

AD-A159 677

EXPERIMENTAL EVALUATION OF SIMULATOR-BASED TRAINING FOR 1/1
MARINE PILOTS(U) NATIONAL MARITIME RESEARCH CENTER
KINGS POINT NY COMPUTER AID T J HAMMELL ET AL

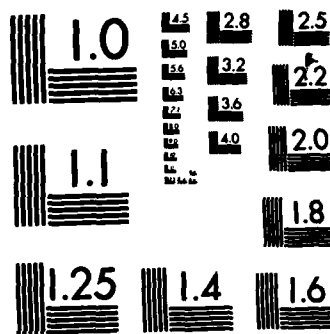
UNCLASSIFIED

MAR 85 CAROF-50-8318-03 USCG-D-26-85

F/G 5/9

NL

END



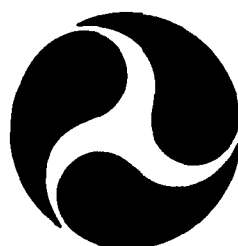
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

②

AD-A159 677

TECHNICAL REPORT

EXPERIMENTAL EVALUATION
OF SIMULATOR-BASED TRAINING
FOR MARINE PILOTS



March 1985

DTIC FILE COPY

DTIC
ELECTE
OCT 02 1985
S E D

U.S. DEPARTMENT OF TRANSPORTATION
MARITIME ADMINISTRATION
Office of Shipbuilding, Operations, and Research
Washington, D.C. 20590

U.S. DEPARTMENT OF TRANSPORTATION
UNITED STATES COAST GUARD
Office of Research and Development
Washington, D.C. 20593

This document has been approved
for public release and sale; its
distribution is unlimited.

85 09 30 030

Accession For	
NTIS GRA&I	☒
DTIC TAB	☐
Unannounced	☐
Justification	
By _____	
Distribution/	
Availability Codes	
Dist	Avail and/or Special
A-1	



LEGAL NOTICE

This report was prepared as an account of government-sponsored work. Neither the United States, nor the Maritime Administration, nor any person (A) Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or (B) Assumes any liabilities with respect to use of or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report. As used in the above, "persons acting on behalf of the Maritime Administration" includes any employee or contractor of the Maritime Administration to the extent that such employees or contractor prepares, handles, or distributes, or provides access to any information pursuant to his employment or contract with the Maritime Administration.

LEGAL NOTICE

This document is disseminated under the sponsorship of the Department of Transportation in the interest of information exchange. The United States Government assumes no liability for its contents or use thereof.

The United States Government does not endorse products or manufacturers. Trade or manufacturer's names appear herein solely because they are considered essential to the object of this report.

The contents of this report do not necessarily reflect the official view or policy of the U.S. Coast Guard and do not constitute a standard, specification, or regulation.

AD-A159677

BIBLIOGRAPHIC DATA SHEET		1. Report No. CG-D-26-85	2.	3. Recipient's Accession No.	
4. Title and Subtitle EXPERIMENTAL EVALUATION OF SIMULATOR-BASED TRAINING FOR MARINE PILOTS				5. Report Date March 1985	
7. Author(s) T.J. Hammell, J.W. Gynther, and V.M. Pittsley				8. Performing Organization Report No. CAORF-50-8318-03	
9. Performing Organization Name and Address Computer Aided Operations Research Facility National Maritime Research Center Kings Point, New York 11024				10. Project/Task/Work Unit No.	
				11. Contract/Grant No.	
12. Sponsoring Organization Name and Address U.S. Department of Transportation Maritime Administration Office of Shipbuilding, Operations, and Research Washington, D.C. 20590				13. Type of Report & Period Covered CAORF Research Study	
				14.	
15. Supplementary Notes Project Managers: Dr. John Gardenier, USCG; Joseph Puglisi, MARAD Project Monitor: LCDR George Naccara, USCG					
16. Abstracts Ship bridge/shiphhandling simulators are becoming increasingly recognized as a potentially beneficial training medium for attaining a number of selected deck officer skills. The utilization of such simulators for marine pilot training began several years ago in Europe. This report describes the conduct and evaluation of a prototype simulator-based training program administered to twelve (12) U.S. pilots from several different pilot associations. The ship bridge/shiphhandling simulator located at the Computer Aided Operations Research Facility (CAORF) was employed during the research. The prototype training program was designed to evaluate (a) the potential effectiveness of simulator-based training for pilots, (b) several specific skill areas for which simulator-based training appears appropriate and (c) the impact of pilot experience on the benefits to be derived from such training. <i>Keywords:</i>					
17. Key Words and Document Analysis. 17a. Descriptors Ship bridge/shiphhandling simulators Simulator-based training Marine pilot training Rate-of-turn indicator, Doppler speed log, RACONS, Emergency shiphhandling.					
17b Identifiers/Open-Ended Items					
17c. COSATI Field/Group					
18. Availability Statement Approved for Release NTIS Springfield, Virginia				19. Security Classification (This Report) UNCLASSIFIED	
				20. Security Classification (This Page) UNCLASSIFIED	
				21. No. of Pages 83	
				22. Price	

PREFACE

Any research effort of this magnitude cannot be successfully accomplished without the cooperation and assistance of many people. The authors would like to express their thanks to all individuals and organizations who contributed so much to the success of this project. In particular, we would like to especially acknowledge the following individuals and organizations for their contributions:

- Captain W. Lascelle (United New York New Jersey Sandy Hook Pilot Association) and Captain J. Bradley (Pilot Association for the Bay and River Delaware) for their assistance, particularly during the design and conduct of the experimental program at CAORF.
- The following organizations for the cooperation, hospitality, and insight provided by their representatives to members of the project team during visits, discussions, and in several cases, vessel transits:
 - Hochschule fur Nautik, Bremen, West Germany
 - Brotherhood of German Pilots, West Germany
 - Charleston Branch Pilot Association, Charleston, SC
 - Corpus Christi Pilots, Corpus Christi, TX
 - Crescent River Port Pilots, New Orleans, LA
 - Exxon U.S.A.
 - Hamburg Polytechnic Institute, Hamburg, West Germany
 - Houston Pilots, Houston, TX
 - Jacobsen Pilot Service, Long Beach, CA
 - Maritime Research Institute Netherlands
 - Northeast Pilot Association, Newport, RI
 - Pilot Association for the Bay and River Delaware, Philadelphia, PA
 - Rotterdam Europort Pilots, Netherlands
 - San Francisco Bar Pilots, San Francisco, CA
 - Tampa Bay Pilots, Tampa, FL
 - United New York New Jersey Sandy Hook Pilot Association, Saint George, Staten Island, NY
- The following organizations for providing individuals who participated in the experimental program on the CAORF simulator:
 - Charleston (S.C.) Branch Pilot Association
 - Corpus Christi Pilots
 - Crescent River Port Pilots
 - Jacobsen Pilot Service
 - Pilot Association for the Bay and River Delaware
 - San Francisco Bar Pilots
 - Tampa Bay Pilots
 - United New York New Jersey Sandy Hook Pilot Association
- Members of the CAORF staff, particularly Captain H. O. Travis, who worked diligently to prepare the many aspects of the simulation for the conduct of the experimental training program.
- Captain C. DeBoer (Rotterdam Pilots) and his staff who provided

the project team with a wealth of information on pilot simulator training, including the opportunity to observe first-hand the simulator training of Dutch pilots.

- Captain G. Zade and his staff at the Hochschule Fur Nautik who provided the project with invaluable insight relating to their experiences in utilizing the ship bridge/shiphandling simulator for the training of German pilots.
- Captain C. Sander and Captain J. Froese at the Hamburg Polytechnic Institute who shared the benefits of their planning as they prepared to commence simulator-based training for pilots on their new Ship Operation and Simulation Facility (SUSAN).

- The Government's project managers, Dr. J. Gardenier (U.S. Coast Guard) and Mr. J. Puglisi (Maritime Administration), and the U.S. Coast Guard Project Monitor LCDR G. Nacarra for their guidance, assistance and timely contributions to the success of the project.

Finally, it should be noted that the support and participation by any of the individuals or organizations cited above does not necessarily imply their agreement with all aspects of this research project or this report. This report represents the author's findings and recommendations, which may or may not reflect the views of these individuals and organizations.

TABLE OF CONTENTS

Paragraph		Page
CHAPTER 1 - INTRODUCTION		
1.1	Background	1
1.2	Project Goal	2
1.3	Experimental Objectives	3
CHAPTER 2 - METHODOLOGY		
2.1	Project Approach	5
2.2	Geographic Data Base	7
2.3	Experimental Variables	9
2.4	Experimental Design	10
2.5	Pilot Participants	10
2.6	Training Program	11
2.7	Experimental Procedures	14
2.8	Ownship Characteristics	14
2.9	Test Exercises	15
2.10	Performance Measures	16
CHAPTER 3 - RESULTS		
3.1	Advanced Instrumentation - Module I	21
3.2	Emergency Shiphandling - Module II	26
CHAPTER 4 - DISCUSSION		
4.1	Training Effectiveness	31
4.2	Areas of Pilot Training	31
4.3	Level of Experience	40
4.4	Pilot Opinions	45
CHAPTER 5 - CONCLUSIONS		57
CHAPTER 6 - RECOMMENDATIONS		61
APPENDIX A - DEBRIEFING QUESTIONNAIRE		65
BIBLIOGRAPHY		75

LIST OF ILLUSTRATIONS

Figure	Title	Page
1	Approach to Lotsedorf and Ball River	8
2	Experimental Design Summary	11
3	Training Schedule	13
4	Segmentation of Test Exercise Turn for Data Analysis	17
5	Module I Training Effectiveness -- Sum of Distance off 1 nm Radius	33
6	Module I Training Effectiveness -- Mean Sum of Differences Between Actual and Desired Rate-of-Turn	33
7	Module I Training Effectiveness -- Minimum Distance to Channel Boundary	34
8	Module I Training Effectiveness -- Number of Course Orders	34
9	Module I Training Effectiveness -- Number of Rudder Orders	35
10	Module II Training Effectiveness -- Minimum Distance to Channel Boundary	37
11	Module II Training Effectiveness -- Number of Rudder Orders ...	37
12	Module II Training Effectiveness -- Number of Course Orders ...	38
13	Module II Training Effectiveness -- Number of Engine Orders ...	38
14	Level of Experience, Module I -- Sum of Differences off 1.0 nm Radius	41
15	Level of Experience, Module I -- Sum of Differences Between Actual and Desired Rate-of-Turn	41
16	Level of Experience, Module I -- Minimum Distance to Channel Boundary	42
17	Level of Experience, Module II -- Minimum Distance to Channel Boundary	42
18	Level of Experience, Module II -- Number of Rudder Orders	43
19	Level of Experience, Module II -- Number of Engine Orders	43

LIST OF TABLES

Table	Title	Page
1	Training Objectives for Prototype Simulator Training Program for Marine Pilots	23
2	Course Correction (Degrees) for Cross-Channel Current	19
3	Module I - Overall Pilot Pretraining Versus Posttraining Comparison	22
4	Module I - Limited Experience, Pretraining Versus Posttraining Comparison	24
5	Module I - Extensive Experience, Pretraining Versus Posttrain- ing Comparison	25
6	Module II - Overall Pilot Pretraining Versus Posttraining Comparison	27
7	Module II - Limited Experience Pretraining Versus Posttraining Comparison	28
8	Module II - Extensive Experience Pretraining Versus Posttrain- ing Comparison	29
9	Pilot Questionnaire Summary Data for Selected Questions	47

EXECUTIVE SUMMARY

BACKGROUND

The U.S. Coast Guard provides for partial credit toward certain mariner licenses, endorsements or renewals based on completing "approved" simulator training. Previous studies in this series have produced the guidelines for approval of simulator training for cadets and for senior mariners who are ship's company. No such guidelines existed for approving simulator training for local pilots. In fact, there was substantial doubt among pilots as to whether current simulator technology could adequately display the shiphandling precision needed for sound pilot training.

THE STUDY

Dramatic recent advances in ship simulator capabilities, along with confirmed success of pilot simulator training programs in Europe, led to this research project. Its objectives were: First, to establish whether valid and credible pilot simulator training was feasible and, second, if it was credible, to formulate approval guidelines for training courses to justify licensing credit. The student was jointly sponsored and funded by the U.S. Coast Guard and Maritime Administration. The Maritime Administration's Computer-Aided Operations Research Facility (CAORF) was the research site. An experimental training program was developed specifically to measure training benefits. (It was not designed to optimize training, although systematic instructional system development principles were

used.) Two senior pilots helped design and conduct the training program. The twelve trainees were pilots of varying experience from the U.S. East, Gulf, and West coasts. Training in three skill areas: Advanced Instrumentation, Emergency Shiphandling and Decisionmaking (in collision emergencies) was administered. Objective measures of shiphandling performance were taken before and after each type of training. Pilot opinions were recorded using debriefing questionnaires. Both objective data and subjective opinions were analyzed to reach the conclusions of this study.

CONCLUSIONS

1. Some forms of simulator training are highly effective in improving pilot skills.
2. Experienced pilots, apprentices, and qualified pilots with limited experience can all benefit from simulator training.
3. Different types of training are needed for pilots with different levels of experience; however, pilots can benefit by mixing different experience levels within the same class.
4. The simulated port area in a training program does not have to be a specific real port, but it should present challenges that are relevant to each trainee's own port.
5. Pilots require higher fidelity training simulation, especially

regarding the fine points of ship motions, than do ship's company mariners.

6. The experimental training program in this study featured:

- a. Small class size (4-5 pilots).
- b. A mixture of senior and less experienced pilots in the same class.
- c. A seminar format with the instructor acting as a seminar leader, rather than as an authoritarian teacher lecturing students.
- d. Coordinators who were highly experienced, active pilots and who were also familiar with the functioning of the specific simulators.
- e. Trainees who were volunteers (not forced by Government to take the training).

7. Within our sample of twelve pilots, the great majority felt:

- a. That simulator training could be beneficial and effective, if properly designed and conducted.
- b. That high simulator fidelity is essential.
- c. That each of the training program features in 6. above is important and beneficial.
- d. That, during the experiment, the amount of time spent on each aspect of training was too short and allowed too few practice runs.

8. The training in this study was designed to measure whether any

such training was of value. A program to optimize training, rather than measurement, would offer more problems and more practice on each problem than this experimental program.

9. Identifying specific types of training for pilots (such as Advanced Instrumentation and Emergency Shiphandling) is aided by a structured research approach described in the body of the report.

RECOMMENDATIONS FOR SIMULATOR TRAINING POLICY AND FOR FURTHER RESEARCH

This study did not require policy and future research recommendations; however, the following are useful indicators of the interests of the study team and the pilot trainees.

1. The Government should encourage, but not require, simulator training for pilots.
2. Several pilot groups for whom training would be particularly cost-effective should be identified. Demonstration training programs should be cost-shared by the pilots and the Government.
3. Additional research should be conducted, specifically:
 - a. More complete identification of the types of simulator training beneficial for pilots.
 - b. Development of a high quality generic port data base for training a wide range of pilot skills.
 - c. Refinement and validation of ship motion models suitable for simulator training for pilots.

d. At-sea validation of the benefits of simulator training.

4. The U.S. Coast Guard is not planning to pursue any such lines of research.

RELATED INFORMATION

The International Marine Simulator Forum (IMSF) a worldwide assembly of visual ship simulator facilities, is undertaking an international survey of pilot simulator training needs and capabilities.

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

The ship bridge/shiphandling simulator has become an important tool for use in research and training within the maritime industry. It has been used successfully to train all levels of deck officers, from cadets through masters. In some cases, simulator-based training is a cost-effective alternative for achieving specific training objectives, while in other cases it enables training and practice in situations that cannot be adequately addressed via other means (e.g., due to safety considerations, or lack of training control). It is generally viewed as a means of augmenting existing training programs. A variety of shipping companies, for example, have made available simulator-based training programs for their senior level deck officers, renting time at the commercial schools world-wide. At the other extreme, all deck cadets at the U.S. Merchant Marine Academy now participate in a shiphandling simulator-based training program, using the government-owned Computer Aided Operations Research Facility (CAORF). Several deck officer labor organizations, (e.g., Marine Engineers Beneficial Association - District Two; International Organization of Masters, Mates, and Pilots) have developed their own shiphandling simulator-based training system to accommodate members. Hence, a variety of shiphandling training systems exist world-wide to accommodate a growing demand.

Pilots, who as a group represent the high extreme of shiphandling skills, have availed themselves of simulator-based training only to a minor extent. This is due to several reasons, such as the lack of experience working with simulators, the level of simulation technology available, and the lack of definitive evidence demonstrating the effectiveness of simulator-based training for pilots. The most notable uses of simulator-based training for pilots occur in Europe -- the Rotterdam Europort pilots who train in Wageningen, Netherlands; the simulation facility at the Hochschule Fur Nautik in Bremen, Germany which has trained German pilots; and the Port Revel model ship basin in Grenoble, France which has been used to train various groups of pilots, including pilots from the United States. The Europort pilots have been training on the simulator at Wageningen for about 10 years. After initially trying the simulator with some degree of reservation, the Dutch have come to rely on simulator-based training as an important part of pilot preparation and refresher training. Each Europort pilot, who is a highly experienced professional bringing large tankers in and out of Europort, undergoes refresher training on the simulator every two years. Their training focuses on the use of electronic aids to navigation and difficult large ship maneuvers in a narrow channel (e.g., turning a VLCC around). Although there are several notable uses of simulator-based training by pilots, the effectiveness, or lack of

effectiveness, of this training media for United States pilots has not been demonstrated.

Several major issues have affected the use of simulator-based training by U.S. pilots. The most dominant of these is the lack of detailed objective information regarding the potential use of this training media by pilots, its capabilities and limitations, requisite simulation characteristics and quality, and so on -- that is, details concerning its training effectiveness for pilots. Based on previous research by the U.S. Coast Guard and U.S. Maritime Administration, it was expected that simulator-based training would be effective for addressing certain piloting skills such as emergency shiphandling. Furthermore, it was expected that the effectiveness of simulator-based training of certain piloting skills would depend on particular pilots' backgrounds (e.g., the amount of experience). The greatest potential value of the simulator-based training of pilots was not as a replacement for parts of current pilot training programs, since these are believed to be effective. Rather, the potential was to augment current training programs where desired by particular groups of pilots. Hence, the necessity existed to develop objective information detailing the potential effective use of simulator-based training by pilots, and to provide guidance information to assist pilots in using this technology.

The U.S. Coast Guard and U.S. Maritime Administration, in response to the growing availability of the shiphandling simulator training technology, initiated research to determine the cost-effectiveness of such training media. This research, which has been conducted by the Computer Aided Operations Research Facility (CAORF), has included experiments investigating

the effectiveness of simulator-based training of maritime academy cadets, chief mates, and masters. A major product of this research is a document which contains shiphandling simulator training system design and application guidelines developed for use by senior deck officers. The guidelines identify the major characteristics of shiphandling training systems, their capabilities and limitations, and recommend specific levels of training system fidelity and quality for addressing various areas of deck officer skill. A simulator functional design specification and application guidelines were also developed for maritime academy cadet training. This document identifies cadet/third mate skills amenable to simulator-based training, recommends a specific training system design for achieving a set of cadet training objectives, and possible detailed guidance information for flexibly integrating simulator-based training into academy curricula as desired.

1.2 PROJECT GOAL

The goal of CAORF's Maritime Pilot Training Investigation is to assist the responsible parties in determining the appropriate role of the ship bridge/shiphandling simulator within the training process of marine pilots. It was the purpose of the experiment reported herein to extend the empirical investigation of simulator-based training to pilots. The techniques developed during the earlier research in this program were tailored for this investigation. The primary focus of the research was on the effectiveness of simulator-based training of experienced pilots. Secondary issues addressed were the effectiveness of such training for different areas of piloting skill; the effectiveness of such training as a function of the level of pilot experi-

ence; and, the opinions of simulator-wise experienced pilots regarding the potential of such training. An experiment, was conducted at CAORF to investigate these issues. Its purpose was to generate objective information addressing the effectiveness of pilot training on shiphandling simulators. This experiment is the subject of this report. Another major product of this effort was the development of guidelines addressing the design and use of the simulator-based shiphandling training system by pilots (Gynther, Hammell and Pittsley, 1984). These guidelines have been developed to be used by pilots when deciding whether or not to use simulator-based training, when evaluating different available training systems, and when developing or using a simulator-based training program.

1.3 EXPERIMENTAL OBJECTIVES

The specific issues that were investigated during the experimental training

program for pilots, which was conducted on the CAORF simulator, were:

- Can a shiphandling simulator be used effectively to assist marine pilots in acquiring selected skills?
- What types of benefits should pilots anticipate from simulator-based training in specific skill areas?
- How do these benefits from simulator-based training vary with the experience level of the pilot?

These are major issues for which this experiment could develop objective data. Although it was beyond the scope of this experiment to comprehensively address each of these issues, it was believed that they could be addressed to an acceptable level of depth to provide guidance to the pilot community regarding the use of simulators for training.

CHAPTER 2

METHODOLOGY

2.1 PROJECT APPROACH

The approach followed in this empirical investigation was similar to that in earlier investigations of this long-term program. It was based on a systematic approach to training, using investigative techniques developed by the Air Force and Navy (i.e., instructional systems development process, systems approach to training, training system analysis), and modified as necessary for application in the maritime industry, and for specific application to the issues of this investigation. A summary overview of the approach follows.

First, the tasks that pilots perform at-sea were identified. This was accomplished by the project team after a review of the deck officer task listing developed during the first phase of the Training and Licensing project (Hammell, Williams, Grasso, and Evans, 1980), a review of the video tapes of piloting activities originally obtained during the Huffner studies (Huffner, 1978), visits to several pilot associations, ship rides in several pilotage areas, and discussions with numerous pilots. These tasks were then reviewed by one of the project's pilot consultants and appropriate alterations made to develop a final set.

Next, the tasks were analyzed into skill and knowledge elements, which were then transposed into a listing of training objectives. These training objectives were then further evaluated

and allocated to the various training media normally available for pilot training -- classroom, at-sea, small vessel, and simulator training. This allocation was determined by identifying the media that appeared to be the most cost-effective means of achieving each training objective. The result of this process was a subset of marine pilot training objectives that appeared to be appropriate for accomplishment via simulator-based training. The skill areas identified for which simulator-based training is potentially a cost-effective medium were:

- Emergency Shiphandling (mainly ramming and grounding avoidance problems)
- Shiphandling
- Vessel Characteristics (unfamiliar vessels)
- Pilothouse Procedures
- Advanced Instrumentation
- Restricted Waters Navigation
- Rules of the Road
- Vessel-to-Vessel Communications
- Restricted Waters Decisionmaking (mainly reaction to collision situations)

This listing was then further scrutinized to identify representative skill

areas for evaluation during this CAORF experiment. At this point in the analysis, the following issues were considered: (a) the simulator capabilities that would normally be available at a commercial training facility, (b) the European simulator-based pilot training experiences, and (c) the causal factors identified in various published accident reports which appear to indicate pilot skill areas that may benefit from additional training.

This list was validated by comparison to independently sampled European opinions. Experienced German pilots, polled informally for their interest in simulator oriented training, expressed various degrees of interest in the following training topics:

Greatest Interest

- Restricted waters maneuvers of concern to the pilots themselves
- Emergency situations (including equipment failures)*
- Communications ship to ship and ship to shore

Moderate Interest

- Outside the simulator review of basic theory and analyses of specific relevant casualties
- Advanced instrumentation
- Master-pilot relationships
- Vessel familiarization with special vessels
- Familiarization with significant changes to port waterways

*Including what this study defined as decisionmaking

Weak Interest

- Area familiarization (not involving changes to the port)

Although the training areas of interest are grouped and labeled differently, the interests are quite common. Local area familiarization is of somewhat weak interest mainly because pilots feel that existing area familiarization training programs are quite adequate. Not that some degree of familiarization cannot be accomplished on a simulator, but rather that simulator training is not fully adequate to the task and that at-sea orientation is adequate. The master-pilot relationship has been previously identified (Gynther, Hammell, Grasso and Pittsley, 1982) as a pre-eminently critical shiphandling requirement for restricted waters navigation. To date, however, simulator training has only evolved to address masters and pilots separately.

A prototype training program was developed for experimental purposes and conducted via the simulator at CAORF. This research, using the developed training program, had the dual role of (1) generating objective data with which to further assess and document the potential use of simulator-based training of pilots and (2) providing a valuable base of data and experience for development of the previously noted consumers guide relating to the use of simulators for training pilots.

As previously noted, this experiment investigated three major issues: (1) the effectiveness of simulator-based training of pilots; (2) the effectiveness of such training for three different areas of piloting skill; and (3) the effectiveness of such training for two different levels of piloting experience. Pilots from East, Gulf, and West Coast ports participated in

the experiment. Both test and training exercises were conducted on the simulator during each of three four-day training programs. Classroom sessions were interspersed with the simulator exercises as part of the training program. The effectiveness of the simulator-based training was determined on the basis of group performance in certain controlled simulator-based shiphandling exercises that immediately preceded and followed segments of the training program. It was assumed that the performance of the pilots on the simulator during both the pretraining and posttraining exercises would be representative of their performance during similar piloting operations at-sea. Observations and comments by the pilot coordinators and pilot participants were also factored into the analysis.

This section addresses the major aspects of methodology used during the preparation and conduct of the experiment. The results of the experiment are documented and discussed in Chapters 3 and 4.

2.2 GEOGRAPHIC DATA BASE

It has been a common belief that a port-specific geographic data base would be necessary for the simulator-based training of pilots. This would represent a very expensive approach if such training were to become a reality for a large segment of the pilot population. Furthermore, the simple cost-effectiveness of simulator-based training would be seriously questioned if it is necessary to develop port-specific data bases for the smaller pilot associations (e.g., 15 to 20 members). Hence, a more cost-effective alternative to the port-specific data base is necessary. Although it is believed by many individuals, particularly pilots, that port-specific data bases are likely to yield the

most effective pilot training, it is necessary to consider training in a generic-port data base due to cost considerations.

The viability of pilot training in a generic port data base was, therefore, a major factor in this experiment. The effectiveness of simulator-based training for pilots was investigated in a generic port data base developed specifically for this experiment. This geographic data base was a hypothetical port specifically designed to assist in the refinement of the skills selected for each training module. A chart of this hypothetical port, Lotsedorf, is contained in Figure 1. Both container and petroleum bulk cargoes are handled in the port. A container terminal is located at Lotsedorf. The petroleum terminal is located further up the Ball River. An anchorage is located in Burton Bay for vessels waiting for a berth at either the cargo terminal or the oil terminal. The topography is barren and rocky. When approaching from seaward, passage must be made via a winding 800-foot-wide channel through dangerous shoal areas. The channel is buoyed; however, ice and frequent storms may disperse these aids such that mariners should navigate with extreme caution. The beacons on Shea's Ledge, North Ledge, and South Ledge also provide fixed frequency racon coverage.

There are also several potential benefits for conducting pilot training in generic data bases. First, pilots may be more receptive to generic data base training because they can participate in training without (a) focusing their attention on the "inadequacies" of the training device for simulating their specific port, or (b) perceiving that they are putting their credentials for pilotage in their port on the line if they should make a mistake. Second,

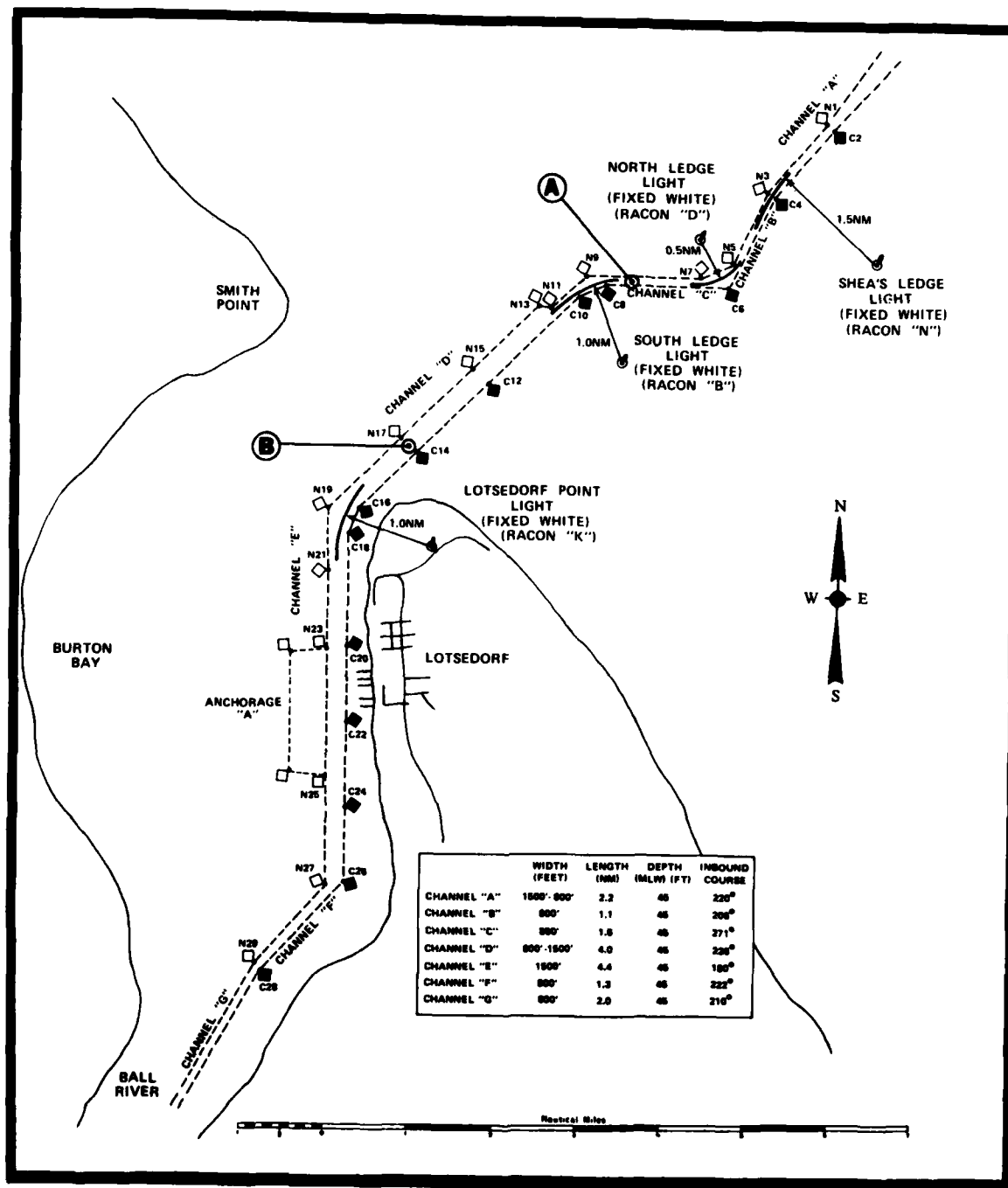


Figure 1. Approach to Lotserdorf and Ball River

the utilization of generic data bases for pilot training would probably also mean that a given simulator class would involve pilots from several geographic locales. A valuable cross-fertilization of expertise may take place, particularly for experienced pilots, since it would potentially allow the exchange of information concerning a variety of successful piloting techniques. Third, for training specific skills, such as advanced instrumentation, a simple generic data base may focus student attention better than a data base with specific port cues.

2.3 EXPERIMENTAL VARIABLES

The principle variable investigated in this experiment was the effectiveness of simulator-based training for pilots. This is a bottom-line issue of concern to pilots, directly relating to the cost/benefit ratio for pilot training using simulators as a supplement to the existing pilot training programs. The training effectiveness was addressed in terms of the improvement/decrement in certain piloting skills that resulted from participation in the training program.

Two secondary variables were investigated in addition to the training effectiveness -- pilot skill areas, and pilot level of experience. Each of these secondary variables was addressed in terms of its impact on the effectiveness of simulator-based training. These secondary variables are discussed below.

Pilot Skill Areas

Three pilot skill areas were examined in this experiment: (a) advanced piloting instrumentation, (b) emergency shiphandling and (c) restricted waters decisionmaking. The first

skill area, advanced piloting instrumentation, involved refining a pilot's ability to effectively employ some of the more sophisticated electronic navigational equipment that are appearing more frequently on today's ships. Pilots, particularly experienced pilots, are well-versed with the equipment that they employ during their transits. However, several independent sources have indicated that pilots may benefit significantly from additional training in utilizing various modern electronic equipments, such as stabilized radar, racons, doppler speed log, and rate-of-turn indicator. Skills related to the use of advanced instrumentation have been a major area of simulator-based training for pilots at the Wageningen (the Netherlands) and Bremen (Germany) training facilities.

The second skill area, emergency shiphandling has been generally recognized as an area for potentially effective training on a simulator. Most pilots are receptive to this type of simulator-based training since it obviously can not be trained effectively at sea due to the high risks involved. The piloting skills associated with keeping a large vessel under control when executing a crash stop in a narrow channel, or turning a large vessel around within a confined channel without tugs, although infrequently used, are well-recognized as important and desirable by many pilots. This type of training on a simulator is also currently provided to European pilots.

The third and final pilot skill area investigated was decisionmaking in emergency or unusual restricted waters situations. Discussions with many pilots have indicated the importance of being able to rapidly respond to common unforeseen difficult problems, such as a vessel unexpectedly departing from an anchorage and crossing

ownship's bow. These types of situations often involve the rapid detection of a problem, the assessment of alternative actions available, the selection of a course of action, and the effective implementation of that action. The use of a simulator to train this area of pilot skills appears especially suited to pilots with a relatively limited amount of experience, since it apparently takes many years of experience to encounter the range of potential problems and to develop the skills necessary for early detection and handling of these situations. The simulator has potential for this area of training since it can be used to provide a pilot with a representative set of problem situations in a relatively short time, which otherwise might require many years of experience. Also, it should also be noted that the risk of such training would be substantially less than at sea.

Pilot Experience

The effectiveness of simulator-based training is likely to depend on many factors. Pilot skill area is, perhaps, the most relevant of these factors. Another important factor may be the level of pilot experience. Simulator-based training may be more effective for highly experienced pilots regarding certain skill areas, and perhaps more effective for pilots with limited experience regarding other skill areas. Two levels of pilot experience were examined regarding the effectiveness of simulator-based training: (a) limited experience (less than 5 years as a licensed pilot), and (b) extensive experience (greater than 10 years as a licensed pilot); see Pilot Participants (Paragraph 2.5) for additional information regarding the qualifications of participating pilots. Apprentice pilots were not considered due to their gen-

eral unavailability. As a result of the reduced shipping in recent years, many pilot associations do not presently have apprentices, nor do they anticipate accepting apprentices for several years.

2.4 EXPERIMENTAL DESIGN

The experimental design for this experiment is summarized in Figure 2. A 1-week experimental training program was provided to three groups of pilots, one group each week. Each of these groups were composed of four experienced pilots. Within each group there was a mix of limited experience and extensive experience pilots. Each 1-week training program was divided into three independent training modules, with each module addressing one of the pilot skill areas discussed above. The objective data used for training effectiveness evaluations were based on pre and postexercises for each pilot, individually conducted before and after each training module. Simulator difficulties prevented obtaining data for the third training module within the experimental program. As a result, the objective data derived from shiphandling performance on the simulator exercises were available for training Modules I and II. Pilot observations and opinion data were collected for each module, including some data for the third training module. Chapters 3 and 4 contain a detailed presentation and discussion of the results obtained during this experimental program.

2.5 PILOT PARTICIPANTS

Twelve licensed pilots participated in this experimental CAORF program. These pilots were equally distributed from East Coast, Gulf Coast, and West Coast ports (i.e., four pilots from each coast). The following organizations provided participants:

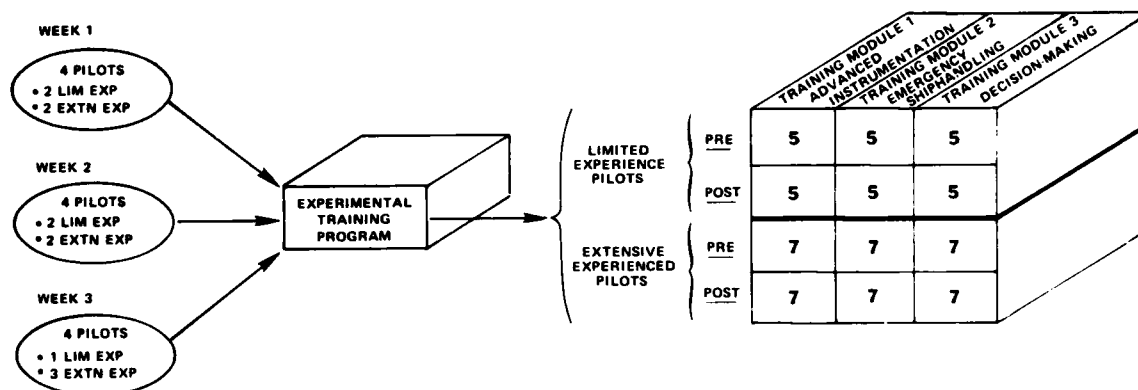


Figure 2. Experimental Design Summary

- United New York New Jersey Sandy Hook Pilot Association
- Pilot Association for the Bay and River Delaware
- Charleston (S.C.) Branch Pilot Association
- Tampa Bay Pilots
- Crescent River Port Pilots (New Orleans)
- Corpus Christi Pilots
- San Francisco Bay Pilots
- Jacobsen Pilot Service (Long Beach)

The average experience across all the participants was 9.0 years as a licensed pilot. The range of this experience was from 1.5 years to 23.0 years. There were five pilots with less than 5.0 years experience and seven pilots with greater than 10.0

years experience. The average age of these individuals was 39.8 years, with their ages varying from 26 to 56 years. Ten of the twelve pilots were between 30 and 50 years old. None of the pilots had previously participated in a training program on an electronic ship bridge/shiphandling simulator, although several had previously been to CAORF as test subjects during other research experiments. One pilot had participated in the simulator training program at Grenoble, France which employs physical ship models.

2.6 TRAINING PROGRAM

The prototype simulator-based training program for pilots that was conducted at CAORF as part of this experiment addressed only a subset of the pilot skills that analysis identified as potentially appropriate for development/improvement via simulator-based training. Limited resources prohibited the investigation of additional skills. The reader should note that

this experimental training program was developed specifically for this experiment, and thus is not necessarily a training program that should be offered to pilots at a commercial training facility. As an experimental training program it was designed to cover several skill areas in order to provide an indication of the possible benefits from simulator-based training. It was not designed to comprehensively address these skills to the level of refinement that might be accomplished at a simulator facility dedicated to training.

The experimental training program was a 1-week program designed for a class of four pilots. It was composed of three training modules, which were based on the three skill areas identified and discussed in Paragraph 2.3. These three modules were (a) Advanced Piloting Instrumentation, (b) Emergency Shiphandling, and (c) Restricted Waters Decisionmaking. The specific training objectives developed for each module are presented in Table 1.

The structure of the training program involved a combination of classroom and simulator training. It is outlined in Figure 3. The training strategy used in the program was a modification of seminar, role playing, and case study techniques, which were considered appropriate for skilled professionals focusing on cognitive tasks. Each training module commenced with the trainees individually handling the ownship in a controlled simulator exercise. This exercise was then discussed during the classroom session as a case study example of a situation requiring particular skills, which would be addressed during the training module. After the classroom session, the pilots participated in a series of exercises on the simulator. They applied and practiced the principles and techniques discussed during

TABLE 1. TRAINING OBJECTIVES FOR
PROTOTYPE SIMULATOR TRAINING PROGRAM
FOR MARINE PILOTS

Training Module I: Advanced Piloting Instrumentation

- The trainee shall be able to effectively execute a constant radius turn under various operational conditions while employing a rate-of-turn indicator, a doppler speed log, and racons.

Training Module II: Emergency Shiphandling Skills

- The trainee shall be able to safely turn an 80,000 dwt tanker around within a confined channel under various operational conditions.

Training Module III: Decisionmaking in Unusual or Emergency Restricted Waters Situations

- The trainee shall be able to effectively respond to an unanticipated vessel departing from an anchorage or berth within a confined channel under various operational conditions.

the classroom period. During this group exercise period, the trainees were rotated between the positions of pilot, helmsman, and observer.

The training program was coordinated by two highly experienced and respected pilots currently active in different pilot associations. Each of these coordinators are articulate individuals as regards piloting and piloting techniques. They possessed previous experience with shiphandling simulators, and were versed with many of the research protocols employed at CAORF. As coordinators they were the primary interface with the pilot par-

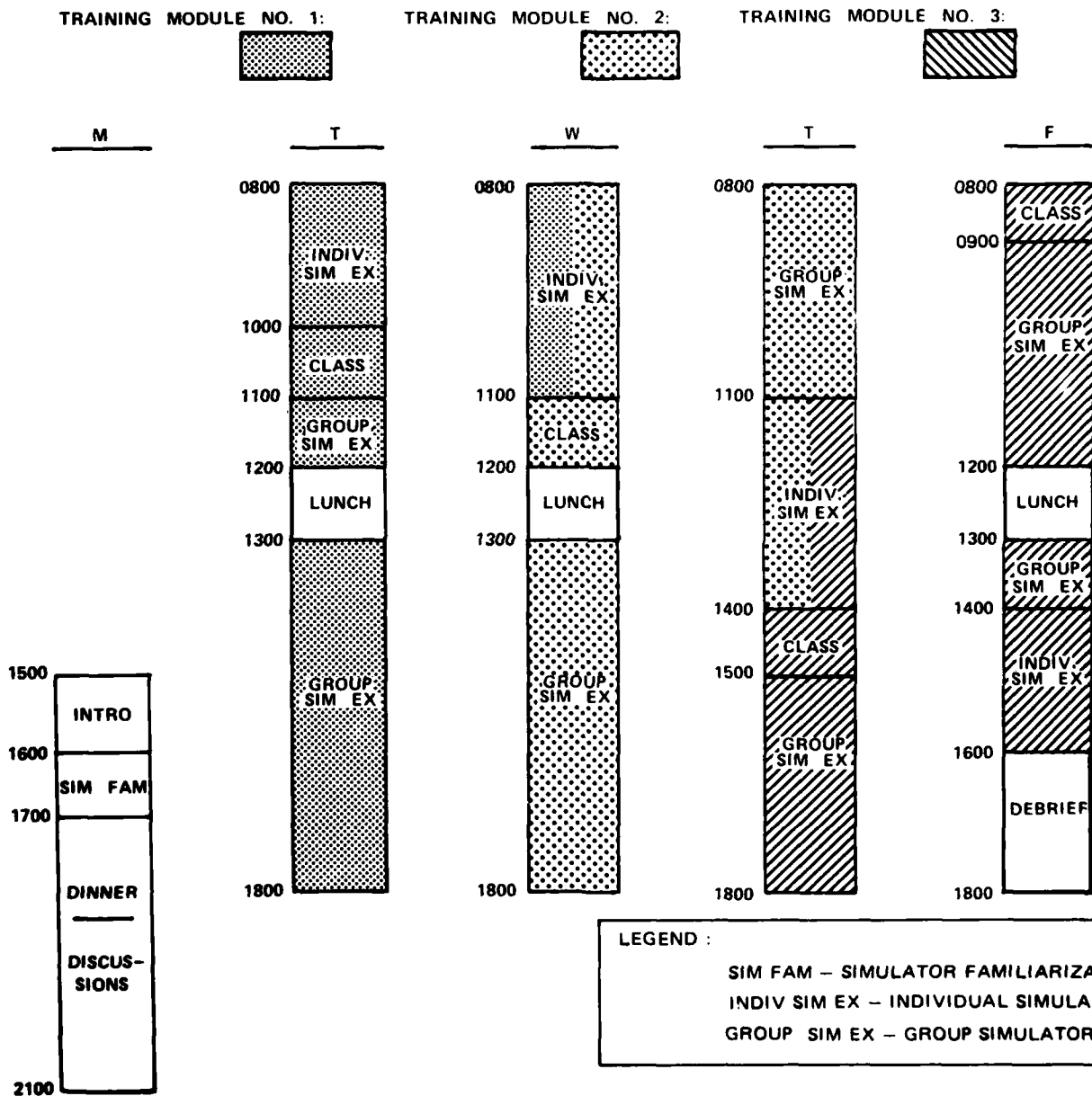


Figure 3. Training Schedule

ticipants, providing technical information, overseeing the various training activities, and directing the training program. They also assisted during the development of the experiment and the training program.

2.7 EXPERIMENTAL PROCEDURES

Extreme care was exercised in conducting the training program to minimize uncontrolled aspects of the experiment which can result from variations in the selection, training, and debriefing of subjects. The following procedures were followed:

- a. Upon initial contact, via his respective pilot association, the pilot participant was appraised of the experimental nature of the training program. He was told that it is anticipated he would receive beneficial training; however, his primary purpose was to assist the CAORF staff in the evaluation of this type of simulator-based training for pilots.
- b. Upon arrival at CAORF, each pilot was provided with additional information during the introductory sessions concerning the purpose of the Pilot Training Investigation, the objectives of this particular experimental training program, and his role during the coming week. He was also provided with an appropriate familiarization of the CAORF simulator including an opportunity to handle the simulated vessel in the generic data base used during the program.
- c. During testing periods, each pilot was on the simulator bridge alone except for a helmsman, who was a member of the CAORF staff. The pilot was provided with appropriate instructions prior to the commencement of each test exercise. After

each test the exercise, he was instructed to refrain from discussing the exercise with other pilots until the next class session. A variety of pertinent maritime films were available for viewing by the pilots when they were not on the simulator during the testing periods.

- d. During the training periods, the pilots were rotated through the position of pilot and helmsman. During Modules I and II those pilots not participating in the exercise were located on the bridge in an unobtrusive location with the coordinator. During Module III, the most advantageous position for the off-watch pilots and the instructor was determined to be at the human factors monitoring station, where they could anticipate, observe, and discuss exercise events without disturbing those pilots handling the simulated vessel.
- e. Upon completion of the training, each pilot was individually debriefed by a member of the research staff, who completed the debriefing questionnaire contained in Appendix A.

2.8 OWNERSHIP CHARACTERISTICS

The following are characteristics of the simulated ship that was used during the experimental training program at CAORF:

- Type: 80,000 dwt tanker
- Length overall (LOA): 800 feet
- Length between perpendiculars (LBP): 763 feet
- Location of pilothouse: Aft

- Beam: 125 feet
- Draft (full load):
 - Fwd - 39.9 feet
 - Aft - 39.9 feet
- Propulsion:
 - Slow speed diesel
 - 23,000 horsepower
 - Single screw
 - Direct pilothouse control

2.9 TEST EXERCISES

Four test exercises were developed for the experimental training program. The purpose of these test exercises was to generate the objective pilot performance data used to assess the gain/loss in performance that resulted from each training module. Test exercise 1 was designed to evaluate trainee performance prior to Training Module I. Test exercise 2 was designed to provide both (a) posttraining performance data for Module I, and (b) pretraining performance data for Module II. Similarly, test exercise 3 was designed to provide (a) posttraining data for Module II, and (b) pretraining data for Module III. Finally, test exercise 4 was designed to provide posttraining performance data for Module III. Due to simulator difficulties, which affected the training program schedule, test exercise 4 was not accomplished. As a result, the objective performance data required to evaluate the training effectiveness of Module III was not available. The subjective evaluation accomplished at the end of the program, however, was conducted for Module III using two groups of pilots. The following is a brief summary of each of the three test exercises that were accomplished and utilized as the basis for the objective analysis described in Chapters 3 and 4.

- Test Exercise 1 - The 80,000 dwt tanker (fully loaded) was positioned inbound on the centerline of Channel C at position A in Figure 1. Initial speed was 8 knots. It was a clear day with unrestricted visibility. A 1.0 knot current was setting towards 090°. Buoys C8 and C10 were missing as a result of a recent storm. The trainee was directed to safely negotiate the 1.0 nm radius turn between Channel C and Channel D utilizing the available aids to navigation. This test exercise was designed to provide pilot performance data prior to Training Module I.
- Test Exercise 2 - The 80,000 dwt tanker (fully loaded) was positioned again inbound on the centerline of Channel C at position A. Initial speed was 8 knots. Visibility was unrestricted, and a 1.0 knot current was again setting towards 090°. As in test exercise 1, buoys C8 and C10 were missing. The trainee was directed to safely negotiate the 1.0 nm radius turn between Channel C and Channel D utilizing the available aids to navigation. Upon completion of the turn and entry in Channel D, the pilot was told that he should turn the ship around in Channel D without tugs since there had been an accident which was obstructing the channel at buoy N19. The 1.0 nm radius turn was designed to provide pilot performance data after Module I, while the turn around was designed to provide performance data prior to Module II.
- Test Exercise 3 - The 80,000 dwt tanker (fully loaded) was positioned outbound on the centerline of Channel D at position B in Figure 1. Initial speed was 8 knots. Visibility was unrestricted

and a 1.0 knot current was setting toward 270°. The trainee was told that he should turn the ship around in Channel D without tugs since there has been an accident which is obstructing the channel at buoy N7.

Once the ship is turned around, the pilot was directed to return to his berth at the oil terminal. As ownship proceeded inbound the visibility was gradually reduced to approximately 0.5 nm. As ownship approached the container terminal, a containership unexpectedly backed into the channel less than 1.0 nm ahead. The containership desired to proceed outbound. The earlier turn around within Channel D was designed to provide post-Module II performance data, while the unanticipated backing of the containership was designed to provide performance data regarding pilot decisionmaking skills prior to Module III.

2.10 PERFORMANCE MEASURES

Two major sources of data were used in the experiment: (1) objective performance data collected during the test scenarios; and (2) subjective observations and opinions of the pilot participants, collected during the debriefing at the end of the training program. The subjective data are comprised of straightforward pilot opinions concerning the specific issues addressed. Their analysis is in Paragraph 4.4 in terms of the proportion of various opinions expressed regarding each issue/question. The objective data, on the other hand, were comprised of various ownship and situation parameters, some of which were automatically recorded by the simulator/computer and some which were manually recorded by an observer. In both cases, these objective data were

transformed into performance measures relevant to the particular training objectives, and then statistically analyzed to evaluate training effectiveness.

Several performance measures were identified for the types of pilot skills involved in Modules I and II. These performance measures were organized into three categories for each module, based on their relevance to the training objectives of the respective module: (a) primary performance measure, (b) secondary performance measures, and (c) third-order performance measures. The primary performance measure is the single measure most applicable to the particular training objectives, pilot skills, and relevant aspects of shiphandling. It represents the bottom-line with regard to each respective training program module. Previous research of this type in the maritime field has shown, however, that for various reasons single performance measures may not be insensitive to differences in performance. Hence, multiple performance measures are necessary to understand the processes involved. Furthermore, these additional performance measures address other relevant, although secondary and third-order, aspects of performance and behavior. They assist in analyzing and interpreting the experimental effects by providing data regarding associated facets of performance.

A description of the performance measures used with each module follows.

Module I - Advanced Instrumentation

The focus of this training program module was the effective utilization of advanced instrumentation, namely the rate-of-turn indicator, the doppler speed log, and the available racons, to execute a constant radius

turn. The ability to achieve a constant radius turn using these instruments provides a set of piloting skills that allows considerable vessel control during the navigation of turns; as such, it represents one effective piloting technique, to augment other available techniques.

- Primary Performance Measure

- Sum of Distances Off 1.0 nm Radius: This performance measure is the sum of the absolute difference in feet between the ideal 1.0 nm radius and the actual position of the vessel's center of gravity, at four different data lines through the turn. These data lines were spaced at intervals of 1/4 of the turn, DL2 through DL5 in Figure 4. The first data line (DL2) was located at the end of the first one-fourth of the turn, and the final data line

placed at the end of the complete turn. Ideally, the vessel should have maintained a precise 1.0 nm radius from the racon throughout the turn. This constant radius was the objective of training in Module I. The summation of this ownship position deviation at each of the data lines provides a relevant measure of the degree to which the pilot was able to maintain the constant radius.

- Secondary Performance Measure

- Sum of Differences Between Actual and Desired Rate-of-Turn: This measure is similar to the previous performance measure in that it is calculated at specific data lines in the turn. To achieve the constant 1.0 nm radius turn, the vessel had to maintain a rate-of-turn of approximately 0.11 deg/sec. This

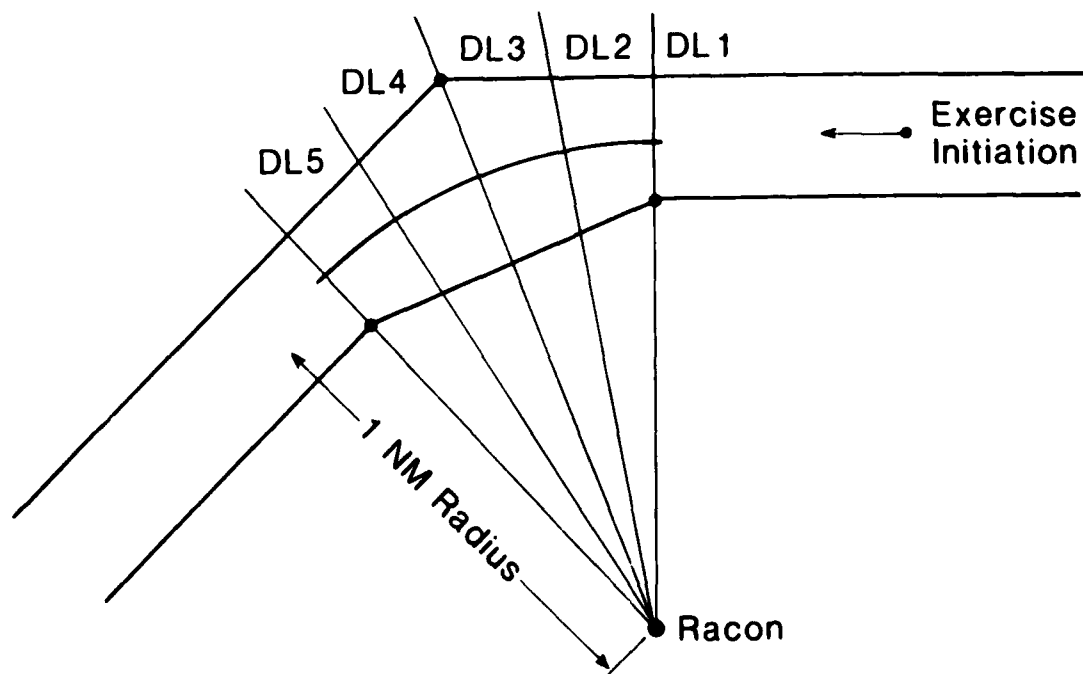


Figure 4. Segmentation of Test Exercise Turn for Data Analysis

value, which has both a theoretical and empirical basis, assumes an average speed over the ground of approximately 7 knots as the ship proceeds through the turn. (Note: the theoretical basis was provided to the trainees as part of the classroom training.) Hence, this measure addresses the differences between the ideal rate-of-turn and the actual rate-of-turn achieved. The data lines at which the rates-of-turn were measured were identical to those employed for the previous measure, with the exception that the final data line at the end of the turn was not used (DL5). This data line was omitted since the vessel, having completed its constant radius turn, should have a zero rate of turn at that point.

● Third-Order Performance Measures

- Number of Rudder Orders -- the number of rudder orders issued during the exercise
- Number of Course Orders -- the number of course orders issued during the exercise
- Minimum Distance to Channel Boundary -- the closest point ownship came to the channel boundary during the exercise
- Channel Excursion -- the number of pilots that had any part of their vessel extend outside the channel boundaries during the exercise

Module II - Emergency Shiphandling

This module emphasized the refinement of skills involved when turning a large tanker around within a confined

channel without tugs. The specific test exercise involved turning an 80,000 dwt tanker around within a 1500 ft channel without tugs, and with a 1-knot current on the starboard bow. Although some pilots may not consider this exercise as emergency ship-handling training, most pilots agreed that it would not normally be attempted except under emergency conditions. The Dutch pilots during their simulator training at Wageningen developed an effective technique for safely accomplishing this maneuver. This technique was the focus during the emergency shiphandling module of the CAORF experimental training program. The technique involves balancing the cross-channel component of the ship's speed against the cross-channel component of the current, according to Table 2, as the vessel slows. The pilot applies a course correction to head up into the current based on his speed through the water at appropriate intervals of time. For the test exercise, this method is extremely helpful for the first 30 degrees of course change (i.e., nearly heading into the current).

● Primary Performance Measure

- Channel Excursions: This measure is the number of pilots that had any part of their vessel extend beyond the channel boundaries. As such, it is clearly a bottom-line performance measure for the situation addressed in Module II. Channel excursions were determined graphically by viewing geographic plots containing the hull outline of ownship throughout the exercise.

● Secondary Performance Measure

- Minimum Distance to Channel Boundary: This measure repre-

TABLE 2. COURSE CORRECTION (DEGREES) FOR CROSS-CHANNEL CURRENT

	COMPONENT CURRENT $\perp$ CHANNEL (MILES/HOUR)						
		$\frac{1}{2}$	1	$1\frac{1}{2}$	2	$2\frac{1}{2}$	3
SPEED THROUGH THE WATER (MILES/HOUR)	9	3	6	9	12	15	18
	8	$3\frac{1}{2}$	7	$10\frac{1}{2}$	14	$17\frac{1}{2}$	21
	7	4	8	12	16	$20\frac{1}{2}$	25
	6	5	10	15	20	25	30
	5	6	12	18	24	30	36
	4	$7\frac{1}{2}$	15	$22\frac{1}{2}$	30	$37\frac{1}{2}$	40
	3	10	20	30	42	57	90
	$2\frac{1}{2}$	12	24	36	53	90	
	2	15	30	40	90		
	$1\frac{1}{2}$	20	42	90			
	1	30	90				
	0						

EXAMPLE:

Cross-Channel Current Component = $1/2$ knot

Speed Through The Water = 8 knots

Course Correction = $3-1/2^0$

Source: J. Jussem and DeBoer, "Seven Years Experience With Simulator Training at VLCC Pilots in the Netherlands," *Proceedings Second International Conference on Marine Simulation*. National Maritime Research Center, Kings Point, New York, 1981.

sents the single point at which ownship was closest to the channel boundary. This distance was measured from the skin of the ship, not the center of gravity, to the channel boundary. The units of measure were "feet". If the vessel went beyond the channel boundary, a zero value was entered.

- Third-Order Performance Measures

- Course correction at 4 knots -- the difference between ownships course and the channel heading when ownship's speed was reduced to 4 knots.

- Number of Rudder Orders prior to 30^0 heading change

- Number of Course Orders prior to 30^0 heading change

- Number of Engine Orders prior to 30^0 heading change

These third-order performance measures are closely related to the Dutch turn around technique, which was emphasized during the experimental training program. Four knots was considered as an appropriate sample point to investigate the pilot's adherence to the recommended course correction provided in Table 2 as he slows the vessel.

For the rudder, course, and engine orders, an upper limit of 30 degrees heading change was chosen because, for the particular test exercises employed, this value appeared to define the limit of the critical region where the Dutch technique was most helpful.

The data analysis focused on changes in each of these performance measures

as a result of the training program, (pre versus posttest performance) yielding multiple measures of training effectiveness. These measures of change in performance (i.e., between the two tests for each module) are the basis for the findings presented and discussed in the subsequent Results and Discussion chapters.

CHAPTER 3

RESULTS

This section presents the results obtained from the CAORF experiment, in terms of the data collected for, and significance of, each of the performance measures. The evidence is summarized herein, but is not discussed. The discussion of the results, addressing each of the issues under investigation, is contained in Chapter 4. The questionnaire data collected from each of the pilots/subjects are presented and discussed in the Discussion chapter.

The results are segmented under each of the two training modules -- Advanced Instrumentation, and Emergency Shiphandling.

3.1 ADVANCED INSTRUMENTATION -- MODULE I

The results pertaining to this module are presented below regarding Training Effectiveness and Pilot Experience.

Training Effectiveness

The training emphasis in Module I focused on maneuvering a vessel around a constant radius turn, such that the ship's track would maintain an appropriate constant radius through the turn. The constant radius of the turn used during the test was 1 nautical mile (nm). Hence, ideally, a 1 nm mile radius would have been achieved during the test scenarios. The statistical data pertaining to this performance measure, and five additional performance measures, are contained in

Table 3. The primary performance measure is the sum of the difference between the actual ship's position and the 1 nm radius at each of four data lines throughout the turn (i.e., see Figure 4, and the explanation in Chapter 2). This primary performance measure, sum of distance off 1 nm radius, was reduced from a mean of 734.0 to 384.9 ($p \leq 0.025$), showing a significant gain in pilot performance. This finding demonstrates the potential effectiveness of advanced instrumentation training for pilots on a simulator.

The secondary performance measure in Module 1 addresses the actual rate-of-turn maintained in comparison with the ideal rate-of-turn (0.11 degrees per minute). Pilot performance regarding this measure was also found to significantly increase as a result of the training program. The mean error in rate-of-turn was reduced from 0.28 to 0.14 ($p \leq 0.001$) as a result of the training program. Whereas the sum of distance off the 1 nm radius represents the bottom-line of performance in this module, the sum of difference between the actual rate-of-turn and the desired rate-of-turn represents the behavior of pilots in achieving that performance.

Two additional performance measures describing specific changes in piloting behavior were also found to change significantly as a result of this training module (see Table 3). The mean minimum distance to channel boundary increased significantly from

TABLE 3. MODULE I - OVERALL PILOT PRETRAINING VERSUS POSTTRAINING COMPARISON

Performance Measure	Mean Value	Pretraining Standard Deviation	Comment	Mean Value	Posttraining Standard Deviation	Comment	t-Test t	p ≤	Binominal Test p ≤
Sum of distances (feet) off 1.0 nm radius at DL2, 3, 4, 5	734.0	359.4	n=9	384.8	305.6	n=10	2.269	0.025*	Mann-Whitney U $\alpha \leq .01$
Mean sum of differences between actual and desired ROT (deg/sec) at DL2, 3, 4	0.28	0.09	n=10	0.14	0.06	n=10	4.093	0.001*	
Number of rudder orders	11.6	7.2	n=12	12.9	6.5	n=12	0.464	N.S.	
Number of course orders	2.25	1.9	n=12	1.17	1.11	n=12	1.702	0.10*	
Minimum distance to channel boundary (feet)	143.0	117.8	n=12	237.5	95.6	n=12	2.158	.025*	
Channel excursion			4/12 yes			1/12 yes			N.S.

*One-tailed test
N.S.: Non-significant

143 feet to 237.5 feet ($p \leq 0.025$). This finding, of course, would be expected to correlate highly with the primary performance measure, sum of the distance off 1 nm radius. The number of course orders issued by the pilots were reduced at a marginally significant level as a result of the training program, from a mean of 2.25 to 1.17 ($p \leq 0.10$).

The remaining third order performance measures did not yield a significant change in performance as a result of this training module. The number and strength of significant results, however, (i.e., four of the six performance measures, including the primary and secondary measures) strongly indicates that effective pilot training was achieved in the advanced instrumentation module.

Pilot Experience

The results pertaining to the impact of experience on the effectiveness of the advanced instrumentation training module are summarized in Tables 4 and 5, for the limited and extensive experienced groups.

Limited Experience. The primary performance measure, sum of distance off 1 nm radius, did not change significantly, even though this mean performance improved substantially between the pretest and posttest (626.5 feet to 447.2 feet). The secondary performance measure, sum of the differences between actual rate-of-turn and desired rate-of-turn, did yield a significant change in performance, with a reduction in the mean error from 0.24 to 0.13 degree per second ($p \leq 0.05$). The behavior of the limited experience group in bringing the vessel around the constant radius turn, therefore, was found to improve significantly as a result of the training module, even though this did

not result in a significant change in the bottom-line vessel performance.

The limited experience group did not show a significant change in performance on the remaining performance measures. In summary, therefore, a positive, although weak, indication of training effectiveness was observed for the limited experienced group of pilots with regard to advanced instrumentation training.

Extensive Experience. The effectiveness of advanced instrumentation training for the pilots with extensive experience was found to be strong, contrary to that observed for the pilots with limited experience, with several performance measures showing significant improvement (Table 5). The sum of distance off 1.0 nm radius, the primary performance measure, showed a significant increase in performance with the mean sum of distances of 1.0 nm radius substantially reduced from 821.1 feet to 343.2 feet ($p \leq 0.05$) as a result of training. The sum of the differences between the actual rate-of-turn and the desired rate-of-turn, the secondary performance measure, was also found to show a significant improvement, with the rate-of-turn error reduced from 0.32 degree per second to 0.14 degree per second ($p \leq 0.005$).

Two of the four third order performance measures were also found to show a significant change in performance. The minimum distance to channel boundary increased from 109.5 feet to 250.0 feet ($p \leq 0.025$). The number of channel excursions was significantly reduced from 4 on the pretest to zero on the posttest ($p \leq 0.06$). These results indicate substantial improvement for the pilots with extensive experience as a result of the advanced instrumentation training.

TABLE 4. MODULE I - LIMITED EXPERIENCE, PRETRAINING VERSUS POSTTRAINING COMPARISON

Performance Measure	Mean Value	Pretraining Standard Deviation	Comment	Mean Value	Posttraining Standard Deviation	Comment	t-Test t	p ≤	Binominal Test p ≤
Sum of distances (feet) off 1.0 nm radius at DL2, 3, 4, 5	626.5	281.3	n=4	447.2	309.6	n=4	0.857	N.S.	
Mean sum of differences between actual and desired ROT (deg/sec) at DL2, 3, 4	0.24	0.08	n=5	0.13	0.06	n=4	2.356	0.05*	
Number of rudder orders	9.4	4.88	n=5	12.4	5.7	n=5	0.89	N.S.	
Number of course orders	2.0	2.0	n=5	1.0	1.0	n=5	1.00	N.S.	
Minimum distance to channel boundary (feet)	233.3	110.5	n=5	200.0	135.1	n=5	0.43	N.S.	
Channel excursion			0/5 yes			1/5 yes			N.S.

*One-tailed test
N.S.: Non-significant

TABLE 5. MODULE 1 - EXTENSIVE EXPERIENCE, PRETRAINING VERSUS POSTTRAINING COMPARISON

Performance Measure	Mean Value	Pretraining Standard Deviation	Comment	Mean Value	Posttraining Standard Deviation	Comment	t-Test t	p ≤	Binominal Test p ≤
Sum of distances (feet) off 1.0 nm radius at DL2, 3, 4, 5	821.1	421.9	n=5	343.2	324.6	n=7	2.12	0.05*	
Mean sum of differences between actual and desired ROT (deg/sec) at DL2, 3, 4	0.32	0.09	n=5	0.14	0.06	n=7	3.89	.005*	
Number of rudder orders	11.9	9.5	n=7	14.7	5.6	n=7	0.67	N.S.	
Number of course orders	2.4	1.9	n=7	1.3	1.3	n=7	1.264	N.S.	
Minimum distance to channel boundary (feet)	109.5	139.7	n=7	250.0	64.5	n=7	2.42	.025*	
Channel excursion			4/7 yes			0/7 yes			0.06

*One-tailed test
N.S.: Non-significant

3.2 EMERGENCY SHIPHANDLING -- MODULE II

The results pertaining to Emergency Shiphandling (Module II) are presented below with regard to Training Effectiveness and Pilot Experience.

Training Effectiveness

The data pertaining to the training effectiveness achieved during the emergency shiphandling module are presented in Tables 6 through 8. The primary, secondary and four third-order performance measures were calculated to evaluate training effectiveness. The difference in the frequency of channel excursions between the pretest and the posttest was the primary measure of training effectiveness. The frequency of channel excursions was significantly reduced from six excursions to zero excursions ($p \leq 0.02$) as a result of this training. This demonstrates a significant bottom-line gain in pilot performance as a result of the training program. The minimum distance to the channel boundary, the secondary performance measure, was found to be marginally significant, but also showing a change in pilot performance representative of positive training effectiveness. The minimum distance to the channel boundary increased from 75.0 feet to 129.2 feet ($p \leq 0.10$). It should be noted, the minimum distance to the channel boundary as used in this investigation is a very conservative estimate of positive changes in performance due to the manner in which it was calculated (see paragraph 2.10).

Three of the four third-order performance measures showed a significant improvement as a result of the emergency shiphandling training. The mean number of rudder orders prior to a 30

degree heading change during the turning around maneuver was reduced from 7.0 to 4.4 ($p \leq 0.05$); the mean number of course orders prior to the 30 degree heading change was increased from 1.9 to 4.3 ($p \leq 0.05$); and the mean number of engine orders prior to the 30 degree heading change was reduced from 6.2 to 3.2 ($p \leq 0.02$). These three performance measures address the behavior of the pilots during the critical early stages of the turning around maneuver (i.e., the greater part of the turning around maneuver during which speed is taken off, and the ownship heading is substantially changed). The number of rudder orders and engine orders prior to the 30 degree heading change were found to be significantly reduced, while the number of course orders was found to significantly increase during this period. The technique addressed in Module II for turning around emphasizes incremental changes/modifications to ownship course in comparison with the channel centerline course, thus promoting the changes that were observed. These findings further substantiate the effectiveness of simulator-based emergency shiphandling training for pilots.

Pilot Experience

The training effectiveness data for the groups of pilots with limited and extensive experience are summarized in Tables 7 and 8.

Limited Experience. The only performance measure to reflect a significant change for pilots with limited experience was the minimum distance to the channel boundary, which increased from 60.0 feet to 170.0 feet ($p \leq 0.05$). This significant finding suggests that the module was effective for training this particular group of pilots. The number of channel excursions, the primary perfor-

TABLE 6. MODULE II - OVERALL PILOT PRETRAINING VERSUS POSTTRAINING COMPARISON

Performance Measure	Mean Value	Pretraining Standard Deviation	Comment	Mean Value	Posttraining Standard Deviation	Comment	t-Test t	$p \leq$	Binominal Test $p \leq$
Channel excursion			6/12 yes			0/12 yes			0.02
Minimum distance to channel boundary (feet)	75.0	105.5	n=12	129.2	83.8	n=12	1.390	0.10*	
Course Correction (deg) at 4 kts	16.7	11.4	n=12	10.7	2.7	n=12	N.A.		
Number of rudder orders prior to 30° heading change	7.0	4.4	n=12	4.4	2.7	n=12		1.745	.05*
Number of course orders prior to 30° heading change	1.9	2.2	n=12	4.3	4.1	n=12		1.787	.05*
Number of engine orders prior to 30° heading change	6.2	2.7	n=12	3.2	3.0	n=12		2.575	0.02

*One-tailed test

N.S.: Non-significant

N.A.: Not appropriate due to unequal variances

TABLE 7. MODULE II - LIMITED EXPERIENCE PRETRAINING VERSUS POSTTRAINING COMPARISON

Performance Measure	Mean Value	Pretraining Standard Deviation	Comment	Mean Value	Posttraining Standard Deviation	Comment	t-Test t	t-Test p ≤	Binominal Test p ≤
Channel excursion			3/5 Outside Channel			0/5 (none) Outside Channel			N.S.
Minimum distance to channel boundary (feet)	60.0	89.4	n=5	170.0	67.1	n=5	2.20	0.05	
Course correction (deg) at 4 kts	15.5	12.2	n=5	10.4	1.9	n=5	N.A.		
Number of rudder orders prior to 300 heading change	7.0	4.9	n=5	4.0	2.9	n=5	1.178	N.S.	
Number of course orders prior to 300 heading change	2.4	2.9	n=5	6.0	5.3	n=5	1.332	N.S.	
Number of engine orders prior to 300 heading change	6.4	2.2	n=5	4.2	3.6	n=5	1.166	N.S.	

*One-tailed test

N.S.: Non-significant

N.A.: Not appropriate due to lack of homogeneity of variances

TABLE 8. MODULE II - EXTENSIVE EXPERIENCE PRETRAINING VERSUS POSTTRAINING COMPARISON

Performance Measure	Mean Value	Pretraining Standard Deviation	Comment	Mean Value	Posttraining Standard Deviation	Comment	t-Test t	p	Binominal Test p
Channel excursion			3/7 yes			0/7 yes			N.S.
Minimum distance to channel boundary (feet)	85.7	121.5	n=7	100.0	86.6	n=7	0.25	N.S.	
Course correction (deg) at 4 kts	17.6	11.6	n=7	10.9	3.3	n=7	N.A.		
Number of rudder orders prior to 300 heading change	8.6	4.0	n=6	4.7	2.7	n=7	2.026	.05	
Number of course orders prior to 300 heading change	3.2	3.5	n=6	1.9	1.1	n=7	N.A.		
Number of engine orders prior to 300 heading change	6.0	3.3	n=6	2.7	2.4	n=7	2.032	.11*	

*One-tailed test

N.S.: Non-significant

N.A.: Not appropriate due to lack of homogeneity of variances

mance measure, did not show a significant difference between the pretest and posttests, even though the frequency of excursions was reduced from three to zero as a result of the emergency shiphandling training. This lack of statistical significance is likely due to the small number of data points in this sample (i.e., five). This interpretation appears particularly appropriate in view of the significant results on the conservative measure of minimum distance to the channel boundary. This minimum distance was increased nearly three times between the pretest and posttest, demonstrating a substantial change in performance. None of the third-order performance measures were found to be significant for this group, even though their means all changed in the expected directions as a result of the training program.

Extensive Experience. Neither the primary or secondary performance measures were found to show a significant change as a result of Module II for

pilots with extensive experience (Table 8). It should be noted, however, that the number of channel excursions was reduced from three on the pretest to none on the posttest. This is similar to that found for the pilots with limited experience. The fact that this measure was significant overall, for both groups of pilots combined as discussed above, strongly suggests that the lack of significance for the nearly identical subgroups is due to sample size only.

Two of the four third-order performance measures were found to yield a significant change in performance. The number of rudder orders prior to the 30 degree heading change was reduced from 8.6 to 4.7 ($p \leq 0.05$). The number of engine orders during this period was reduced from 6.0 to 2.7 ($p \leq 0.10$). The significance of these results suggests that pilot behavior did change as a result of the training program, although this was not demonstrated in the bottom-line primary and secondary performance measures.

CHAPTER 4

DISCUSSION

The results obtained during this investigation yielded a number of significant changes in pilot performance and behavior as a result of the training program. These data may be interpreted in a number of ways. This section interprets the results in terms of the major issues under investigation, and reaches summary conclusions. The discussion is divided into four major subsections, the first three of which address the simulator data, and the fourth which addresses an analysis of the pilot opinion questionnaires. The subsections are: (1) effectiveness of simulator-based training for pilots, (2) pilot skill areas for which simulator-based training would be most effective, (3) the experience level of pilots most likely to benefit from simulator-based training, and (4) pilot opinions regarding the potential of simulator-based training.

4.1 TRAINING EFFECTIVENESS

The effectiveness of simulator-based training for pilots is the issue of primary concern to this investigation. The substantial number of performance measures that show a significant increase in pilot performance as a result of training for both modules strongly demonstrates the potential effectiveness of simulator-based training for pilots. Nine out of 12 performance measures across both modules showed significant gains in performance; the primary performance measures in both modules yielded a significant positive training gain.

Hence, it can be concluded that pilots may potentially benefit from simulator-based training.

This finding is extremely important. It should be cautioned, however, that this finding does not imply that all pilots can benefit from any form of simulator-based training. Rather, it shows the potential benefits that can accrue from appropriate training programs. The areas in which simulator-based training may be useful for pilots is discussed further below.

4.2 AREAS OF PILOT TRAINING

The analysis preceding the simulator training experiment identified several areas of pilot skill for which simulator-based training might be effective (see Chapter 2, Methodology). The Advanced Instrumentation and Emergency Shiphhandling areas were selected from the candidate set on the basis of their potential training effectiveness within the constraints imposed on this experiment. The overall gain in performance as a result of both Module I and Module II training programs, as discussed above regarding training effectiveness, demonstrates the potential of simulator-based training for both Advanced Instrumentation and Emergency Shiphhandling. Four of the six performance measures for the Advanced Instrumentation module and five of the six performance measures for the Emergency Shiphhandling module were found to show significant performance gains. Furthermore, not only were the gains significant, but the magnitude

of differences were substantial for most measures. Hence, it can be concluded that both Advanced Instrumentation and Emergency Shiphandling areas can be effectively addressed for pilots via simulator-based training programs.

The finding that effective training for pilots was achieved on each of the two training modules selected suggests that the highly structured investigative approach used for selection has a high degree of validity. That is, the two areas chosen for this experiment were selected from a larger group similarly identified, and thus to some extent are representative of the rationale that was used to select each of the potential areas. The strong positive findings in this experiment tend to verify the structured analysis process used, and thus further suggest that the other training areas similarly identified may also have good potential for training benefit from a simulator-based training approach.

A further discussion of the findings pertaining to each module of the training program is presented below.

Advanced Instrumentation

The benefits accrued as a result of the Advanced Instrumentation training module are shown in Figures 5 through 9. The performance objective of this module was to maintain a 1.0 nm radius through the turn, using available instrumentation (e.g., rate-of-turn indicator, doppler speed log, racon). Being able to maintain a perfect 1.0 nm radius using these instruments would provide the pilot with additional relevant information under conditions of reduced visibility (i.e., ownship position through the turn). Since these instruments are not commonly available on most ships or in most pilotage waters, they represented

an area of skill in which pilots could potentially gain from simulator-based training. The primary performance measure associated with maintaining a 1.0 nm radius is the summation of position errors from that ideal track through the turn; as discussed in the Methodology section, it is calculated on the basis of four data lines spaced throughout the turn. The ownship position throughout the constant radius turn was much more closely aligned with the ideal 1.0 nm radius of that turn as a result of the training program (Figure 5). The mean discrepancy, in terms of the summed deviations at the four data lines, was nearly halved as a result of the training program (734 feet versus 384 feet). It provides strong evidence for the effectiveness of simulator-based training in addressing advanced instrumentation aids for piloting. This increase in trackkeeping performance provided improved vessel navigation in terms of fixing ownship's position. It was achieved as a result of maintaining the vessel rate-of-turn more closely to the ideal (0.11 degrees per minute) for this turn; a corresponding improvement in the mean sum of differences between the actual rate-of-turn and the desired was achieved (Figure 6).

A direct benefit of maintaining a constant radius through the turn is that the distance to the channel boundary is maximized, placing ownship in an optimum position throughout the turn and minimizing the chance of an excursion beyond the channel boundary. The minimum distance to the channel boundary, which is a single point performance measure, should yield performance similar to the sum of distances off the 1.0 nm radius. That is, a larger minimum distance to the channel boundary should be obtained when the constant radius turn (i.e., in this case 1.0 nm) is best maintained. As

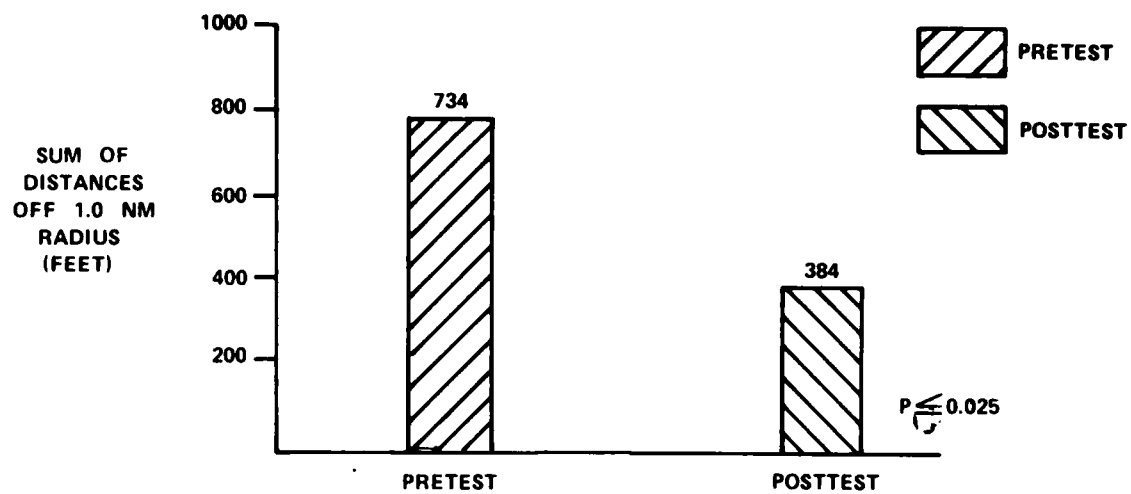


Figure 5. Module I Training Effectiveness -- Sum of Distance Off 1 nm Radius

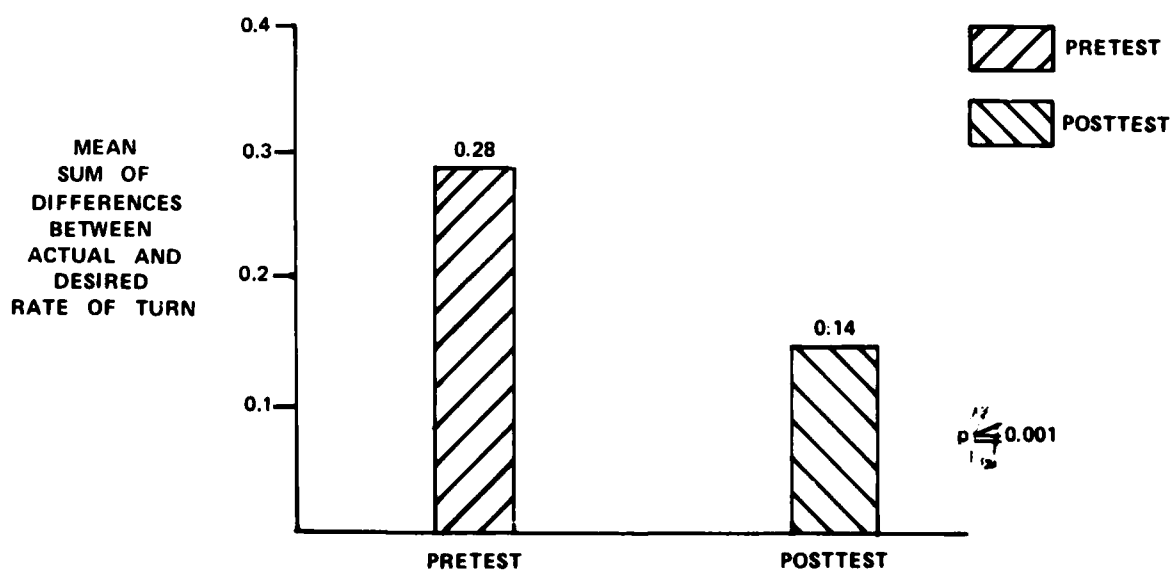


Figure 6. Module I Training Effectiveness -- Mean Sum of Differences Between Actual and Desired Rate-of-Turn

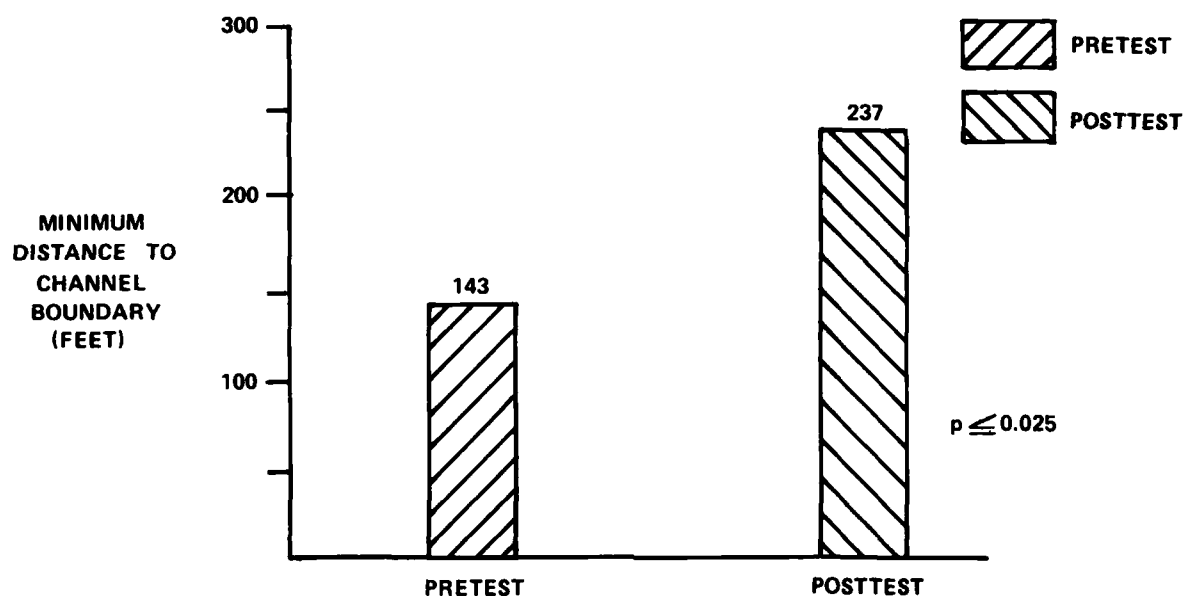


Figure 7. Module I Training Effectiveness -- Minimum Distance to Channel Boundary

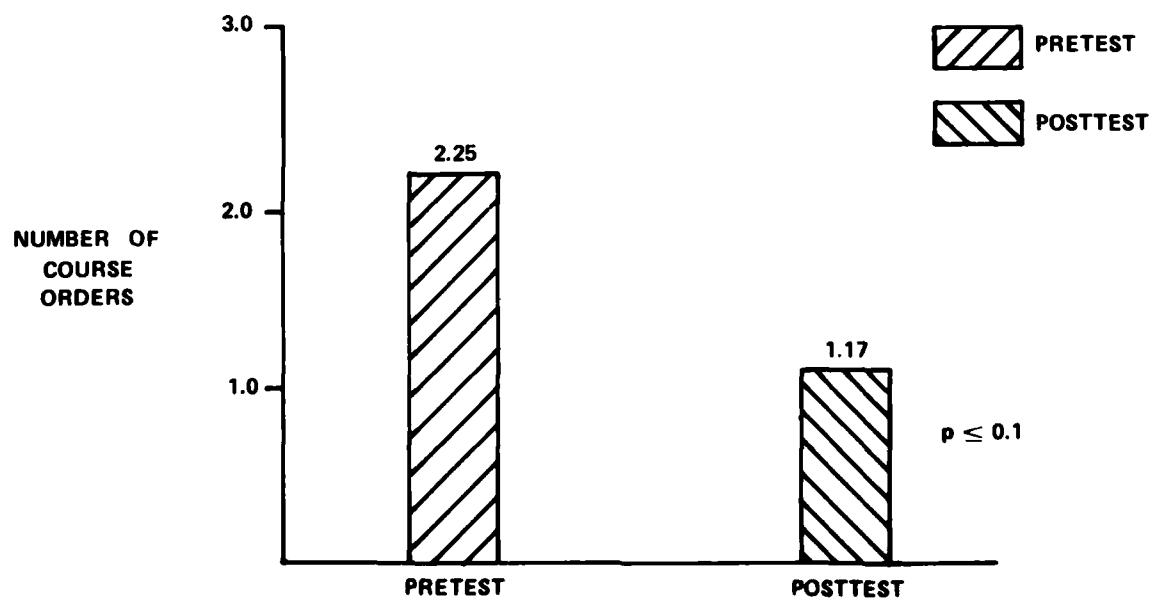


Figure 8. Module I Training Effectiveness -- Number of Course Orders

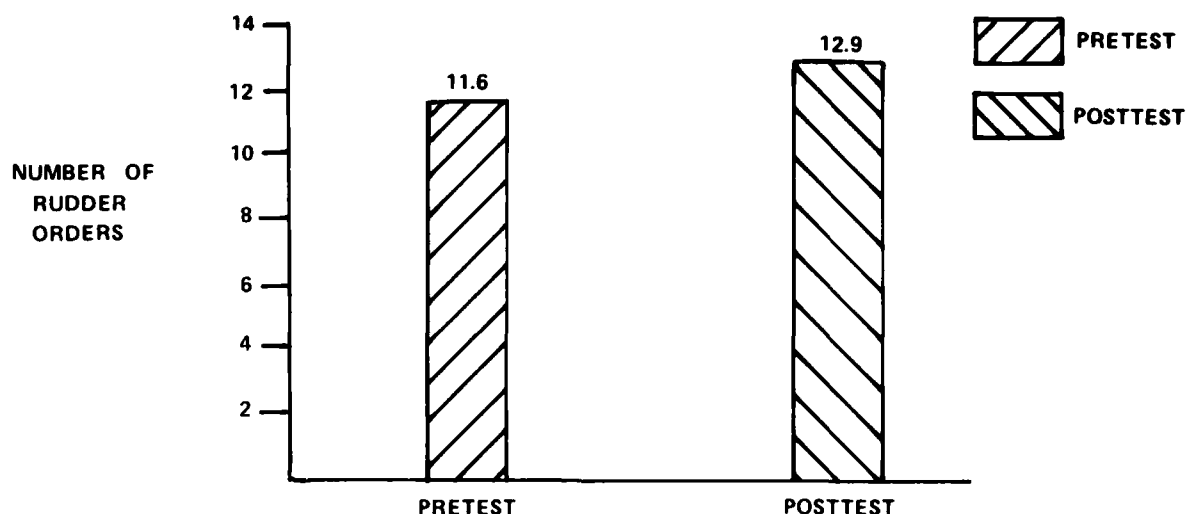


Figure 9. Module I Training Effectiveness -- Number of Rudder Orders

can be seen in Figure 7, the minimum distance to the channel boundary increased substantially as a result of training, similar to that which occurred for the sum of distances off the 1.0 nm radius. This finding further substantiates the potential of simulator-based training of pilots with regard to advanced instrumentation.

The technique used to achieve a constant rate-of-turn maneuver is sensitive to the initial ownship position when entering the turn, ownship speed, and maintenance of an optimum rate-of-turn configured for that particular turn. Course headings, typically, are not relevant in conducting this type of maneuver since the rate is sensitive to amount of rudder. Hence, course orders would be expected to decrease, and rudder orders would be expected to correspondingly increase. The results, although not conclusive in this regard, strongly suggest that these changes in behavior did occur. The mean number of course orders used to achieve the turn prior to the advanced instrumentation training was 2.25 (Figure 8). After the training

program was completed, the mean number of course orders used was reduced to 1.17. This halving of the number of course orders as a result of the training program was marginally significant ($p \leq 0.10$). This level of significance has been accepted in the past for this type of research, due to the relatively low power of the statistical tests resulting from the highly variable performance data usually obtained in this type of experiment. Variable in simulator training research data can result from several factors. However, it should be noted that a primary factor is usually the relatively small number of subjects used in order to minimize cost of the experiment. Based on the significance of the primary and secondary measures, therefore, the difference in course orders as a result of the training program is likely to be significant.

Conversely, the number of rudder orders was not found to differ significantly as a result of the training program, although the mean value did increase slightly (Figure 9). Nevertheless, the proportionate number of

rudder orders to course orders appears to have changed as expected, suggesting that the pilots modified their behavior in transiting the constant radius turn as a result of the simulator-based training program.

In summary, the Advanced Instrumentation training program resulted in changes in pilot behavior and performance as expected, achieving improvement in shiphandling performance pertaining to constant radius turn techniques. The empirical findings show that significant benefits for pilots may exist as a result of participation in simulator-based Advanced Instrumentation training.

Emergency Shiphandling

The simulator-based training program was found to be effective for the type of emergency shiphandling addressed during this program, as evidenced by the significant changes in performance summarized in Table 6. The bottom-line measure of shiphandling performance is the number of collisions, ramming, and groundings, and in terms of this experiment, the frequency of channel excursions. The turning around maneuver that was addressed in this module was believed to be quite difficult, to the extent that a significant potential for going beyond the channel boundaries existed. Hence, this became the primary performance measure. The significant difference in the number of channel excursions before and after the training (i.e., six excursions before, none afterwards) alone attests to the potential effectiveness of simulator-based training for this area of pilot skills. The number of other significant performance measures also showing a training gain (i.e., 3 of the remaining 5) further substantiates this finding. A summary of the findings pertaining to emergency shiphandling

are presented in Figures 10 through 13 and discussed below.

The six channel excursions resulting from the pretests shows the difficulty of turning a large vessel around in a relatively narrow channel. The absence of any channel excursions on the posttest demonstrates the effectiveness of simulator-based training in polishing the skills of experienced pilots. The turning around maneuver was accomplished by using a specific technique, which has been developed by Dutch pilots in the port of Rotterdam. The effectiveness of this relatively brief (only 8-hours long) training program attests to the potential effectiveness of simulator-based training for pilots, as well as the high-level of skills and knowledge possessed by the pilots participating in this experimental program. These pilots were able to rapidly learn and apply the Dutch technique in a difficult shiphandling situation. Commercial training programs would certainly spend considerably more time addressing and practicing appropriate emergency shiphandling, as do the Dutch pilots during their week long refresher training program at Wageningen.

The minimum distance to the channel boundary during the turn around maneuver was found to improve in direct correspondence to the number of channel excursions, increasing from 75 feet to 129 feet (Figure 10). This represents an increase of 72% as a result of the training program. Although the level of statistical significance of this increase is marginal ($p \leq 0.10$), the method of calculation together with the number of channel excursions suggest that the obtained level of statistical significance is a conservative estimate. The computed mean distances were based on the actual distance for each vessel that did not go beyond the channel boundaries,

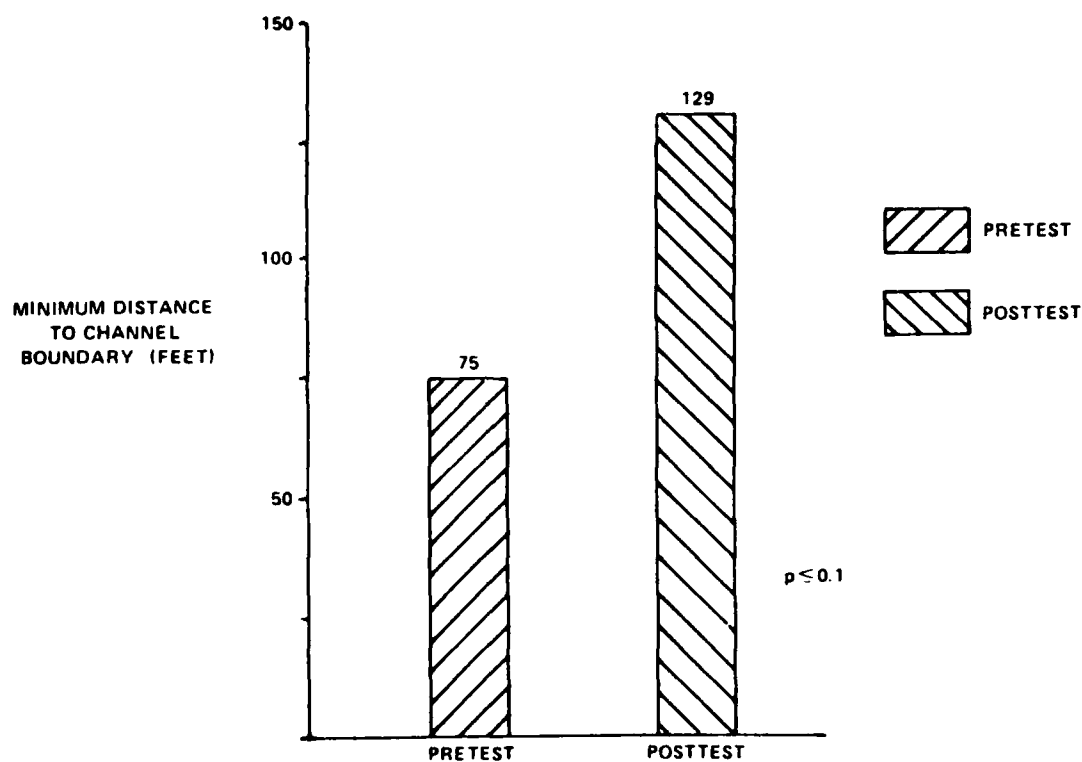


Figure 10. Module II Training Effectiveness -- Minimum Distance to Channel Boundary

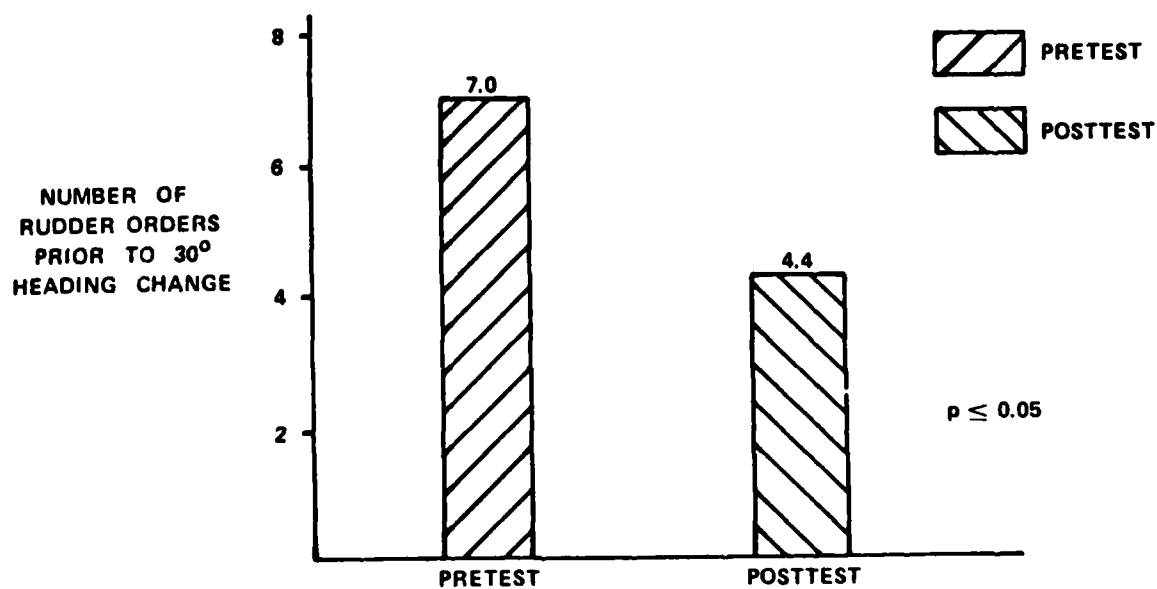


Figure 11. Module II Training Effectiveness -- Number of Rudder Orders

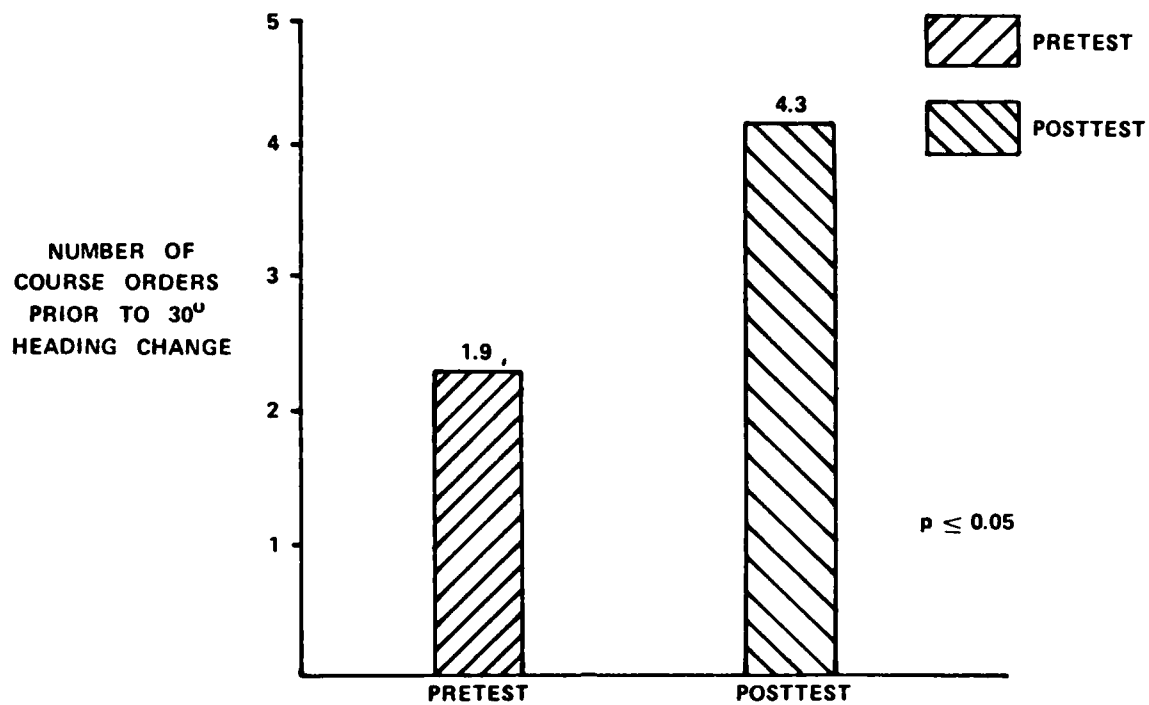


Figure 12. Module II Training Effectiveness -- Number of Course Orders

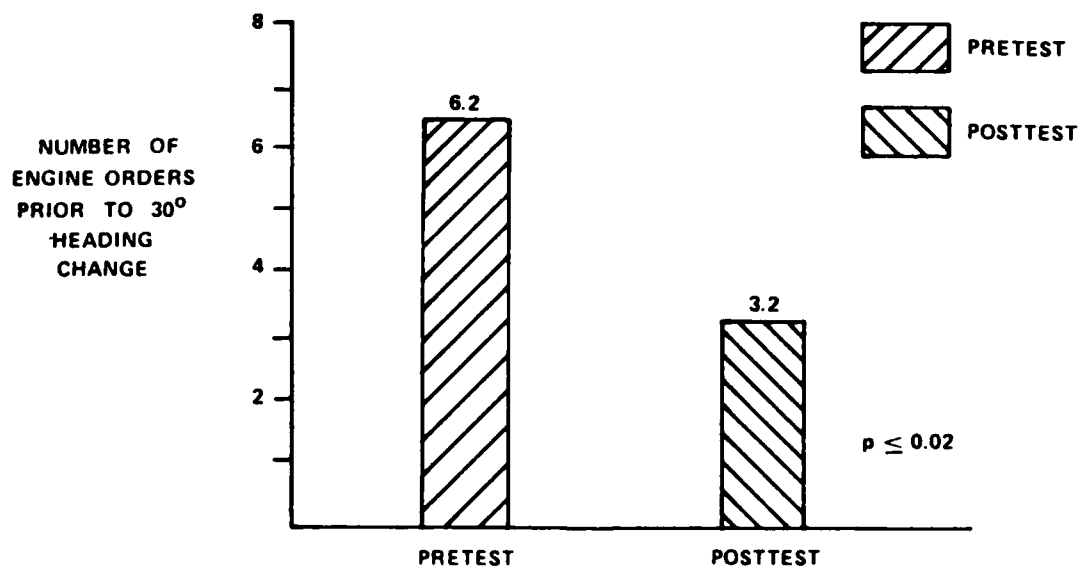


Figure 13. Module II Training Effectiveness -- Number of Engine Orders

and a value of "zero" for those vessels that went beyond the channel boundary. Thus, these mathematical computations included the ratios of distances for vessels staying within the channel, while adding only a zero (i.e., rather than a negative value) for those that went outside the channel. The resulting performance measure, therefore, is weighted in favor of providing a within-channel value. Hence, the difference between pretest and posttest performance as calculated for this measure would be conservative. This marginally significant result should thus be interpreted as definitely significant. The simulator was found to be an effective medium for training emergency shiphandling techniques to pilots.

The turning around technique developed by the Dutch places considerable emphasis on the early stages of the turning around process. During the early period the speed of the vessel should be reduced and the vessel's heading changed appropriately in correspondence with the procedure outlined in Table 2. A 30 degree heading change with respect to the channel centerline was chosen in this experiment to represent the point at which the early stages of the turn around maneuver were concluded. This was used as a reference datum for evaluating performance. The turning around technique relies on a difference between the shipheading and the channel centerline's course in correspondence with the current's magnitude and direction, and ownship speed. Hence, it was expected that the number of rudder orders given would decrease, and the number of course orders would conversely increase, as a result of the training program. The number of rudder orders issued prior to a 30 degree heading change was significantly reduced as a result of the training program, from 7.0 on the pretest to 4.4

on the posttest (Figure 11). Correspondingly, the number of course orders were significantly increased from 2.2 on the pretest to 4.1 on the posttest (Figure 12). These findings are consistent with the Dutch technique employed, and as expected. They provide the rationale for improved pilot performance in turning the large vessel around in a narrow channel, in terms of changes in pilot shiphandling behavior during that maneuver.

The early stages of the Dutch turning around technique focus on balancing the ship's cross channel velocity vector with that of the current, and hence require the pilot to modify the ship's heading as a result of changes in ownships speed. As the speed decreases, greater heading changes are made to counter balance the current, and thus to ideally keep the center of ownship in the center of the channel (note, course would ideally remain along the channel centerline). If sufficient distance ahead is available, little if any use of the engine during these early stages is necessary. Rather, the engine is stopped, and as the ship's speed falls off over time course corrections are made to counter balance the current. It was expected, therefore, that the training program would result in fewer engine orders during the early stages of the turn around maneuver. A significant reduction in the number of engine orders given was, in fact, obtained (Figure 13). The mean number of engine orders dropped from 2.25 prior to the training program to 1.17 following the training program. This finding further describes the changes in pilot behavior that led to improved turning around performance.

In summary, the Emergency Shiphandling training module was found to be effective. Significantly fewer channel excursions occurred after the training

program, with the pilots using correspondingly less of the channel width to turn the vessel around. These emergency shiphandling performance improvements were directly related to observed changes in pilot behavior as a result of the training program.

4.3 LEVEL OF EXPERIENCE

The third major issue addressed by this experiment is the difference in the effectiveness of simulator-based training for different groups of pilots. The experiment investigated pilots with limited experience (i.e., less than 5-years) and pilots with extensive experience (i.e., greater than 10-years). These two categories of pilot experience, although appearing straightforward, are actually somewhat complex. The differences in entry qualifications and training programs for the various pilot organizations make it difficult to categorize the amount of experience a pilot has. For example, some pilots enter the piloting profession after having had a considerable amount of experience as a deck officer (i.e., on a sea-going vessel, a tug boat, etc.). Although these individuals may have had only limited experience as a pilot since joining the pilot organization, they may have had considerable experience as deck officers and in working with pilots. Other pilot organizations, at the opposite extreme, do not have any prerequisite experience requirements for entering the piloting profession. These organizations, however, typically have a very extensive training program spanning a number of years. The pilot/subjects within both the limited and extensive experienced groups represented both types of backgrounds, although they all met the established criteria for years experience as a licensed pilot within their assigned groups. As a result, these classifi-

cations should be viewed as approximate.

The analysis investigated each of the two pilot experience groups independently, with regard to each of the two training modules. Particular caution should be exercised in interpreting the findings relating to experience, since relatively small sample sizes were used in each group. The results are discussed below regarding Advanced Instrumentation and Emergency Shiphandling.

Advanced Instrumentation

The pilots with extensive experience appear to have benefited more from the Advanced Instrumentation training than did those with limited experience. The differences in training effectiveness for the two groups are reflected in the three performance measures presented in Figures 14 through 19. The track radius error showed a significant positive training gain for the extensive experience group, while a similar result was not obtained for the limited experience group (Figure 14). This finding demonstrates that the Advanced Instrumentation training program was effective for the experienced group of pilots. The lack of a significant finding on this measure for the limited experience group does not show that the training was ineffective; rather, it indicates that the data were insufficient to demonstrate an effective gain. It should be noted that the limited experience group did achieve a relatively large difference in performance (i.e., 626.5 feet on the pretest versus 447.2 feet on the posttest), even though it was not found to be statistically significant. This lack of statistical significance may be due to the power of the test, resulting from the relatively small sample size. A relatively small

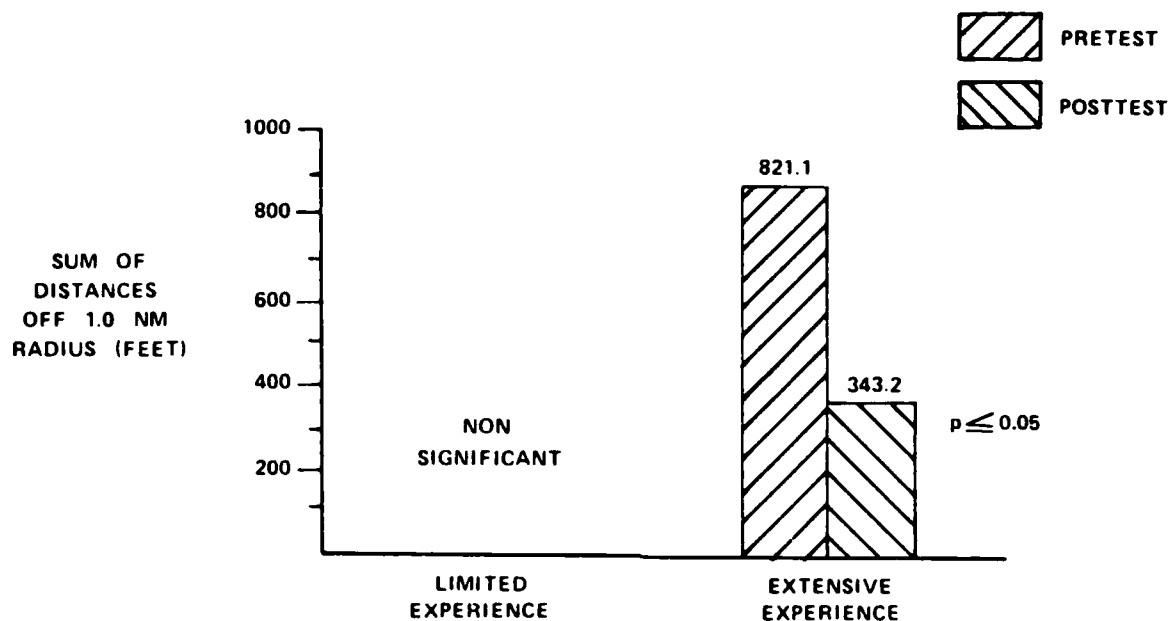


Figure 14. Level of Experience, Module I --
Sum of Differences off 1.0 nm Radius

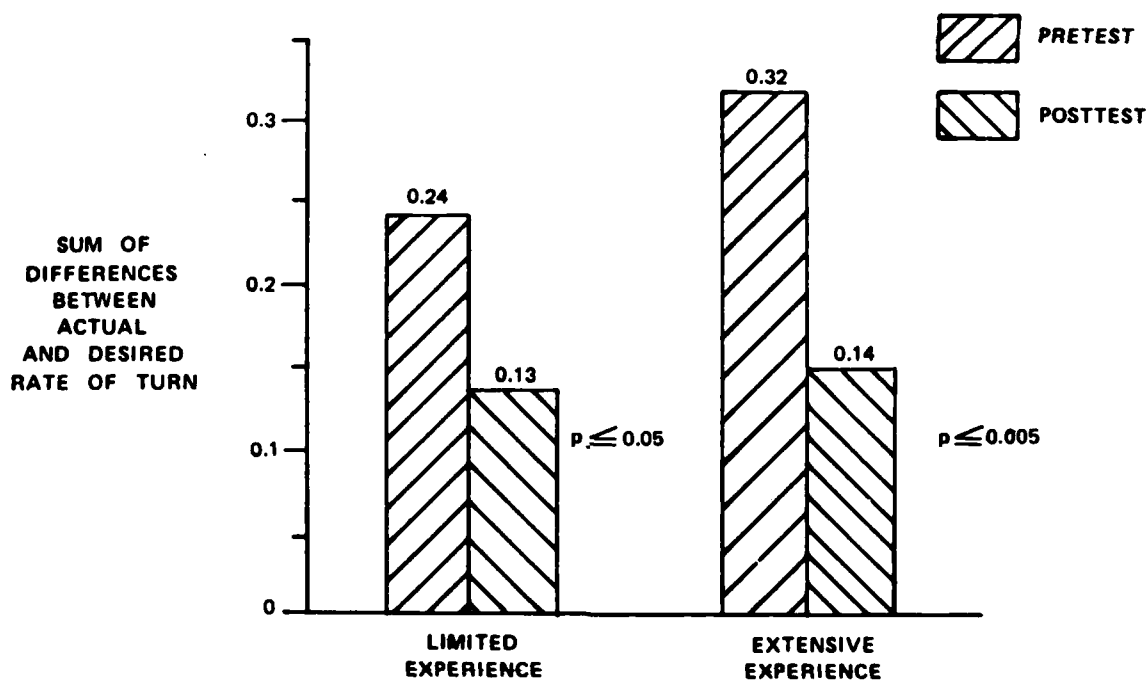


Figure 15. Level of Experience, Module I --
Sum of Differences Between Actual and Desired Rate-of-Turn

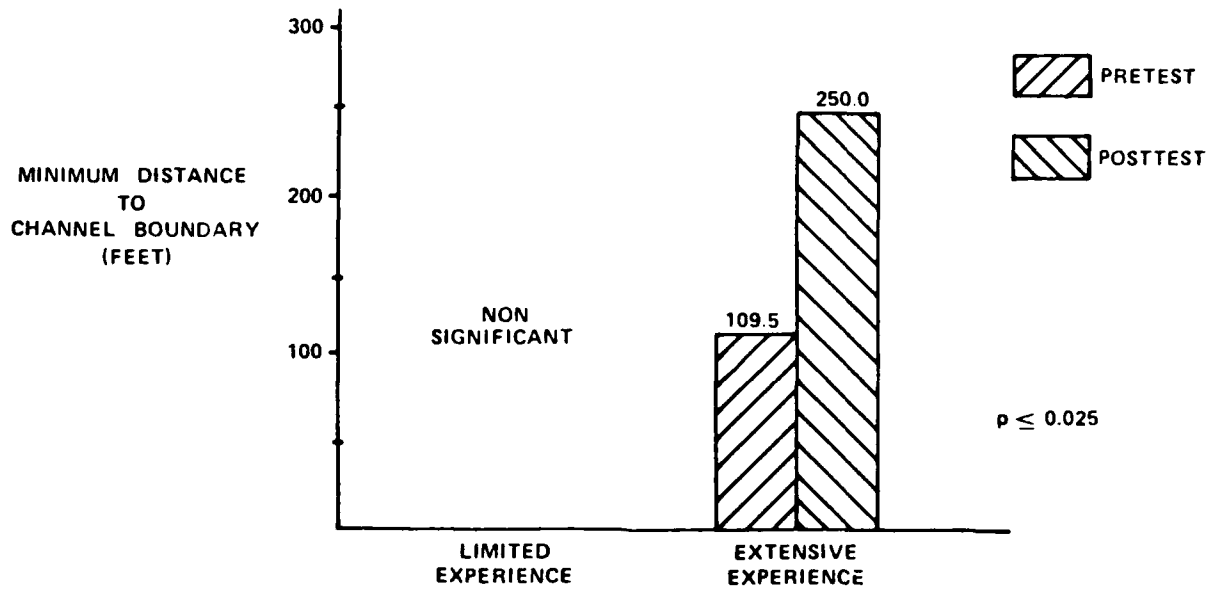


Figure 16. Level of Experience, Module I -- Minimum Distance to Channel Boundary

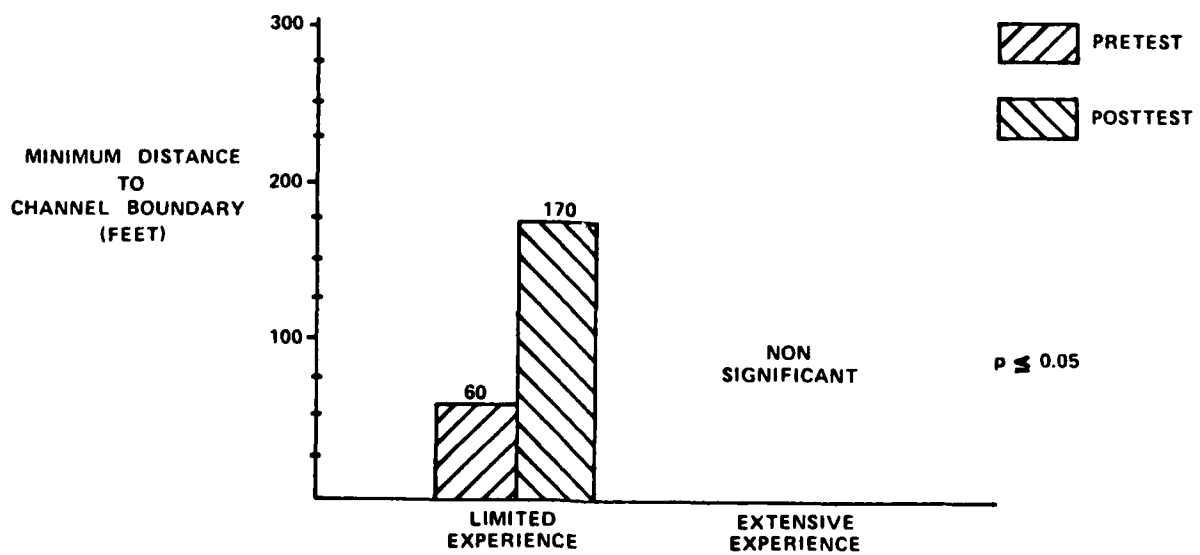


Figure 17. Level of Experience, Module II -- Minimum Distance to Channel Boundary

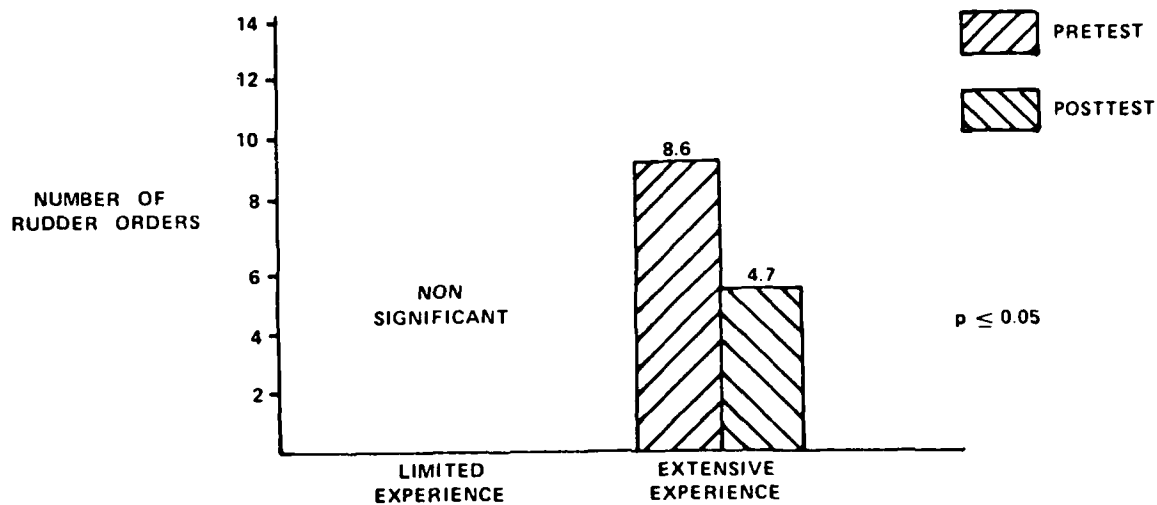


Figure 18. Level of Experience, Module II -- Number of Rudder Orders

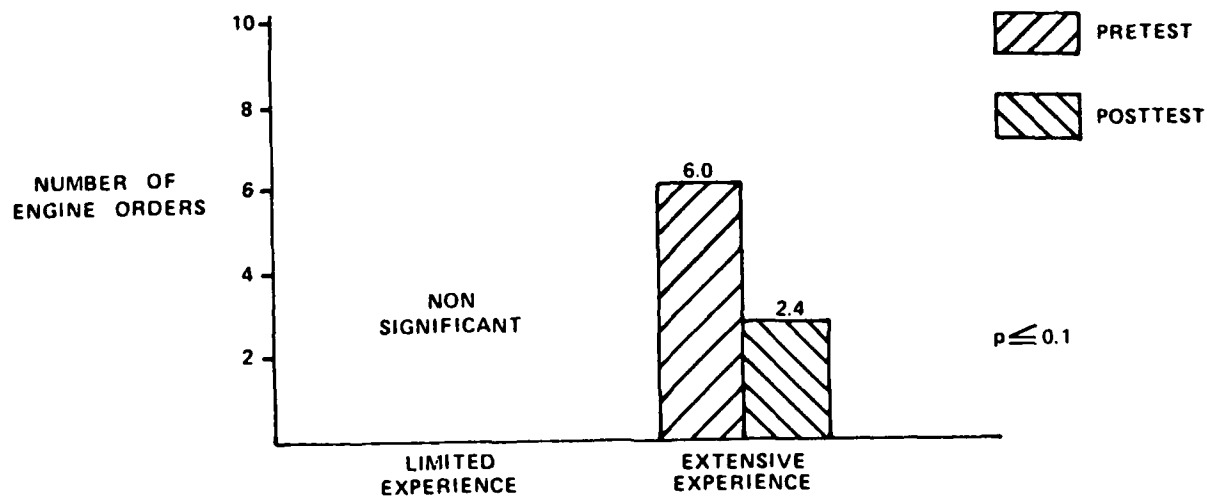


Figure 19. Level of Experience, Module II -- Number of Engine Orders

number of pilot/subjects were used in this condition due to cost and experimental design considerations. This results in relatively low statistical power for these types of real-world experiments, and greatly increases the chances of not obtaining statistically significant results even though they do exist.

Both groups of pilots achieved a significant positive training gain in the rate-of-turn error, a secondary performance measure (Figure 15). These results support the above contention that the training program was effective for both groups, and that the lack of significance of the substantial track radius error reduction was due to the power of the statistical analysis.

The minimum distance to the channel boundary was found to be significant for the extensive experience group, but not for the limited experience group (Figure 16). The mean minimum distance to the channel boundary did not change appreciably for the limited experienced group, hence the lack of statistical significance. This finding supports the above contention that the extensive experience group benefited more from the Advanced Instrumentation module than did the limited experience group.

In summary, the experimental results indicate that both groups of pilots benefited from the Advanced Instrumentation training module. The extensive experience group, however, was found to benefit more from this training than the limited experience group. The reasons for this difference are not apparent from the data collected.

Emergency Shiphandling

The training benefits of the Emergency Shiphandling module for the two pilot

groups appear somewhat opposite to those found for the advanced instrumentation module. The pilots with limited experience appear to have benefited greater from this module than did those with extensive experience. The primary performance measure, frequency of channel excursions, did not show a significant difference for either group separately as a result of the training program. Since this measure was found to be statistically significant with both groups combined, it can therefore be concluded that the lack of significance for either group when separated is due to the small number of pilots in each group and the resultant low statistical power.

The limited experience pilots significantly improved their minimum distance to the channel boundary as a result of the training program (Figure 17). This measure is closely related to the number of channel excursions. This group of pilots on the posttest nearly tripled their pretest minimum distance to the channel boundary (i.e., 60 feet to 170 feet). The pilots with extensive experience, on the other hand, achieved a relatively small increase in the minimum distance to the channel boundary (86 feet to 100 feet), which was not statistically significant. It is concluded on the basis of these findings that the pilots with limited experience benefited more from the Emergency Shiphandling module than did the pilots with extensive experience.

The extensive experience pilots did, interestingly, change their behavior as a result of this Emergency Shiphandling module, although it was not reflected in a statistically significant change in vessel performance. The number of rudder orders and the number of engine orders used by this group was significantly reduced as a result of the emergency shiphandling

training (Figures 18 and 19). These findings are in direct correspondence with those for the total group of pilots, as discussed previously; and they are in the direction expected. These findings suggest that the technique used to achieve the vessel turn around by the extensive experience group of pilots changed as a result of the training program. Their level of activity reduced considerably in terms of both rudder orders and engine orders. Furthermore, it should be noted that although a significant difference in the distance to the channel boundary was not achieved, the mean difference that did occur was in the positive, rather than negative, training gain direction. Hence, as a result of these significant changes in behavior, it is concluded that the pilots with extensive experience also showed training gain as a result of this module.

In summary, the above findings suggest differences in the potential benefits to be accrued from simulator-based training on the basis of the pilot/student level of experience. Although both groups of pilots showed benefit from each of the two training modules, those with extensive experience appeared to gain more from the Advanced Instrumentation module, while those with limited experience appeared to gain more from the Emergency Ship-handling. The findings are not strong with regard to the differences between the groups, probably a result of the small sample size used. Furthermore, the pilots in both groups, although technically fitting into the respective categories, differ substantially in their backgrounds. Hence, a conclusion cannot be reached as to which groups of pilots will definitely benefit more from either the Advanced Instrumentation or the Emergency Ship-handling training. On the other hand, the number of differences found be-

tween the two groups strongly suggests, as was expected, that the benefits to be derived from the different areas of simulator-based training of pilots will depend on their backgrounds, such as level of experience. This finding was not unexpected, since the benefits to be derived from any training program depend heavily on the backgrounds of the particular students. Hence, it is likely that apprentice pilots, limited experienced pilots, and extensively experienced pilots will derive differential benefits from the simulator-based training in the various areas of piloting skill. The extent of benefits to be achieved from such training by these groups, however, cannot be determined on the basis of these data.

4.4 PILOT OPINIONS

Pilots in the United States have received relatively little exposure to simulator-based training programs. Pilots have participated in simulator experiments, but these are substantially different than a structured training program designed specifically to address the improvement of piloting skills. A broad range of opinion exists in the piloting community regarding the potential effectiveness of simulator-based training. An important part of the empirical data collected as a part of this experiment, therefore, was the opinion of pilots with regard to the potential of simulator-based training as a result of their having participated in a structured training program. For that reason, the pilots participating in this experiment were viewed not only as subjects, but also as evaluators. Discussions concerning the various aspects of the training program were carried out during the free moments of the course. In addition, a debriefing questionnaire was administered to each pilot individually at the conclusion

of the training program. The intent was to collect as much information as possible regarding the pilots' view points, insights, recommendations, etc.

A production training facility would normally modify various aspects of the program (i.e., including simulator, modules, etc.) after each time the course is presented, on the basis of inputs from instructors and students. This, of course, is the approach the Rotterdam pilots followed after first instituting simulator-based training. For example, the Dutch spent approximately two years in refining the hydrodynamic characteristics of the ship models they were using, to make them acceptable to the pilots. Due to the experimental nature of the training program used in this investigation, it remained the same for the three times it was presented (i.e., thus maintaining the necessary degree of experimental constancy across the three groups). The information summarized herein provides an overview of the pilots' observations and opinions.

The questionnaire analysis and discussion is presented below in two parts. The first part provides a summary of the questionnaire data, with regard to the specific issues being addressed. The second part focuses on the larger issues of interest to this investigation (i.e., potential of simulator-based training for pilots), integrating the questions and responses as appropriate.

Questionnaire Summary

The questionnaire addressed a variety of issues pertinent to the investigation, including (1) benefits gained from each of the three training modules; (2) the potential for pilot training regarding each of the three modules; (3) problems and recommended improvements for each of the three

modules; and (4) the general potential of simulator-based training for pilots. Sixteen of the 34 questions address the general value and potential of simulator-based training for pilots. These are the issues of primary concern to this investigation, and are discussed in detail. The remaining questions address specific details of the particular experimental training program provided. These details are of substantial importance from the standpoint of designing and conducting pilot training. A brief overview of these is provided. If the training program material developed for this investigation were to be used to provide additional training to pilots, these latter observations would be extremely important to the improvement of that program. All of the information collected from this questionnaire has been carefully analyzed with regard to the development of the training system guidelines for pilots which is a separate document being developed under this project.

The methodology for administration of the questionnaire was presented previously in the methodology section. It should be recalled that the questionnaires were filled out by an analyst during a debriefing session with each individual pilot at the completion of the week's training program and experiment. The views expressed by the pilots in the questionnaire reflect not only their experiences as students/evaluators in the training program, but also as evaluators who spent considerable time discussing simulator-based training issues.

A summary of the specific responses of the pilots to the 16 primary questions addressing the value and potential of simulator-based training is presented in Table 9. The questions and responses are grouped according to each of the three training modules and a

TABLE 9. PILOT QUESTIONNAIRE SUMMARY DATA FOR SELECTION QUESTIONS*

Question**	Responses
Advanced Instrumentation 1. Module rating (1 → 10 highest) 5. Learned something valuable? 7. Valuable for apprentices? 8. Valuable for experienced pilots, periodically?	7.58/10 (mean value) 11/12 (yes) 11/12 (yes) 11/12 (yes)
Emergency Shiphandling 11. Module rating (1 → 10 highest) 12. Is this valuable? 14. Valuable for apprentices? 15. Valuable for experienced pilots, periodically?	6.58/10 (mean value) 11/12 (yes) 11/12 (yes) 9/12 (yes)
Decisionmaking 19. Module rating (1 → 10 highest) 20. Learned something valuable? 22. Valuable for apprentices? 23. Valuable for limited experience pilots? 24. Valuable for experienced pilots, periodically?	6.29/10 (mean value) (8 pilots) 3/8 (yes) 7/8 (yes) 8/8 (yes) 3/8 (yes)
General 27. Simulator potential for apprentices? 28. Simulator potential for licensed pilots? 32. Beneficial training in generic port?	11/12 (yes) 11/12 (yes) 11/12 (yes)

*The subset of questions pertaining to the value and potential of simulator-based training.

**Question number and brief description, from debriefing questionnaire (Appendix A).

general category. All of the pilots participated in the Advanced Instrumentation and Emergency Shiphandling training modules. Eight of the 12 pilots were able to partially participate in the decisionmaking training module, while one group of four pilots were unable to participate in this module due to simulator problems. Hence, the questionnaire data pertaining to this module is not considered to be of the same quality as that of the first two modules.

A substantial number of specific issues were raised by the pilots regarding many of the questions. These issues dealt with qualifications to their answers, generally regarding (1) conditions under which their answers would be given one way or another (i.e., yes versus no); and (2) policy issues pertaining to how such training would come about. Several examples of caveats expressed by pilots are:

- The piloting problems and instruments addressed should be specific to each pilot's port area.
- The instrumentation addressed should represent a real break through, rather than commonly available instruments.
- The emergency shiphandling techniques addressed should represent new techniques, rather than techniques with which the pilots have experience.
- Although the content of simulator-based training has good potential, its actual value would depend on local availability and cost.
- Simulator-based training would not be an acceptable substitute for aspects of current pilot training programs; rather, its value is as a supplement to current programs to

further enhance pilot skills. The use of simulator-based training should be voluntary, rather than mandatory.

The final two points in this list were expressed by most pilots. They strongly approve of their current training programs, but do feel that value may be had from simulator-based training as discussed below. They further feel that the positive benefits to be potentially gained from such training would be negated if it were forced upon them. The pilots believe that the need for simulator-based training and its potential value is a local port issue, depending on a variety of factors (e.g., current training program, port characteristics, issues to be addressed by simulator-based training, individual pilot backgrounds, and so on). When simulator-based training is provided it should be tailored to the needs of a particular port. The final issue is the financing for such training. The use of simulator-based training by pilots will directly depend on the cost of such training, and the available financing.

Training Program Value and Potential

The questions addressing the value and potential of simulator-based training were generally concerned with: (1) the value of that module as experienced by the pilots; (2) the pilots' perceived value of that module for apprentice training; and (3) the pilots' perceived value of that module for periodic refresher training of licensed pilots. The responses to these issues are presented in Table 9.

Advanced Instrumentation. The Advanced Instrumentation module was evaluated by the pilots as having value as conducted, and as having potential for both apprentices and

experienced pilots. The pilot ratings of this course had a mean value of 7.58 out of a possible 10 points. This above average rating reflects the value of the Advanced Instrumentation module as presented. Each of the training modules, as noted previously, can and should be improved as a result of each application. The ratings given to this and the other two modules reflect the initial presentation of each; improvements could certainly be made as a result of the pilots recommendations and the staff recommendations stemming from this initial conduct of the training program. The high proportion (i.e., 11/12) indicating something of value was learned from this module further substantiates the rating. Of greater importance to this investigation, however, is the potential for such training. A very high proportion of the pilots stated that the Advanced Instrumentation type of training had some value for both apprentices and experienced pilots (i.e., 11/12 and 12/12 respectively). These opinions are in good correspondence with the performance data collected regarding the training effectiveness of the Advanced Instrumentation module.

The piloting skills and knowledge addressed under the Advanced Instrumentation module are not in common practice in most ports, and hence were believed to have potential training value. The findings, both performance and opinion data, substantiate that Advanced Instrumentation training does have value and potential. It should be cautioned, however as noted above, that these findings pertain to the general potential of such training. As several of the pilots stated, the relevancy of Advanced Instrumentation training, and hence the benefits to be had by any particular group of pilots, will depend on the degree of experience the pilots have had with the par-

ticular instruments, the local conditions in their particular ports (e.g., availability of racons), and so on. These findings demonstrate the potential value of Advanced Instrumentation simulator-based training; they do not address the specific value of this type of training for any particular port or group of pilots. The specific value would, of course, depend on the particular aspects of Advanced Instrumentation addressed, as well as the pilot and port characteristics.

Emergency Shiphhandling. The pilot opinions regarding the value and potential of the Emergency Shiphhandling module were similar to those of the Advanced Instrumentation module. The mean rating given to the module as taught was 6.58 out of a possible 10 points (see Table 9). This above average value is supported by the high proportion that indicated they learned something valuable from the emergency shiphhandling module (i.e., 11 out of 12 pilots). A high proportion of the pilots felt that this type of training would be of value for apprentices (11 out of 12), while two-thirds of (9 out of 12) indicated that periodic Emergency Shiphhandling training would be of value for licensed pilots. This is the type of training that the Rotterdam/Europort pilots participate in every two years.

On the basis of the questionnaire responses it can be concluded that pilots believe simulator-based Emergency Shiphhandling training has value for both apprentices and experienced pilots. This conclusion corresponds well with the performance data from the training program, which demonstrated an improvement in Emergency Shiphhandling skills as a result of the training. Of the three pilots that felt the Emergency Shiphhandling training would not be of value to experienced pilots, one said it was because

the techniques were not new to him; another stated it would depend on the situation addressed. If the appropriate issues are addressed during this module, therefore, the proportion of pilots supporting Emergency Ship-handling for licensed pilots would be similar to that supporting the Advanced Instrumentation training.

Decisionmaking. The pilot opinions regarding the Decisionmaking module were found to differ from those of the previous two modules. A difference of opinion was expected, since it was believed that the Decisionmaking module would be most appropriate for pilots with limited experience, and perhaps also for apprentice pilots. Furthermore, only one group of pilots completed the Decisionmaking module; a second group of pilots completed the majority of the Decisionmaking module, while the third group of pilots did not participate at all in this module. Simulator problems caused this discrepant application of the third module. It is likely, therefore, that the pilot opinions expressed regarding this module are affected by the manner in which it was presented during the program.

The rating given to the Decisionmaking module by the pilots had a mean value of 6.29 out of a possible 10 points. Eight pilots answered the questions regarding this module. Although this rating is above five on a scale of one to ten, it is also the lowest of the three modules. Only three of the eight pilots felt that they had learned something valuable from this module. On the other hand, a high proportion of the pilots felt that this type of training would be of value for apprentice pilots (i.e., seven out of eight pilots), and virtually all of the pilots felt it would be of value to pilots with limited experience (i.e., eight of eight). On

the other hand, the pilots generally felt that the Decisionmaking module would not be of benefit as refresher training for experienced pilots (i.e., three out of eight pilots felt it would be of benefit). Hence, it can be concluded on the basis of the pilots opinions that the Decisionmaking module has potential value for the training of apprentices and pilots with limited experience. It is not believed to have very much benefit for the training of experienced pilots. These findings cannot be further substantiated with empirically derived data, since the data were not available from the experiment. Furthermore, the findings regarding this module should be treated cautiously due to the relatively small sample size (i.e., eight pilots) and the difficulties encountered in conducting this training.

General Potential. Responses to the three major questions pertaining to the general potential of simulator-based training for pilots (i.e., questions 27, 28 and 32) are included in Table 9. These questions addressed the potential of such training for apprentices and licensed pilots, and also addressed the potential of conducting such training in a generic port data base. Whereas the preceding questions addressed the specific modules presented during the training program and the potential for similar modules in a production training program, these latter questions addressed the broad issue of simulator-based training without regard to any particular modules. A large proportion of the pilots (i.e., 11 out of 12) felt that simulator-based training had potential for both apprentices and licensed pilots. As noted above, however, this statement should be interpreted cautiously. The pilots had many specific concerns regarding the effective application of simulator-

based training, several examples of which have been presented earlier in this subsection. Hence, their support for such training in general should be viewed to indicate that the potential is good if it is used appropriately.

The geographic data base used during this experiment was that of a generic port, Lotsedorf. The characteristics of this port were specifically developed to create the desired training encounter situations; to enable the conduct of a structured training program, and to enable the collection of desired empirical data. It should be noted that this port was not developed to be fully representative of the range of piloting conditions likely to be encountered by the participating pilots in their respective pilot regions, and certainly is not representative. Nevertheless, the Lotsedorf port was believed to embody sufficient characteristics as part of this experimental training program to be representative of the generic port concept for pilot training. The simulator-based training of pilots in their own port data base would certainly have value beyond that of a generic data base, although the latter was also believed to have significant value for training pilots. The costs associated with developing a large number of specific port data bases to train various groups of pilots would likely be prohibitive, thus making the generic port concept an attractive alternative. Furthermore, for the purposes of this experiment pilots from a variety of ports were brought together, this also necessitated a generic port data base. Most of the pilots (11 out of 12) supported the use of a generic data base for the training of both apprentice and experienced pilots. It should be noted, however, that several pilots were critical of the training program's partial focusing on issues that are not

of current relevance in their respective port areas. For example, several pilots expressed disinterest in learning about the use of racons since these devices are not currently available in their port area. Operational training programs, using a generic port data base, should certainly focus on those issues of local interest to the pilots being trained. The opinion was generally expressed that the generic port concept is good if that generic port has characteristics (e.g., bank effects; racons; etc.) that are relevant to the particular pilot's port. Hence, valuable training could be provided in the generic port context, when addressing issues of local concern. This finding suggests that a single well-developed generic port data base may be adequate for effective training use by most pilots, substantially reducing the potential cost of such training.

Specific Training Program Content

A variety of comments and recommendations were made by the pilots regarding the specific content of the experimental training program conducted at CAORF. The detailed response data are contained in Appendix A. Several specific findings are discussed below.

Advanced Instrumentation. The Advanced Instrumentation module, as noted earlier, was generally well received. Several pilots indicated they felt it had the greatest potential for simulator-based training. Several pilots stated that the length of this module, as conducted, was insufficient. This is certainly likely to be the case, since the module was developed to address a relatively large amount of material in a brief period of time, due to experimental considerations. A production training module that would address advanced instrumentation should probably span a

considerably longer period of time. Pilot comments regarding insufficient length addressed both the classroom and the simulator sessions. Additional comments about this module were:

- Several pilots criticized the module as not addressing issues that are directly pertinent to their port (e.g., racons are unavailable in their port).
- Improvements to the course recommended by the pilots included: (1) bringing the ship all the way into the port at once, as opposed to doing it in segments; (2) providing more situation-type of experiences, as opposed to the more sterile practice exercises that were addressed; (3) providing more practice time; (4) providing more difficult scenarios; and (5) providing more port-specific problems (i.e., not geography specific, but conditions more specific to their local ports).
- The pilots recommended additional areas of Advanced Instrumentation that simulator-based training might address: (1) advanced portable electronic navigation aids, such as the Portable LORAN Assist Device (PLAD); (2) advanced radar plotting aids (ARPA); (3) bow thruster indicator; (4) controllable pitch propeller; (5) portable fathometer; (6) advanced radar techniques; (7) radio direction finder; and (8) use of Advanced Instrumentation with bank effects.

Emergency Shiphandling. Most pilots generally felt that the Emergency Shiphandling module was worthwhile as conducted and that the Dutch turning around technique was useful. Several pilots, however, expressed the opinion that the particular turning around

technique addressed was either not their concept of Emergency Shiphandling, unrealistically easy, or too clinical. Several pilots felt very strongly about the value of simulator-based Emergency Shiphandling training, both in the form provided during this program, as well as with regard to other aspects of Emergency Shiphandling not addressed by this program. Several pilots suggested that this is the major area of potential benefit for the simulator-based training of pilots. Several comments regarding this module included:

- The simulator provides a safe situation for developing skills and trying new techniques.
- More time should be spent on the bridge, rather than in the classroom; the converse was also cited.
- Several pilots felt the program length was about right, while others felt it should be expanded to address other types of emergency situations.
- Several pilots felt that the turning around technique took too much time; they would like to see more rapid and varied situations.
- The ship's handling characteristics, as modeled, were generally felt to be too good for developing the emergency shiphandling skills addressed.
- Several course improvements were recommended: (1) both shorter and longer program lengths; (2) a wider variety of emergency situations, as well as exposure to a larger number of situations; (3) shorter duration situations; and (4) a range of associated conditions under which to

practice the maneuvering, such as poor visibility, a more narrow channel, more current, and time constraints.

- Additional areas of Emergency Ship-handling training that were recommended included: (1) comparison of average and poor handling ships in similar scenarios; (2) use of emergency anchoring; (3) addressing rudder failure conditions; (4) addressing power failure conditions; (5) creation of scenarios that require very quick thinking; (6) addressing crosscurrents with course changes; (7) addressing winds; (8) requiring anchoring in a short time; (9) addressing speed together with anchoring; (10) addressing bank effects; (11) addressing ship/ship interaction; (12) turning around in an anchorage; and (13) addressing fog onset with oncoming traffic.

Decisionmaking. The pilots had relatively poor experience with the Decisionmaking module due to the simulator problems. Nevertheless, a number of observations were made by eight of the pilots that had some experience with this module. They include the following:

- Several pilots felt this module was good, since it addressed specific situations in a realistic context.
 - The ownship handling characteristics were called out as being too good, and hence somewhat unrealistic.
 - Several pilots felt that this module should be combined with the emergency shiphandling module, such that the emergency training would be placed in the context of the situations that occurred in this module.
- More local problems were requested by several pilots.
 - The course improvements recommended included: (1) having only partial astern rpm available; (2) use of a poor handling vessel for ownship; (3) comparison of various ship types and handling characteristics; and (4) use of more situations that require stopping.
 - Additional areas of Decisionmaking that were recommended included: (1) mechanical breakdowns (engine, steering); (2) techniques for stopping the ship completely; (3) a situation with a small boat running across ownship's bow; (4) loose steering; (5) quartermaster error; (6) bank effects; (7) abrupt dives toward the bank, shoal, and dock; and (8) having a meeting ship lose power and/or steering.

The above observations provide a number of recommendations relevant to the further development of the three training modules addressed in the experimental training program. Commercial training establishments, as well as pilot groups, would benefit from the careful consideration of these comments with regard to the development of training programs for pilots.

Simulator-based Training Potential

The major issues of concern to this investigation have been: (1) the effectiveness of simulator-based training for pilots; (2) the pilot skill areas for which simulator-based training would be effective; and (3) the pilot experience levels for which simulator-based training would be effective. The empirically derived results agree well with the questionnaire results on each of these issues.

- The pilots participating in this experiment generally felt that simulator-based training does have potential for both experienced and apprentice pilots.
- The content of the training presented to pilots should address issues of local interest, although not necessarily in a local geographical context; that is, the particular issues, conditions, etc., should be of specific local interest, although the port could be generic.
- Different types of training should be provided to pilots of differing experience levels (e.g., apprentices, limited experienced pilots, extensively experienced pilots).
- The ship model characteristics (ship hydrodynamics, environmental hydrodynamics, etc.) are particularly critical, and require extensive validation/modification by pilots prior to training. Pilots are especially sensitive to the vessel model's handling characteristics. Furthermore, the pilots generally expect a poor handling ship in a simulator-based training program, since it represents the extreme set of conditions which they believe are more appropriate to such training.
- Pilots expressed an interest in having a large number of short runs, rather than several relatively long runs. Although this may be at variance with their actual experiences at-sea, it provides the pilots with an opportunity to explore a wide range of conditions and possible responses.
- The length of the training modules were generally considered to be too short. This was expected, as a

result of the cost/effective nature of constructing an experiment. The primary intention of this program was to generate as much useful information as possible from the experiment, necessitating allowance of only the minimum amount of time for the various piloting issues addressed during training. A commercial training program should spend considerably more time addressing the issues of each module.

- The pilots also indicated that the use of simulator-based training should be to augment their current training programs, and not simply be used in place of certain aspects of their current training. This statement should not be interpreted that present training programs are deficient; rather it indicates the healthy attitude of professionals seeking to improve the quality of their service.
- The generic data base was found to be generally well-accepted by the pilots, with specific comments citing the desire for port-specific training within a generic port data base if conducted in an appropriate manner.

In summary, the questionnaire opinions correspond very well with the experimental results. The empirical data unequivocally demonstrate that simulator-based training can be effective for pilots. Pilot observations confirm this finding, and support the potential effectiveness of such training. Pilot support of simulator-based training, based on the small sample size used during this investigation, was not unequivocal. Rather, it was highly qualified. Simulator-based training is supported as having potential by pilots, but only when properly used in direct correspondence to local conditions and issues, and with regard

to the particular pilot/trainee backgrounds. As one pilot implied, this experimental training program confirmed his belief that simulator-based

training does have potential for training pilots, and that it is still in the developmental stage.

CHAPTER 5

CONCLUSIONS

The major issues of interest to this investigation were: (1) the potential effectiveness of simulator-based training for pilots; (2) the pilot skill areas for which simulator-based training is potentially effective; and (3) the pilot experience levels for which simulator-based training would be effective. In addition to addressing these issues, this experiment has addressed additional secondary issues. Conclusions regarding each of these, as developed in the previous Results and Discussions sections, are provided below.

1. The findings of this experiment strongly demonstrate the potential effectiveness of simulator-based training for pilots. The empirical data showed substantial training gains for the pilots. This was supported by the observation of the pilots themselves, in which a high proportion felt that they had gained from this training program, and also felt that simulator-based training has potential for improving pilot skills. Both the empirical data and the pilot opinions are not unequivocal in this regard. They show strong support for simulator-based training, but do not indicate that all such training would be either desirable or effective. Rather, these findings indicate the potential for such training if conducted under the right conditions and conducted appropriately.
2. Simulator-based training is effective for addressing Advanced Instrumentation and Emergency Ship-handling piloting issues. This conclusion is based on the empirical data which showed both training modules to be effective, and on the opinions of the pilots which indicated the value and potential of these training modules.
3. Simulator-based training is expected to be effective for most of the additional training areas indicated in this investigation (see paragraph 2.1, Project Approach). This conclusion is reached on the basis of the correspondence between (1) the findings of the structured training analysis that identified the areas of piloting skill that appear to have potential for simulator-based training, (2) the strong training effectiveness findings for the two selected modules, (3) the opinions of the pilots supporting the two selected modules, and (4) the pilots' opinions regarding the potential of the third module for training apprentice and limited experienced pilots. The strong agreement regarding these issues supports the contention that similar results would likely pertain to the other potential areas for simulator-based training identified in paragraph 2.1.
4. Simulator-based training appears to have potential for apprentice pilots, licensed pilots with limited experience, and licensed

pilots with extensive experience. The particular aspects of piloting skills for which such training will be effective is likely to differ substantially for each of these groups. Both the empirical data and the opinions of the pilots indicate differential training effectiveness for different groups of pilots (i.e., extensive experience versus limited experience). Unfortunately, the empirical data are insufficient to identify the most appropriate areas of training for the different levels of pilot experience. Nevertheless, they do support the contention that the benefits to be gained from simulator-based training will vary for each group of pilots with regard to the particular shiphandling skills addressed.

5. The effectiveness of simulator-based training is likely to be heavily dependent on the particular piloting issues associated with each port, and on the specific backgrounds of the individual pilots. This conclusion has been reached on the basis of the empirical data showing differences between the groups of pilots, observations of substantial individual differences within groups during the experiment, and the opinions of the pilots. For this reason, simulator-based training cannot be said to be effective for all pilots in all ports. Rather, the effectiveness of such training will depend on the skill areas being addressed, particular port characteristics, and the individual pilot/trainee background.
6. Pilot opinion of simulator-based training is, for the most part, positive. Although pilot opinion has been generally thought to be negative toward simulator-based

training, this was not found to be the case. Rather, the apparently negative opinion stems from (1) the belief that pilot training needs are beyond simulator capabilities (i.e., which they are for certain skills, although other skills can be properly addressed via simulator-based training); (2) the belief that simulator-based training should not be used in place of current training practices (rather, it has potential value to augment current training programs and hence upgrade piloting skills); and (3) the belief that the application of simulator-based training will be required of pilots and misdirected as a result of regulators not being sensitive to particular pilot local needs and practices. When addressing the potential merits of simulator-based training unencumbered by these other considerations the pilots were generally very positive.

7. A generic data base for pilot training can be effective. The empirical data demonstrated the effectiveness of pilot training using a generic data base. Pilot opinion was largely in agreement with the effectiveness of a generic data base. However, the particular situations, skills, conditions, etc., addressed during the training program should be tailored to the pilots' local port characteristics. In other words, the geography need not be the same, but the issues addressed (e.g., bank effects) should be those of particular relevance in the pilots' port. This finding is particularly important, since it strongly suggests that effective pilot training can be achieved without the substantial expense of modeling each pilots' port. It should also be noted, that this finding does not mean to imply that all piloting skills ad-

dressable via simulator-based training can be effectively achieved using a generic port. Rather, the generic port may be appropriate for training a large proportion of such skills.

8. The training system characteristics are particularly important for the training of pilots. This importance appears greater than that for the training of deck officers. The training program content should be specifically tailored to meet the needs of each group of pilots. This would include the skills being addressed, as well as the situations and conditions contained in the exercises. A relatively large number of short-duration exercises should be employed in the training program. These should focus on the extreme situations likely to be encountered by the pilots. They should provide the pilots with a relatively difficult challenge, and enable them to practice a variety of techniques that safety and other considerations would not allow trying at-sea. Finally, the level of simulation fidelity is very critical. The pilots were unanimously critical of the ship hydrodynamics, even though considerable care and development had been focused on providing an appropriate ship model. Similar concern had been experienced at other facilities training pilots (e.g., Europort pilots trained at Wageningen). The pilots are extremely sensitive to the hydrodynamic characteristics of the vessel, and would prefer a relatively poorly handling vessel that represents the more difficult end of the scale. Although similar criticism was not placed on the environmental aspects of the simulation, it is expected that this

conclusion would apply equally to other aspects of simulation fidelity closely aligned with pilot tasks (e.g., bank interaction with ownship).

9. The mechanics of the training program, in terms of class size (i.e., four pilots), mixture of extensive and limited experienced pilots (i.e., usually two in each group), the case study/seminar training method used for programs involving experienced students, the coordinator roles provided by the pilot consultants and so on, represent an effective training program strategy for the conduct of piloting training. This conclusion is based on the careful analysis and development work leading to the training program, the strong empirical results demonstrating the effectiveness of the training program, and the opinions of the pilots showing support for the training program.
10. A governmental requirement for all pilots to participate in simulator-based training at this time would likely be ineffective. This conclusion is reached on the basis of the opinions of the pilots. Although they were generally strongly supportive of the potential for simulator-based training as a means of improving piloting skills, they were equally strongly adverse to the concept of such training being required. The findings of this investigation, although strongly supportive of the potential effectiveness of simulator-based training for pilots, also suggest that the effectiveness can vary substantially depending on many factors.

CHAPTER 6

RECOMMENDATIONS

As a result of the conduct and analysis of the experimental training program described within this report, several pertinent recommendations have been identified and discussed below. It should be noted that these recommendations are the authors' recommendations relating to the implementation and future research of marine pilot simulator-based training. They do not necessarily reflect the views or intentions of either the U.S. Coast Guard or the Maritime Administration who sponsored this research.

1. Government agencies should positively encourage pilots to avail themselves of simulator-based training. Such training should not be required. As evidenced by this experiment, simulator-based training of pilots is in the developmental stage. It has been examined here, and is believed to have potential for the acquisition, maintenance, an improvement of selected piloting skills. It should, therefore, be considered as a means for augmenting/upgrading the current training practices of pilot organizations. It is further recommended that the appropriate use of simulator-based training be left to the discretion of each pilot organization. This would enable each organization to cost effectively use simulator-based training as one medium of a multi-media approach to meet their particular training needs.
2. An investigation should be undertaken to identify those pertinent areas of shiphandling skill for which cost/effective simulator-based training can be provided for pilots. The investigation should thoroughly document those skill areas having potential benefit from simulator-based training, and determine those skill areas for which simulator-based training would be effective. The final evaluation of effectiveness should be based on a combination of structured subjective analysis and empirical research. The intent would be to develop a thoroughly documented catalog of pilot skill areas amenable to simulator-based training. The first step of this catalog is the guidelines document developed by this project addressing simulator-based training system design for pilots. The experiment reported herein conducted a limited analysis of this type, identifying several possible areas of piloting skill amenable to simulator-based training. A much more thorough investigation directly designed for this purpose is recommended to investigate and identify those areas for which simulator-based training would be cost/effective for pilots.
3. Several pilot groups should be identified for which simulator-based training would be particularly effective, and also acceptable to the pilots. Appropriate training programs should be set-up on a

cost-shared basis between the pilots and the government. The purpose of these initial training programs would be twofold: (1) to achieve effective pilot training where needed; and (2) to encourage the use of simulator-based training on the part of pilots by providing prototype training programs in certain areas. This will help to educate pilots regarding the cost/effectiveness of simulator-based training, as well as its acceptability. A major problem today with the acceptance of simulator-based training is the lack of direct knowledge by pilots of the capabilities and limitations of this training medium.

4. A high quality generic port data base should be developed that will contain representative critical characteristics of ports around the country as they pertain to the simulator-based training of specific pilot skill areas. This generic data base should have the characteristics to become a standardized training port for pilots. The data base should be developed so as to enable commercial training facilities to transpose its characteristics into an appropriate simulation data base (i.e., visual and radar images, hydrodynamics). A catalog of the generic port characteristics should be cross-indexed with the appropriate ports around the country to provide guidance information concerning potential use. This development should include the validation of the generic port characteristics.

5. Government agencies should provide assistance to pilot organizations to help them in the development and use of simulator-based training programs. In addition to the financial assistance noted above, it

is recommended that the government provide technical training assistance for the development of effective training programs.

6. An effort should be conducted to thoroughly develop several representative ship hydrodynamic models. This developmental effort should include at-sea validation as necessary. Its purpose should be to develop several representative models that have met the approval of pilot organizations, and which can be made available to commercial training establishments. The hydrodynamic fidelity of the vessel and the environment are of major concern to pilots, as evidenced during this investigation. The lack of acceptable ship models would likely represent a major stumbling block to the effective use of simulator-based training by pilots. Hence, it is in the interest of the industry and maritime safety that models be developed which meet the approval of pilot organizations, and hence assist in facilitating the simulator-based training of pilots.

7. Organizations that intend to use all or parts of the experimental pilot training program developed for this investigation should use the data reported herein, and otherwise available, to update those training modules. Effective use of this material would require modification of the modules in accordance with the observations of the pilots and the project staff. This is considered essential for effective use of this material.

8. At-sea validation of the findings achieved during the Training and Licensing Project should be undertaken to provide the bottom-line

information regarding the effectiveness of simulator-based training. The findings from this experiment and the earlier investigations during this project have documented benefits and limitations of simulator-based training of mariners. These findings, however, have been confined to the simulator environment. As a result, the use of simulator-based training has been growing slowly, even though

the data suggest it is a potentially strong medium for improving shiphandling proficiency. Demonstration of the effectiveness of this medium for improving at-sea shiphandling proficiency is a necessary pre-requisite for achieving substantially increased industry use of this powerful tool and the resulting benefits to shiphandling safety.

APPENDIX A
DEBRIEFING QUESTIONNAIRE

The following questionnaire will be administered by one of the research staff. Although responses to many questions are specified, there is a comment space available after each response. The staff member should encourage comments by the trainees.

Instructions to Trainee:

In answering the following questions, please do not hesitate to criticize any aspect of the training program here at CAORF - simulator, seminar coordinator, conditions, etc. Your honest answers, both negative and positive will be of help to both CAORF and this project. Be specific as possible when asked for comments.

MODULE I: ADVANCED INSTRUMENTATION

1. On a scale of one to ten, ten being excellent, how would you rate the "advanced instrumentation" segment of the training program?

1 2 3 4 5 6 7 8 9 10

Comments: 7.58 Average

2. Was the amount of time allocated to the use of racons appropriate?

YES NO

Comments: 8/12 Yes

3. Was the amount of time allocated to the use of the rate-of-turn indicator appropriate?

YES NO

Comments: 10/12 Yes

4. Was the time allocated to the use of the doppler speed log appropriate?

YES NO

Comments: 11/12 Yes

5. Do you feel that you learned something valuable which you can use in your pilotage port from the "advanced instrumentation" segment of the training program?

YES NO

Comments: 11/12 Yes

6. What other types of "advanced instrumentation" should be considered for this type of training?

(Various)

7. Do you feel that such training in "advanced instrumentation" would be valuable for apprentice pilots?

YES NO

Comments: 11/12 Yes

8. Do you feel that periodic optional training in "advanced instrumentation" would be valuable for experienced pilots to keep abreast of the recent developments in such bridge equipment?

YES NO

Comments: 11/12 Yes

9. If an "advanced instrumentation" module was offered at a commercial simulator facility, what changes should be implemented?

Comments: (Various)

10. Was the simulation of the handling characteristics of the 80,000 dwt tanker suitable for the "advanced instrumentation" training?

YES NO

Comments: 9/12 Yes

MODULE II: EMERGENCY SHIPHANDLING

11. On a scale of one to ten, ten being excellent, how would you rate the "emergency shiphandling" segment of the training program?

1 2 3 4 5 6 7 8 9 10

Comments: 6.58 Average

12. Do you concur that such training in turning around within confined channels is a valuable training exercise for developing selected shiphandling skills that may be appropriate in emergency situations?

YES NO

Comments: 11/12 Yes

13. What other types of exercises do you believe could be appropriate for developing selected shiphandling skills that may be appropriate in emergency situations?

Comments: (Various)

14. Do you feel that such training in "emergency shiphandling" skills would be valuable for apprentice pilots?

YES NO

Comments: 11/12 Yes

15. Do you feel that periodic optional training in "emergency shiphandling" would be valuable for experienced pilots in order to refresh seldom-used skills?

YES NO

Comments: 9/12 Yes

16. If an "emergency shiphandling" module was offered at a commercial simulator facility, what changes should be implemented?

Comments: (Various)

17. Was the simulation of the handling characteristics of the 80,000 dwt tanker suitable for the "emergency shiphandling" training?

YES NO

Comments: 8/12 Yes

18. Was there adequate time allocated within the training program for refining your skill in turning around the 80,000 dwt tanker within the confined channel?

YES NO

Comments: 12/12 Yes

MODULE III: DECISIONMAKING

19. On a scale of one to ten, ten being excellent, how would you rate the "decisionmaking" segment of the training program?

1 2 3 4 5 6 7 8 9 10

Comments: 6.29 Average

20. Do you feel that you learned something valuable which you can use in your pilotage port from the "decisionmaking" segment of the training program?

YES NO

Comments: 3/8 Yes

21. What other types of decisionmaking situations do you believe would be appropriate for development/refinement via such simulator training?

Comments: (Various)

22. Do you feel that such "decisionmaking" training would be valuable for apprentice pilots?

YES NO

Comments: 7/8 Yes

23. Do you feel that such "decisionmaking" training would be valuable for licensed pilots with limited experience?

YES NO

Comments: 8/8 Yes

24. Do you feel that such "decisionmaking" training would be valuable as a refresher for licensed pilots with extensive experience?

YES NO

Comments: 3/8 Yes

25. If a "decisionmaking" module was offered at a commercial simulator facility, what changes should be implemented?

Comments: (Various)

26. Was the simulation of the handling characteristics of the 80,000 dwt tanker suitable for the "decisionmaking" training?

YES NO

Comments: 4/8 Yes

GENERAL

27. Do you believe that shiphandling simulators have a role in the training process of apprentice pilots?

YES NO

Comments: 12/12 Yes

28. Do you believe that shiphandling simulators have a role in the training process of licensed pilots?

YES NO

Comments: 11/12 Yes

29. Would you recommend that another member of your pilot association attend a similar simulator-based training program at a commercial training facility if the tuition cost was \$3000?

YES NO

Comments: 4/12 Yes

30. Would you recommend that another member of your pilot association attend a similar simulator-based training program at a commercial training facility if the tuition cost was \$1000?

YES NO

Comments: 7/12 Yes

31. What is the maximum duration that a simulator training program could have without seriously impacting your job and personal schedule?

2 Days 1 Week 2 Weeks Other: _____

Comments: 6 -- 2 Weeks; 4 -- 1 Week; 1 -- 2 Days

32. Do you now believe that marine pilots can receive beneficial training on a shiphandling simulator within a generic port?

YES NO

Comments: 11/12 Yes

33. Did the computer-generated visual scene cause you problems during this experimental training program?

YES NO

Comments: 5/12 Yes

34. Should this training program have included exercises under simulated nighttime conditions?

YES NO

Comments: 5/11 Yes

BIBLIOGRAPHY

Federal Register, Volume 48, No. 19, Thursday, January 27, 1983, p. 3914.

Gynther, J.W., T.J. Hammell and V.M. Pittsley. Guidelines for Marine Pilot Simulator-based Training Systems. National Maritime Research Center, Kings Point, New York, 1984.

Gynther, J.W., T.J. Hammell, J.A. Grasso and V.M. Pittsley. Simulators for Mariner Training and Licensing: Guidelines for Deck Officer Training Systems. U.S. Coast Guard and Maritime Administration, Washington, D.C., 1982.

Hammell, T.J., J.W. Gynther, M.E. Gaffney and J.A. Grasso. Simulators for Mariner Training and Licensing. Phase 2: Investigation of Simulator Characteristics for Training Senior Mariners. U.S. Coast Guard and Maritime Administration, Washington, D.C., 1981.

Hammell, T.J., J.W. Gynther, J.A. Grasso and D.C. Lentz. Simulators for Mariner Training and Licensing. Phase 2: Investigation of Simulator-based Training for Maritime Cadets. U.S. Coast Guard and Maritime Administration, Washington, D.C., 1981.

Huffner, J.R. Pilotage in Confined Waterways of the United States: A Preliminary Study of Pilot Decisionmaking. Maritime Institute of Technology and Graduate Studies. Linthicum Heights, Maryland, July 1976.

Huffner, J.R. Pilotage in the Port of New York. Maritime Institute of Technology and Graduate Studies. Linthicum Heights, Maryland, July 1978.

Hussem, J., C. DeBoer and P.J. Paymans. "Seven Years Experience with Simulator Training of VLCC Pilots in the Netherlands", Proceedings of the Second International Conference on Marine Simulation. Computer Aided Operations Research Facility, Kings Point, New York, June 1981.

Maritime Transportation Research Board. Proceedings: Symposium on Piloting and VTS Systems. National Academy of Sciences, Washington, D.C., 1980.

Willms, O. "The Training of Pilots on A Shiphandling Simulator", Proceedings of the Second International Conference on Marine Simulation. Computer Aided Operations Research Facility, Kings Point, New York, June 1981.

END

FILMED

11-85

DTIC