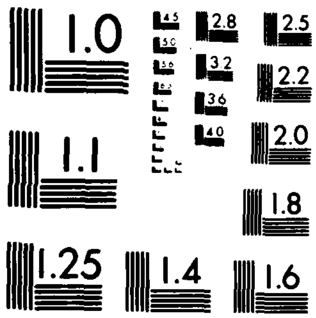
AD-A135 601 REPORT OF THE COMMITTEE TO ASSESS THE COMPUTER AIDED OPERATIONS RESEARCH FACILITY (CAORF)(U) NATIONAL RESEARCH COUNCIL WASHINGTON DC MARINE BOARD OCT 83 1/1

UNCLASSIFIED N00014-82-G-0032 F/G 14/2 NL

END
DATE
FILMED
1 84
DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A

AD-A135 601

2

Report of the Committee To Assess the Computer Aided Operations Research Facility (CAORF)

DTIC FILE COPY

Committee to Assess CAORF

Marine Board

Commission on Engineering and Technical Systems

National Research Council

2

REPORT OF THE COMMITTEE
TO ASSESS THE COMPUTER AIDED
OPERATIONS RESEARCH FACILITY
(CAORF)

Committee to Assess CAORF
Marine Board
Commission on Engineering and Technical Systems
National Research Council

National Academy Press
Washington, D.C.
1983

NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the committee responsible for the report were chosen for their special competences and with regard for appropriate balance. This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

The National Research Council was established by the National Academy of Sciences in 1916 to associate the broad community of sciences and technology with the Academy's purposes of furthering knowledge and of advising the federal government. The Council operates in accordance with general policies determined by the Academy under the authority of its congressional charter of 1863, which establishes the Academy as a private, nonprofit, self-governing membership corporation. The Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in the conduct of their services to the government, the public, and the scientific and engineering communities. It is administered jointly by both Academies and the Institute of Medicine. The National Academy of Engineering and the Institute of Medicine were established in 1964 and 1970, respectively, under the charter of the National Academy of Sciences.

This report represents work supported by Grant Number N00014-82-G-0032 between the Office of Naval Research and the National Academy of Sciences.

Copies available in limited quantity from:

Marine Board
Commission on Engineering and Technical Systems
National Research Council
2101 Constitution Avenue, N.W.
Washington, D.C. 20418

Printed in the United States of America

MARINE BOARD
of the
COMMISSION ON ENGINEERING AND TECHNICAL SYSTEMS
NATIONAL RESEARCH COUNCIL

John E. Flipse, Chairman
Texas A&M Research Foundation
College Station, Texas

John F. Wing, Vice Chairman
Booz, Allen and Hamilton
Bethesda, Maryland

William M. Benkert
American Institute
of Merchant Shipping
Washington, D.C.

Kenneth A. Blenkarn
Amoco Production Company
Tulsa, Oklahoma

Donald F. Boesch
Louisiana Universities
Marine Consortium
Chauvin, Louisiana

H. Ray Brannon
Exxon Production Research
Houston, Texas

Clifton E. Curtis
Center for Law and Social Policy
Washington, D.C.

Robert G. Dean
University of Florida
Gainesville, Florida

Edward D. Goldberg
Scripps Institution of Oceanography
LaJolla, California

Arthur J. Haskell
Matson Navigation Company
San Francisco, California

James A. Higgins
Stanley Associates
Washington, D.C.

Bramlette McClelland
McClelland Engineers, Inc.
Houston, Texas

William M. Nicholson
Annapolis, Maryland

Fredric Raichlen
California Institute of Technology
Pasadena, California

Clifford M. Sayre
E. I. DuPont de Nemours and Company
Wilmington, Delaware

William H. Silcox
Standard Oil Company of California
San Francisco, California

Julian H. Singman
Maritime Institute for Research
and Industrial Development
Washington, D.C.

Nathan Sonenshein
Global Marine Development, Inc.
Newport Beach, California

Marshall P. Tulin
University of California
Santa Barbara, California

James G. Wenzel
Lockheed Missiles and Space Company
Sunnyvale, California

STAFF

Jack W. Boller, Executive Director
Donald W. Perkins, Assistant Executive Director
Charles A. Bookman, Senior Staff Officer
Aurora M. Gallagher, Senior Staff Officer
Richard W. Rumke, Senior Staff Officer
Gale M. Munson, Administrative Assistant
Doris C. Holmes, Financial Assistant
Phyllis Johnson, Secretary
Terrie Noble, Secretary
Joyce Somerville, Secretary

COMMITTEE TO ASSESS CAORF

Robert L. Wiegel, Chairman
University of California
Berkeley, California

Walter S. Chambers
Naval Training Equipment Center
Orlando, Florida

C. Lincoln Crane
Exxon International, Inc.
Florham Park, New Jersey

Jesse Orlansky
Institute for Defense Analyses
Alexandria, Virginia

Milton Pikarsky
IIT Research Institute
Chicago, Illinois

John B. Sinacori
John B. Sinacori Associates
Hollister, California

William E. Smith
ORI, Inc.
Silver Spring, Maryland

REPORT OF THE COMMITTEE TO ASSESS CAORF

BACKGROUND

In the spring of 1983, the U.S. Maritime Administration (MarAd) asked the Marine Board to assess the Computer Aided Operations Research Facility (CAORF), and to provide advice about the best use of this facility in the national interest. Following approval of the Governing Board of the National Research Council, a committee was appointed with the expertise considered necessary to perform the task.*

MARAD AND CAORF

The U.S. Maritime Administration is charged with enhancing and maintaining the economic strength of the maritime industry of the United States. Within the agency's interpretation of its mission is support of the research, development, and engineering analysis to gain a better understanding of factors important to maritime productivity, and to stimulate technological innovation. The interactions of the man, ship, and waterway were identified as a problem needing systematic analysis, and in 1970, planning began for a program to address it. As a result, the Computer Aided Operations Research Facility was designed, built, and officially inaugurated in 1976. CAORF is a full-size ship maneuvering simulator equipped with the instruments of a typical ship's bridge and computer-generated images of the view from the windows and computer-controlled ship response.

*A brief summary of the committee's expertise is given following the report. The areas in which the Marine Board considered representation essential include research laboratory management; human factors research; simulation engineering, facility design, and research; mathematical modeling of ship behavior; port and harbor design; and ship operations.

TASK

The committee was directed to address the question, "In what manner can CAORF most effectively serve the nation, both government and industry, over the next decade?" and to assess

1. The physical facility, including the simulator itself, in comparison to other facilities, the state of the art, and prospective advances in technology in the United States and abroad;
2. The research program performed at CAORF, with particular emphasis on the research topics funded by MarAd and other federal agencies, and the relevance of such research to the requirements of U.S. maritime industries. The procedures followed in review and dissemination of CAORF research results in comparison with comparable research performed at other simulation facilities were also to be considered;
3. The government-contractor management structure under which CAORF is maintained and operated, with particular emphasis on the appropriateness of the division of responsibilities now in effect; and
4. Alternative arrangements by which CAORF, a unique national resource, may more effectively serve government and industry, with particular emphasis on alternative organizational approaches such as multi-agency funding, and management by an academic or non-profit organization.

ORGANIZATION OF REPORT

Owing to the request by MarAd for policy guidance, the committee offers its conclusions and recommendations in the succeeding section, followed by sections elaborating the facts and reasoning that lead to them. Brief sections describe the methods and organization of the study.

CONCLUSIONS AND RECOMMENDATIONS

SUMMARY STATEMENT

A ship simulator designed for research, development, and engineering analysis, CAORF is unique in the United States. Although there are several ship simulators in this country designed for training, the requirements for training simulation are not so exacting as those for research simulators, and the modes of operation for these two kinds of simulators differ considerably. The use of a ship simulator for research and engineering analysis offers the potential for cost-effective examination of many questions--for example, the limits of piloted ship controllability, the equivalence of training on simulators with training at sea, and analysis of alternative waterway configurations. Simulation can expand the range of experimentation, and of alternatives considered, and substitute for expensive or hazardous full-scale tests. Thus, CAORF is a unique and valuable national resource. It is not, however, being used to best advantage.

CAORF has received insufficient direction and management in the national interest and insufficient involvement by industry. Urged increasingly by MarAd to find outside support, CAORF's long-term research program begins to resemble its short-term research program.

The single greatest deficiency of CAORF is the lack of validation for its uses. Specifically, CAORF's mathematical ship models and data on training and other human performance characteristics need to be compared to actual ship behavior and human performance in the real world. Validated models and studies would be CAORF's signal contribution to maritime research and development, and need to be given top priority. Validation is also the most important of the efforts that would strengthen the program and enhance its acceptance by the community of users.

Other needed actions are to increase the MarAd staff at CAORF to direct and support this government-owned facility, particularly a research facility manager, research program director, and senior scientists and analysts. Some of these needs can be filled by contractors, but the government cannot (as now) accomplish every objective and function by contract. Independent direction and review is required. CAORF very much needs the equivalent of a board of directors for its research program. The individual members (representatives of industry, other government agencies, researchers, naval architects and engineers) should be of sufficient experience, credibility, and position to help develop the research program, monitor its progress, and evaluate its results and effectiveness in an objective and independent manner.

The Physical Facility, Particularly Its Software and Validation

Physical Facility

o The concept of the CAORF facility and its capabilities are not obsolete in comparison to other facilities for operations research. Some of the simulator subsystems are obsolete, particularly in ease of maintenance and flexibility for expansion. While many of these subsystems were (of necessity) special developments when CAORF was originally built, they can now be acquired as standard products with built-in aids to maintenance. The electronic and computer components in question are also those for which advancing general technology is improving the performance-to-cost ratio.

o The hardware subsystem that may hold back future expansion is the central processing unit and its peripherals and interfaces, owing to high failure rate and limited capacity. It is vitally important to CAORF's effectiveness in operations research to have large real-time simulation processing capacities.

RECOMMENDATION: Replacement of the central processing unit, its peripherals and interfaces--and the order of replacement--should be undertaken as part of a detailed plan. This detailed plan for maintenance and replacement should be developed in accordance with the needs of the research program.

RECOMMENDATION: Replacement of the other aging subsystems, such as the visual and radar-image generators and situation displays should be postponed as long as possible. Replacement costs for these items will fall in the next few years as the manufacturers shift from special-purpose to standardized production.

Software

o CAORF simulations (in terms of system and software) are carefully documented and correlated with calculations and computer results from the scientist who developed the mathematical model.

o Several potential applications of CAORF simulation will require the additional capacity of ship response to ocean waves (six as opposed to the present three degrees of freedom of motion).

Validation

o CAORF simulation has not been validated to a level compatible with its research goals. It should be understood that no mathematical model of ship behavior has been fully validated by comparison to actual ship maneuvers, even though the CAORF model represents the state of the art. Nevertheless, the validation data available to the committee do not provide sufficient quantitative information to support any conclusions about the accuracy of the results achieved in the simulator relative to the full-scale maneuvering performance of vessels.

o This lack of validation raises fundamental questions about CAORF research results, particularly in restricted-waterways studies, and figures prominently in the reluctance of some potential users to engage the facility.

o Many of CAORF's users now (and those anticipated for the near future) look to the results of CAORF's simulation to provide the technical basis for critical design decisions. The quality of that technical basis very much depends on the assumption that the predictions of ship maneuvering are valid for the intended purposes.

o Moreover, one of the most significant services CAORF could perform as a national facility would be to provide to qualified users mathematical models and computer programs modeling ship behavior that are sufficiently valid to support the expenditure of enormous resources on harbors, waterways, ships, and bridges.

RECOMMENDATION: The level of accuracy of the CAORF model should be established relative to the type of work to be performed. A program needs to be initiated and consistently supported to validate the CAORF mathematical model(s) by comparison with full-scale ship trials at sea and in the restricted waters of ports and harbors. This should be the top priority for the immediate future.

The Research Program

Long-Term Research Plan, Basic Research

o CAORF is an important national resource that is not now being used to full advantage.

o The MarAd program of basic research and development has received insufficient attention and support. This is critical in validation of the CAORF models, an item that has appeared in five-year plans of the past but has not been pursued.

o Projects funded by agencies other than MarAd and by industry are given priority of access and time, but there are no systematic procedures to gain an understanding of the research needs of these maritime interests, to determine those that are shared, or to evaluate relative importance, urgency, or appropriateness for the CAORF facility.

o Pressure to develop outside sources of funds has not been balanced by sufficient foresight respecting its effects on the R&D program. This is most particularly evidenced in the lack of emphasis on (1) establishing the level of accuracy of the CAORF simulation for the applications; (2) other research to enhance the state of the art of CAORF simulation; and (3) research to pursue advanced concepts.

Research and Engineering Projects, Dissemination

o Much of CAORF's work today, and anticipated for the near-term future, is engineering design and analysis for industry and government agencies (such as widening and deepening of navigational channels). This is a valuable application of CAORF's capabilities.

o Most of the research reports produced by CAORF are competent. There are some important exceptions that indicate that the technical review process is unable to correct inadequate work.

o The efforts made to disseminate the results of CAORF research are slight, relative to their importance. More effort needs to be made to invite critique, to explore and follow up the wider implications or applications of research projects, and to inform the community of actual and potential users.

RECOMMENDATION: A better system than the present one needs to be instituted for developing and carrying out the long-term research plan for CAORF. This system needs to include methods for much greater participation by industry, other government agencies, academic and research institutions, and should be an integral part of MarAd's R&D program. An oversight technical and scientific group selected from these interests should report directly to the administrator of MarAd.

RECOMMENDATION: A similar group (which could be a subset of the larger oversight group, or alternatively, a research consortium formed for this purpose) is needed to monitor and assess the research program and advise the government manager of CAORF.

RECOMMENDATION: Research or engineering studies conducted for other government agencies and industry should be offered at rates that cover full costs with an allowance for development.

RECOMMENDATION: All CAORF research reports should receive full, independent technical review. The smaller monitoring group or consortium might take responsibility for ensuring technical review. In addition, much more effort needs to be made to publish the results of CAORF research in refereed scientific and engineering journals.

The Management Structure, Including Government-Contractor Relationship

o The management structure of CAORF should be consistent with operation of a research facility conducting studies of national importance and aiming for the highest degree of validity in its results.

o The structure seems to be evolving from an early attempt to model CAORF operations on those of training simulators used by the military services. The operational objective is still to maximize the hours of simulator use, but this balance of time is more appropriate to training simulators than to research simulators. At its present stage of evolution, CAORF is organized and staffed for individual projects.

o Missing from the management structure is the over-all guidance and foresight necessary to a long-term R&D program. As noted in other conclusions, there is no regular participation by other government agencies and industry in development of the research plan or in assessing emerging R&D needs.

o The government presence in the management of CAORF is minimal by choice. All functions, besides those of a single resident manager and some program review, are accomplished by contractors. There are problems inherent in reliance on contractors without an adequate system of checks and balances, and provision for independent input, review, and evaluation.

o There is also insufficient staffing for in-depth analysis of research methods and results, or of research and developments elsewhere. The research staff is balanced in favor of research psychologists, in accordance with the five-year plans of the past that emphasized human factors. The present set of CAORF projects and draft five-year plan emphasize engineering hydrodynamics and operations analysis.

o The evidence suggests conscientious and generally competent performance by CAORF's contractors. Clear documentation of the engineering and maintenance of the facility, the software, and research projects is available from both.

RECOMMENDATION: Besides the oversight technical and scientific groups of preceding recommendations, CAORF needs a senior-level R&D manager, an administrator, and analysts (either employees of the government or from independent sources, such as other research facilities, universities, or other government agencies).

RECOMMENDATION: Validation of CAORF models, as well as subsequent refinement and validation, should be conducted by unbiased experts.

RECOMMENDATION: Efforts need to be made to achieve wide distribution of validated models and research results. These are of national importance and are needed for many applications beyond those appropriate for CAORF simulation.

DESCRIPTION AND ASSESSMENT OF THE PHYSICAL FACILITY INCLUDING SOFTWARE AND VALIDATION

PHYSICAL FACILITY, ENGINEERING AND MAINTENANCE

CAORF offers a duplicated ship's bridge with the equipment that would normally be found on a merchant vessel. The view outside the windows (240° horizontal, 24° vertical) is generated directly by a small computer from digitized data bases created by the contractor staff for particular waterways or desired scenes, and displayed on a cylindrical screen by five video projectors. The radar display is also computer generated and controlled. The visual scene and radar-image generators are coordinated by the main computer. Other bridge equipment (steering, propulsion, and thruster controls and displays) is driven by the main computer. The main software program, modeling the ship and its response, is run on the main computer (actually two SEL-85 mainframe computers, operating in parallel). Incidental equipment includes radio, loudspeaker, phones, and whistle.

A control station is outfitted with situation displays showing the location of all ships in the experiment, controls to introduce changes or malfunctions, and a data terminal for communication with the central computer. Steering and propulsion can be controlled from this station. Control of the propulsion plant can be transferred from the bridge to the control station and vice versa.

There is also a human factors station that allows unobtrusive observation of behavior during an experiment. The station is primarily used for experiments in which human responses are dependent variables; for example, rudder, engine, and course orders. Five closed-circuit cameras and four microphones transmit to screens, speakers, and recorders at this station. This type of data collection is manpower-intensive and the results may be of limited utility, measured by cost-effectiveness.

CAORF recently purchased a small tugboat simulator from Tracor-Hydronautics, Inc., to be used independently or interactively with the main ship simulation.

At the time CAORF was created, many pieces of equipment had to be custom-designed or adapted from existing equipment. The central computer is no longer manufactured. Owing to the number of functions demanded of the two central computers and the amount of data required, they are now very nearly at capacity. The limitation is principally in memory, and while this might be solved momentarily by the addition of a hard disk drive, it ultimately requires replacement of the computers. The decision would have to be made on the basis of future research plans.

While almost nothing in the physical system is new, it has been continuously maintained and repaired. Spare parts are stockpiled, duplicate units are held in readiness to replace those that fail (to avoid interrupting experiments with repairs), and a day a week is set aside for maintenance and replacements.

A report two years ago (Heilweil, 1981) indicated that "Half the CAORF budget for the past 5 years has been expended for maintenance and engineering support tasks....it is estimated that after all CAORF enhancements are completed, maintenance & engineering services would require only about 20 percent of the budget." The maintenance and engineering support budget is now 43 percent of the total CAORF budget.* Enhancements are never, in fact, complete. CAORF has added several recently to meet the demands of research.

Of the care and attention dedicated to maintenance of the CAORF physical facility, some is owing to the age and uniqueness of its parts, and some to the CAORF operational philosophy (maximum use, maximum availability). New equipment and changes in utilization policy could result in lower maintenance costs.

SOFTWARE

The original software program (to simulate ship motions and response) was written by Sperry from the mathematical model supplied by Davidson Laboratory. The programs for the visual-image generator and display for the control station were written by subcontractors. All provided detailed documentation, and subsequent changes and modifications have also been documented. This documentation is of inestimable value to anyone who needs to understand the program (such as new programmers or potential users).

MATHEMATICAL MODELS

The single most critical question about CAORF simulation is, does it duplicate (and how well) the behavior of the vessels and the environment it simulates?

CAORF Mathematical Models

At CAORF, standard methods for determining the equations of ship motion are used in which coefficients for a particular ship are obtained from captive model tests and are then used with the traditional equations of motion (basically, a Taylor series expansion of the forces and moments that act on a maneuvering ship in three degrees of freedom -- surge, sway, and yaw). For a particular application at CAORF, the equations are also modified to include other effects not represented in the standard equations, such as currents, wind, shallow water, narrow channels, tow-line forces, and bank and bottom effects. The mathematical representations of such effects are derived analytically or from test data when possible, otherwise judgment or physical intuition is used.

The basic models were developed by well-known ship hydrodynamicists from a combination of tow-tank testing and full-scale observations. For a new model of a particular ship with a significantly different size and shape from those previously tested, a series of captive model tests is performed to obtain the coefficients of the standard equations of motion. The trajectories predicted by such equations are then compared with observations made on the

*The 1983 CAORF budget is just over half the 1981 budget, and the maintenance and engineering services (M&ES) budget has also been halved. The present M&ES budget is 23 percent of the 1981 total CAORF budget.

particular full-scale ship or one of similar design. Such observations permit a reasonably accurate estimate of the timing parameters of various maneuvers, such as time to turn 90°, course corrections for small rudder angles, and others. The equations are then adjusted to approximate the maneuver response times for the simulator. This provides a model of moderate fidelities. It is close to the existing state of the art in modeling capabilities.

LEVELS OF ACCURACY AND APPLICATIONS

For many uses, a model of moderate fidelities is probably adequate (for example, the several CAORF studies on placement of navigational aids in turns). For others, however, "the accuracy and requirements are rather more stringent," as the director of a foreign ship simulator facility explains, "because one is frequently investigating the range of operational strategies for a particular ship, harbour and environment; and as important design decisions may be based on the outcome of the investigations, it is obviously essential to know precisely the limits of accuracy" (McCallum, 1982).

Critical investigations for which the levels of accuracy of CAORF simulation need to be known precisely would include collision studies and engineering analysis of alternative channel configurations.

Although it is well known that the maneuvering characteristics of vessels in restricted waterways are dramatically different from those of the same vessels at sea, and that they experience in these regimes hydrodynamic forces (from passing ships, banks and bottoms, currents) unlike those encountered in the deep ocean, the characteristics and forces are not yet well understood. The results of model tests for this regime indicate the possibility of larger effects than previously estimated in, for example, the added hydrodynamic mass for minimal underkeel clearance in berthing and unberthing situations, but also anomalous results that may indicate scaling effects (Ball and Markham, 1982). Attempts have been made to gain improved understanding of ships' behavior in restricted waterways with photographic records from calibrated cameras (Wride et al., 1975), and tracking of ships in harbor transits (Eda et al., 1979). For some simulations (as for example in the simulations scheduled of alternative configurations of the Panama Canal's Gaillard Cut), CAORF's staff and consultants make close observations of commands, instruments, and response aboard vessels, and these are used to check and modify the simulations.

Nevertheless, as the previously cited commentator continues, "The only satisfactory criterion against which to test a model is a series of real ship trials, and very few comprehensive full-scale trail results are currently available." These are the trials of the Esso Bernicia, Esso Osaka, USS Compass Island (Clarke et al., 1970; Crane, 1979; Morse and Price, 1961) of which only the Esso Osaka trials include maneuvers in shallow water. The full-scale trials were invaluable for verification and correction of mathematical models, but extrapolation is still necessary for maneuvering characteristics in the very shallow underkeel clearance typical of large, fully laden ships in the channels of the United States, which is 2.5 percent of ship's draft, and less (Marine Board, 1983). The trials required of vessels by international agencies (and U.S. Coast Guard regulations) are for a limited set of maneuvers in deep water.

Thus, the limits of accuracy of CAORF simulation are not precisely known for these applications. Validation of mathematical models by full-scale trials is extremely difficult and expensive (Dand, 1982; McCallum, 1982; Norrbin, 1971; Sibul et al., 1979; Society of Naval Architects and Marine Engineers, 1983a), but essential. It is essential to realizing the potential benefits of simulation in critical studies, and to the cost savings possible by substituting simulations for more full-scale experiments. The need for such models is likely to be much greater in the near future than in the recent past (and interest has been growing) as cooperative international efforts continue to specify minimum maneuvering characteristics of vessels (Society of Naval Architects and Marine Engineers, 1983b), and interest increases in the use of simulation for engineering analysis.

Some of the potential applications of CAORF simulation would require the capability to model ship behavior in six degrees of freedom. The additional three degrees of freedom (heave, pitch, and roll) would be necessary if full simulation is desired of the transition area between the ocean and harbor entrance channel, for example, or of offshore lightering operations.

DOCUMENTATION

The documentation of the CAORF simulation programs and their relevant mathematical models was reviewed for adequacy and completeness. This was accomplished by an inspection of the CAORF Project Documents Index and a spot check of ten documents randomly selected from the Index. In each case, the documents selected were correctly located in the files and upon inspection were found to be current, complete, and in excellent detail (Models 4, 5 and 6, for simulation of tugboat, shallow water, and near bank effects). While time did not permit an evaluation of document accuracy relative to the computer programs, the thoroughness and level of detail of each document indicates that it would be excellent also.)

CAORF documentation must be rated as one of the very best in the ship simulation field.

VALIDATION

It is always necessary to ask whether information gained by using a simulator applies to what might be learned by collecting similar information in the real world. Obviously, a simulator, whether a mathematical model or a computer-based dynamic device, attempts to duplicate selected aspects of the real world in order to exert some control, not otherwise available, over what might also be learned in the real world. This general argument applies to any use of simulation. For CAORF, this general question is very much one of the validity of the mathematical model (covered in the preceding section) and of the simulation.

It is recognized widely that simulators must be validated for the purposes of their use. This means that information based on experiments performed in simulators must somehow be confirmed, at least in part, by comparing it with information collected independently in real life. The extent of agreement then lends credibility to other information, also collected in simulators, where additional validation is not attempted or is not practical. There is not and need not be any confusion about the fact that validation concerns comparing information collected in simulators with information collected in real life.

While CAORF is not a training simulator, an interesting area of research at the facility is the effectiveness of simulator training. In five reports of training experiments claiming to validate the effectiveness or cost-effectiveness of simulator training, neither data on performance in the real world nor cost data are presented. The reports show that performance in the simulator improves with experience, but do not show that performance aboard ship improves with simulator training -- as it may.

Included in the two previous five-year plans (1976, 1980), were validation of CAORF simulation by comparison to full-scale, instrumented ship trials, and cost-effectiveness studies of the use of simulation for training. These were not pursued. Validation has a one-line mention in a table of the latest five-year plan (in draft), and is not identified as essential to the plan.

THE RESEARCH PROGRAM

PLANNING

Assessment of research needs and development of the five-year and one-year research plans are carried out by the CAORF staff supplied under contract by Ship Analytics. The documents are reviewed by the resident MarAd manager, and sent for comment to the research and development offices at MarAd headquarters.

The assessment of research needs is conducted by CAORF staff, i.e., Ship Analytics staff, based on what they see as emerging needs, issues, and needed projects. Some of these are indicated by ongoing or completed studies, others are suggested by marketing efforts carried out by Ship Analytics personnel and the resident MarAd manager. A questionnaire is sent to ship operators asking for their ideas for MarAd research and development,* but according to the executives the committee questioned, there is no follow-up, and many have stopped responding. The CAORF research plan is presented at the annual CAORF symposium, and comments are invited. No formal mechanisms are employed other than these to gain industry or agency views, nor for independent oversight of the research program.

PROGRAM

CAORF staff estimates that the simulator is used 2300 to 2400 hours a year. As the experimental time is four days a week, 10 hours a day, and one day a week is scheduled for maintenance (2600 hours a year, total; 2080, experimental), this must be an estimate of all active time. Even as a high estimate, however, and in accordance with the reports of others, it indicates an emphasis on active simulator hours. Optimizing the number of active hours of simulator use is typical of training facilities: for research facilities, the

---

* For the Fleet Management Technology Program, not CAORF.

percentage of active simulator hours is about 25 percent. Maximizing the number of active simulator hours will not by itself enhance R&D productivity. The objective of nearly constant use of the simulator seems to have been articulated early in the CAORF program, and preserved. It may have resulted from modeling this prototype facility on the operation of the simulator facilities available at the time, which were principally training facilities.

Together with the recent emphasis on finding as much work as possible from paying customers, yearly objectives are coming to dominate the long-term research program. The draft five-year plan gives highest priority to projects for MarAd that will enhance those that are anticipated from industry and other agencies (principally port and harbor improvements, and navigation of ports and harbors). Because MarAd's mission is to improve the safety and productivity of the maritime industry, there is no confusion of purpose in collapsing the five-year program to the one-year programs, and, indeed, the program as outlined is responsive to MarAd's mission. Nevertheless, basic questions remain unanswered, and some of these are vital to the accuracy of the results of CAORF projects, to their applicability, and to the acceptance of CAORF R&D and engineering analyses in the communities it exists to serve.

The principal question is the level of accuracy of simulated ship behavior. This question has been raised many times, but has not been answered. Validated models are needed for many applications. Two that were raised by the ship operators with whom the committee consulted are gaining a better understanding of the dynamics affecting cargoes in deep-sea operation,* and another is developing training programs in critical operations for use on with small computers aboard ship. CAORF's inability to deliver such models and lack of attention to validation affect its credibility in both the research and operations communities. A thoroughgoing validation effort would need the collaboration of the wider maritime community, and its importance and potential return on investment would very likely attract the needed participation.**

CAORF has not established a strong presence in the research or professional communities. The presentation of CAORF work is now principally at specialty conferences, its own annual symposium, and the international meeting of the marine simulator community (MARSIM). Participation in the technical programs and publication in the refereed journals of the professional organizations*** would widen CAORF's audience among potential users, serve as a source of new ideas and joint efforts, and subject the methods, results, and findings of CAORF simulation to constructive critique.

---

* CAORF staff says this is not within the facility's mission.

** This is the committee's opinion; the CAORF staff disagrees that industry would be willing to make the investment. CAORF has perhaps not pursued the issue strongly enough in the national interest.

***For example, ASNE Journal (American Society of Naval Engineers), Journal of Marine Technology, Journal of Ship Research, Journal of Waterways, Harbors and Coastal Engineering (American Society of Civil Engineers), The Naval Architect.

There is also a continuing need for interdisciplinary exchange of information and joint efforts to accomplish some important goals that CAORF has in common with regulatory agencies, industry, and others; for example, collaboration in the establishment of ship-maneuvering criteria, human performance measures, and improved understanding of some little-understood phenomena that have implications for marine operations (such as the interest in ships' navigability in fluid mud). To improve its own models and research projects, CAORF must become and stay current with pertinent research and data gathering efforts undertaken elsewhere.

FUNDS

MarAd has reduced funding of CAORF in recent years (from about $6 million in 1981 to about $3.2 million in 1983), and has encouraged the staff to find outside sources of support. The estimate for 1984 is that about $1 million to $1.5 million of support for CAORF projects will come from outside sources (other government agencies and industry).

CAORF conducts projects for MarAd and for other clients (government agencies, port authorities, and industry) in accordance with five-year and one-year research plans. The present five-year plan is in draft, and has not yet been reviewed and approved by MarAd.* The one-year plan (June 1983 to June 1984) indicates the following division of projects by simulator hours.

Projects	Estimated Percentage of Annual Simulation Hours
Commercial	73
Research	
ongoing	13
committed	14
planned	30
Total	130

The extra 30 percent allows flexibility for scheduling problems or delays and proposed or planned studies that are not carried through to commitment. The emphasis on "commercial" (as used in CAORF plans, "commercial" includes all sources of funds other than MarAd) use of the simulator is evident. Nevertheless, MarAd staff estimates that these sources will contribute only a third of the budget ($1.5 million of a total of $4.2 million). By any accounting, the commercial clients are being offered a bargain. Alternative costing procedures might be reviewed, and comparisions made on a regular basis between actual costs for the recent past and planned costs.

*It is now undergoing review and revision.

TECHNICAL REVIEW, QUALITY OF REPORTS

All CAORF reports receive some form of outside technical review, according to the CAORF manager, including his own, and by those he designates. They are regularly sent to appropriate heads of MarAd R&D divisions.

The committee reviewed approximately 30 CAORF reports. They are generally competent in experimental design, statistical treatment, relevance, and appropriateness of conclusions and claims. There are some exceptions, and these are almost exclusively reports claiming to validate CAORF simulation, training, or use for engineering analysis. CAORF and MarAd staff acknowledge the inadequacies of two of these reports. Nevertheless, they were published and continue to be distributed. The technical review process is essential to CAORF's credibility, and needs to be strengthened.

Few CAORF reports have been submitted to refereed scientific or engineering journals.

DISTRIBUTION OF RESULTS

Aside from the annual symposium, few avenues are explored for distributing and promoting discussion or critique of CAORF results. Representatives of industry with whom the committee consulted indicated that the reports are either too general or too descriptive of experimental methods to be useful to them. There is doubtless much of potential value to several users in the research undertaken for MarAd and for commercial clients, but there are few ways that it might reach them.

There is no stated policy addressing proprietary information, and the issues appear to be handled as they arise. CAORF staff indicates that projects are cost-shared when possible to enable publication of reports. While no agreement is made not to release the results or report of a project, some are not published, although they will be made available if requested.

The percentages of funds allocated to projects is estimated by the CAORF manager to be:

Commercial	30 percent
Cost-shared	30 percent
MarAd	40 percent
	100 percent

GOVERNMENT-CONTRACTOR MANAGEMENT STRUCTURE

MarAd has one resident manager of the CAORF program, and a financial assistant. The engineering and maintenance staff and research staff are provided under three contracts (see summary table) with two contractors. The division of contract funds is

Maintenance and engineering modifications	42 percent
Daily management and operational support	16 percent
Research management and staff	42 percent

CAORF Contracts, FY 1983*

	Maintenance, Engineering Modifications	Operations	Technical Research, Experiment, and Management Support
TYPE	Cost plus fixed fees	Cost plus fixed fees	Indefinite quantities
CONTRACTOR	Sperry	Ship Analytics	Ship Analytics
TOTAL $	1,394,223	540,836	1,358,956
LABOR $	-	329,000	1,280,000
MY	13	5.3	15.5
SUBCONTRACTOR	500,000 (5MY) 175,000 (Materials)	166,000 (Subjects & Davidson Laboratory)	-
WORK STATEMENT	A. Improvements 2 data bases 2 equipment integrations 2 software mods 2 sets of ship coefficients 2 ship bows B. Maintain Equip.	A. Operate system B. Provide subjects C. Provide consultant	A. Tasks 12 experiment designs 10 pre-simulation reports 10 experiments conducted 10 draft reports 1 five year plan 1 symposium support B. Other industry liaison proposals non-MarAd user liaison research topic survey

*There are in addition, two small contracts for the research library (separately managed) and report production.

Both contractors are manufacturers of simulators, and both have long been under contract to CAORF. Ship Analytics offers a simulator very much like an economy version of CAORF, and has sold one in part to the Coast Guard for research and another to a seamen's union for training. Ship Analytics offers simulator research and training at its facility in North Stonington, Connecticut, and markets its own services; it also markets those of CAORF as part of its contract with MarAd. In the opinion of both the CAORF and the MarAd staffs, the market is insufficient to support many competing facilities. However, owing to the privileges of access and experience, the role of the contractor in promoting CAORF has the appearance of a conflict of interest. This relationship is not, to the committee's knowledge, prohibited by law, regulation, or contract exclusions. At its inception, CAORF was excluded from training by objections from owners of commercial simulation-training facilities. These, together with the labor unions that own training simulators, have indicated to the committee that they may wish to compete for simulation research as well, since they have idle time. Because of its long relationships with three main contractors (now two),* and lack of independent expert advice, MarAd has limited its ability to judge the merits of competing proposals for simulation research.

This points up the deeper problem with the existing government-contractor relationship: it fails to provide R&D leadership or foresight, and independent evaluation and analysis.

The committee wishes to emphasize that the performance of the on-site MarAd staff and of the contractors appears to be competent and conscientious. Nevertheless, management of the research program and administration of a facility with a $4.2 million budget is more than one person can reasonably be expected to do. While many commercial clients express satisfaction with the results of CAORF simulation, and enthusiasm for the possibilities that could be realized using the facility, several mentioned the staff's lack of experience in marine operations.

ALTERNATIVE ARRANGEMENTS

The selection among alternative institutional arrangements should be guided by CAORF's basic needs for stronger direction and management in the national interest; attention to validation, basic research, analysis, and advanced concepts; improved working relationships with industry and government agencies; and independent program review and oversight.

As the mission of MarAd is coextensive with improving the safety and productivity of the maritime industries, CAORF has not suffered from confusion about its purpose as funding balances have shifted. It needs, however, to develop closer associations and cooperative efforts with the private sector,

* Mar Ad has also contracted for CAORF-related research, services, or hardware with J.J. Henry, J.J. McMullen, Systems Control, Inc., Hydronautics (now Tracor-Hydronautics), Webb Institute, Reese-Chambers Systems Consultants, and others.

and with university and other research institutions.

Formal mechanisms for achieving these closer ties should be directed to the validation effort, which needs to be formulated and overseen by an independent group of experts, and to development of a more informed and comprehensive research program.

The need for stronger direction and management in the national interest requires a stronger government presence at CAORF. This can be achieved in a number of different ways, and attention needs to be given to the lessons learned at other government research facilities. Among these, according to a recent report (Federal Laboratory Review Panel, 1983), are the unworkability of detailed management ("micromanagement") from the Washington headquarters of an agency (this pitfall has been avoided in the management of CAORF), and the constraints of the civil service system. CAORF needs, at a minimum, a director of research, an administrator, and senior-level analysts. There are many available solutions for attracting top-level people and retaining a desirable amount of flexibility: exchanges of personnel with other government agencies (through, among other programs, the Intergovernmental Personnel Act, which is a state-federal exchange, and includes research and professorial staff at state universities); a rotation system such as that of the National Science Foundation; fellowships; and government-industry exchange programs.

An alternative that might be considered is one similar to the operation of observatories and laboratories by the National Science Foundation (NSF). NSF contracts with the American Association of University Presidents (AAUP). The contractor (AAUP) is responsible for staffing the facilities, and has formed consortia of interested universities for each area of research (for example, the University Consortium for Atmospheric Research, which oversees the National Center for Atmospheric Research).

Attention also needs to be given to stable funding. Owing to the existing and potential interest of government agencies and maritime industries, there may be opportunities to form a limited partnership with investors for research that would yield an investment return. This could be investigated as the research program is developed and carried out with guidance from the larger maritime community. The most appropriate funding arrangements may be clarified by the development of the research program.

METHODS OF THE ASSESSMENT

The committee met twice, in Kings Point and Great Neck, New York, and in Washington, D.C., and visited the CAORF facility as a committee and in smaller groups three times. In preparation for undertaking its assessment, the committee attended the Fifth Annual CAORF Symposium, which afforded an opportunity to become acquainted with the scope and results of research undertaken by CAORF, and to meet and talk with the clients, researchers, interested parties, and staff. Operators of other simulator research and training facilities were consulted, including two from foreign countries, as well as representatives from the U.S. Coast Guard, U.S. Army Corps of Engineers, and U.S. Navy. Two members of the committee met with representatives of three ship operators to discuss research needs and their evaluation of CAORF's usefulness.

The committee was much assisted in its task by a detailed bibliography of more than a hundred articles and reports compiled by the National Maritime Research Center, and by the Center's prompt distribution of requested materials.

Materials reviewed by the committee include CAORF research reports; the draft five-year research plan; proceedings of the annual CAORF symposia; the three major contracts for engineering and maintenance, operations, and research support; and the documentation of the mathematical model and software.

The conclusions and recommendations represent the consensus of the committee.

REFERENCES

Ball, D. J. and A. Markham (1982), "Maximum Added Mass for a Berthing Tanker in Very Shallow Water," The Dock and Harbour Authority, 63: 209-210.

CAORF Research Staff (1983), "CAORF Five-Year Research Plan, Preliminary Draft."

Clarke, D., D. R. Patterson, and R. K. Wooderson (1970), "Manoevering Trials with the 193,000 Tonne d.w. Tanker Esso Bernicia," Research Report NS 295, British Ship Research Association.

Crane, C. L., Jr. (1979), "Maneuvering Trials of the 278,000 dwt Esso Osaka in Shallow and Deep Water," Exxon International, Inc., New York.

Dand, I. W. (1982), "Ship Hydrodynamics and the Design of Port Approach Channels," Report NMI R 148, National Maritime Institute, U.K.

Eda, H., R. Falls, and D. A. Walden, "Ship Maneuvering Safety Studies," Trans. SNAME, 87 : 229-250.

Federal Laboratory Review Panel (1983), "Report of the White House Science Council," Office of Science and Technology Policy, Executive Office of tne President, May 1983.

Heilweil, J. (1981), "Engineering Support and Maintenance of the CAORF Research Simulator," Marsim '81: Proceedings of the Second International Conference on Marine Simulation, Vol. I, B-3, June 1-5, 1981, Kings Point, New York.

McCallum, I. R. (1982), "Horses for Courses: The Mathematical Modelling Requirements of Maritime Simulators," Paper Presented at Su-mer Computer Simulation Conference, July 19-21, 1982, Denver, Colo.

Morse, R. V. and D. Price (1961), "Maneuvering Characteristics of the Mariner Type Ship (USS Compass Island) in Calm Seas," Sperry Gyroscope Co., New York.

Norrbin, N. H. (1971), "Theory and Observation on the Use of a Mathematical Model for Ship Maneuvering in Deep and Confined Waters," SSPA Publication No. 68, Swedish State Shipbuilding Experimental Tank, Gothenberg.

Sibul, O. M., W. C. Webster, and J. V. Wehausen (1979), "A Phenomenon Observed in Transient Testing," Schiffstechnik, November 1979.

Society of Naval Architects and Marine Engineers (1983a), "Design and Verification for Adequate Ship Maneuverability," Paper prepared by H-10 Panel (Ship Controllability) for 1983 SNAME Annual Meeting.

Society of Naval Architects and Marine Engineers (1983b), Notes on Ship Controllability (Revised), H. Eda, ed. (New York: SNAME).

Wride, A. T. A. and W. E. Wills (1975), "Behavior of Large Ships in Shallow and Confined Waters (South Hampton)," National Physical Laboratory, England.

MATERIALS REVIEWED
CAORF REPORTS

Proceedings of CAORF Annual Symposia, 1-5, 1979-1983

Report No.	Title
CAORF 90-7801-01	Validation of the Computer Aided Operations Research Facility
CAORF 40-7901-01	Mathematical Models of Human and Ship Responses for Minimum Time Turns
CAORF 40-7901-02	Models of Pilot Behavior for Maneuvering Ships
CAORF 30-7913-01	Simulation Evaluation of Predictor Steering, Short Range Collision Avoidance, and Navigation Displays
CAORF 50-7918-02	The Effectiveness of Active vs. Passive Trainee Participation and Segmented vs. Integrated Structure on the Acquisition of Shiphandling Skills
CAORF 50-7919-02	Transfer of Training from Low to High Fidelity Shiphandling Simulators
CAORF 50-8004-01	Simulators for Mariner Training and Licensing, Phase 3: Investigation of Horizontal Field of View Requirements for Simulator-Based Training of Maritime Cadets
CAORF 41-8005-04	Pilot Performance, Phase 2: An Assessment of the Contribution of Shallow Water Maneuvering Information in Harbor Transits
CAORF 20-8104-02	The Application of CAORF Simulation as a New Technology for the Determination of Dredging Requirements
CAORF 15-8110-02	Assessment of Simulator-Based Training for the Enhancement of Cadet Watch Officer Performance
CAORF 90-7802-01	Validation of Mate Behavior on CAORF
CAORF 24-7905-02	Review of the Galveston Deepwater Channel Study and Description of the CAORF Demonstration Runs

CAORF 24-7905-01	Investigation of Large Tanker Transits through a Deepwater Channel into the Port of Galveston
CAORF 46-8001-01	Helmsman Performance on Ships During Turning Maneuvers
CAORF 36-8003-01	Passage Planning: An Objective Assessment of a Bridge Management Procedure vs. Integrated Electronic Aids
CAORF 42-8009-02	Tug Usage for Control and Deceleration in Restricted Waterways
CAORF 24-8012-01	Investigation of Large Tanker Transits of a Proposed Deepwater Channel into the Port of Corpus Christi, Texas
CAORF 52-8101-01	Efficiency of Simulation in the Acquisition of Local Ship Handling Knowledge as a Function of Previous Experience

JOURNAL ARTICLES

"Cardiff Ship Simulator Opened," High Speed Surface Craft, September 1982, p. 16.

"Cardiff Ship Simulator Royal Opening," Seaways, September 1982, p. 11.

"Computer Generated Imagery for Training Simulators," Displays, January 1981, p. 199.

"The Decca Ship Simulator (Impressions of Pilots)," The Pilot, April 1977, p. 40.

"________, (letter to the editor)," The Pilot, October 1977, p. 80.

"Empirical Investigation of Simulator/Training System Characteristics," Navigation, Summer 1980, p. 106.

"Establishing the Credibility of Simulations," Simulation, March 1980, p. 101.

"'Lookout' for a Future in Simulator Training," Motor Ship, December 1981, p. 78.

"Marconi's New Training Simulator: An Important Research Tool," Motor Ship, November 1981, p. 97.

"On the Evaluation of Training Devices," Human Factors, December 1979, p. 711.

"Selecting Simulator Characteristics to Address Practical Navigation Problems," Navigation, vol. 27, no. 4 (Winter 1980-81), p. 318.

"Ship Handling Simulators: Key to Safer Shipping," Shipcare & Maritime Management, November 1980, p. 23.

"Simulation for Training and Decision-Making in Large-Scale Control Systems, Part 1: Types of Training Simulators," Simulation, August 1980, p. 39.

"________, part 4: Marine-System Trainers," Simulation, September 1980, p. 94.

"________, part 9: Broad Conclusions," Simulation, November 1980, p. 159.

"Simulation: Past, Present and Future," Safety at Sea, November 1980, p. 17.

"Simulation Stimulation," Fairplay, 8 October 1981, p. 3.
"Simulators and Training," Marine Engineering/Log, March 1981, p. 114.
"State-of-the-Art Training," Exxon Marine, Winter 1982/83, p. 9.
"A Surfeit of Simulators," Safety at Sea, November 1980, p. 14.
"United Airlines Experience with Computer Generated Visual Systems," Navigation, Winter 1977-78, p. 352.
"UK Simulator Comes Onstream," Seatrade, June 1977, p. 77.

CONFERENCE PAPERS, REPORTS, MISCELLANEOUS

Arnott, Douglas R., F. Eugene Guest, and Douglas Hard (1979), "Simulator Training for Improved Shiphandling Skills." Paper presented at Fourth Ship Technology and Research Symposium (STAR), April 25-28, 1979, Houston.
Carpenter, Max H. and Wayne M. Waldo (1979), "The Essentials of a Ship Simulator," Paper presented at Marine Navigation Meeting, November 6-8, 1979, Yorktown, Virginia.
Chea, Francisco (1982), "A Summary of Visual Displays for Shiphandling Simulators," Technical Note: NAVTRAEQUIPCEN TN-64, Naval Training Equipment Center, Orlando.
Cook, Roger C. (1979), "Selecting Simulator Characteristics to Address Practical Navigation Problems," Paper presented at the Institute of Navigation's National Marine Navigation Meeting, November 8-20, 1979, New Orleans.
Fiore, Alfred E. and Thomas J. Hammel (1980), "Simulators for Training, Certification and Recertification," Paper presented at 1980 Tanker Conference, May 11-14, 1980, Coronado, California.
Gardenier, John S. (1979), "Issues in Simulator Training and Licensing," Paper presented at Institute of Navigation's National Marine Navigation Meeting, November 6-8, 1979, Yorktown, Virginia.
Gustavsson, Kurt W. (1979), "New Simulator Systems and Program Alternatives," Paper presented at Institute of Navigation's Marine Navigation Meeting, November 6-8, 1979, Yorktown, Virginia.
Hammell, Thomas J. (1980), "Role of Simulators in the Mariner Training and Licensing Process," Paper presented at International Symposium on Ship Operations, September 23-24, 1980, New York.
Hammell, Thomas J. and John S. Gardenier (1981), "Training and Certification via Simulators in the United States," Paper presented at Second International Conference on Human Factors at Sea (Ergosea 81), October 5-8, 1981, Plymouth, England.
Institute for Perception, TNO (1978), A Large-Scale Simulation System for the Study of Navigation and Driving Behavior (Soesterberg, Netherlands: TNO).
Ivergard, T. (1975), "Simulators," In Ergonomics and Reliability in the Handling of Ships: A Critical Literature Review, pp. 75-82 (Gothenburg: Swedish Ship Research Foundation).
Martin, P. (1979), "Ship Handling Simulators," Paper presented at Man and Navigation: An International Congress of the Institutes of Navigation, September 10-14, 1979, Sussex, England.

McCallum, I. R. and A. J. Rawson (1982), "The Cardiff Ship Simulator--Design Features and Operational Pnilosophy," Paper presented to a joint meeting of the Western Joint Branch, Royal Institution of Naval Architects, and the South Wales Branch, Institute of Marine Engineers, February 1, 1982.

Moraal, Jan (1980), "Evaluating Simulator Fidelity," Paper presented at Conference on Manned Systems Design: Methods, Equipment and Applications, September 22-25, 1980, Freiburg im Breisgau, West Germany.

Nishioka, T. and Y. Matsurra (1979), "Training Sim` `or and Its Application," Paper presented at Third International Symposium on Ship Operation Automation (ISSOA-79), November 26-29, 1979, Tokyo.

Steele, B. N. and R. F. Hansford (1976), "The Use of Simulators in Training--A Practical Approach," Paper presented at Symposium on the Operation of Large Ships, March 10-12, 1976, London.

Whitman, B. N. and D. A. Hard (1977), "The Use of Simulators as Training Tools for Shiphandling," Paper presented at 1977 Tanker Conference, June 6-8, 1977, Woodlands, Texas.

Zade, G. (1976), "Simulators in the Training of Maritime Ships' Officers," Schiff & Hafen, 28: 1116-1118.

SUMMARY OF COMMITTEE EXPERTISE

Robert L. Wiegel, chairman, is professor of civil engineering at the University of California, Berkeley, and a consulting ocean and coastal engineer. He has specialized for many years in the response of ocean and coastal structures to environmental forces, both in the development of environmental design criteria and in advanced design concepts. Professor Weigel is a former member of the Marine Board and member of the National Academy of Engineering.

Walter S. Chambers is manager of visual technology research simulation at the Naval Training Equipment Center in Orlando, Florida. Mr. Chambers's engineering research has concentrated on the development and use of technologies of visual simulation for research and training.

C. Lincoln Crane, a research and development associate in the tanker department of Exxon International, Inc., has long been active in promoting and conducting research in vessel maneuverability. He participated in the full-scale trials of the Esso Osaka in shallow water, and serves as chairman of the Ship Controllability Panel of the Society of Naval Architects and Marine Engineers.

Jesse Orlansky is a member of the technical staff of the Institute for Defense Analyses. He has conducted many studies of the cost and effectiveness of alternative methods of training. These include evaluations of flight simulations, maintenance simulators, and computer-based instruction.

Milton Pikarsky is director of transportation research and research professor at the Illinois Institute of Technology, where he recently directed the completion and preliminary trials of a locomotive and railroad car simulator. Formerly commissioner of public works for the city of Chicago, and chairman of the Chicago Transit Authority, Mr. Pikarsky is a member of the National Academy of Engineering.

John B. Sinacori is president of John B. Sinacori Associates, Hollings, California, a simulation engineering firm. An aeronautical engineer, Mr. Sinacori's principal area of concentration has long been the development and validation of simulation for flight training and for research in advanced design concepts.

William E. Smith is executive scientist at ORI, Inc., Silver Spring, Maryland, specializing in design of advanced control systems. He was for many years director of the ship dynamics simulation branch of the David W. Taylor Naval Ship Research and Development Center, where he directed research and modeling to gain detailed understanding of the dynamic behavior of naval surface ships and submarines.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO. AD-A135	3. RECIPIENT'S CATALOG NUMBER 601
4. TITLE (and Subtitle) REPORT OF THE COMMITTEE TO ASSESS THE COMPUTER AIDED OPERATIONS RESEARCH FACILITY (CAORF)		5. TYPE OF REPORT & PERIOD COVERED Final report
		6. PERFORMING ORG. REPORT NUMBER ---
7. AUTHOR(s) Committee to Assess CAORF		8. CONTRACT OR GRANT NUMBER(s) N00014-82-G-0032
9. PERFORMING ORGANIZATION NAME AND ADDRESS Marine Board of the National Research Council, Washington, D.C. 20418		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS ---
11. CONTROLLING OFFICE NAME AND ADDRESS Office of Naval Research Department of the Navy Arlington, Virginia 22217		12. REPORT DATE October 1983
		13. NUMBER OF PAGES
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) ---		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Distribution of this report is unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

---

18. SUPPLEMENTARY NOTES

Financial support provided by the Departments of Interior, Commerce, State and Energy, U.S. Coast Guard, Navy, Army Corps of Engineers, Maritime Administration, and National Science Found.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Simulation research
Ship simulator
Computer Aided Operations Research Facility (CAORF)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The physical facility, research program, government-contractor management structure, and other features of the Computer Aided Operations Research Facility (CAORF) of the U.S. Maritime Administration are evaluated, and suggestions offered for improvement and alternative arrangements.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-014-6601

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

MED

8