nautical miles). Nevertheless, the reduced range of maneuver was achieved without a reduction in CPA. This was accomplished by making substantially larger maneuvers, which is also believed to be more appropriate in the stand-on situation (i.e., 42.5 degrees on the posttest versus 15.0 degrees on the pretest) ($t = 5.32$, $p \leq 0.01$).

The training effectiveness achieved for this group regarding bridge procedures, contrary to that found for the two distributed training groups, was mixed. The pretest performance on frequency of master notification, visual bearing use, and radar bearing information use was considered acceptable. The posttest performance did not differ significantly in these aspects, and hence was also acceptable. The accuracy and format of the information passed to the master was observed to

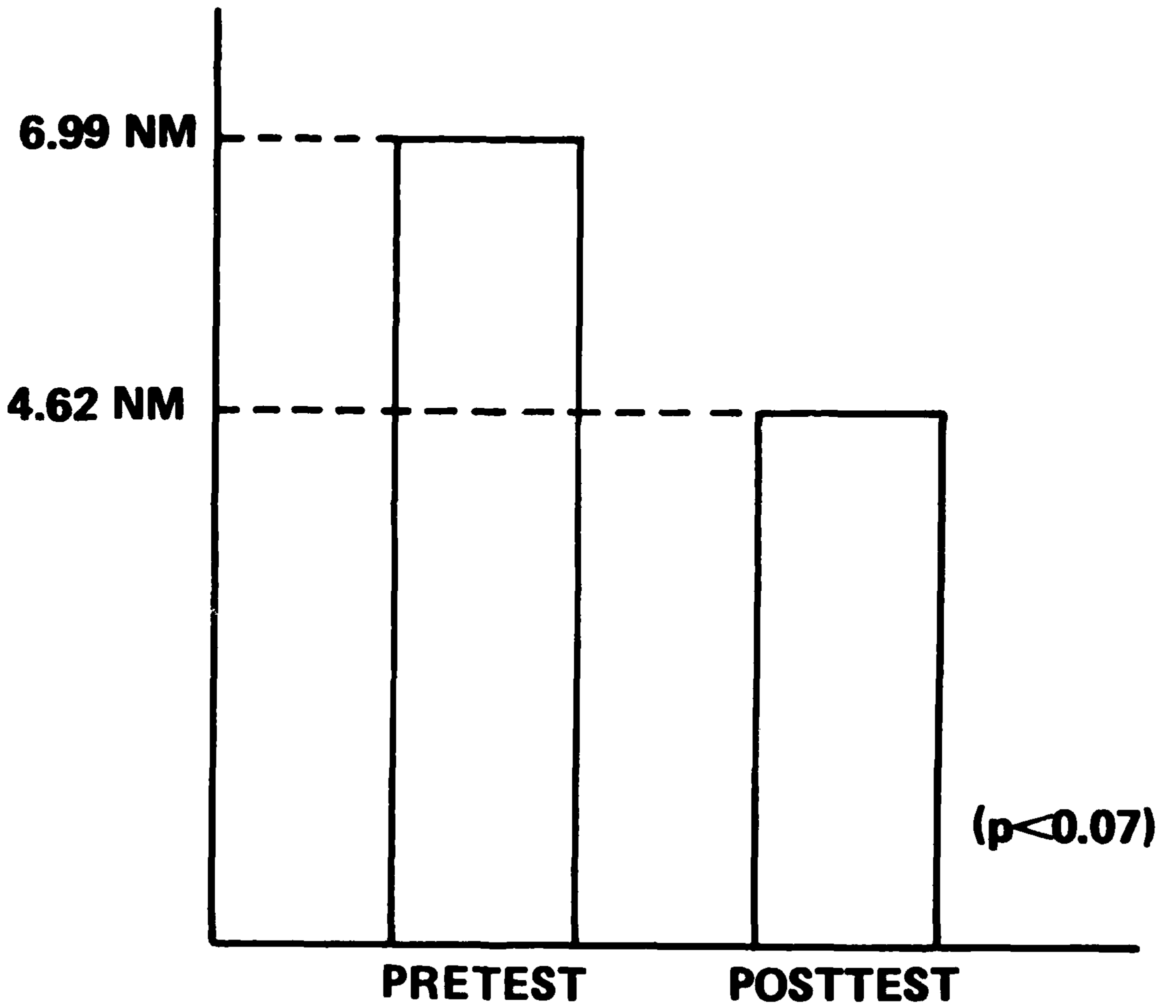

Figure 17. Pretest/Posttest Comparison: Range of Maneuver, Ft. Schuyler Group (Day)

improve on the posttest as a result of training. The range at which the master was notified, however, decreased significantly on the posttest (i.e., 11.97 miles to 9.18 miles on the posttest). The 9-mile notification range appears acceptable, as did the 12-mile notification range. Hence, it is difficult to evaluate the change as positive or negative. The findings, therefore, appear to indicate performance improvement as a result of the training, where such improvement was necessary.

One interesting performance measure for the concentrated training group was the number of rudder orders. There were significantly more rudder orders during the posttest than during the pretest (Figure 18): 9.20 as compared to 2.33 ($t = 7.05$; $p \leq 0.0005$). In fact, the mean number of rudder orders by the concentrated training group was three times higher than either of the distributed training groups. This extremely high number of rudder orders during the posttest would appear to indicate a high level of uncertainty. Since a high level of rudder activity was not present during the pretest, it would appear to indicate that the training program itself may have generated this uncertainty. One plausible explanation for this would be that the training program presented too much material in too short a time period (i.e., the deficiency of a concentrated training program).

The above findings attest to the effectiveness of the simulator-based training program for cadets, even when presented in a concentrated form. Some limited findings did, however, suggest that undesirable aspects of the concentrated program may result (e.g., uncertainty).

3.3.4 DAY TRAINING/NIGHT TRAINING COMPARISON. Recent research at CAORF has indicated that the skills required for safely handling a vessel at night differ from the skills required to safely handle a vessel during the day. As a result, since mariners operate at-sea under both daytime and nighttime conditions, training under both conditions is recommended (Hammell, Gynther, Grasso, and Gaffney, 1980). In this experiment, one Kings Point group was trained and tested during daytime conditions, and another Kings Point group was trained and tested during nighttime conditions. The following is a discussion of the relative success of the day training and the night training in improving cadet performance under the relevant ambient lighting conditions.

As discussed in Section 3.2.1, the King Point cadets who were tested under daytime conditions and were administered the daytime training had satisfactory performance

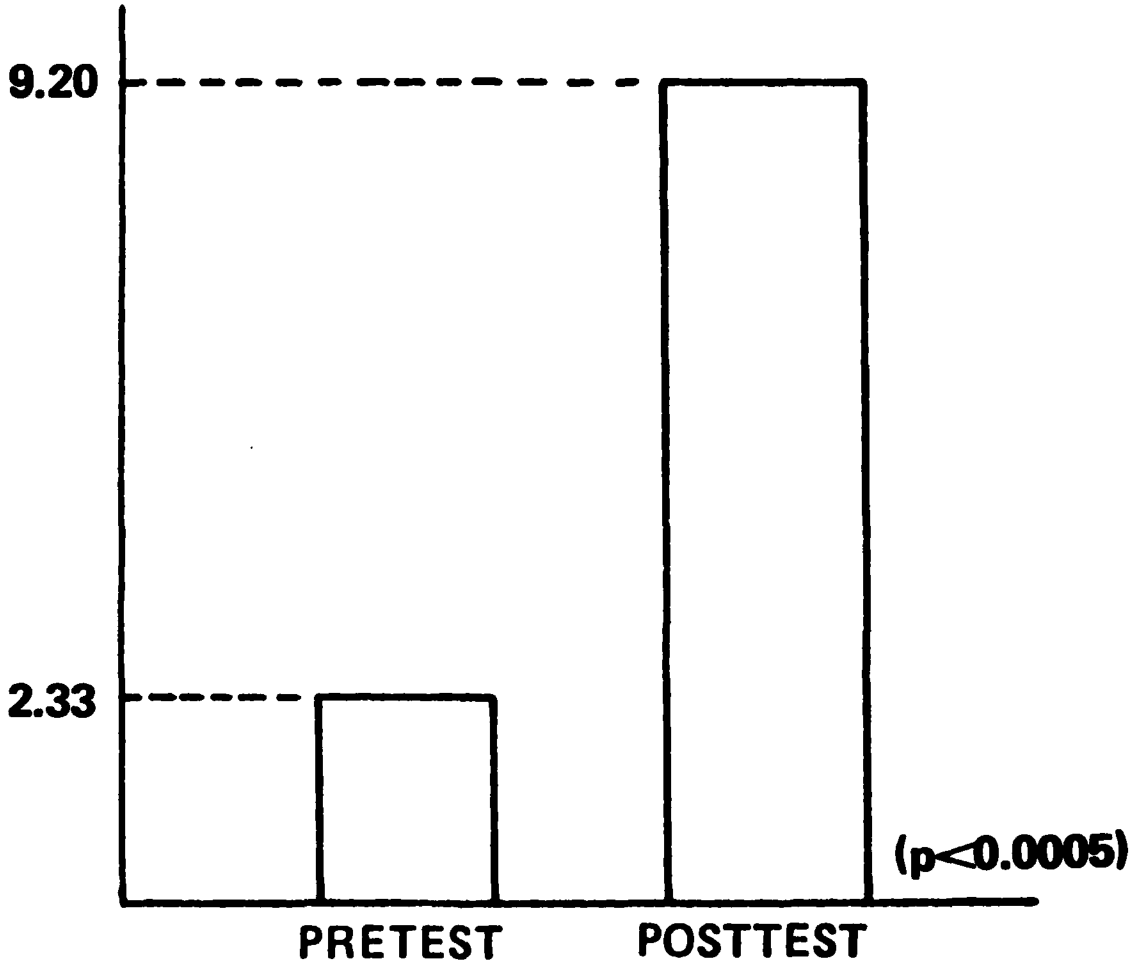

**Figure 18. Pretest/Posttest Comparison: Number of Rudder Orders
Ft. Schuyler Group (Day)**

during the pretest with regard to CPA, range of maneuver, etc. The br... procedures utilized by the group (e.g., notification of master, VHF communications, number of visual bearings) were in need of improvement. In retrospect, the most important objectives of the day training program were to (a) reinforce the proper control actions of the cadets and (b) emphasize the use of proper bridge procedures. The latter is important because it improves the inherent safety of the navigational process.

In contrast, the cadets who were tested under nighttime conidtions (see Section 3.2.4) and were administered the nighttime training program maneuvered extremely early (some may say that they were gun-shy) with a marginally acceptable magnitude of course change. As with the day group, appropriate bridge procedures were also lacking although not as many deficiencies were observed. In retrospect, the most important objectives of the night training program were to (a) give the cadets the necessary skills and confidence to handle traffic vessels at night and (b) emphasize the proper use of bridge procedures. It should be noted that little information was available regarding cadet performance when the course was developed; a more effective course could likely be developed now on the basis of data collected during this investigation.

From the comparison of the day and night training programs, the following interpretations are drawn:

- It appears that cadets should be given simulator-based training for open-sea rules of the road situations under both day and night conditions. Under daytime conditions, the incoming cadets were more lax in their bridge procedures (e.g., notification of master, taking visual bearings) than under nighttime conditions. If they had been trained under nighttime conditions only, as some would advocate, they would not have had the necessary training to overcome their natural tendency to use lax bridge procedures during daytime operations.

- Although it appears that cadets should be trained under both daytime and nighttime conditions, it also appears that the cadet training program should emphasize nighttime training. The cadets appear deficient in more areas at night (e.g., evaluative skills, proper bridge procedures) than during daytime operations.

3.3.5 DISTRIBUTED VERSUS CONCENTRATED TRAINING. The comparison of the effectiveness of distributed training versus concentrated training is difficult to make on a statistical basis due to the significant differences between input characteristics of the distributed group (day Kings Point) and the concentrated group (day Fort Schuyler). The following is a subjective comparison of the success of each training program to teach the appropriate rules of the road skills as measured on the posttraining test scenario.

On the posttest, the distributed group had an acceptable mean CPA (1.57 nautical miles). The group's mean range of maneuver (7.29 nautical miles) appears early by the analysis discussed in Section 3.2.2, however, it reflects the emphasis of the instructor as indicated in Section 3.3.1. The magnitude of course change (41.7 degrees) was appropriate as were the bridge procedures utilized.

On the posttest, the concentrated group had an acceptable mean CPA (0.85 nautical mile). The group's mean range of maneuver (4.6 nautical miles) is also acceptable. The masters in the rules of the road experiment had a narrower CPA with only a slightly smaller mean range of maneuver. As discussed in Section 3.3.3, some may feel that new 3rd mates should be more conservative than masters in this situation and maneuver at a slightly greater range (i.e., 4.5 to 4.9 nautical miles). The magnitude of course change (42.5 degrees) was an improvement from the pretest, but was still somewhat lower than that of the senior deck officers. It should be noted that the concentrated group had three times more rudder orders than the distributed group. As discussed in Section 3.3.3, this rudder activity may indicate that a higher level of uncertainty is attributable to the concentrated training program.

Based on the above findings it appears that the distributed training program is preferable to the concentrated training program as administered in this experiment for the following reasons: (a) the concentrated training program appeared to overcorrect the range of maneuver, bringing it down to a range which although equivalent to that observed for experienced masters is not considered appropriate for new 3rd mates; (b) the concentrated training program appeared to generate uncertainty as indicated by the extremely high rudder activity; and (c) the weight of other experimental evidence favors the distributed practice as the more effective method for learning, especially in the early stages (Sanford and Wrightman, 1970). A week's time period for acquiring the desired rules of the road skills may have been satisfactory if the classroom time and simulator time had been increased (i.e., full-time course for the week in lieu of 6 hours of simulator-based training per day in addition to regular courses). However, such an approach should be used with caution since there is evidence in the literature to indicate that retention of the skills acquired would be better if the training were conducted over a longer time period (Woodworth and Schlosberg, 1954).

SECTION 4
RESULTS AND DISCUSSION: PORT APPROACH RELATED SKILLS

4.1 GENERAL

As previously discussed in Section 3, the Phase 2 cadet training experiment actually contained two experiments: one experiment evaluating the experimental objectives for the rules of the road related skills and one experiment evaluating these experimental objectives for the port approach related skills. This section contains the results and a discussion of the experiment which relates to the evaluation, training, and reevaluation of port approach related skills. The detailed results of the port approach planning training module are contained in Appendix B.

In analyzing these results, the same precautions discussed in Section 3 for the rules of the road related skills should be observed. In addition, due to the nature of the port approach training as a bridge team exercise, each of the two Kings Point experimental groups had only two bridge teams which were administered the pretest scenario and the posttest scenario. As a result of this small sample size, no statistically significant results can be reported for the port approach training module. However, appropriate trends have been identified in the data and their impact discussed herein.

The findings are discussed below as follows:

Input Characteristics
Day
Night
Training Effectiveness
Day
Night

4.2 INPUT CHARACTERISTICS

4.2.1 DAY. The day Kings Point group, which was tested under daytime conditions, on the pretest scenario, had no channel excursions. However, the large magnitude of the maximum track deviation for the group (1235.5 feet to the left of channel centerline) indicates a tendency to place the vessel in greater risk than is required. First, a maximum track deviation of 1235.5 feet (≈400 yards) is greater than 80 percent of the distance between the channel centerline and the channel bank (500 yards). The channel width for this training program was 1000 yards. Second, the direction of this maximum track deviation to the left of the channel centerline could have been dangerous if outbound traffic had been encountered and ownship had been on the wrong side of the channel. Although no traffic vessels were utilized during the port approach pretest, this information was not available to the cadets, who should have been maintaining a vigilant watch for traffic vessels.

This large maximum track deviation, which occurred in leg 1, appears to be due principally to the large initial offset from the range line (1200 feet to the left of centerline) that resulted from the turn the students performed as they approached leg 1 (Figure 19). This indicates a lack of understanding the maneuvering of ownship in the presence of a 40 knot wind from 310 degrees true. No current was used in the test scenario. This interpretation is supported by the use of 10 degrees more rudder angle in turn 1 than was planned (Figure 20). Similarly in turn 2, the students used 10 degrees more rudder angle than they had planned (Figure 21). It appears that (a) students do not have a sense for the responsiveness of the vessel to a given rudder angle, or (b) they do not understand the effect of a 40-knot wind on the responsiveness of the vessel, or (c) they have difficulty in determining the geographic position of the vessel relative to their desired turn initiation point and as a result require large rudder orders to compensate.

The ability of the students to determine the position of the vessel during the pretest scenario can be obtained by comparing the vessel's position at a given time on the students' navigation plot to its actual position at the same time on the computer-generated historical track plot for the run. However, it is much more difficult to label this ability as acceptable or unacceptable. In leg 1, the navigational fix error for the day Kings Point group was 622.5 feet. While not unacceptable, this accuracy could be improved as witnessed by an accuracy of 450 feet for the same group during the posttest. In any restricted waters scenario in which the channel is not well marked (i.e., bounded by land or fixed aids to navigation), the position fixing ability and the shiphandling ability of the mariner work in concert to accomplish a safe transit.

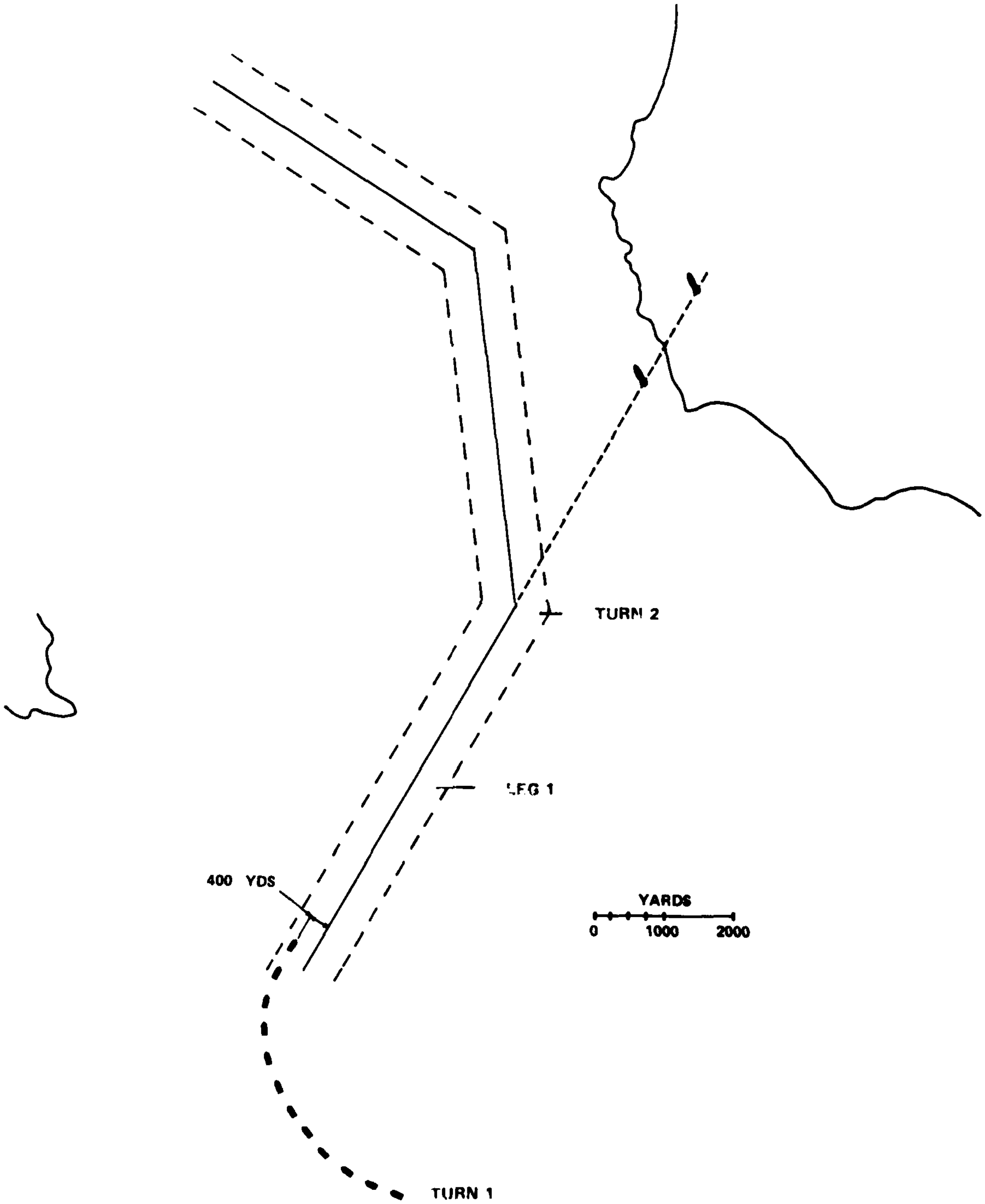

Figure 19. Initial Offset from Range Line of Approach to Leg 1 – Kings Point Group A (Day)

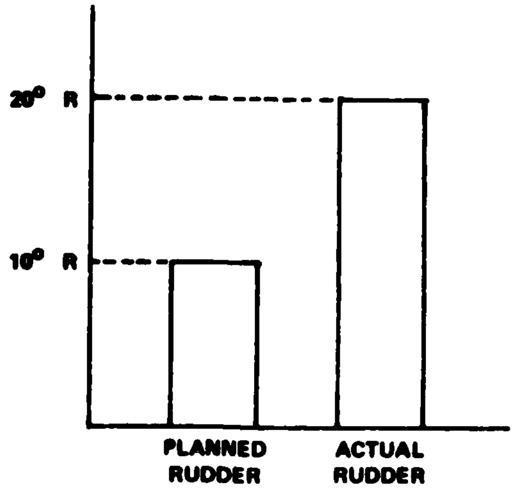

Figure 20. Input Characteristic: Planned/Actual Rudder Comparison in Turn — Kings Point Group A (Day)

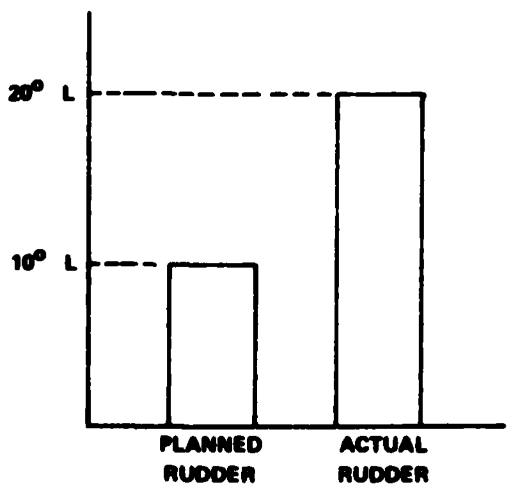

Figure 21. Input Characteristic: Planned/Actual Rudder Comparison in Turn 2 — Kings Point Group A (Day)

The VHF communications procedures used by the students in executing their port approach plan could be improved. Not only did one bridge team fail to make any VHF calls, but the other team's format, accuracy, and management of its communications with the vessel traffic system, the pilot station, other ships and the tugs had several deficiencies (i.e., late reports, omitted reports, inaccurate information).

Finally, the division of work and the coordination between the members of the bridge team were relatively high. This may be attributable to the fact that the bridge team consisted of cadets who have been classmates for 4 years. They had been through the same training programs, had a working knowledge of the abilities of the other team members, and were used to working together. These are conditions that will not be found often during their careers in the U.S. Merchant Marine. To know the meaning of proper bridge teamwork and to execute it with individuals who have dissimilar backgrounds, ages, education, etc., is quite another issue.

4.2.2 NIGHT. With regard to the input characteristics of cadets on the port approach test scenario at night, mixed results were obtained. One bridge team had a channel excursion; the other did not. One bridge team had a large maximum track deviation (2464 feet), the other did not (423 feet). One team had a large initial range offset (1200 feet); the other did not (400 feet). Since the port approach planning test scenario utilized bridge teams as opposed to individual students as discussed in Section 2.12, a sample of only two runs was available to define the input characteristics of cadets in the port approach scenario at night (or day). With the experimental group that was tested daytime, both bridge teams (subgroups) exhibited similar behavior. Nonsignificant trends could then be identified. However, with the mixed results obtained from this small sample size (2), it is difficult to interpret these results and develop a set of input characteristics for cadets at night.

However, it appears safe to say that the cadets had difficulty fixing the vessel's position at night. This is similar to the interpretation advanced for the day group. One night bridge team had a mean navigation fix error of 620 feet. This was equivalent to that observed for both day bridge teams and determined to be lacking in Section 4.2.1. In addition, the other night bridge team had a mean navigation fix error of 1583 feet, which was viewed as definitely unacceptable.

4.3 TRAINING EFFECTIVENESS

4.3.1 DAY. As a result of the simulator-based training program, the day Kings Point group improved its ability to handle the vessel under various wind conditions. From pretest to posttest, the team members reduced their maximum track deviation from 1235.5 feet to 335.0 feet. They reduced their mean track deviation from 419.5 feet to 291.0 feet. These figures indicate a trend toward keeping the vessel in the center of the channel, thereby reducing the risk of grounding. This may be a result of not only a better understanding of the maneuvering characteristics of the vessel, but also a better appreciation of the use of the range in leg 1. Figure 22 illustrates the difficulty that one of the night groups had in understanding and utilizing the range on the pretest versus their improved performance on the posttest.

From pretest to posttest, the cadets reduced their initial channel centerline offset after completing the turns from a mean value of 1200 feet in leg 1 during the pretest to a mean value of 300 feet during the posttest. Likewise in leg 2, they had a mean centerline offset of 700 feet during the pretest and only 275 feet during the posttest. From pretest to posttest, the cadets also reduced the differential between the planned rudder angle and the actual rudder angle in both turns. In turn 1 during the pretest, the group planned a mean rudder of 10 degrees right but required 20 degrees right. During the posttest, the group planned a mean rudder of 12.5 degrees right and required only 15 degrees right (Figure 23). In turn 2 during the pretest, the group planned to use 10 degrees left rudder but utilized 20 degrees left rudder. During the posttest they planned to use 10 degrees left rudder and used 10 degress left rudder (Figure 24). These figures appear to indicate a better understanding of the rudder requirements in the turns after training.

In addition, the overall confidence of the cadets in the port approach scenario also apparently increased as evidenced by the reduction from pretest to posttest in the number of rudder orders issued: 12.5 rudder orders on the pretest compared to 5 rudder orders on the posttest. In previous CAORF experiments, fewer rudder orders have been interpreted as an indication of less uncertainty as to the proper rudder order for the particular situation.

The VHF communications procedures used by the cadets were improved as a result of the training program. During the posttest, both groups utilized the VHF

NIGHT CONDITIONS

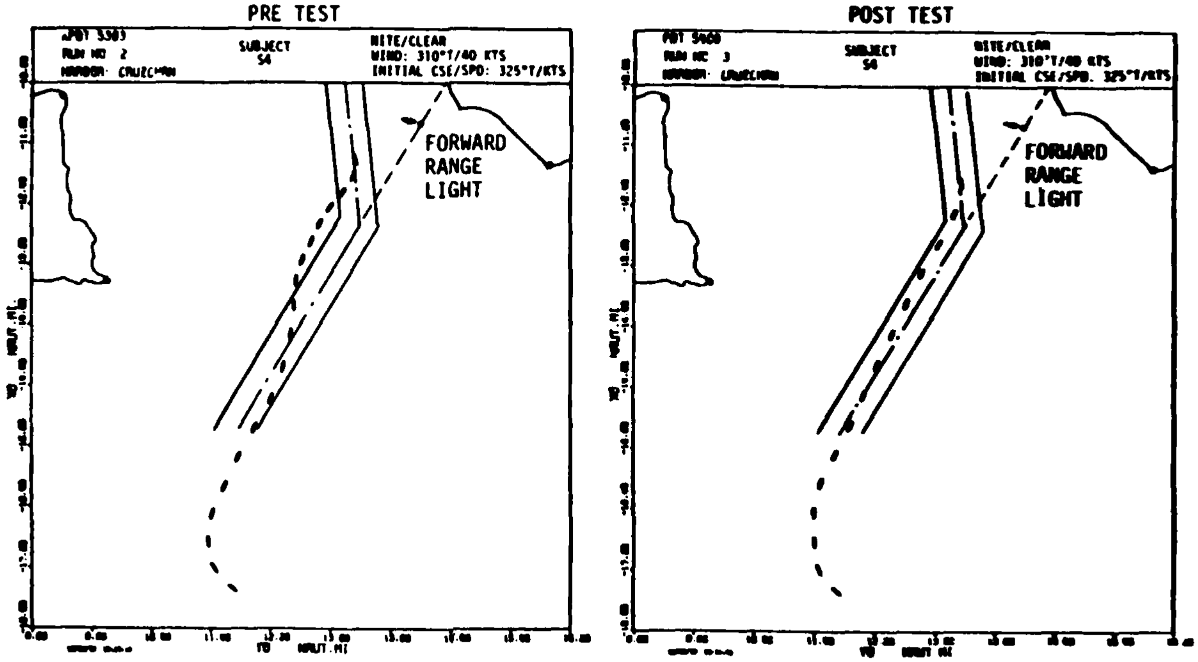

Figure 22. Comparison of Pretest and Posttest, Night Conditions

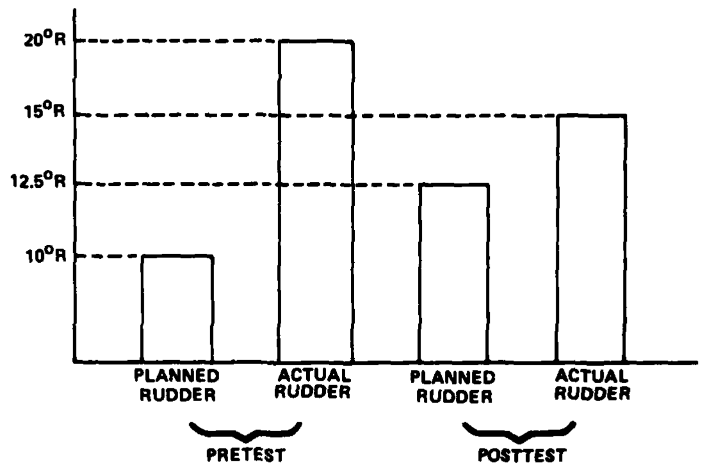

Figure 23. Pretest/Posttest Comparison: Planned/Actual Rudder Comparison for Turn 1 – Kings Point Group A (Day)

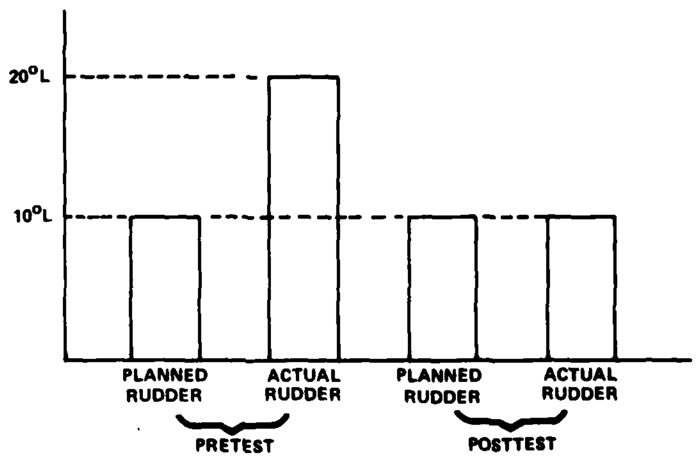

Figure 24. Pretest/Posttest Comparison: Planned/Actual Rudder Comparison for Turn 2 – Kings Point Group A (Day)

communications, as compared to only one group on the pretest. The format, accuracy, and management of the VHF communications were also more professional on the posttest.

Finally, as previously discussed in Section 4.2.1, the cadet ability of fixing the position of the vessel appeared to increase as a result of the training program. The mean navigation fix error for the day group was 622.5 feet during the pretest. After training, it was 450 feet during the posttest.

4.3.2 NIGHT. The simulator-based training program produced mixed results in the performance of the night Kings Point group. One bridge team (subgroup) had an unsuccessful run during the pretest (i.e., channel excursion) and a successful run during the posttest (i.e., no channel excursion). The other bridge team had a successful run during the pretest and an unsuccessful run during the posttest. A majority of the other performance measures reflect this inconsistency. One performance measure, however, that indicated substantial improvement, from pretest to posttest for both bridge teams in the night Kings Point group was navigation fix error. The mean navigation fix error during the pretest was 1101.5 feet; during the posttest, it was 504.0 feet (Figure 25).

In interpreting these results, several points should be made. First, the simulator-based training was successful in improving the students' ability to accurately determine the geographic position of ownship at night. This is an important aspect of safely navigating in a port approach scenario as discussed in Section 4.2.1. Second, the failure of the remaining performance measures to indicate an improvement in the students' ability to handle the vessel may be a result of the sample size being too small (a risk that was recognized during the experiment's design). As a result, one abnormal run substantially skews the results. It may be an indication that more training time is required for nighttime operations than for daytime operations. The latter interpretation is similar to an observation made from the rules of the road training results (Section 3.4).

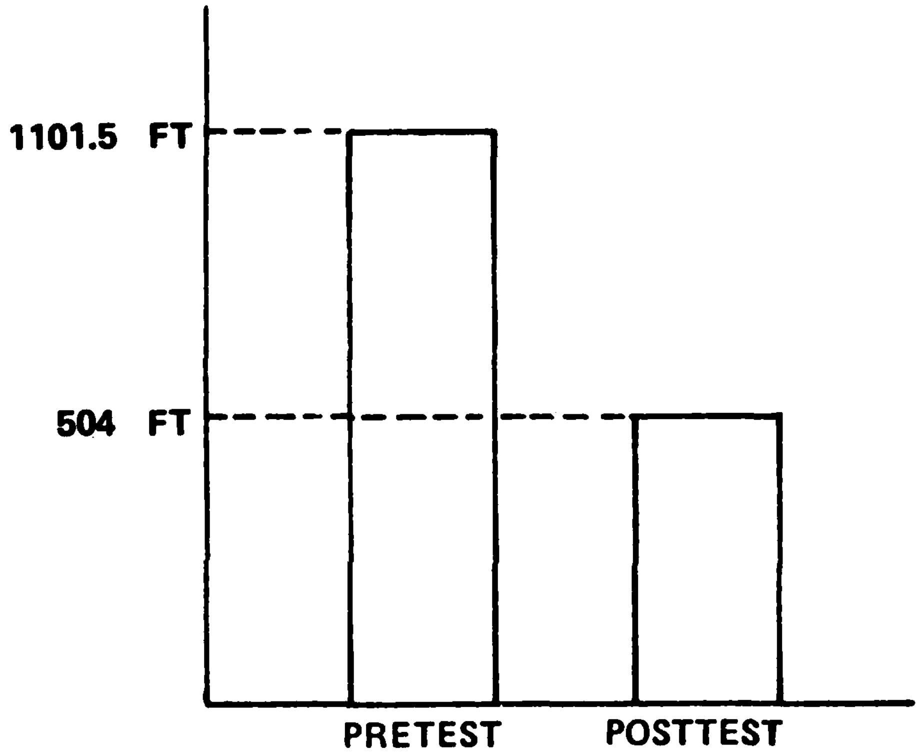

Figure 25. Pretest/Posttest Comparison: Navigation Fix Error — Kings Point Group B (Night)

SECTION 5
CONCLUSIONS

5.1 GENERAL

This cadet training experiment, conducted during Phase 2 of the training and licensing project, was designed to achieve several objectives:

- Evaluate the shiphandling related skill level of cadets who have completed 6 months of at-sea training and are ready to assume duties of a 3rd mate after successfully completing the written examination.

- Evaluate the effectiveness of a simulator-based prototype training program for improving the skills of a cadet/3rd mate.

- Evaluate the cost effectiveness of alternative simulator characteristics and other training-related factors with regard to improving the skills of a cadet/3rd mate.

- Provide a simulator-based training course in shiphandling for cadets.

The following discussion, summary and the conclusions reached herein reflect the integration of the previously presented findings across the three groups trained and the two training modules (i.e., rules of the road and port approach planning). They are an extrapolation of the experimental findings from the controlled environment of the CAORF experiment to the potential real-world application at future simulator-based training facilities. This was the first known ship bridge simulator-based training course conducted at the cadet level. As a result, it provides important insight into the proper use of simulators and simulator-based training for cadets, an area which in recent months has come under increased national and international scrutiny as previously discussed.

These conclusions are based on simulator-based training research using 12 cadets from the U.S. Merchant Marine Academy (Kings Point) and 6 cadets from the New

York State Maritime Academy (Fort Schuyler). Statements are made concerning cadet characteristics and cadet training at Kings Point and Fort Schuyler. It should be cautioned that the samples of cadets from Kings Point and Fort Schuyler (i.e., 12 and 6 students, respectively) were small, in some instances the smallest possible group to statistically investigate. Hence, the inferences made from these data pertaining to the cadet population as a whole should be viewed cautiously since substantial differences may exist between the samples and the overall population of cadets. Nevertheless, these data do provide an initial objective look at the skills possessed by graduating cadets/3rd mates, and the potential effectiveness of simulator-based training programs. Obviously, this data base should be expanded to provide a more accurate representative view of the cadets, as well as broaden the scope of skills investigated.

5.2 ENTERING 3RD MATE CHARACTERISTICS

Immediately prior to the training program, each cadet participating in the experimental training program undertook a test in which he stood watch alone on the bridge. The data collected from this test represents the skill level of cadets who are nearing graduation and will shortly receive their 3rd mates license. These findings are independent of the training program itself since they were obtained prior to the conduct of the training program.

The overall performance of cadet/entering 3rd mates was found to be acceptable. However, performance regarding specific skills was often found to have room for substantial potential improvement as a result of specific additional training. The potential exists, therefore, for a simulator-based training program to significantly impact the skill level of the entering 3rd mate.

A summary of the findings and conclusions is presented below:

- Although collisions and few groundings were experienced during the experiment, the CPAs achieved with traffic vessels under open sea conditions were less than 1 nm on the average and considered as marginally acceptable. The instructors felt that substantially larger CPAs should be achieved by 3rd mates on watch in these situations. The achieved CPA represents the culmination of several aspects of man/ship system performance. Several of these contributory aspects of performance that impact the resultant CPA are addressed below.

- Stand-on vessel action under Rule 17 at night was on the average taken too early. The cadets appeared to have a lack of confidence at night, with their overly cautious early action possibly conflicting with the intent of the International Rules of the Road.

- Vessel handling problems were observed under high wind conditions (i.e., 40 knots). It appears that these difficulties were due to the degree of understanding (1) the responsiveness of the vessel to various rudder angles, (2) the effect of a high wind on the responsiveness of the vessel, or (3) difficulty in determining the geographic position of the vessel.

- The available information was not fully utilized in evaluating and responding to the developing situations. The cadets overemphasized the radar information, while often neglecting the visual information. This may be due to a variety of factors, including (1) proficient radar plotting skills perhaps resulting from an effective radar training program; (2) a lower level of visual skill expertise due to the lack of equivalent practical visual training. For example, it was observed that several of the cadets did not understand or know how to use the information presented to them by range lights.

- Substantial room for improvement was observed in the communication and bridge procedures used by the cadets. Areas for improvement included notification of the master regarding an impending situation, communication of maneuvering orders to the helmsman, bridge management and VHF communications.

- The performance of the Kings Point and Fort Schuyler cadet groups appeared to be equivalent in terms of the results of their actions (e.g., CPA). However, differences were observed in the control actions and bridge procedures they used to achieve their performance. This finding indicates that differences in the control actions and procedures practiced by deck officers may stem from academy training.

It should be noted that this investigation is focusing on the potential areas of training improvement for cadets via the use of the simulator. Hence, the study is not addressing the many areas in which cadet performance is excellent; these areas, obviously, would not require improved training.

The above conclusions were reached on the basis of the data collected, the measures used to evaluate performance, and observations by the instructors and investigating personnel. These conclusions pertain to the particular cadet samples investigated, and presumably relate to the overall 1st class cadet population. Again, note that due to the small sample of cadets investigated, these findings should be treated cautiously.

5.3 TRAINING EFFECTIVENESS

The entering characteristics of the cadets/3rd mates address their level of skill prior to the simulator-based training program. The training program would, ideally, improve the cadet performance in the areas noted above. However, the entry skill information found during this investigation was not available when the training program was developed for this experiment. Rather, the training program was developed prior to the collection and analysis of the input characteristics; it was developed with regard to the anticipated training needs. As a result, several of those areas found to warrant improvement were addressed during the training program, while others were not directly addressed.

The simulator-based training program was found to be effective in upgrading specific skills at the cadet level. This course was the first known simulator-based training program for cadets. Its success documents the ability of such training to improve cadet and entering 3rd mate performance on the bridge of a vessel.

The findings presented below pertain to the gains in performance as a specific result of this simulator-based experimental training program. That is, they pertain to the change in cadet/new 3rd mate performance above the entry level as summarized above.

- The training program was found to be effective in improving certain cadet skills. Observations of improved cadet skills were in the following groups:

- Rules of the road perceptive and decisionmaking skills
- Port approach shiphandling and navigation skills
- Overall bridge procedures including helm orders, VHF communications, bridge team organization/communications, and notification of the master

- The simulator training program was effective in improving the cadet skills during both nighttime and daytime training conditions. The need for improvement in cadet skills differed between nighttime and daytime, as concluded earlier regarding the entry level cadet performance. The effectiveness of the training program was based on improvement in interacting with threat traffic vessels and improved bridge procedures under both operational lighting conditions.

- The simulator-based training program was effective in improving cadet skills in the port approach training module. The skills improved in this module, however, differed for daytime and nighttime operations. Position fixing and shiphandling skills improved with the daytime training conditions. The position fixing skills, only, improved under the nighttime training conditions; this may indicate a requirement for additional nighttime training.

- The distributed training program (i.e., training distributed over a 6-week period) was more effective than the concentrated training program (i.e., same training provided over a 1-week period). The particular conditions of this experiment, however, suggest that this finding should be treated cautiously since a wide variety of differences also existed between these groups as noted earlier.

- It is the opinion of the cadets that simulator-based training in general, and this program in particular, is of substantial benefit. It was their opinion that the simulator-based training program provides benefit beyond that of at-sea training. They viewed such training as a supplement to at-sea training.

- Simulator-based training appears to be an effective supplement to at-sea training for cadets. Several shortcomings were observed on entering the experimental training program which would likely be corrected during the mate's initial break-in period at sea; several of these were correct during the simulator-based training program, underscoring its effectiveness to the at-sea training program.

5.4 SUMMARY

This experiment pioneered in (1) providing simulator-based training to Maritime Academy cadets, (2) objectively assessing the shiphandling skill of graduating cadets/entering 3rd mates, and (3) providing an indication of the benefits associated with an effective simulator-based training program for addressing rules of the road and port approach planning. The potential for effective cadet training on the simulator is evident from this investigation.

SECTION 6
RECOMMENDATIONS

This investigation represents the initial thrust into a new application for the new ship bridge/shiphandling simulator. Hence, the impact of these findings are broad in scope, affecting many aspects of cadet/3rd mate behavior and the role of the simulator in achieving improved training cost effectiveness. This project, although only scratching the surface, has opened a new area of investigation. The wide variety of issues raised regarding cadet training and the use of simulators have been addressed only at the cursory level. The thrust of this investigation should continue to adequately define behavior/skills required of the cadets/entering third mates, and to determine the cost effective role of the simulator as integrated with the academy curriculum. Many issues must be more fully investigated based on a larger sample of academy cadets, to provide an appropriately valid picture of the role of the simulator.

The cadet training program should be expanded so as to provide meaningful training to a substantial segment of the cadet population. The experimental program only addressed a very small number of cadets having, at best, only minor impact on the cadet population. Since the training program has been shown to be effective, it should be expanded to provide not only experimental data but a substantial impact on the training of a larger segment of the cadet class.

Training emphasis by the Academy should be placed on those areas of cadet skills that have been shown to warrant improvement in this study. Considerable data has been collected regarding the skills of the graduating cadets/3rd mates. These data should be used by academies for both simulator-based and nonsimulator training programs so as to better prepare cadets to perform the duties of the 3rd mate upon entering active service.

Careful attention should be given to the design characteristics of the simulator, based on the information developed during this investigation. Relevant information has been developed to be used as a starting point in the design of a simulator for the training of cadets. Considerable additional information is required to fully address this issue.

Specific recommendations are made below regarding each of the above four areas.

6.1 EXPANDED CADET TRAINING

The experimental cadet training program initiated at Kings Point and Fort Schuyler address a total of 18 cadets. This training program, which was found to be effective, should be expanded so as to provide a meaningful amount of training to a significant segment of the cadet population. Several recommendations are made below in this regard:

- The training program at Kings Point should be expanded to provide meaningful training for a larger segment of the cadet population. The number of trainees addressed should be expanded from 12 to at least several dozen. This would provide important information regarding the effectiveness of simulator-based training as integrated in a meaningful way into the overall cadet curriculum. In addition, substantial experimental information could be generated from this expanded program, providing much greater insight into the issues addressed by this investigation, as well as expanding the breadth of this investigation to look at several of the other critical issues.

- Investigation of cadet training should be expanded to look at other skills areas of 3rd mates/cadets. This would include, for example, emergency shiphandling.

6.2 CADET TRAINING EMPHASIS

Much of the information generated during this study impacts the emphasis placed during cadet training. The results of the pretraining test, for example, delineate the skills of the graduating cadets; these further identify potential areas for addressing the training programs. Recommendations regarding training emphasis are summarized below.

- Future simulator-based training programs should focus on specific training objectives derived from the training needs identified as a result of the pre-training test scenario. As additional pre-training test scenarios are administered and as additional information is collected regarding the entering 3rd mate cadet skills, then the subsequent training programs should focus appropriately in specific areas.

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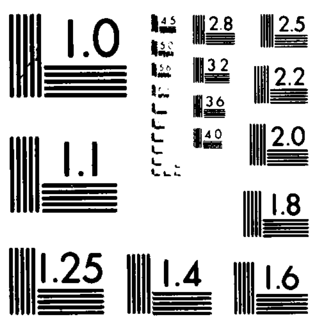

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- Specific areas of focus for cadet simulator-based training, based on the information collected during this investigation, are recommended below:
  - Proper use of VHF communications
  - Proper notification of the master regarding threat vessels
  - Use of visual bearing information, in addition to radar information
  - Use of multiple navigational information sources
  - Both daytime and nighttime training should be provided; nighttime training should receive the greatest emphasis.

- A distributed training program, as opposed to a concentrated training program, should be implemented when addressing the rules of the road or port approach planning modules as investigated under this study. The distributed training program is typically recommended as superior to the concentrated training program. Special case considerations, however, could alter this recommendation.

6.3 SIMULATOR DESIGN CHARACTERISTICS

This investigation was set up to look at only one simulator design characteristic, day versus night. Information was collected, in addition, on other aspects of simulator design as a byproduct of the overall investigation. Several recommendations, which are relevant to simulator design and the development of training system acceptance criteria, can be made in this regard.

- The whole task bridge simulator should be seriously considered for providing cadet training. This investigation identified the effectiveness of the simulator, although not the cost. Additional investigation should be undertaken to determine the cost effectiveness of such simulator-based training. It does appear, however, to be a viable means of achieving improved training for cadets, as well as supplementing other forms of cadet training. Additional investigation, as noted above, is necessary to adequately delineate these issues.

- The simulator used for cadet training should have both a daytime and a nighttime visual scene capability. The different skills that were observed during the daytime and nighttime operations indicate that training under both lighting conditions has been beneficial. Of course, the cost effectiveness issue should also be investigated in this regard.

- Several desirable simulator characteristics are recommended below as derived and interpreted from the data collected in this investigation:
  - Simulated VHF communications
  - Mate/master communications
  - Visual bearings capability (e.g., pelorus)
  - Multiple navigation information sources (e.g., pelorus, radar, depth sounder)

- A remote observation station should be provided to present the ongoing scenario to those trainees not actively engaged in the problem on the bridge. This remote station permits discussion of issues, as well as the analysis of the problem using a variety of available technical information. It is believed that a substantial amount of training gain is derived from the observations/discussions that took place at the remote monitoring station. This station has the advantage of enabling the discussion without interfering with bridge operations.

6.4 CONTINUATION OF CADET TRAINING RESEARCH

The experimental simulator-based cadet training program should be continued to further and more fully investigate important issues arising from the current study. Many of these issues are central to the cost effectiveness of simulator-based training for maritime academy cadets. The wide variety of such potential recommendations are beyond the scope of this report. The more important recommendations are presented below:

- The proper role of simulator-based training within the 4-year cadet curriculum should be determined. The simulator may cost effectively address training at multiple levels, along with a variety of training objectives within the 4-year curriculum. Cost effective utilization of the simulator in this regard should be determined.

- The skills that should be possessed by the entering 3rd mate should be delineated. This data base would specifically identify the set of 3rd mate skills, which may include skills not currently possessed by 3rd mates, for which the maritime academies are preparing cadets. This would form the data base from which the training objectives, which represent the specific detailed goals of the academy training programs, could be developed. The training objectives would explicitly identify the goals of maritime academy cadet training. The training objectives should be developed in a high level of detail, addressing the specific behaviors to be exhibited by graduating cadets.

- The cadet/academy training objectives should be grouped into one of the following four training technique categories, based on their method of achievement:

  - Classroom training
  - At-sea training
  - Small vessel handling training
  - Simulator-based training

  This development would explicitly identify that proportion of the Academy goals that can cost effectively be achieved via the use of a simulator, as well as by other means. The proportion of the 4-year training program that should be devoted to at-sea training, simulator training, and the other methods of training would be determined. This mix of training strategies may vary somewhat from one maritime academy to another based on the resources available to conduct this professional training.

- The achievements of at-sea training for cadets should be investigated to determine the set of specific skills achieved or improved as a result of such training. This should address both the training ship and the commercial vessel riding programs. This o[illegible]ld provide the necessary information from which to evaluate the cost effectiveness of achieving specific training objectives via at-sea training.

- A much wider segment of the cadet population should be investigated with regard to their entering skills and the effectiveness of simulator-based training. This wider population should be drawn not only from Kings Point and Fort Schuyler, as was done in this investigation; it should also draw from cadets at other maritime academies. This is particularly relevant due to the wide range of differences observed between the Kings Point and Fort Schuyler cadets.

- A set of effective performance measures should be developed, based on validity and reliability tests. The performance measures used to evaluate deck officer performance, as well as provide feedback during training, typically present a shortcoming to the investigation. An effort should be initiated to develop adequately validated performance measures, ones that accurately indicate behavior of the deck officers.

- The cost effectiveness of simulator characteristics should be directly investigated for cadet training. The investigation conducted in this study attempted to only cursorily investigate one simulator characteristic. More direct investigation of several simulator characteristics should be carried out, due to their potential impact of the cost effectiveness of simulator training.

- The effectiveness of advanced training technology concepts integrated into the simulator should be investigated. Recent evidence suggests that simulator-based training cost effectiveness can be greatly improved as a result of the use of advanced training technology concepts built into the training device. The impact of these concepts on cadet training should be thoroughly investigated.

- The extent and impact of the nonstandardized bridge procedures observed among new 3rd mates in this study should be determined. The investigation should determine if this nonstandardization is a problem, and if so, to what extent. Furthermore, if greater standardization is desired, the appropriate use of the simulator in achieving such standardization should be evaluated. Simulator-based training does appear to be an excellent tool for achieving standardization of operating procedures.

- The transfer of training from the simulator to at-sea performance should be determined for cadets, as has been recommended for masters level deck officers. The transfer of training represents the bottom-line issue regarding the effectiveness of simulator-based training. This issue should definitely be pursued. A variety of alternatives are available to thoroughly investigate transfer of training for cadets. Furthermore, due to the relatively controlled nature of entering 3rd mate performance on the bridge, this type of investigation should be substantially more feasible at the cadet level than at the masters level.

- Training system acceptance criteria should be developed for use by the U.S. Coast Guard in evaluating and approving cadet simulator-based training systems. Simulator training standards being developed for senior marine licensing may require additional research for adaptation to the cadet/3rd mate level.

6.5 SUMMARY

The variety of recommendations made above attest to the breadth of this investigation which has generated a substantial amount of information regarding cadet/entering 3rd mate skills and the effectiveness of simulator-based training programs for cadets. The major recommendation is that this investigative effort should continue and expand to generate additional specific information to assist the evaluation and possible implementation of simulator-based training programs for cadets.

APPENDIX A
RESULTS: RULES OF THE ROAD

A.1 INPUT CHARACTERISTICS

The following results describe the proficiency levels of cadet skills prior to the simulator-based training program. These skills were evaluated on the rules of the road test scenarios described in Section 3.2. It should be noted that the cadets used in this program were graduating seniors who became 3rd mates within a month after the completion of the program. The input characteristics of these cadets have been organized into three groups: (1) Kings Point Group A, which was tested under daylight conditions (Table A-1), (2) Kings Point Group B, which was tested under nighttime conditions (Table A-2), and (3) Fort Schuyler, which was tested under daylight conditions (Table A-3). Each group had six students. Comparisons are also made between (1) Kings Point cadet performance under daylight and nighttime conditions (Table A-4) and (2) Fort Schuyler and Kings Point cadet performance under daylight conditions (Table A-5). In each table, the mean value, the standard deviation, and any comments are specified for each of the applicable 13 performance measures.

TABLE A-1. PRETEST: KINGS POINT GROUP A (DAY)

Performance Measure	Mean Value	Standard Deviation	Comments
CPA	0.828 nm	0.358	--
Collision	---	---	No collisions
Range of Maneuver	5.490 nm	1.761	--
Magnitude of Course Change	51.7°	32.7°	--
Number of Course Orders	3.33	1.75	--
Number of Rudder Orders	1.33	2.07	--
Master Notified	---	---	83% (5/6)
Range Master Notified	7.5 nm	1.64	--
VHF Communications	---	---	16.7% (1/6)
Range VHF Communications	---	---	--
Number of Visual Bearings	1.83	2.32	--
Number of Radar Requests	3.17	1.17	--

TABLE A-2. PRETEST: KINGS POINT GROUP B (NIGHT)

Perormance Measure	Mean Value	Standard Deviation	Comments
CPA	0.895 nm	0.251	--
Collision	---	---	No collisions
Range of Maneuver	9.019 nm	2.795	--
Magnitude of Course Change	18.33°	7.64	--
Number of Course Orders	5.17	2.86	--
Number of Rudder Orders	2.67	3.56	--
Master Notified			100% (6/6)
Range Master Notified	11.68 nm	0.74	--
VHF Communications	---	---	16.7% (1/6)
Range VHF Communications	---	---	--
Number of Visual Bearings	4.83	5.23	--
Number of Radar Requests	4.83	1.47	--

TABLE A-3. PRETEST: FT. SCHUYLER GROUP (DAY)

Performance Measure	Mean Value	Standard Deviation	Comments
CPA	0.923 nm	0.355	--
Collision	---	---	No collisions
Range of Maneuver	6.998 nm	3.213	--
Magnitude of Course Change	15^{o}	5^{o}	--
Number of Course Orders	3.33	0.52	--
Number of Rudder Orders	2.33	1.37	--
Master Notified	---	---	100% (6/6)
Range Master Notified	11.97 nm	0.73	--
VHF Communications	---	---	66.7%(4/6)
Range VHF Communications	7.58	1.88	--
Number of Visual Bearings	4.50	1.97	--
Number of Radar Requests	2.00	0.89	--

TABLE A-4. PRETEST COMPARISON KINGS POINT GROUP A(DAY) VERSUS KINGS POINT GROUP B (NIGHT)

Performance Measure	Kings Point A		Kings Point B		T-Test	Comments
	Mean Value	Standard Deviation	Mean Value	Standard Deviation		
CPA	0.828 nm	0.358	0.895 nm	0.251	t=0.38; ns	--
Collision	---	---	---	---	---	No collisions
Range of Maneuver	5.49 nm	1.76	9.02 nm	2.80	t=2.62; $p \leq 0.025$	KP(B) maneuvered farther out
Magnitude of Course Change	51.7°	32.7	18.3°	7.6	t=2.44; $p \leq 0.025$	KP(A) had a greater magnitude of course change
Number of Course Orders	3.33	1.75	5.17	2.86	t=1.34; $p \leq 0.11$	Trend: KP(B) had more course orders
Number of Rudder Orders	1.33	2.07	2.67	3.56	t=0.79; ns	--
Number of Engine Orders	---	---	---	---	---	No engine orders
Master Notified	---	---	---	---	----	KP(A) 83% (5/6); KP(B) 100% (6/6)
Range Master Notified	7.50 nm	1.64	11.68 nm	0.74	t=5.69; $p \leq 0.0005$	KP(B) notified the master further out
VHF Communications	---	---	---	---	---	KP(A) 16.7% (1/6); KP(B) 16.7% (1/6)
Range VHF Communications	---	---	---	---	---	--
Number of Visual Bearings	1.83	2.32	4.83	5.23	t=1.28; ns	--
Number of Radar Requests	3.17	1.17	4.83	1.47	t=2.16; $p \leq 0.05$	KP(B) had more radar requests

TABLE A-5. PRETEST COMPARISON: KINGS POINT GROUP A (DAY) VERSUS FT. SCHUYLER GROUP (DAY)

Performance Measure	Kings Point A		Fort Schuyler		T-Test	Comments
	Mean Value	Standard Deviation	Mean Value	Standard Deviation		
CPA	0.828 nm	0.358	0.923 nm	0.355	t=0.46; ns	--
Collision	---	---	---	---	---	No collisions
Range of Maneuver	5.49 nm	1.76	6.998 nm	3.213	t=1.008; ns	--
Magnitude of Course Change	51.7^{o}	32.7	15^{o}	5	t=2.72; $p \leq 0.025$	KP had a greater magnitude of course change
Number of Course Orders	3.33	1.75	3.33	0.52	t=0; ns	--
Number of Rudder Orders	1.33	2.07	2.33	1.47	t=0.98; ns	--
Number of Engine Orders	---	---	---	---	---	No engine orders
Master Notified	---	---	---	---	---	KP 83% (5/6); FS 100% (6/6)
Range Master Notified	7.50 nm	1.64	11.97 nm	0.734	t=6.098; $p \leq 0.0005$	FS notified the master farther out
VHF Communications	---	---	---	---	---	KP 16.7% (1/6); FS 66.7 (4/6)
Range VHF Communications	---	---	---	---	---	--
Number of Visual Bearings	1.83	2.32	4.5	1.97	t=2.15; $p \leq 0.05$	FS had more visual bearings
Number of Radar Requests	3.17	1.17	2.0	0.894	t=-1.95; $p \leq 0.05$	KP had more rada requests

A.2 TRAINING EFFECTIVENESS

The following results describe the change in proficiency levels of cadet skills as a result of the simulator-based training program's rules of the road module. The training program described in Section 2.9 was administered to the three groups of cadets under three different conditions. First, Kings Point Group A, which was tested under daylight conditions, was administered the training program under daylight conditions over a 5-week period (Table A-6). Second, Kings Point Group B, which was tested under nighttime conditions, was administered a training program under nighttime conditions over a 5-week period (Table A-7). Third, the Fort Schuyler Group, which was tested under daylight conditions, was administered the same training program under daylight conditions in 1-week (Table A-8). For each group, the mean value and standard deviation on the pre- and posttest, the training effectiveness score, the t-test results, and any comments are specified for each of the applicable 13 performance measures.

TABLE A-6. TRAINING EFFECTIVENESS: KINGS POINT GROUP A (DAY)

Performance Measure	Pretest		Posttest		Training Effectiveness:	T-Test	Comments
	Mean Value	Standard Deviation	Mean Value	Standard Deviation	Posttest Minus Pretest		
CPA	0.828 nm	0.358	1.570 nm	0.503	0.742 nm	t=2.95; $p \leq 0.01$	Greater CPA on the posttest
Collision							No collisions
Range of Maneuver	5.49 nm	1.76	7.29 nm	1.66	1.8 nm	t=1.82; $p \leq 0.06$	Maneuvered farther out on the posttest
Magnitude of Course Change	51.7°	32.7	41.7°	10.4	-10.0°	t=0.71; ns	--
Number of Course Orders	3.33	1.75	1.67	0.52	-1.66	t=2.23; $p \leq 0.025$	Fewer course orders given on posttest
Number of Rudder Orders	1.33	2.07	3.17	4.31	1.84	t=0.94; ns	--
Number of Engine Orders	---	---	---	---	---	---	No engine orders
Master Notified	---	---	---	---	---	----	Pre 83% (5/6) Post 100% (6/6)
Range Master Notified	7.5 nm	1.64	11.68 nm	1.45	4.18 nm	t=4.68; $p \leq 0.005$	Notified the master farther out on posttest
VHF Communications	---	---	---	---	---	---	Pre 16.7% (1/6) Post 16.7% (1/6)
Range VHF Communications	---	---	---	---	---	---	--
Number of Visual Bearings	1.83	2.82	5.17	1.47	3.34	t=2.98; $p \leq 0.01$	More visual bearings on posttest
Number of Radar Requests	3.17	1.17	1.83	1.17	-1.34	t=1.99; $p \leq 0.05$	Less radar requests on posttest

TABLE A-7. TRAINING EFFECTIVENESS: KINGS POINT GROUP B (NIGHT)

Performance Measure	Pretest Mean Value	Pretest Standard Deviation	Posttest Mean Value	Posttest Standard Deviation	Training Effectiveness: Posttest Minus Pretest	T-Test	Comments
CPA	0.895 nm	0.251	0.910 nm	0.50	0.015 nm	t=0.06, ns	--
Collision	---	---	---	---	---	---	No collisions
Range of Maneuver	9.02 nm	2.80	5.91 nm	2.16	-3.11 nm	t=2.16; $p \leq 0.05$	Maneuvered closer on posttest
Magnitude of Course Change	18.33°	7.64	27.50°	13.23	9.17°	t=1.47; $p \leq 0.10$	Larger course change on posttest
Number of Course Orders	5.17	2.86	2.83	1.17	-2.34	t=1.86; $p \leq 0.05$	Fewer course orders given on posttest
Number of Rudder Orders	2.67	3.56	2.67	1.51	0	t=0; ns	--
Number of Engine Orders	---	---	---	---	---	---	No engine orders
Master Notified	---	---	---	---	---	---	Pre: 100% (6/6); Post: 100% (6/6)
Range Master Notified	11.68 nm	0.74	10.12 nm	1.16	-1.5 nm	t=2.6 $p \leq 0.025$	Notified master closer on posttest
VHF Communications	---	---	---	---	---	---	Pre: 16.7% (1/6); Post: 16.7 (1/6)
Range VHF Communications	---	---	---	---	---	---	Posttest average range = 7.52 nm
Number of Visual Bearings	4.83	5.23	5.67	2.16	0.84	t=0.36; ns	--
Number of Radar Requests	4.83	1.47	1.83	0.75	-3.0	t=4.48; $p \leq 0.005$	Less radar requests on posttest

TABLE A-8. TRAINING EFFECTIVENESS: FT. SCHUYLER GROUP (DAY)

Performance Measure	Pretest		Posttest		Training Effectiveness:	T-test	Comments
	Mean Value	Standard Deviation	Mean Value	Standard Deviation	Posttest Minus Pretest		
CPA	0.923 nm	0.355	0.849 nm	0.275	-0.074 nm	t=0.38; ns	--
Collision	---	---	---	---	---	---	No collisions
Range of Maneuver	6.998 nm	3.213	4.620 nm	0.875	-2.378 nm	t=1.74; $p \leq 0.07$	Maneuvered closer on posttest
Magnitude of Course Change	15^{o}	5.00	42.5^{o}	10.60	27.5^{o}	t=5.32; $p \leq 0.01$	Larger course change on posttest
Number of Course Orders	3.33	0.52	2.60	0.89	-0.73	t=1.62; $p \leq 0.10$	Fewer course orders on posttest
Number of Rudder Orders	2.33	1.37	9.20	1.79	6.87	t=7.05; $p \leq 0.0005$	More rudder orders given on posttest
Number of Engine Orders	---	---	---	---	---	---	No engine orders
Master Notified	---	---	---	---	---	---	Pre: 100% (6/6); Post: 100% (6/6)
Range Master Notified	11.97 nm	0.73	9.18 nm	1.25	-2.79 nm	t=4.4; $p \leq 0.005$	Notified master closer on posttest
VHF Communications	---	---	---	---	---	---	Pre: 66.7% (4/6); Post: 100% (6/6)
Range VHF Communications	7.58 nm	1.88	8.16 nm	1.06	0.58 nm	t=0.64; ns	--
Number of Visual Bearings	4.50	1.98	4.20	0.84	-0.30	t=0.34; ns	--
Number of Radar Requests	2.00	0.89	1.80	0.45	-0.20	t=0.48; ns	--

APPENDIX B
RESULTS: PORT APPROACH

B.1 INPUT CHARACTERISTICS

The following results describe the proficiency levels of cadet skills prior to the port approach module of the simulator-based training program. These skills were evaluated on the port approach test scenario described in Section 2.11. It should be noted that the cadets used in this program were graduating seniors who became 3rd mates within a month after the completion of the program. The input characteristics of these cadets have been organized into two groups: (1) Kings Point Group A, which was tested under daylight conditions (Table B-1), and (2) Kings Point Group B, which was tested under nighttime conditions (Table B-2).

TABLE B-1. PRETEST: KINGS POINT GROUP A (DAY)

Performance Measure	Bridge Team 1	Bridge Team 2	Average
Channel Excursion	No	No	No
Maximum Track Deviation	1157 ft (L)	1314 ft (L)	1235.5 ft (L)
Mean Track Deviation	736 ft (L)	103 ft (L)	419.5 ft (L)
Number of Track Crossings	1	1	1
Turn 1:			
Rudder Order Deviation (Plan/Actual)	10°R/20°R $+10^\circ$	10°R/20°R $+10^\circ$	10°R/20°R $+10^\circ$
Initial Range Offset	1200 ft (L)	1200 ft (L)	1200 ft (L)
Leg 1:			
Course Mode Good Deviation (Plan/Actual)	$031^\circ/033^\circ$ $+2^\circ$	$031^\circ/033^\circ$ $+2^\circ$	$031^\circ/033^\circ$ $+2^\circ$
Course to Steer Deviation (Plan/Actual)	$030^\circ/030^\circ$ 0°	030°/None N/A	030°/Mixed N/A
Navigation Plot	Yes	Yes	Yes
Navigation Fix Error	620 ft	625 ft	622.5 ft
Turn 2:			
Rudder Order Deviation (Plan/Actual)	10°L/20°L $+10^\circ$	10°L/20°L $+10^\circ$	10°L/20°L $+10^\circ$
Initial Centerline Offset	700 ft (R)	700 ft (R)	700 ft (R)
Number of Course Orders	5	3	4
Number of Rudder Orders	13	12	12.5
Number of Engine Orders	0	2	1
VHF Communications	Yes	No	Mixed

TABLE B-2. PRETEST: KINGS POINT GROUP B (NIGHT)

Performance Measure	Bridge Team 1	Bridge Team 2	Average
Channel Excursion	Yes	No	50% No
Maximum Track Deviation	2464 ft (L)	423 ft(L)	1443.5 ft (L)
Mean Track Deviation	608 ft (L)	406 ft (L)	507 ft (L)
Number of Track Crossing	2	1	1.5
Turn 1:			
Rudder Order Deviation (Plan/Actual)	15^{o}R/20^{o}R +5^{o}	10^{o}R/15^{o}R +5^{o}	12.5^{o}R/17.5^{o}R +5^{o}
Initial Range Offset	1200 ft (R)	400 ft (L)	1200 ft (R); 400 ft (L)
Leg 1:			
Course Made Good Deviation (Plan/Actual)	031^{o}/019^{o} -12^{o}	031^{o}/031^{o} 0^{o}	031^{o}/025^{o} -6^{o}
Course to Steer Deviation (Plan/Actual)	028^{o}/Multiple Course N/A	025^{o}/035^{o} +10^{o}	026.5^{o}/N/A N/A
Navigation Plot	Yes	Yes	Yes
Navigation Fix Error	620 ft	1583 ft	1101.5 ft
Turn 2:			
Rudder Order Deviation (Plan/Actual)	15^{o}L/N/A	10^{o}L/10^{o}L (0^{o})	12.5^{o}L/N/A N/A
Initial Centerline Offset	600 ft (R)	900 ft (R)	750 ft (R)
Number of Course Orders	N/A	3	N/A
Number of Rudder Orders	N/A	3	N/A
Number of Engine Orders	N/A	0	N/A
VHF Communications	N/A	Yes	N/A

B.2 TRAINING EFFECTIVENESS

The following results describe the change in proficiency levels of cadet skills as a result of the simulator-based training program's port approach module. The training program described in Section 2.11 was administered to the two groups of cadets under two different conditions. First, Kings Point Group A, which was tested under daylight conditions, was administered the training program under daylight conditions (Table B-3). Second, Kings Point Group B, which was tested under nighttime conditions, was administered the training program under nighttime conditions (Table B-4). The pretest and posttest scores and the training effectiveness scores for each of the applicable 16 performance measures are specified for each bridge team individually as well as for the entire group. The group scores represent an average score based on the two bridge team scores.

TABLE B-3. TRAINING EFFECTIVENESS: KINGS POINT GROUP A (DAY)

Performance Measure	Pretest	Posttest	Training Effectiveness (Post-Pretest)
Channel Excursion	No	No	No change
	(1) = No	(1) = No	(1) = No change
	(2) = No	(2) = No	(2) = No change
Maximum Track Deviation	1235.5 ft (L)	335.0 ft (L)	-900.5 ft
	(1) = 1157 ft (L)	(1) = 380 ft (L)	(1) = -77 ft
	(2) = 1314 ft (L)	(2) = 290 ft (L)	(2) = -1024 ft
Mean Track Deviation	419.5 ft (L)	291 ft (L)	-128.5 ft
	(1) = 736 ft (L)	(1) = 298 ft (L)	(1) = -438 ft
	(2) = 103 ft (L)	(2) = 284 ft (L)	(2) = -181 ft
Number of Track Crossings	1	0	-1
	(1) = 1	(1) = 0	-1
	(2) = 1	(2) = 0	-1
Turn 1			
Rudder Order Deviation (Plan/Actual)	10°R/20°R	12.5°R/15°R	2.5°R/-5°R
	(1) = 10°R/20°R	(1) = 15°R/15°R	(1) = 5°R/-5°R
	(2) = 10°R/20°R	(2) = 10°R/15°R	(2) = 0°/-5°R
Initial Range Offset	1200 ft (L)	300 ft (L)	-900 ft
	(1) = 1200 ft (L)	(1) = 300 ft (L)	(1) = -900 ft
	(2) = 1200 ft (L)	(2) = 300 ft (L)	(2) = -900 ft
Leg 1:			
Course Made Good (Pl an/Actual)	031°/033°	031°/031°	0°/0°
	(1) = 031°/033°	(1) = 031°/031°	(1) = 0°/-2°
	(2) - 031°/033°	(2) = 031°/031°	(2) = 0°/-2°
Course to Steer Deviation (Plan/Actual)	030°/NA	030°/N/A	0°/N/A
	(1) = 030°/030°	(1) = 030°/030°	(1) = 0°/0°
	(2) = 030°/None	(2) = 030°/ Multiple Courses	(2) = 0°/N/A

NOTE: (1) = Bridge Team 1
(2) - Bridge Team 2

TABLE B-3. TRAINING EFFECTIVENESS: KINGS POINT GROUP A (DAY) (Continued)

Performance Measure	Pretest	Posttest	Training Effectiveness (Post-Pretest)
Navigation Plot	Yes	Yes	No change
	(1) = Yes	(1) = Yes	(1) = No change
	(2) = Yes	(2) = Yes	(2) = No change
Navigation Fix Error	622.5 ft	450 ft	-172.5 ft
	(1) = 620 ft	(!) = 600 ft	(1) = -20 ft
	(2) = 625 ft	(2) = 300 ft	(2) = -325 ft
Turn 2:			
Rudder Order Deviation (Plan/Actual)	10^{o}L/20^{o}L	10^{o}L/10^{o}L	0^{o}/-10^{o}
	(1) = 10^{o}L/20^{o}L	(1) = 10^{o}L/10^{o}L	(1) = 0^{o}/-10^{o}
	(2) = (10^{o}L/20^{o}L	(2) = 10^{o}L/10^{o}L	(2) = 0^{o}/-10^{o}
Initial Centerline Offset	700 ft (R)	275 ft (L)	-425 ft
	(1) = 700 ft (R)	(1) = 150 ft (L)	(1) = -550 ft
	(2) ft (R)	(2) = 400 ft (L)	(2) - -300 ft
Number of Course Orders	4	5	+1
	(1) = 5	(1) = 5	(1) = 0
	(2) = 3	(2) = 5	(2) = +2
Number of Rudder Orders	12.5	5	-7.5
	(1) = 13	(1) = 6	(1) = -7
	(2) = 12	(2) = 4	(2) = -8
Number of Engine Orders	1	0.5	-0.5
	(1) = 0	(1) = 1	(1) = +1
	(2) = 2	(2) = 0	(2) = -2
VHF Communications	50% Yes	Yes	+ 50%
	(1) = Yes	(1) = Yes	0%
	(2) = No	(2) = Yes	+100%

NOTE: (1) = Bridge Team 1
(2) = Bridge Team 2

TABLE B-4. TRAINING EFFECTIVENESS: KINGS POINT GROUP B (NIGHT)

Performance Measure	Pretest	Posttest	Training Effectiveness (Post-Pretest)
Channel Excursion	50% No	50% No	No change
	(1) = Yes	(1) = No	(1) = +100%
	(2) = No	(2) = Yes	(2) = -100%
Maximum Track Deviation	1458.5 ft (L)	1176.5 ft	-282 ft
	(1) = 2464 ft (L)	(1) = 853 ft (L)	(1) = -1611 ft
	(2) = 423 ft (L)	(2) = 1500 ft (R)	(2) = +1077 ft
Mean Track Deviation	507 ft (L)	580 ft (L)	+73 ft
	(1) = 608 ft (L)	(1) = 275 ft (L)	(1) = -333 ft
	(2) = 406 ft (L)	(2) = 885 ft (L)	(2) = +479 ft
Number of Track Crossings	1.5	1.5	0
	(1) = 2	(1) = 2	(1) = 0
	(2) = 1	(2) = 1	(2) = 0
Turn 1:			
Rudder Order Deviation (Plan/Actual)		15°R/12.5°R	+2.5°R/-5°R
	(1) = 15°R/20°R	(1) = 20°R/15°R	(1) = +5°R/-5°R
	(2) = 10°R/15°R	(2) = 10°R/10°R	(2) = 0°/-5°R
Initial Range Offset	800 ft	650 ft	-150 ft
	(1) = 1200 ft (R)	(1) = 500 ft	(1) = -700 ft
	(2) = 400 ft (L)	(2) = 800 ft	(2) = +400 ft
Leg 1:			
Course Made Good Deviation (Plan/Actual)	031°/025°	031°/29.5°	0°/+4.5°
	(1) = 031°/019°	(1) = 031°/027°	(1) = 0°/+8°
	(2) = 031°/031°	(2) = 031°/032°	(2) = 0°/+1°
Course to Steer Deviation (Plan/Actual)	026.5°/N/A	029.5°/N/A	+3°/N/A
	(1) = 028.°/Multiple Course	(1) = 029°/	(1) = +1°/N/A
	(2) = 025°/035°	(2) = 030°/030°	(2) = +5°/-5°

NOTE: (1) = Bridge Team 1
(2) = Bridge Team 2

TABLE B-4. TRAINING EFFECTIVENESS: KINGS POINT GROUP B (NIGHT) (Continued)

Performance Measure	Pretest	Posttest	Training Effectiveness (Post-Pretest)
Navigation Plot	Yes (1) = Yes (2) = Yes	Yes (1) = Yes (2) = Yes	No change (1) = No change (2) = No change
Navigation Fix Error	1101.5 ft (1) = 620 ft (2) = 1583 ft	504 ft (1) = 208 ft (2) = 800 ft	-597.5 ft (1) = -412 ft (2) = -783 ft
Turn 2:			
Rudder Order Deviation (Plan/Actual)	12.5°L/N/A (1) 15°L/N/A (2) 10°L/10°L	15°L/15°L (1) = 20°L/15°L (2) = 10°L/15°L	+2.5°/N/A (1) = +5°/N/A (2) = 0°/+5°
Initial Centerline Offset	750 ft (R) (1) = 600 ft (R) (2) = 900 ft (R)	975 ft (R) (1) = 450 ft (R) (2) = 1500 ft (R)	+225 ft (1) = -150 ft (2) = +600 ft
Number of Course Orders	N/A (1) = N/A (2) = 3	7.5 (1) = 11 (2) = 4	N/A (1) = N/A (2) = +1
Number of Rudder Orders	N/A (1) = N/A (2) = 3	9.5 (1) = 11 (2) = 8	N/A (1) = N/A (2) = +5
Number of Engine Orders	N/A (1) = N/A (2) = 0	0 (1) = 0 (2) = 0	N/A (1) = N/A (2) = 0
VHF Communications	N/A (1) = N/A (2) = Yes	Yes (1) = Yes (2) = Yes	N/A (1) = N/A (2) = Yes

NOTE: (1) = Bridge Team 1
(2) = Bridge Team 2

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